MAKING ABANDONED MINE LANDS (AML) PROFITABLE—WORKSHOP
PROCEEDINGS AND ABSTRACTS

Virginia T. McLemore and Bonnie Frey, editors

New Mexico Bureau of Geology and Mineral Resources

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A NM EPSCoR Sustainability Innovative Working Group Workshop

New Mexico Bureau of Geology and Mineral Resources

A division of New Mexico Institute of Mining and Technology

Socorro, New Mexico 87801

St. Anthony uranium mine, Laguna, Cibola County

Questa waste rock piles, Taos County

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Mill foundations and waste rock piles Gladstone, Silverton CO

Rosedale mine, Socorro County

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Special thanks to NM EPSCoR for the award supporting this workshop. Additional thanks to Melissa Coverdale, Gloria Gutierrez-Anaya, Nelia Dunbar and Van Romero for their advice and assistance with workshop planning and to Marcus Silva, Connie Apache, Alexandra Pearce and Amy Trivitt-Kracke for their assistance with the program compilation. Chris Armijo provided technical assistance during the meeting. Amy Trivitt-Kracke transcribed notes during the meeting and designed Figure 1.

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- Toltec Mesa Resources
- New Mexico Bureau of Geology and Mineral Resources (https://geoinfo.nmt.edu/index.html)
- New Mexico Mineral Museum (https://geoinfo.nmt.edu/museum/home.html)
- University of New Mexico (http://www.unm.edu/)

NM EPSCoR SUSTAINABILITY INNOVATION WORKING GROUP MEETING LEADERS

Bonnie Frey (New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology)

Virginia McLemore (New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology)

Jose Cerrato (University of New Mexico)

Dan Cadol (New Mexico Institute of Mining and Technology)

Johanna Blake (U.S. Geological Survey)

Sumant Avasarala (University of New Mexico)

WORKSHOP DATES AND LOCATION

10 a.m. Tuesday, March 27, through 2 p.m. Wednesday, March 28, 2018

Room 253, New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, New Mexico

SUMMARY STATEMENT

For the past five years, a team of researchers from the University of New Mexico (UNM) and New Mexico Institute of Mining and Technology (NMIMT) has been addressing issues associated with uranium mining and natural processes that affect the mobility of uranium. This research was funded by the New Mexico EPSCoR's Energize New Mexico award (https://www.nmepscor.org/). As our funding period comes to a close, we are looking for opportunities to continue as a team, to build on our strong knowledge base, and to make long-term plans with our collaborators. Our team has built collaborative technical relationships with industry and governmental agencies, putting us in an excellent position to identify areas of mine wastes (both mine waste rock piles and tailings) throughout New Mexico that could have potential for the recovery of critical metals and other commodities.

The purpose of this workshop is to examine the feasibility of combining mine reclamation (not limited to uranium mines) with potential recovery of critical minerals and other commodities. Participants include industry and government experts. Our team has received New Mexico EPSCoR Sustainability Innovation Working Group funding for this purpose.

Abandoned mine lands (AML) are lands that were excavated, left unreclaimed, where no individual or company has reclamation responsibility, and where there is no closure plan in effect. These may consist of excavations that have been deserted and where no further mining is intended in the near future. AML includes mines and mine wastes left unreclaimed on land administered by Federal, State, private, and Tribes because the current owner was not legally responsible for reclamation at the time the mine was created. These mine features also are called inactive, legacy, and orphaned mines. The environmental health and physical safety impacts from many of these sites has not been well identified (Bureau of Land Management, 2014). Many of these AML sites have potential for additional mineral production. The NMBGMR has collected published and unpublished data on many of the AML sites in New Mexico since it was created in 1927 (McLemore et al., 2005a, b; McLemore, 2017; https://geoinfo.nmt.edu/geoscience/hazards/mines/aml/home.html;), but the AML inventory is not complete. Completing the AML inventory for New Mexico to identify and characterize mines and associated mine wastes (including tailings) will help identify mine wastes appropriate for potential critical metals and other commodities recovery in the future.

The growing market for alternative technologies like solar panels, wind turbines, batteries, electric cars, desalination, and carbon capture and storage require nontraditional elements for their manufacture (Table 1). In addition, President Trump signed an executive order (Presidential Executive Order (EO) No. 13817) that requires the Departments of Interior and Defense to develop a list of critical minerals. A "critical mineral," as defined by EO No. 13817, "*is a mineral (1) identified to be a nonfuel mineral or mineral material essential to the economic and national security of the United States, (2) from a supply chain that is vulnerable to disruption, and (3) that serves an essential function in the manufacturing of a product, the absence of which would have substantial consequences for the U.S. economy or national security*" (Schulz et al., 2017; Fortier et al., 2018). Disruptions in supply chains may arise for any number of reasons, including natural disasters, labor strife, trade disputes, resource nationalism, conflict, and so on.

Some of these critical minerals are associated with metals, uranium, industrial minerals and coal deposits in New Mexico (McLemore, 2011, 2013, 2017, 2018; Eriksson, 2017; John and Taylor, 2017). Many of these critical minerals are found in historic or abandoned mines and mining districts. For example, vanadium and molybdenum, by-products of uranium mining, as well as commodities such as selenium and rare earth elements, are associated with sandstone uranium deposits in the Grants uranium district (Breit, 2017). Some waste rock piles and tailings could be potential resources for critical minerals needed for U.S. technologies (Bellenfant et al., 2013). Potential mineral recovery from mine wastes has the potential not only to support cleanup efforts financially, but to remove metals that could be part of the environmental and public safety hazard. There is a considerable need for research in this area, which this workshop would help to address.

This report presents the abstracts, oral presentations, and posters given at this workshop. It also includes summaries of the discussion and recommendations for future research.

TABLE 1. Selected uses of critical minerals and other commodities found in or associated with mineral deposits in New Mexico (Committee on Critical Mineral Impacts of the U.S. Economy, 2008; McLemore, 2011, 2013, 2017; Schulz et al., 2017; Fortier et al., 2018).

Commodity	Selected Uses
Copper	Electrical wire, pipe, plumbing, motors, machinery, computers
Molybdenum	Stainless and structural steel, superalloys, chemicals, cast iron
Uranium	Fuel for nuclear reactors, projectiles, shielding of radioactive materials, medical applications
Rare earth elements	Catalyst, glass, polishing, rechargeable batteries, magnets, lasers, glass, TV color phosphors
Vanadium	Batteries, alloy in steel, superconductive magnets, jet engines, airframes
Selenium	Solar panels, catalysts in chemical industry, glass
Arsenic	Wood preservative, insecticide, semiconductors used in laser diodes and LEDs
Tellurium	Infrared devices (night vision), solar cells
Titanium	Jet engines (superalloys) and airframes (titanium alloys), armor

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Breit, G.N., 2017, Resource potential for commodities in addition to uranium in sandstone-hosted deposits; *in* P.L. Verplanck, M.W. Hitzman (Editors), Rare Earth and Critical Elements in Ore Deposits: Society of Economic Geologists, Special Publication v. 18, p. 323-337

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McLemore, V.T., 2013, Tellurium Deposits in New Mexico: SME Annual Meeting Preprint 13-104, 8 p., http://geoinfo.nmt.edu/staff/mclemore/projects/mineralresources/documents/13-104.pdf

McLemore, V.T., 2017, Mining districts and prospect areas of New Mexico: New Mexico Bureau of Geology and Mineral Resources, Resource Map 24, 65 p., scale 1:1,000,000.

McLemore, V.T., 2018, Rare Earth Elements (REE) Deposits Associated with Great Plain Margin Deposits (Alkaline-Related), Southwestern United States and Eastern Mexico: *Resources*, *7*(1), 8; 44 p., doi:10.3390/resources7010008; http://www.mdpi.com/2079-9276/7/1/8

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Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, and Bradley, D.C., eds., 2017, Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: U.S. Geological Survey Professional Paper 1802, 797 p., https://doi.org/10.3133/pp1802.

EXPECTED OUTCOMES OF THIS WORKSHOP

- Identify mine wastes that can be used to extract critical minerals or other commodities essential to the U.S. economy and security
- Identify other potential technologies that can be developed for reprocessing of mine wastes
- Identify hazards, especially those that can be removed or mitigated through profitable activities
- Identify funding sources for research in these areas.

