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

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INTRODUCTION

New Mexico's mineral wealth is among the richest of any state in the U.S. In 2015, New Mexico ranked 10th in coal production, 2nd in copper production, and 20th in total nonfuel minerals production (McLemore, 2017). Most of the state's production comes from oil, gas, coal, copper, potash, industrial minerals (potash, perlite, cement, zeolites, etc.) and aggregates. Other important commodities include molybdenum, gold, uranium, and silver. However, legacy issues of past mining activities forms negative public perceptions of mining, and inhibits future minerals production in the state. Some legacy mines have the potential to contaminate the environment; the Gold King uncontrolled release into the Animas River is a recent example. At the time the General Mining Law of 1872 was written, there was no recognition of the environmental consequences of discharge of mine and mill wastes or the impact on drinking water, and riparian and aquatic habitats. Miners operating on federal lands had little or no requirement for environmental protection until the 1960s-1970s, although the dumping of mine wastes and mill tailings directly into rivers was halted by an Executive Order in 1935. It is important to recognize that these early miners were not breaking any laws, because there were no laws to break, but legacy issues still exist.

The New Mexico Bureau of Geology and Mineral Resources (NMBGMR) has been examining the environmental effects of mine waste rock piles and tailings throughout New Mexico since the early 1990s (http://geoinfo.nmt.edu/staff/mclemore/projects/environment/home.html). There are tens of thousands of inactive or abandoned mine features in 274 mining districts in New Mexico (McLemore, 2017; including coal, uranium, metals, and industrial minerals districts), however many of them have not been inventoried or prioritized for reclamation. The New Mexico Abandoned Mine Lands (AML) Bureau of the New Mexico Mining and Minerals Division (NMMMD) estimates that there are more than 15,000 abandoned mine features in the state (http://www.emnrd.state.nm.us/MMD/AML/amlmain.html). The U.S. Bureau of Land Management (BLM) recently estimated that more than 10,000 mine features are on BLM lands in New Mexico and only 705 sites have been reclaimed (http://www.blm.gov/wo/st/en/prog/more/Abandoned_Mine_Lands/abandoned_mine_site.html). The New Mexico AML Program has safeguarded over 2,300 mine openings since inception in 1981 in about 250 separate construction projects (some of which were focused on coal gob reclamation and not safeguarding). The BLM, U.S. Forest Service, and many private mining companies have also reclaimed some of these mine features.

The NMBGMR has collected published and unpublished data on the districts, mines, deposits, occurrences, and mills since it was created in 1927 and is slowly converting historical data into a relational database, the New Mexico Mines Database (McLemore et al., 2005a, b). More than 8,000 mines are recorded in the New Mexico Mines Database and more than 7,000 are inactive or abandoned. These mines generally include two or more actual mine features.

Most of these mine features do not pose any physical or environmental hazard and many more, pose only a physical hazard, which is easily but costly to remediate. But a complete inventory of these features is needed. Some of these inactive or abandoned mine features can pose serious health, safety and/or environmental hazards, such as open shafts and adits (some concealed by deterioration or vegetative growth), tunnels and drifts that contain deadly gases, highwalls, encounters with wild animals, radon and metal-laden waters. Other sites have the potential to contaminate surface water, groundwater and air quality. Heavy metals in mine waste piles, tailings and acid mine drainage can potentially impact water quality and human health.

Many state and federal agencies and mining companies have mitigated many of the physical safety hazards by closing some of these mine features, but very few of these reclamation efforts have examined the long-term environmental effects. There is still potential for environmental effects long after remediation of the physical hazards, as found in several areas in New Mexico (for example Terrero, Jackpile and Questa mines). Some of these observations only come from detailed geochemical and electron microprobe studies that are not part of a remediation effort.

The NMBGMR in cooperation with the Mineral Engineering Department at New Mexico Tech and the NMAML program is conducting research on legacy mine features in New Mexico. The objective of our research is to develop a better procedure to inventory and characterize legacy, inactive or abandoned mine features in New Mexico. This project will inventory, characterize, and prioritize for remediation the mine features in three mining districts in New Mexico: the Jicarilla Mountains district in Lincoln County and the North Magdalena and Rosedale districts in Socorro County for the N MAML Program. Additional mining districts in Socorro County are being examined as well. The project involves field examination of the mines features and collecting data on the mine features (Bureau of Land Management, 2014). 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. Not only will samples be collected for geochemical and geotechnical characterization, but the mine features will be mapped, evaluated for future mineral-resource potential, and evaluated for slope stability.

WHAT ARE ABANDONED MINE LANDS (AML)?

