MINERALOGY AND CHEMISTRY OF MINE WASTE ROCK PILES IN MINING DISTRICTS IN SOUTHERN COLORADO AND NEW MEXICO

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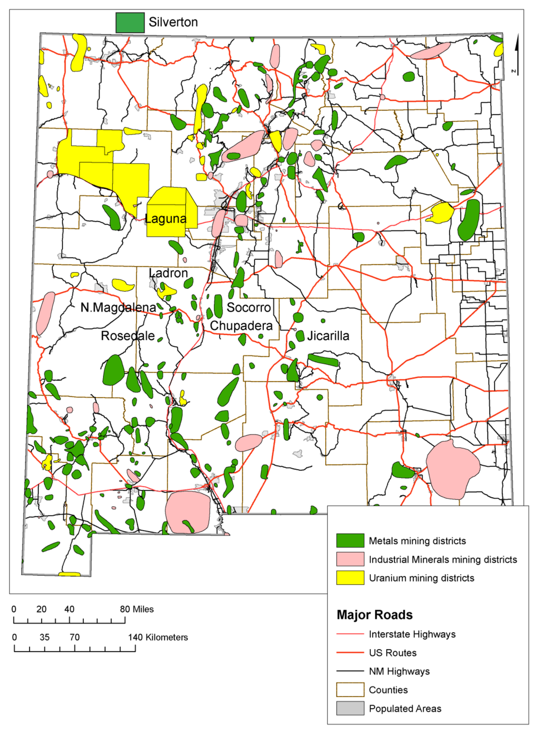
ABSTRACT

Legacy issues of past mining activities forms negative public perceptions of mining, and inhibits future minerals production in the state. There are tens of thousands of inactive or abandoned mine features in mining districts in New Mexico and southern Colorado (including coal, uranium, metals, and industrial minerals districts), however many of them have not been inventoried or prioritized for reclamation. Abandoned Mine Lands (AML) are areas that were mined and left unreclaimed where no individual or company has reclamation responsibility (also called inactive, legacy and orphaned mines). These may consist of excavations that have been deserted and where further mining is not intended. Most of these mine features do not pose any physical or environmental hazard and others, pose only a physical hazard, which is easily but costly to remediate. But a complete inventory of these features is needed. Some of these 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 safe guarding 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 and mines in the Silverton, Colorado area).

The NMBGMR in cooperation with the Mineral Engineering Department at New Mexico Institute of Mining and Technology, EPSCoR and the NM AML program is conducting research on legacy mine features in New Mexico and southern Colorado. The project involves field examination of the mine features and collecting data on the mine features. 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 are samples collected for geochemical and geotechnical characterization, but the mine features are being mapped, evaluated for future mineral-resource potential, and evaluated for slope stability.

Some waste rock piles and tailings could be potential resources for critical minerals and other commodities needed for U.S. technologies. 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 hazards. Some of the critical minerals identify recently by the U.S. Department of Interior are found in some of the existing mining districts, including legacy mines. Most of the waste rock piles surrounding the mine features are suitable for backfill material in areas of remediation.

Mining Districts Studied



INTRODUCTION

The New Mexico Bureau of Geology and Mineral Resources (NMBGMR) has been examining the mineral-resource potential and environmental effects of mine waste rock piles and tailings throughout New Mexico since the early 1970s (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) Program of the New Mexico Energy, Minerals, and Natural Resources Department, Mining and Minerals Division (EMNRD MMD) 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 New Mexico AML Program estimates they have safe guarded approximately 2,600 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 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 U.S. Park Service has identified 71 mine features in 7 parks in New Mexico, of which 12 have been mitigated and 34 require mitigation (https://www.nps.gov/subjects/abandonedminerallands/upload/NPS_AMLinv-2013-1231-2.pdf). Additional sites have been reclaimed by the responsible companies and the Superfund program (CERCLA). Data in the NMBGMR mining archives suggest that these numbers are minimal conservative estimates of the actual number of unreclaimed mine features in the state.

WHAT ARE ABANDONED MINE LANDS (AML)?

A mine (or mine feature) is any opening or excavation in the ground for extracting minerals, even if no actual mineral production occurred. Abandoned Mine Lands (AML) are areas that were excavated, 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 near future. AML includes mines and mine features left unreclaimed on land administered by Federal, State, private, and Native Americans 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.

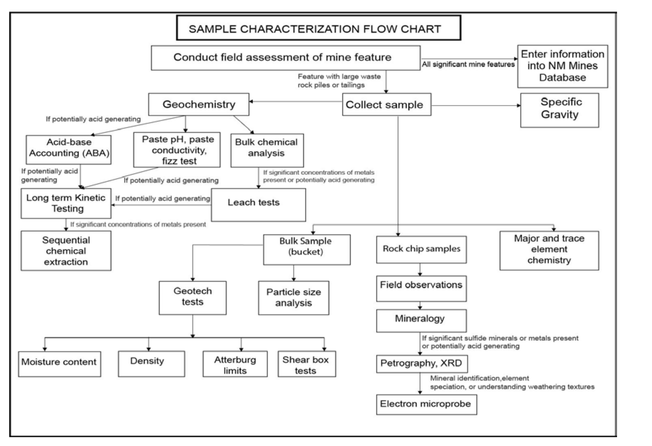
WHY STUDY AML DISTRICTS?