RESULTS OF WORKSHOP

The workshop culminated in a couple of hours of discussion that met the expected outcomes of the workshop (see the list on p. 9). Below is a list of proposed research areas. An outline of the full discussion begins on p. 11. One major concern expressed at this workshop is to involve the communities at the very beginning of any research activities.

Proposed research areas

1. Identify potential mineral resources in New Mexico
2. Perform an inventory and characterization of AMLs
3. Develop new or improved methods for mineral or metal extraction, particularly those that ensure selectivity of commodities of interest, including the use of novel adsorptive materials and chemical ligands
4. Investigate metal reactions with organic matter, which is particularly relevant in organic-rich formations in New Mexico (including coal and uranium deposits)
5. Conduct a holistic study of mine and mill waste management with the objective of understanding challenges (permitting, economics, technology, communication among stake holders, risk management)
6. Non-market valuation of the impact of dust from abandoned mine lands on communities
7. Facilitate a process that would allow industry to share its challenges with academia as research problems, determining feasibility and developing cost analysis together and partnering with regulators and communities throughout the process
8. Investigate the accumulation of metals in plants in semi-arid climates, using the results to design phytomining and phytoremediation projects
9. Determine the technical and economic feasibility of making water-saving fertilizers from the mineral wastes in New Mexico
10. Investigate the environmental health impact of abandoned mine lands

DISCUSSION DETAILS

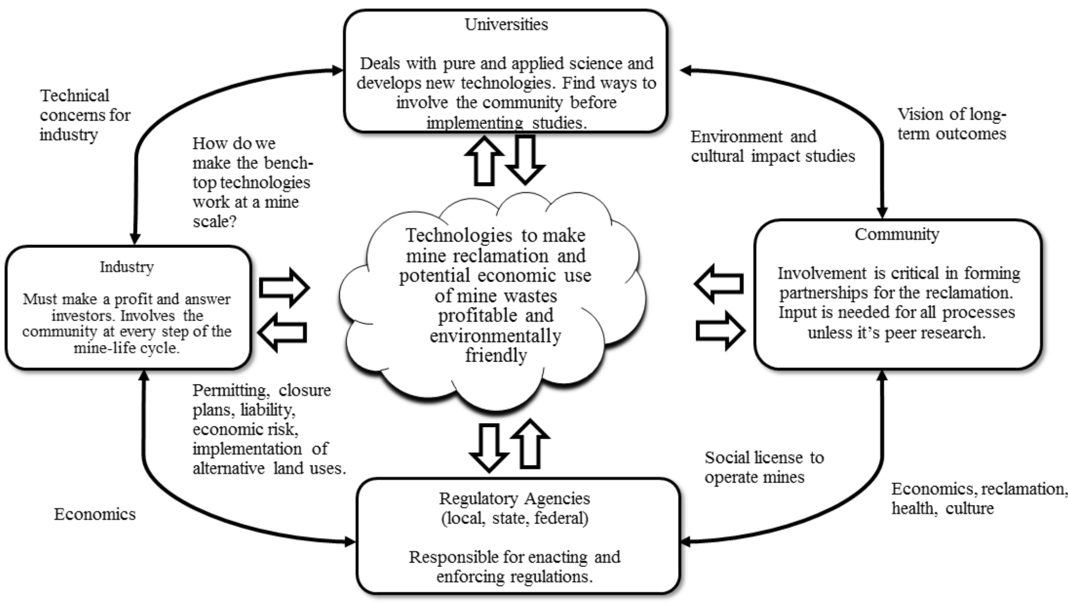

FIGURE 1. Summary of discussion on making mine wastes profitable (designed by A. Trivitt-Kracke).

Identify mine waste for extraction

- Coal deposits and fly ash
  - Including rare earth elements
- Cost of mining and processing
  - Can a small mine be permitted and subsequently profitable?
  - What commodities can be mined in United States as small mines?
- Identify resources in municipal land fills
- Inventory of potential deposits
  - Mineral resources
  - Mineralogy/chemistry and other characterization
  - Known processing techniques
- Identify products, by-products, and co-products of AML and active mines
- Knowledge gap of distribution of critical minerals in mineral deposits, especially as co-products and by-products and how can we economically recover them

Identify technology for reprocessing

- Refining in-situ leaching
- Reprocessing tailings
    - Especially copper, gold, and uranium (without unintended consequences)
- Recovering tellurium and other commodities without risking major production (selective technologies)
- Second life-expand beyond mineral extraction
    - Interim stabilization
    - Alternative energy or land use (farming)
- Expand mine waste for fertilizer
    - From gold and silver mines and adopt to new geoenvironments
- Minimize health and environmental impacts at beginning of the mine-life cycle
- Can commodities be recovered from landfills?
- How do you remove cobalt from acidic leach solutions without changing the pH (ie., copper heap solutions)?

Hazard mitigation

- Develop a database of published and unpublished studies
    - Selective technology
    - Case studies
- Mining for reclamation
- Stable land forms

Social Nexus

- Mexican mines - 25% goes into R&D
- Case studies of success and unsuccessful projects
- Community involvement
    - Community ownership
    - Involve from beginning/part of the process
    - Teach-in
    - Educate the community
    - Educate investors
    - Workshops
    - Meetings
    - Field trips
    - Open meetings

Economics

- Commodity life cycles

  - Life cycle flow charts
  - USGS - NMIC
- Mine for reclamation
  - Example - cover materials
- Market research
- Benefits
- Full cost accounting to identify other potential beneficiaries
- Trade off – investor profit for minimizing investor risk

Unintended consequences

- Gold King spill
- Clean Water Act and unintended discharge to groundwater

Hurdles

- Stockpile vs. other resource models
- China's dominance over the life cycle (including price) of many critical minerals
- Streamlining the permitting to <2 years
- Risk management
- Passing of a Good Samaritan Law that allows companies who did not create mining waste at a site and who are not legally required to clean it up to reclaim this legacy mine sites by reducing the liability standards imposed by current federal environmental statutes
- Liability shields
- Communication between regulators and industry
- Communication between industry and researchers

Recommendations

- U.S. government stockpiling critical minerals
- Fast-track permitting for critical minerals
- Public education on paradigm shifts
  - Reclamation to include resource recovery
  - Mining for reclamation
- Quantify resources in mine waste and landfills
- Bibliography of projects involving resource recovery from mine waste
  - Successful and unsuccessful projects
- Compiling databases of water quality (example, Grants)
- Database of alternative land use
  - Where they have worked or didn't work.

Opportunities

- Outreach to other groups that are exploring same objectives

- Salt evaporation/extraction
- Improved water quality with economic benefits
- New filtration technology
- Alternative commodities
- construction, elements, minerals
- Alternative land use
- energy, pump storage, farming, waste disposal, wildlife preservation
- Disposal and recycling of waste
- Sludges, electronics
- Small scale community/building dump

Collaborations

- Industry-university consortium
- Economists
    - Fall cost accounting
- National laboratories
- US EPA Office of R&D
    - The EPA National Mining Group
- Industry/researcher dialogue on research needs
- Those addressing unintended consequences
    - Ecologists, health researchers, etc.