Lands that were mined and left unreclaimed where no individual or company has reclamation responsibility. These may consist of excavations, either caved in or sealed, that have been deserted and where further mining is not intended. Also called inactive, legacy and orphaned mines.

PURPOSE OF NMBGMR AML PROJECT

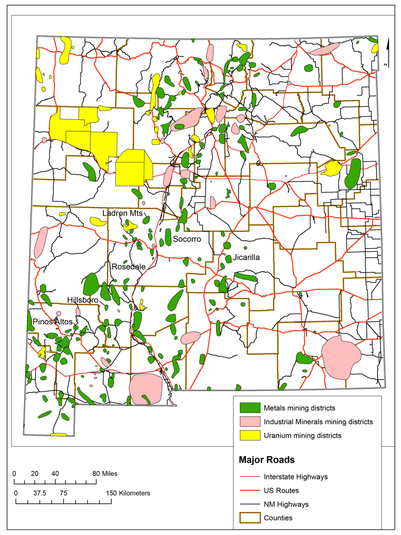
To develop a relatively quick and inexpensive procedure to inventory and characterize AML (legacy) mines
Characterize existing waste rock piles for backfill material
Determine if there is potential for leaching metals or acid drainage from waste materials
Provide data on mining districts, mines, and mills in New Mexico

- Help plan and assess reclamation procedures
- Determine background concentrations
- Understand geologic processes
- Compare trace-element concentrations in mined versus undisturbed areas
- Provide background data that can assist with the planning of future mining operations

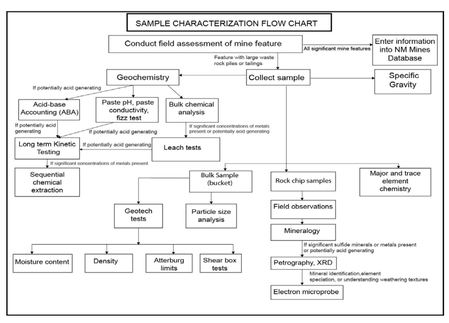
To make informed decisions about

- Economic impacts
- Resource development and management (mineral-resource potential)
- Impacts on water supplies
- Impacts on land use
- Environmental impacts, including potential sources of AD (acid drainage) or other MIW (mine influenced waters)
- Physical hazard assessment and remediation

MINING DISTRICTS



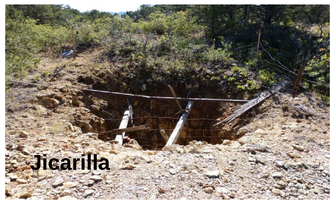
SAMPLE CHARACTERIZATION FLOW CHART

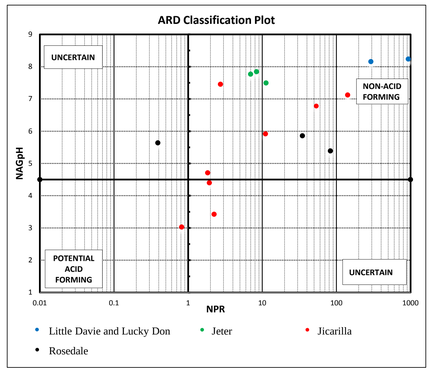


POTENTIAL FOR ACID DRAINAGE

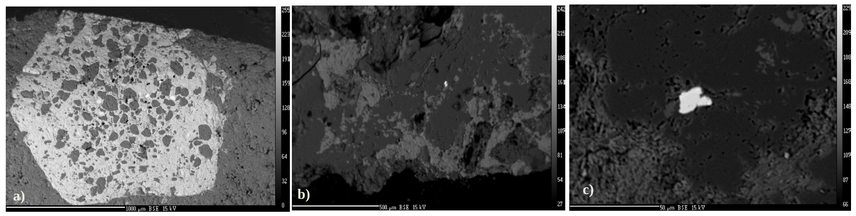
Acid Rock Drainage (ARD) classification plot of composite waste rock pile samples from various districts. Little Davie, Lucky Don (Socorro district), Jeter (Ladron Mountains district), and Rosedale district samples are in Socorro County. Jicarilla district is in Lincoln County.

INVENTORY AND FIELD SAMPLING

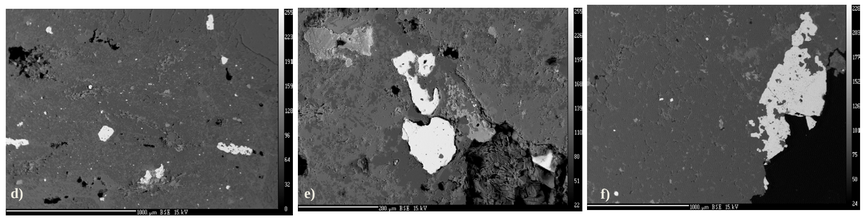




ELECTRON MICROPROBE ANALYSES BACKSCATTERED ELECTRON (BSE) IMAGES OF SAMPLES



Figures a) Backscattered electron images of quartz grain replacing Fe-oxide in sample Jic410. This is likely supergene replacement.
b) Backscattered electron images of Fe-oxide grain in sample Jic412. Note how altered and pitted the grain is as a result of weathering.
c) Backscattered electron images of pyrite grain in sample Jic412. Note how pristine the pyrite grain is.



Figures d, e, f) Backscattered electron microprobe images of pyrite and Fe-oxide grains distributed in sample Jic802. Note how pristine the pyrite is in Figure d, but pitted in Figures e and f.

ELECTRON MICROPROBE ANALYSES

Grab samples from waste rock piles were mounted in epoxy and polished. These polish sections are then coated with carbon and analyzed using the electron microprobe. Quantitative and qualitative analyses were used to determine textures and chemical composition of the minerals.

Chemical analyses of pyrite grains in samples from Jicarilla waste rock piles

Sample Number	S (%)	Fe (%)	Cu (%)	As (%)
Gold Stain A-01	53.07	47.36	0.08	0.03
Gold Stain A-02	33.63	31.11	32.90	0.02
Gold Stain A-03	54.67	45.84	0.03	0.02
Gold Stain B-01	52.56	47.50	0.01	0.02
Gold Stain B-02	52.52	47.59	0.01	0.02
Gold Stain B-03	52.68	47.09	0.02	0.03
Jic413 A-01	53.69	47.39	0	0.02
Jic413 A-02	53.02	47.47	0	0.03

PRELIMINARY CONCLUSIONS

- Primary igneous crystallization, pre-mining hydrothermal alteration and weathering, and post-mining blasting, hauling, dumping, and emplacement into the rock pile and subsequent weathering affect the composition of the waste materials.
- Pyrite grains are found in some waste rock piles; quantitative analyses of some samples indicate arsenic (As) percentages between 0.02-5%. Pitted textures observed in microprobe analyses are consistent with arsenic being leached from pyrite.
- Although the uranium mines (Lucky Don, Little Davie, and Jeter) show high radioactivity (up to 100 times background) and locally >100 ppm U, these samples do not have any ARD potential.
- Some samples from the gold mines from the Jicarilla district indicate potential ARD.

ACKNOWLEDGEMENTS

This report is part of on-going studies of mineral resources in New Mexico, supported by the New Mexico Bureau of Geology and Mineral Resources (NMBGMR), Nelia Dunbar, Director and State Geologist. Funding for this project is from

- New Mexico Bureau of Geology and Mineral Resources (NMBGMR)
- Energy Minerals and Natural Resources Department and the U.S. Department of the Interior, Office of Surface Mining and Reclamation (OSMRE)
- Mineral Engineering Department of NMIMT
- New Mexico Geological Society
- New Mexico EPSCoR (funded by the National Science Foundation award #IIA-1301346)

Bonnie Frey assisted with the paste pH analyses and EPSCoR funding. Kelsey McNamara assisted with the XRD analyses and Lynn Heizler assisted with the electron microprobe analyses. Mark Mansell set up the GIS project. Amy Trivitt provided database and mining archives archives support. William Zuta, Navid Mojtabai, Ingar Walder, Bonn Ducia, John Ducia and Ashlynne Winton assisted in the field and with laboratory analyses. The Cameca SX-100 electron microprobe at NMIMT was partially funded by NSF Grant STI-9413900.

REFERENCES

Bureau of Land Management, 2014, Abandoned Mine Land Inventory Study for BLM-Managed Lands in California, Nevada, and Utah: Site and Feature Analysis: Department of the Interior, Bureau of Land Management, National Operations Center, Denver, CO., 24 p., http://www.blm.gov/pgdata/etc/medialib/blm/wo/blm_library/BLM_pubs.Par.79469.File.dat/BLM-AML-Inventory-CA-NV-UT_Nov2014.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., Hoffman, G., Smith, M., Mansell, M., and Wilks, M., 2005a, Mining districts of New Mexico: New Mexico Bureau of Mines and Mineral Resources, OF-494, CD-ROM.

McLemore, V.T., Krueger, C.B., Johnson, P., Raugust, J.S., Jones, G.E., Hoffman, G.K. and Wilks, M., 2005b, New Mexico Mines Database: Mining Engineering, February, p. 42-47.