SCHEDULE

Day 1, March 27, 2018

1) 10 a.m. – 10:10 a.m. Welcome (Dr. Stephen Wells, NMIMT president)
2) 10:10 a.m. – 10:30 a.m. Introductions and review of the New Mexico EPSCoR program (Bonnie Frey, NMBGMR)
3) 10:30 a.m. – 10:55 a.m. Overview of uranium mining and new mining technologies (Bruce Thomson, UNM)
4) 10:55 a.m. – 11:10 a.m. **Break**
5) 11:10 a.m. – 11:35 a.m. Critical minerals and abandoned mines (AML) in New Mexico (Virginia McLemore, NMBGMR)
6) 11:35 a.m. – 12:00 p.m. USGS databases and critical minerals (Jeff Mauk, USGS)
7) 12:00 p.m. – 1:00 p.m. **Break for lunch**
8) 1:00 p.m. – 1:25 p.m. Overview of the DOE-LM Defense Related Uranium Mines program (William Dam, DOE Office of Legacy Management)
9) 1:25 p.m. – 1:50 p.m. Environmental health research initiatives of the UNM METALS Superfund Research Center (Johnnye Lewis, UNM)
10) 1:50 p.m. – 2:15 p.m. Potential commodities in tailings in New Mexico (Ibrahim Gundilier, NMBGMR)
11) 2:15 – 2:40 p.m. Recovery of Residual Metal Values from Mine Tailings and Dynamic Leach Circuits (Bill Chavez, NMIMT)
12) 2:40 p.m. – 2:55 p.m. **Break**
13) 2:55 p.m. – 3:20 p.m. Extracting metals from mine waste (Ingar Walder, NMIMT)
14) 3:20 p.m. – 3:45 p.m. Effects of mine waste on the larger communities: the Gold King spill (Johanna Blake, USGS)
15) 3:45 p.m. – 4:10 p.m. Closing in on the Holy Grail – Beneficial Use of Hard Rock Waste as a Source for Biomineral Fertilizers (Dr. Andrew Harley, Duraroot Environmental Consulting)
16) Poster session at 4:15 p.m. (Virginia McLemore, NMBGMR, Chair)
17) 5:30 p.m. **Dinner in courtyard, NMBGMR**

Day 2, March 28, 2018

1) 9:00 a.m. – 9:10 a.m. Establishing collaborations between industry and universities (Don Miller, Americas Tailings, Inc. co-founder and director)
2) 9:10 a.m. – 9:35 a.m. High uranium in groundwater in New Mexico (Dennis McQuillan, NMED; San Jose district / Espanola Basin)
3) 9:35 a.m. – 10:00 a.m. Hurdles to mining of AMLs: A case history of Nacimiento Mine (Bob Newcomer, Toltec Mesa Resources)
4) 10:00 a.m. – 10:10 a.m. Concluding remarks (Virginia McLemore)
5) 10:10 a.m. – 10:25 a.m. **Break**
6) 10:25 a.m. – 12:00 p.m. Discuss knowledge gaps, future needs, potential actions and funding opportunities
7) 12:00 p.m – 1:00 p.m. **Lunch**
8) 1:00 p.m. – 2:00 p.m. General discussion of collaboration activities, adjourn

ATTENDEE LIST

Bill Auby	AML, Bureau of Land Management, Energy and Minerals
Kirby Biggs	Environmental Protection Agency
Johanna Blake	U.S. Geological Survey
Michael Briggs	Freeport-McMoRan Inc.
David Burleigh	New Mexico Institute of Mining and Technology
Dan Cadol	New Mexico Institute of Mining and Technology
Samantha Caldwell	New Mexico Institute of Mining and Technology
Jose Cerrato	University of New Mexico, Civil Engineering Department
William Chavez	New Mexico Institute of Mining and Technology
Bill Dam	Department of Energy Office of Legacy Management
Juan de Dios Pineda	New Mexico Institute of Mining and Technology
Nelia Dunbar	New Mexico Bureau of Geology and Mineral Resources
Dave Ennis	New Mexico Mining and Minerals Division
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Bonnie Frey	New Mexico Bureau of Geology and Mineral Resources
Liliya Frolova	New Mexico Institute of Mining and Technology
Mike Gingles	United States Tailings Remediation
Ibrahim Gundiler	New Mexico Bureau of Geology and Mineral Resources
Andrew Harley	Duraroot Environmental Consulting
Eliane El Hayek	University of New Mexico
Eshani Hettiarachchi	New Mexico Institute of Mining and Technology
Kris Larkin	New Mexico Institute of Mining and Technology
Johnnye Lewis	University of New Mexico Metals Superfund Research Center
Jeffrey Mauk	U.S. Geological Survey
Virginia McLemore	New Mexico Bureau of Geology and Mineral Resources
Dennis McQuillan	New Mexico Environment Department
Don Miller	Americas Tailings, Inc.
Navid Mojtabai	New Mexico Institute of Mining and Technology
Robert Newcomer	Toltec Mesa Resources
Alexandra Pearce	New Mexico Institute of Mining and Technology
Steve Raugust	Excelsior Mining
Amber Rheubottom	New Mexico Environment Department
Adam Ringia	Laguna ENRD
Van Romero	New Mexico Institute of Mining and Technology
Gayan Rubasinghege	New Mexico Institute of Mining and Technology
Tom Shelley	Freeport-McMoRan Inc.
Marcus Silva	New Mexico Institute of Mining and Technology
Diane Tafoya	U.S. Forest Service
Bruce Thomson	University of New Mexico, Emeritus
Amy Trivitt-Kracke	New Mexico Bureau of Geology and Mineral Resources
Jeroen Van Nes	Freeport-McMoRan Inc.
Carmen A. Velasco	University of New Mexico
Ingar Walder	New Mexico Institute of Mining and Technology
Haoying Wang	New Mexico Institute of Mining and Technology
Brett Waterman	Freeport-McMoRan Inc.
Stephen Wells	New Mexico Institute of Mining and Technology

ORAL ABSTRACTS

Presentations are included on the Web page

GOLD KING MINE AND THE ANIMAS RIVER

Johanna M. Blake, U.S. Geological Survey

The Gold King Mine is located in a highly mineralized area in the western San Juan Mountains of southwestern Colorado. Historically and currently, acidic and metal-laden waters from hydrothermally altered deposits drained into nearby streams. On August 5, 2015, an estimated three million gallons of sediment and metal-laden water were released from the Gold King Mine into Cement Creek, a tributary to the Animas River. This release flowed south in the Animas River into New Mexico, into the San Juan River, and finally into Lake Powell, Arizona. The U.S. Environmental Protection Agency estimated that close to 540 tons of metals, mostly iron and aluminum, entered the Animas River over the 9-hour period of the Gold King Mine release. This, however, was not the first time a large release has occurred from this mining district. In 1974 and 1978, large releases occurred that carried acid mine drainage down Cement Creek into the Animas River (U.S. Bureau of Reclamation, 2015).

Surface water samples collected in the Animas and San Juan Rivers during 2016 snowmelt and in the Animas River in three 2016 monsoonal storms were evaluated for dissolved (<0.45 µm) and total concentrations of metals such as aluminum, iron, lead, manganese, and arsenic. Dissolved concentrations of aluminum, iron, and lead range between 0.70% and 14% of the total concentrations; manganese and arsenic have higher dissolved concentrations compared to total concentrations (1.2%-75%). Concentrations of total aluminum, iron, lead, manganese, and arsenic increase during the rising limb of all hydrographs, suggesting a relationship with sediment concentrations, which increase with increasing streamflow. Aluminum and iron have the highest total concentrations, 63,400 µg/L and 82,500 µg/L, respectively. Metals such as lead and arsenic are known to adsorb to iron, aluminum, or manganese, which are present in the total water analyses. A National Uranium Resource Evaluation study of this area from the 1970s found that aluminum and iron have the highest concentrations of all elements found in streambed sediments, which suggests that the sediment in these rivers is partially composed of aluminum and iron. For the total surface water chemistry, in snowmelt samples, the relations of aluminum and iron to lead and arsenic are positive and linear, while in monsoonal samples, the relations are polynomial. Further evaluation of the chemistry of the watershed sediments, the stream bed sediments, and suspended sediments will help us to better understand the geochemical processes in the Animas and San Juan Rivers.

CONSIDERATIONS INVOLVING METALS RECOVERY FROM MINE TAILINGS AND LEACHED ORES: BASE AND PRECIOUS METALS

William X. Chávez, Jr., Minerals Engineering Department, New Mexico Institute of Mining and Technology, Socorro, NM

Recovery of residual base and precious metal values from mine tailings and leached ore materials involves detailed assessment of the quantity, mineralogy, and, especially, the geochemical nature of ore-host minerals. These observations not only characterize potentially recoverable minerals, but also provide necessary and substantive information about the metallurgical parameters of ore minerals and challenges concerning their ultimate recovery.

Because most mine tailings have been treated to selectively float or suppress particular minerals – some of which may now be considered valuable even though previously regarded as either unrecoverable economically (e.g., silver-containing sphalerite from polymetallic vein systems; Julcani, Perú; copper from Mississippi-Valley-type Pb-Zn systems) or as gangue (e.g., rutile from porphyry Cu-Mo ore deposits, southwest U.S.) – and because many tailings have undergone geochemically-significant weathering since deposition, the mineralogical assessment and metallurgical aspects of tailings treatment are substantial concerns (e.g., VHMS tailings from the Buchans District, Newfoundland). Further, although some tailings contain economically-interesting quantities of residual metals, deleterious elements may present environmentally-significant issues when considering tailings retreatment (e.g., gold recovery from arsenopyrite-bearing tailings; Lupin, NWT; Homestake, South Dakota).

Second-treatment of leached ores generally requires much less investment in time and effort, largely because leaching technologies are relatively modern, and consequently the knowledge of ore grades and recoveries from first-pass treatment are usually well-known or can be determined easily; in addition, re-leaching of previously-treated ores is inexpensive and provides low-cost recovery of metal values (e.g, Chuquicamata, Chile; Radomiro Tomic, Chile; Tyrone, New Mexico).

DEPARTMENT OF ENERGY’S DEFENSE-RELATED URANIUM MINES PROGRAM

William L. Dam, DOE Office of Legacy Management

The U.S. Department of Energy (DOE) Office of Legacy Management (LM) manages defense sites nationwide that were part of the nuclear weapons complex. These sites include former uranium mines, mills, used to supply the weapons program from 1947 to 1970. In 2014, DOE identified 4,225 uranium mines in the Defense-Related Uranium Mines (DRUM) report to Congress. While many mills and other sites have been remediated or reclaimed, numerous DRUM sites were abandoned and not reclaimed. Other sites have been reclaimed to contour and revegetate waste rock piles and close portals or install bat gates.

About half of the DRUM sites are located on public lands managed by the U.S. Bureau of Land Management (BLM). DOE-LM launched funding for the DRUM program in FY2016 to characterize locations and current conditions. This work includes conducting historical geological review of mine locations, collecting field data including gamma radiation and metal concentrations in soil and water, and screening physical safety hazards and radiological/metals risks to human health and the environment. Outputs include a database and reporting results.

For the DRUM program, DOE-LM will establish partnerships with federal, state, and tribal governments and obtain access agreements on private land to conduct the DRUM program. The current plan is to focus on DRUM sites located on public lands to complete 2,500 sites within five years. DOE-LM entered into four interagency Memorandum of Understandings (MOUs), and Inter-agency agreements (IAA’s) with BLM and the U.S. Forest Service (USFS). The program prioritized locations based on significant ore production and began in Utah and Colorado, then is expanding to New Mexico, Wyoming and Arizona, as well as other states.

AN OVERVIEW OF MINERAL PROCESSING PRINCIPLES PERTAINING TO TAILINGS PROCESSING

Ibrahim Gundiler, Emeritus, New Mexico Bureau of Geology and Mineral Resources

A brief review of mineral processing principles and techniques will be reviewed, and pitfalls in application of these techniques for mine and mill tailings will be discussed. Some examples of successful application of these methods in tailings reprocessing will be presented.

CLOSING IN ON THE HOLY GRAIL – BENEFICIAL USE OF HARD ROCK WASTE AS A SOURCE FOR BIOMINERAL FERTILIZERS

Andrew Harley, Principal Scientist, Duraroot Environmental Consulting, 4626 Weld County Road 65, Keenesburg, CO 80643, aharley@duraroot.com, 720.840.4703

The large volumes of waste produced at mining operations are expensive to manage, and frequently cited as an obstacle in the environmental sustainability of mining. The majority of waste produced is still placed into storage facilities, and the reclamation and long-term management of these facilities has become an important part of modern mine development and mine closure.

Over the past few years, the applications of certain microorganisms have gained importance in the field of applied environmental microbiology. Amongst them, biomineral processing of metal mining from ores, concentrates, industrial wastes, overburdens with microorganisms and/or their metabolites. This process still produces waste material requiring management.

This paper describes a novel technique that combines the extraction of metals from mine waste using environmentally safe chemistry, followed by biodigestion of secondary waste from this process to generate an additional commodity. This process results in a zero-waste facility and multiple revenue streams. Bench-scale and pilot test data will be presented, as well as a description of projects currently being permitted.

MULTIGENERATIONAL EFFECTS OF EXPOSURES TO MINE WASTE ON TRIBAL LANDS: LEARNING TO BREAK THE CYCLE

Johnnye Lewis, Ph.D., Director, UNM METALS Superfund Center

More than 160,000 abandoned hard rock mines remain in the Western US in the same states that are home to the majority of Native American communities and populations in the country. We have calculated that ~600,000 Native Americans live within 10 km of abandoned mines. The increased reliance on local resources, cultural practices, as well as the lack of infrastructure in many of these communities can significantly increase exposures in this population. Such exposures can result from a greater reliance on potentially contaminated surface water sources, ceremonial and traditional practices, increased time on the land, and longer durations of residence. The work of the UNM METALS Center brings together a multidisciplinary team to integrate an understanding of cultural practices, environmental mobility, and health effects associated with the exposures to these complex mixtures. The team approach integrates expertise in engineering, geochemistry, mineralogy, inhalation toxicology, geography, molecular toxicology, exposure science, traditional knowledge, immunology, neurodevelopment, mathematics and statistics, policy, and art to better understand the cycle of exposure through site-specific mixtures and characteristics of waste to inform interventions to break exposure cycles, develop effective warning systems, or reverse toxicological processes. The Center's work builds on population studies spanning three generations, and moves from populations to cell systems and animal research models to not only identify relationships between exposures and health, but to understand underlying mechanisms that might manifest in multiple disease endpoints. The approach provides new targets for interventions to improve health. Ultimately, in partnership with three Native communities, to inform policies that reduce risk and improve overall community health while the slow process of remediation is negotiated and implemented. On Navajo Nation alone, more than 500 abandoned uranium mines underscore the need for costeffective interventions and new approaches to protect health. Examples of findings from our environmental research and the contextual impact of those results on health will be presented and discussed.

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USGS GEOSPATIAL DATABASES AND CRITICAL MINERALS

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One of the key missions of the U.S. Geological Survey (USGS) Mineral Resources Program is the collection and dissemination of mineral resources information. This information is foundational to mineral resource and geoenvironmental assessments, as well as ore deposit research. The data are also used by other government agencies (State and Federal), private industry, and the general public for land management, mineral exploration, geoenvironmental and mineral commodity supply chain studies, and other purposes.

In the 1960's, the USGS and the U.S. Bureau of Mines developed national-scale mine and mineral deposit databases. After the Bureau of Mine's closure in 1966, the USGS acquired custody of their Minerals Availability System (MAS) and Minerals Industry Location System (MILS) databases. In 2000, the MAS/MILS was merged with the USGS Mineral Resource Data System (MRDS) to form a single database. Much of the data initially captured in the Mineral Resource Data System was recorded prior to the development and widespread use of modern geospatial technologies. Additionally, differing data entry procedures of both the Bureau of Mines and USGS resulted in duplicative and conflicting information. Due to these issues, it was decided that the USGS needed to develop a new, modern mineral resources database of the United States.

The mission of the USGS Mineral Deposit Database Project (USMIN) is to produce a 21st century geospatial mineral deposit database by: (1) digitizing mining-related features from historic USGS topographic maps to obtain locations for past and current mining operations, and (2) building geospatial mineral deposit databases that include information on the location, geology, production, resources, history, and type of deposit.

Recent publications by USMIN include a database showing symbols of mining-related features that were digitized from historical USGS topographic maps in the western conterminous U.S. This represents more than 500,000 point and polygon mine symbols from approximately 67,000 maps of 22 western states. Work is underway on states east of the Mississippi River, and these will be published serially as work is completed. This database includes prospect pits, mine shafts, adits, quarries, open-pit mines, tailings piles and ponds, gravel and borrow pits, and other mining-related features.

The current focus of the USMIN geospatial mineral deposit databases is on critical minerals, with recent releases of databases for rare earth elements and rhenium in the U.S., and the global distribution of selected deposits of 22 critical minerals described in the recently released USGS Professional Paper 1802. Other U.S. commodity databases, such as for hafnium, tin, titanium, tungsten, and zirconium, are in progress. USMIN has also recently published a database on mineral deposits and prospects within a 200-square-mile area near Carlin, Nevada, and a database of significant deposits of gold, silver, copper, lead, and zinc in Alaska. The data provided have many uses, including for land use planning, assessing abandoned mine lands and mine-related environmental impacts, assessing the quantity and quality of mineral resources from Federal, State and private lands, and mapping mineralized areas and systems for input into the land management process. The Bureau of Land Management helps fund the USMIN project, and the group collaborates with other Federal and State agencies.

CRITICAL MINERALS AND ABANDONED MINES (AML) IN NEW MEXICO

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A "critical mineral," as defined by Presidential Executive Order No. 13817, "*is a mineral (1) identified to be a nonfuel mineral or mineral material essential to the economic and national security of the United States, (2) from a supply chain that is vulnerable to disruption, and (3) that serves an essential function in the manufacturing of a product, the absence of which would have substantial consequences for the U.S. economy or national security*". Some of these critical minerals are found in New Mexico and are found in existing mining districts, including Abandoned Mine Lands (AML). AML are lands that were excavated, left unreclaimed, where no individual or company has reclamation responsibility, and where there is no closure plan in effect.

The NMBGMR in cooperation with the Mineral Engineering Department at New Mexico Tech is conducting research on AML and other legacy mines in New Mexico. The objective of our research is to develop a better procedure to inventory and characterize legacy, inactive or AML mines in New Mexico and determine future mineral-resource potential, including critical minerals. The project involves field examination and collecting data on these mines. Samples are collected to determine total whole-rock geochemistry, mineralogical, physical, and engineering properties, acid-base accounting, hydrologic conditions, particle size analyses, soil classification, shear strength testing for stability analysis, and prioritization for remediation, including hazard ranking.

Numerous critical minerals are found in New Mexico. Potash is currently mined in the Carlsbad potash district. Tellurium is found in several districts in New Mexico; the most important tellurium deposits are found associated with AML and legacy mines in the Organ Mountains, Dona Aña County and at Lone Pine near Wilcox, Colfax County. Selenium is recovered from anode slimes generated in the processing of copper and many of the sandstone uranium deposits in New Mexico have potential for by-production selenium. Indium, cadmium, gallium, germanium, and other elements are trace constituents found in many of New Mexico's mineral deposits in Grant, Hidalgo, Lincoln, and Socorro Counties and could be recovered during their processing or perhaps even during reclamation. Beryllium is found in veins and replacement deposits in Socorro and Sierra Counties. Lithium is found in predominantly three types of deposits in New Mexico, pegmatites, lake beds, and brines. There are challenges to overcome in producing these critical minerals from AML and legacy mines, but the future of these commodities is exciting and making them come true relies on mining these rare materials from the ground.

HIGH GROUNDWATER URANIUM IN THE ESPAÑOLA BASIN

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Low-grade uranium mineralization in the Tesuque Formation east of the Rio Grande between Española and Santa Fe was discovered in 1954, and a small amount of uranium was produced from the San Jose mining district in 1957. Carnotite, schroekingerite, and autunite occur in sandstones and conglomerates, often associated with clay galls, carbonaceous material, chert, opal and fossil bone fragments. Uranium mineralization also occurs in some pegmatites that have intruded Proterozoic rocks in the Sangre de Cristo Mountains.

Within this mineralized area east of the Rio Grande, elevated levels of uranium (up to 74 pCi/L = 110 µg/L) were discovered in several public water supply systems during a statewide testing initiative conducted in 1975-79. Extensive testing of private domestic water wells began in 1995 and approximately half of all wells tested in this area, to date, produced water with uranium in excess of the 30 µg/L the drinking water standard. A significant number of wells had uranium concentrations greater than 100 µg/L, with one well measuring 1,820 µg/L. Since industrial sources of uranium exist in the Española Basin west of the Rio Grande, studies were performed to determine the isotopic signatures of the uranium in groundwater. U-234 to U-238 ratios were determined for samples collected from 52 water supply wells located in the mineralized area east of the Rio Grande in 1995, and were determined to be consistent with natural uranium. An additional 13 wells in the mineralized zone were sampled in 2012 for isotopic analysis by three different laboratories. Ratios of U-234 to U-238 were similar to the naturally occurring ratios detected in the 1995 study. Ratios of U-235 to U-238 also were consistent with natural geologic sources. Manmade U-236 was not detected in any well water sample east of the Rio Grande.

Most uranium ingested in drinking water is excreted in urine within several days, but some uranium is stored in the body, primarily in the bones, liver and kidneys. The primary health concern of ingested uranium is chemical kidney toxicity. The drinking-water standard is intended to address both nephrotoxicity and radiation hazards of alpha particles emitted by uranium isotopes. Urine testing can determine if a person has recently been exposed to high levels of uranium via ingestion or inhalation. Detection of greater than 0.2 µg/L of uranium in urine is a notifiable condition that must be reported to the New Mexico Department of Health.

Concentrations of uranium in drinking water can be decreased by blending, and by anion exchange or membrane filtration treatment technology. Public water utilities often use blending due to the high cost of water treatment. Many private domestic well owners have installed point-of-use (kitchen sink) household treatment systems. Membrane filtration with effective pore size of 0.001 µm decreases uranium concentrations while minimizing water consumed by the treatment process, relative to reverse osmosis with effective pore size of 0.0001 µm. Management of uranium-bearing drinking-water treatment waste, which is often discharged to an onsite wastewater system, is an ongoing issue.

In summary, naturally occurring uranium, sometimes far in excess of the 30 µg/L health standard, has impacted numerous water supply wells east of the Rio Grande between Española and Santa Fe. This uranium originates from natural mineralization that occurs widely in basin fill and Proterozoic rocks.

LEVERAGING MINING EXPERTISE, TECHNOLOGY ADVANCES AND MOTIVATED STAKEHOLDERS TO REVITALIZE HISTORICAL TAILINGS SITES

Don Miller, Americas Tailings, Inc., Denver, CO

Americas Tailings is a Denver-based *Earth-Friendly* resource company focused on securing rights to develop historical tailings sites in the western USA and, by applying modern, commercially-viable, environmentally-friendly processing technologies, to extract the metals value and remediate the tailings sites. The company will describe its ongoing collaboration with the State of Utah School and Institutional Trust Lands Administration and the University of Utah to inventory historical tailings sites in Utah, perform preliminary desk-top evaluation in order to rank the sites by economic value and environmental risk liability, and investigate priority sites for potential reprocessing, remediation and revitalization; the company will outline its strategic association with Duraroot, an environmental management firm focused on applying new processing technology to develop sustainable solutions by creating value through recovery of end-use products; the company will explain the rationale behind establishing a Colorado non-profit corporation, U.S. Tailings Remediation, to manage physical remediation efforts, and to perform research and development activities that will support public and private initiatives; and the company will provide an overview of the spreadsheet structures and customized Contemplor Software that it uses to inventory and evaluate tailings sites.

HURDLES TO MINING ABANDONED MINE LANDS: NACIMIENTO COPPER MINE – AN EXAMPLE

Bob Newcomer, C.P.G., P.G.

The Nacimiento copper mine in north-central New Mexico is a "red bed" copper deposit in the Triassic-age Aqua Zarca Sandstone. The mineralization is stratabound in faulted and steeply dipping sedimentary rocks adjacent to the Nacimiento uplift. Estimates of between 128 and 192 million pounds of copper are present as in-place reserves, as well as additional copper in low-grade ore piles and tailing. Mining in the area dates to the 1500s or earlier, with the most significant development, including open pit mining, milling and concentration occurring in the 1970s. A failed effort to leach the copper in situ occurred in the 1980s. Since the abandonment of the mine in the late 1980s, the property has been subject to the assessment of the environmental liabilities by various agencies and has an extensive regulatory history. Ongoing remediation of the site is being conducted by the USDA Forest Service as well as the State of New Mexico. There appears to be potential profitable opportunities and benefits with redevelopment and extraction of the copper resources. Aside from the economic benefit, it could lead to an ultimate closure/reclamation of the mine to current regulatory standards, offset by the economic benefit. There are numerous hurdles to any redevelopment, including reducing a potential operator's liability, capitalization, necessary permitting and water rights acquisition. There are typically long lead times with permitting and the efforts would face continuous feasibility analysis and evaluation of mine plan alternatives under current and projected copper values. Beyond this it would require infrastructure upgrades, identifying and attracting a qualified workforce, and ultimately obtaining a "social license" or some level of acceptance by the community.

URANIUM DEVELOPMENT AND WATER IN NEW MEXICO: LESSONS FROM THE PAST AND STRATEGIES FOR THE FUTURE

Bruce M. Thomson, Ph.D., P.E.

The last uranium boom in New Mexico began in the late 1940's during a time when water and environmental protection regulations were nearly non-existent. Early projects consisted of surface or shallow underground mines and had little impact on regional water resources. However, by the time uranium production peaked in the late 1970's nearly all mining was from deep underground mines and annual mine dewatering flows exceeded 30,000 acre-ft/yr. More than 10 uranium mills processed ore at one time or another in New Mexico and disposed of their waste in unlined tailings ponds. This presentation will discuss the impacts of past uranium development on water resources and consider them in the context of current treatment technologies, water and waste management strategies, water and environmental regulations, and our understanding of the hydrogeology of northwestern New Mexico. Strategies for minimizing impacts of future uranium development on water resources will be presented.

METAL RECOVERY FROM MINE WASTE MATERIAL AT THREE MINE SITES IN NORWAY

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Nickel and copper leaching experiments has been performed on mine waste from three different mine sites in Norway using acid-leach column experiments. Nickel experiments were performed on tailings from an anorthosite hosted illmenite deposit in Sothern Norway and a waste rocks from layered mafic intrusive complex hosting a massive nickel sulfide deposit. Copper leaching experiments has been performed on tailings from processing several volcanogenic massive sulfide (VMS) deposits at Sulitjelma, Northern Norway.

The ilmenite deposit contains trace amounts of pyrite, pentlandite and chalcopyrite besides the major minerals anorthite, pyroxene, illmenite, and magnetite. The tailings deposit is in the order of 50 million tons. The waste rocks of the nickel deposits contain pyrrhotite, pentlandite, chalcopyrite and pyrite as sulfide minerals, with high Ni-ferrous olivine (dunite), calcium-rich plagioclase, and pyroxene as the major minerals. The tailings from the VMS deposit contains pyrite, chalcopyrite, sphalerite, galena with amphibole, chlorite and minor feldspar as silicate minerals. There is also glass from the nearby smelter interbedded in the tailings. The VMS tailings pond contains a total mass of around 5-7 mill. tons.

Two kinetic cell tests (6 kg samples) were run to evaluate nickel leaching from tailings under a controlled setting with weakly addition of deionized (DI) water and low pH (2.5-3) process water from the mine. In addition, two leach cells were run with continues input of sulfuric acid and process-water. The leaching reached 30-40 mg/L nickel in leachate with minor cobalt.

Four kinetic leach cells were installed with waste material from the nickel deposit. The columns contain approximately 5 kg sample. The first 8 weeks were run with addition of DI water, while eight weeks with pH=2 sulfuric acid rafinate and then 8 weeks of pH=1.5 sulfuric acid. There is a high acid consuming effect from the olivine, however, this also contribute to nickel in solution. Nickel level is around 5-15 mg/L in the leachate, while cobalt is below 1 mg/L.

Two kinetic test leach columns with 2-3 kg tailings from the VMS deposit has been running for approximately two years with weekly addition of DI water. Leachate reaches pH around 1.5 with copper concentrations around 100-150 mg/L. Iron concentrations are over 1000 mg/L. More that 15% of the tailings have been leached out over the time of the experiments.

These experiments show the potential of extracting metals from waste material using standard leaching methods. There are on the market small metal solvent extraction electro winning and ion exchange systems that can be connected to the leaching units and thereby make it feasible to extract common elements from waste materials, that have either not extracted well the metals in a prevous mineral processing method, or metals that were not extracted originally. This will be further investigated in these research projects.

POSTER ABSTRACTS

Posters are included on the Web page

OVERVIEW OF THE BLM ABANDONED MINE LANDS PROGRAM

William Auby, Bureau of Land Management, New Mexico State Office

The goals of the BLM Abandoned Mine Lands Program are to restore watersheds impacted by abandoned mines, protect public health and safety, and reduce government liability. BLM uses risk-based decision making to accomplish these goals.

The first step is to determine where abandoned mine features occur on the public lands. Inventory crews walk the area around Mining Districts to find abandoned mine features and collect data. The data are recorded into a database where abandoned mine features are tracked from discovery through remediation and monitoring and maintenance. Currently, the Abandoned Mines and Site Cleanup Module database holds over 100,000 features discovered on public lands. Many more have yet to be inventoried.

A variety of closure methods are used that preserve wildlife habitat and cultural features while mitigating physical safety threats to public land users. Abandoned mines may also pose an environmental threat. Site investigations are conducted to identify contaminants of concern and exposure pathways. BLM developed soil screening-level concentrations for metals based on the recreational visitor exposure scenario. Additionally, BLM looks at other factors such as site access and visitation in ranking the risk of a mine. The risk assessment helps determine if an action is needed and ranks the site in terms of priority. BLM has performed a variety of response actions to address environmental threats such as acid mine drainage, metal contaminated soil, and radiation exposure.

ANALYSIS OF URANIUM-BEARING DUST IN THE VICINITY OF JACKPILE MINE

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Closed mines pose potential risks to the environment and human health. Uranium mine contamination of surface water, groundwater and soil have received moderate attention, but few studies have investigated dust transport of uranium. The presence of uranium-bearing dust, potentially initially distributed during active mining periods, has implications for remediation efforts and environmental and human health. Frequent dust storms intensify aeolian transport of uranium in semiarid settings. At the Jackpile Mine in Laguna Pueblo, New Mexico, 15 sets of four dust traps were installed at heights of 0.25 m, 0.5 m, 1.0 m and 1.5 m above the soil surface. Trap locations extended from within the mine pit to locations 4 km downwind. Dust from these sites was collected approximately every two months. Additionally, soil samples from each site were collected and sieved into eight size classes. All samples were acid digested, and the uranium content analyzed using an ICP-MS. Results show that surface concentrations of uranium vary substantially across the landscape. Distance from the pit shows no correlation with uranium in the upper 5 cm of soil. Other factors appear to control accumulation, such as vegetation height and density and topographic relief, which are known to have a significant impact on wind speeds, soil erosion and dust deposition. Our study site has over 150 m of relief and intricate topography that leads to a range of wind speeds among the sites. The soil uranium content determined at 15 sites was compared to site elevation and vegetation height. Correlations suggest that elevation and vegetation height influence the erosion and deposition of uranium-bearing particles. Dust mass was measured at each dust trap and converted into a flux ($g/d/m^2$). The relationship between mass flux and height above ground followed a power law relationship as supported by previous aeolian research. In general, higher uranium concentrations were associated with smaller particle size classes. Concentrations for 4 of 6 metals of concern were higher in the dust compared to the local soil, a trend we attribute to particle size fractionation during aeolian transport.

PARAGENESIS OF URANIUM MINERALS IN THE GRANTS MINERAL BELT, NEW MEXICO: APPLIED GEOCHEMISTRY AND THE DEVELOPMENT OF OXIDIZED URANIUM MINERALIZATION

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Deposition of reduced uranium ores in the Grants Uranium District, New México, was succeeded by locally well-developed oxidation and the generation of secondary or tertiary uranium (vanadium, selenium) minerals. Detailed study of these succeeding-generation minerals indicates that oxidation of reduced uranium mineralization was effected by carbonate-, sulfate- and phosphate-bearing meteoric waters that engendered a series of generally hydrated uranyl-carbonate (e.g., andersonite, ($Na_2Ca(UO_2)(CO_3)_3 \cdot 6H_2O$; Chávez, 1979)) and sulfate (e.g., zippeite-like minerals, Mt. Taylor mine, Chávez, 1988; $K_4(UO_2)_6(SO_4)_3(OH)_{10} \bullet 4H_2O$; see also Moench and Schlee, 1967)) minerals. Initial X-ray diffraction (XRD) analyses of reduced uranium minerals from organic-rich arkosic sandstones of the Westwater Canyon Member of the Jurassic-age Morrison Formation from the Mt. Taylor mine show that various organic compounds are associated with the strongly-reducing environment characterizing primary uranium minerals and associated V, Mo, and Se. Oxidation of these reduced, organic-rich host rocks apparently produced carbonic acid and generated weakly acidic solutions capable of continued oxidation of uranium. Deposition of native selenium (Poison Canyon mine; Tessendorf, 1979) and weakly-crystallized MoS_2 as "jordisite" (Kao et al., 2001) suggests that the oxidation environment was variable immediately following uranium deposition and that weathering-derived supergene solutions served to modify both reduced and initially-oxidized uranium-vanadium ores. Dehydration reactions converted some uranium-vanadium oxides such as tyuyamunite [$Ca(UO_2)_2V_2O_8 \cdot (5\text{-}8)H_2O$] to their dehydrated equivalents [meta-tyuyamunite, $Ca(UO_2)_2V_2O_8 \cdot (3\text{-}5)H_2O$]; XRD analyses of green oxide coatings and black ores from the Section 31 mine show that the ores host andersonite and gypsum, indicating that CO_3^{2-}(aq) and SO_4^{2-}(aq)-bearing, oxidizing groundwaters were responsible for developing a series of paragenetically-complex carbonate and sulfate minerals that reflect local groundwater compositions and composition changes through time. Comparison of Grants Mineral Belt uranium mineralogy with the paragenesis of U-V minerals in other regions of the Colorado Plateau suggests that regional oxidation (Adams and Saucier, 1981) was likely responsible for uranium transport and later oxidative replacement of reduced uranium minerals (compare to Arizona Strip breccia pipe-hosted U-(Cu, Ag, Ni, Co) mineralization; e.g., see Van Gosen and Wenrich, 1989; Wenrich, Van Gosen, and Finch, 1992). Latest oxidation is attributed to supergene processes coinciding with the onset of regional uplift and erosion in Laramide times of the southern portion of the Colorado Plateau. Current oxidation of reduced uranium minerals is post-mining, and attributed to current groundwater conditions.

NEW INORGANIC-ORGANIC CARBON-BASED HYBRID MATERIAL FOR SELECTIVE URANIUM CAPTURE

Liliya V. Frolova, Chase Kicker, Snezna Rogelj, New Mexico Institute of Mining and Technology

Uranium contamination in drinking water is a major health concern in some parts of the United States, including New Mexico, and many other parts of the world. To minimize health risks from uranium contamination in drinking water, an efficient uranium filtration method is highly desired. Based on our experience of organic modification of carbon surfaces, we made an organic modification of commercial graphite particles for selective uranium adsorption from natural water sources. The material is high-cost effective and very chemically stable. The modified graphite shows high selectivity toward uranium even in the presence of competing cations such as calcium and magnesium. It further demonstrates that uranium adsorption is not hindered by the presence of many other cations or by a change in the pH of the natural water samples. To reuse the water filter, it is important to release all of the adsorbed uranium yet maintain the full functionality of the adsorbent. We have shown that a simple acidic or basic wash of our filter is sufficient to remove all of the bound uranium; this fully regenerates the filter. In fact, our material remains stable and fully functional after several washing cycles. Finally, thus collected uranium can be easily be extracted for further use in industry as an alternative to uranium mining.

EFFECT OF CALCIUM AND CARBONATE ON URANIUM (IV) UPTAKE BY *BRASSICA JUNCEA*

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We investigated the potential of *Brassica juncea* for U (VI) uptake using a combination of controlled hydroponic experiments and spectroscopic analyses. The mining and processing of U has left a legacy of contamination that is concerning to affected communities due to potential ecological and health risks. Although it is known that U can hyper-accumulate in plants such as *Brassica juncea,* we have limited knowledge about the specific mechanisms affecting U bioaccumulation under environmentally relevant conditions. Experiments were performed under controlled pH (7.5) and Calcium (Ca) concentrations (0.3-6 mM) over a range of U concentration (30-700 µg/L). Uranium accumulation was only detected in the roots at concentrations ranging from 30-900 mg/Kg with respect to the initial U concentration. The bioaccumulation of U followed pseudo-second order kinetics, suggesting that the chemisorption is the main mechanism affecting U uptake. The Uranium bioaccumulation factor decreased from 1 to less than 0.5 when $Ca_2UO_2(CO_3)_3$ became the dominant species in water. These results indicate that Ca affects U bioavailability by altering the uptake effectiveness by plant roots to the same exposure level of U. Only at low Ca level, cluster of U particles were detected by SEM-EDX in the roots cells wall explaining the weak translocation of U to the shoots. The results from this study have important implications for the use of *Brassica juncea* for phytoremediation in contaminated sites.

MINERALOGY DEPENDENT DISSOLUTION OF INHALED URANIUM IN SIMULATED LUNG FLUIDS IN URANIUM MINE LANDS, NEW MEXICO

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The smaller dust particles (PM_{10} or less) can pass through the human respiratory tract, ultimately reaching the lungs. In places where mining occurred, these dusts were long considered health problem due to contamination with heavy metals such as uranium. During exposure, the metals upon the metals can either accumulate in the lungs causing irritation and radiation damage or dissolve in lung fluids and thereby enter the blood stream, as complexed species. Upon entering the blood stream they may excrete or stay complexed with other biological components where they may alter the natural body fluid compositions. The uranium complexation in human biological systems may yield different health conditions depending on several factors, including the mineralogy of the uranium in the source material. In this study, leaching of uranium from (1) dust samples collected around Jackpile mine area, (2) fine-grain sediments from St. Anthony Mine and, a (3) U_3O_8 standard was investigated in two different simulated lung fluids (SLF). The two SLFs mimic two different lung conditions: Gambel's solution (GS) simulates the upper lung conditions with which inhaled dust first interacts, while Artificial Lysosomal Fluid (ALF) mimics the lung conditions at phagocytosis, a defensive mechanism against foreign inhaled bodies. Our results indicate that the dissolution of uranium in dust in these two different SLFs depends not only on the fluid pH and composition but also on the uranium mineralogy of the source material and on the mode of sediment transport. Dust transported via wind demonstrates higher dissolution in GS while dusts and sediment collected around mine pits are more soluble in ALF. The ability of uranium to complex with the organic and inorganic ligands in these lung fluids (for example, uranium containing clay leached out in the presence of amino acids and ammine complexes), may alter the composition, thereby disturbing body functions. In addition to the experimental studies, geochemical simulations have been done using PHREEQC 3.3.8. for these two lung fluid systems with single uranium mineral phase. The results demonstrate differences in the extent of uranium dissolution depending on the parent material. Therefore, uranium mineralogy may play an important role in leaching inside the lungs and in subsequent complexation, potentially influencing any resultant health impact.

MINERALOGICAL AND KINETIC CONSIDERATIONS FOR IN-SITU RECOVERY OF URANIUM FROM NEW MEXICO DEPOSITS

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Though dormant, the world-class Grants Uranium District in northwestern New Mexico remains a highly attractive prospect for development and academic research. Estimated remaining uranium resources in the District likely exceed what was mined in the entire state 1947-2002 (340 million lbs uranium oxide), which generated $4.7 billion in revenue. A form of uranium mining, alkaline in situ recovery (ISR), may be a candidate for exploiting the remaining and vast reserves of uranium in New Mexico.

Alkaline ISR is “solution mining”, where an array of injection and extraction wells circulate a chemical lixiviant to leach uranium from a water saturated ore body. ISR has emerged as the most desirable method of uranium recovery as it has distinct economic and environmental advantages over underground and open pit operations. However, unlike an operation where the ore is physically excavated for processing, ISR is a “blind” process, and the deposit mineralogy can confound leaching efforts in unexpected ways. If ISR is to be economically viable in New Mexico, it is important to gain an understanding of how mineralogy affects leaching. Here, we detail a study seeking to link detailed mineralogical and chemical characterization of mineralized Grants Uranium District materials to their amenability to alkaline leaching via micro-scale batch tests.

INVENTORY AND CHARACTERIZATION OF INACTIVE/ABANDONED MINE (AML) FEATURES IN NEW MEXICO

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Abandoned mine lands (AML) are lands that were mined and left unreclaimed where no individual or company has reclamation responsibility and there is no closure plan in effect. These may consist of excavations, either caved-in or sealed, that have been deserted and where further mining is not intended in the future. The New Mexico Bureau of Geology and Mineral Resources (NMBGMR) and the Mineral Engineering Department at New Mexico Tech in cooperation with the New Mexico AML program is conducting research to develop a better procedure to inventory and characterize legacy, inactive, or abandoned mine features in New Mexico. Fieldwork involves completion of mine inventory forms which detail location, lithology, feature condition, vegetation, and potential environmental and physical hazards. The results of this study will prioritize the mine features in selected mining districts in New Mexico for safeguarding and remediation. Some sites have the potential to contaminate surface water, groundwater and air quality. Heavy metals in mine waste or tailings and acid mine drainage can potentially impact water quality and human health. Laboratory work on these samples includes geochemistry from a professional lab as well as in-house petrography, X-ray diffraction, electron microprobe, paste pH, and particle size analysis.

SPECIATION AND REACTIVITY OF URANIUM AND ORGANIC MATTER IN ABANDONED MINE WASTES FROM LAGUNA- NEW MEXICO

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We applied spectroscopy, microscopy, and water chemistry techniques to investigate the speciation and reactivity of organic matter on uranium (U) binding from abandoned U mine waste from the Jackpile Mine in Laguna Pueblo, New Mexico. Preliminary studies using fixed angle X-ray fluorescence (XRF) analysis show 3.14% carbon (C). Results from microprobe mapping suggest that uranium particles are surrounded by carbon inclusions. We hypothesize that the presence of carbon in the mine waste influences the uranium binding and therefore its release to the environment. Loss on ignition (LOI) analysis showed that 12.98±0.25% mass was lost. The change on mass after the LOI might be due to the loss of organic content of the samples. Analyses with X-ray photoelectron spectroscopy (XPS) show changes on the carbon binding after the LOI experiments and the oxidation of U (IV) to U(VI). The mean concentration of acid extractable for mine waste was 0.54±0.1% U before LOI and 0.64±0.01% U after LOI. Basic Extractions of the Particulate Organic Matter (BEPOM) and Excitation Emission Matrix (EMM) show the presence of humic and fulvic-like groups in the mine waste. Findings from this study are relevant to identify how the binding of U and C in mine wastes can influence U mobilization in order to inform risk assessment and reduction strategies.

BIOGRAPHIES OF PARTICIPANTS

William Auby is the State Program Lead for the Mining Law program and the Abandoned Mine Lands program for Bureau of Land Management New Mexico. His primary responsibility is oversight of mine permitting, compliance, and reclamation of hard-rock mining on public lands as well as discovery, evaluation, safeguarding and environmental clean-up of abandoned mines. In his 27 years with BLM, he has been involved in a wide variety of public lands mineral issues. Bill served as Project Manager for the environmental clean-up of an abandoned metal mine near Tucson, Arizona. More recently he completed the clean-up of legacy uranium mines near Grants, New Mexico. He has a Master's Degree in Geology from Northern Illinois University. After graduation, Bill worked in the petroleum industry as a mudlogger in the Permian Basin and an exploration geologist for Gold Fields Mining Corporation. He first started working for BLM in Phoenix District and then in the Tucson Field Office.

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Bonnie Frey has been a geochemist with the New Mexico Bureau of Geology and Mineral Resources for more than 10 years. She received a master's degree from New Mexico Institute of Mining and Technology studying mantle sources of basalts using rare earth elements and high-field-strength elements. After completion of her degree, she studied dissolution of depleted uranium (DU) munitions at Yuma Proving Grounds and phytoremediation of a DU firing range in New Mexico with colleagues at New Mexico State University, New Mexico Institute of Mining and Technology, and the Army Corps of Engineers. Since then she has run an analytical laboratory for the Bureau of Geology, working with colleagues from more than nine departments on the New Mexico Institute of Mining and Technology campus. This multi-discipline experience served her well as she became the co-lead of the uranium transport research team, which is a component of the 5-year New Mexico EPSCoR Energize New Mexico project, an NSF-funded program. Bonnie and other members of this research team have organized a workshop, also funded by NM EPSCoR, to investigate the extraction of critical materials from mine wastes, a topic that team members realized was of mutual interest. Bonnie is the moderator for this workshop, Making Abandoned Mine Lands Profitable.

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Don Miller is a 4th Generation mining family. He is a Senior Management Executive, holding Senior Management and Officer positions for seven mining companies. With over 35 years of direct experience with various natural resources companies, Don’s expertise includes mine operations, organizational and operational optimization, development of new properties, reorganizations, culture and change management, and International merger and acquisition due diligence. Don worked for major corporations, including, Getchell Gold Corporation, Newmont Mining/Gold Companies, and Cyprus Coal and Cyprus Minerals Companies. He has worked in nine countries in The Americas, Australia and Indonesia. His background includes working in gold, platinum/palladium, garnet, turquoise, copper, molybdenum, silver, lead, zinc, uranium, coal, lithium, talc, and iron ore. Don is Principal of GEM 2025 Group, an International consulting firm with a focus on The Americas. He has developed and implemented programs in operational optimization, privatization of nationally-held industries, mergers and acquisitions support teams; and conducted global organizational effectiveness reviews and audits. Don and his family successfully designed, built and operated the first all-natural garment care and dry cleaning plant in the Western United States. Company was profitable in eight months and sold within four years to a major competitor in the industry. Don received numerous ECO awards for its environmentally-friendly cleaning system. Don holds an M.B.A. from the University of Phoenix, is a graduate of the Executive Management and Human Resources Program at Penn State University, and received his B.S. Degree in Business (Industrial Relations Major) from the University of Arizona. Don speaks fluent Spanish and is a cultural expert on several Latin America countries. Co-Founder and Director, Americas Tailings, Don has been a leader in developing an innovative processing and remediation company (formerly Metallum Novus) which secures and processes tailings for precious and strategic metals. The Earth-Friendly resource company is focused on securing rights to develop historical tailings sites in the Western U.S. and, by applying modern, commercially-viable, environmentally-friendly processing technologies, reprocessing and extracting the metals value, remediating the tailings sites, and revitalizing the treated dirt to convert into topsoil.

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Bob Newcomer is an environmental and water resources consultant with nearly 40 years of professional experience. He is currently Principal of Toltec Mesa Resources LLC in Albuquerque, NM. Over his career he has worked for several consulting firms (Golder Associates, Tetra Tech, Daniel B. Stephens and Associates and John Shomaker and Associates) in Albuquerque, NM. Early in his career he was a minerals exploration geologist with Freeport Exploration in Tucson, AZ and Denver, CO. He holds master’s degree in Geology from New Mexico State University and a bachelor’s degree in Geology from Northern Arizona University. He also completed additional graduate work in hydrogeology at the University of Arizona and geochemistry at Pennsylvania State University. He is a registered geologist in Arizona, California, and Texas and a Certified Professional Geologist by the American Institute of Professional Geologists. He has several decades of experience working with the mining industry to support their permitting, environmental compliance, closure and reclamation needs. He also has experience with abandoned mine lands, having worked on projects for the New Mexico Mining and Minerals Division, the USDA Forest Service, Army Corps of Engineers RAMS Program and several private clients. Bob is a presenter for this workshop, Making Abandoned Mine Lands Profitable.

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Dr. Juan de Dios Pineda has been bestowed Doctor Honoris Causa for Tianjin Foreign Studies University, China, on December 2015 for his contributions in the area of public policy and international education. In 2014, the University of Santander in Mexico conferred to Juan the title of Doctor Honoris Causa for his research in the area of Higher Education. In 2012, Juan was appointed as a member of Academic Committee of China Ministry of Education's National Research-Latin American Research Center. He is the author or principal editor of seventeen books. His last two books about "Teacher´s Professionalization in Mexico" and "Comparing Higher Education in China, United States, and Mexico" were translated and published into Mandarin in 2015. He received his Ph.D. in Education from the University of New Mexico in 2007. He is a visiting professor at the University of Puebla, Mexico, and Tianjin Foreign Studies University. Currently, Dr. Pineda is the Special Assistant to the VP for Research and Economic Development at New Mexico Institute of Mining and Technology and director of New Mexico Institute of Mining and Technology Latin American Initiatives Office. Previously, Juan was the Director of the Center for Water Governance and Public Policy and Research Professor at the University of New Mexico.

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For the last 13 years, **Jeronimus van Nes** has been working in areas related to mine engineering including mine planning, ore control, slope stability, projects, feasibility studies, etc. He received a Master's degree in Geological Engineering from Delft University of Technology in the Netherlands and a second Master's in Mining Engineering from Colorado School of Mines. After completion of his degree, he worked at the FMI Safford, Morenci, and Tyrone Mines as a Mine Engineer and managed short range and long-range projects relating to the mineplan. Jeronimus is currently the Chief Mine Engineer at the Tyrone and is mainly focusing on identifying and implementing opportunities to extend the mine-life of the site.

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