- History of mining districts
- Mineral collecting
  - o Identification of minerals
- Potential environmental issues
  - o Physical hazards
  - o Acid rock drainage and high metal concentrations
  - o Water quality
- Mineral-resource potential
  - o Are there any minerals or other commodities left to mine today or in the future?
- **Understanding geologic processes**

PROCEDURE

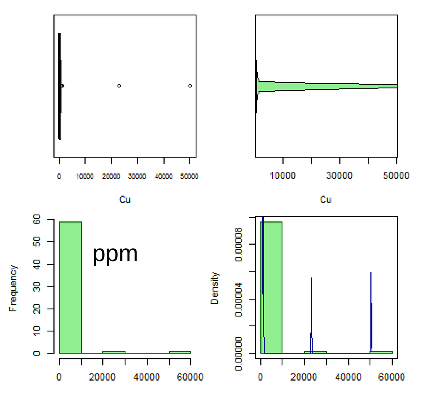
- Inventory the mines and mine features
  - o History of the site (production, commodities, mining methods, processing facilities)
- Preliminary characterization
  - o Paste pH, mineralogy, chemistry, stability, particle size
- Prioritize mine features for additional
- Petrography, mineralogy, and chemistry
  - o Microscope examination
  - o XRD (X-Ray Diffraction)
  - o Electron microprobe
  - o Chemical analyses of minerals
  - o Whole rock geochemistry
- ABA/NAG (acid base accounting/net acid generation) tests, paste pH
- Particle size analyses
- Hazard ranking
- Evaluation of mineral-resource potential

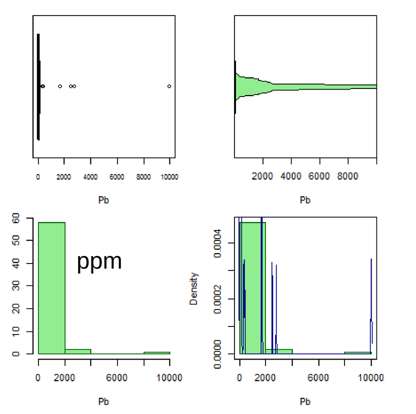
SAMPLING

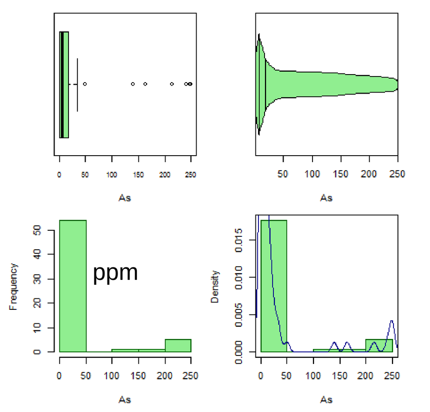


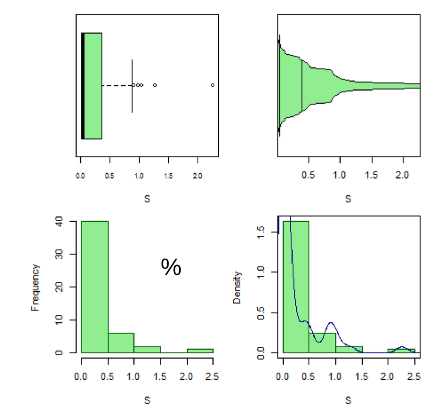
RESULTS

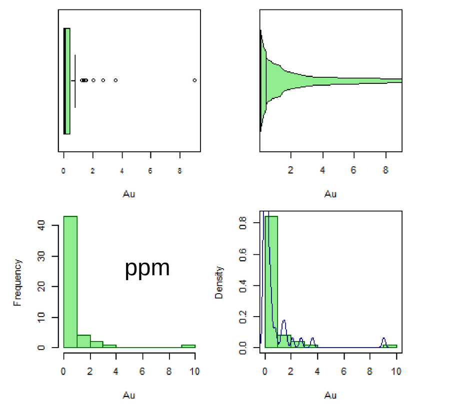
SAMPLE	paste pH	CaO	Fe2O3 T	MnO	S	C	As	Au	Ag	Cu	Pb	Sb	U	V	Zn
		%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
average in soils (USGS PP1270)					0.16	2.5	7			25	19	0.66	2.7	80	60
all samples, n=61															
avg	5.92	3.13	4.61	0.15	0.27	0.86	32.82	0.58	45.93	1379.69	349.11	15.75	47.92	119.72	335.82
std dev	1.38	5.90	3.61	0.23	0.45	1.70	68.56	1.42	108.75	7035.31	1370.42	39.30	154.01	194.73	1238.15
min	2.8	0.09	0.95	0.01	0.01	0	0.4	0.001	0.5	2	3	0.06	1.43	7	12
max	8.24	35.3	19.48	1.3	2.26	10	250	9.03	530	50400	10000	250	1000	1280	8480
Silverton, Colo, n=4															
avg	3.73	1.16	7.36	0.40	1.21	0.31	200.88	0.90	51.58	509.50	4242.50	93.20	4.92	126.25	2504.25
std dev	1.60	1.52	1.21	0.25	0.74	0.12	57.60	0.75	42.33	159.75	3866.31	106.12	1.98	8.81	3986.53
min	2.8	0.2	5.79	0.14	0.53	0.2	139.5	0.104	2.8	347	1690	15.6	3.07	119	308
max	6.12	3.43	8.34	0.61	2.26	0.4	250	1.585	100	698	10000	250	7.07	138	8480
St. Anthony, Laguna, n=3															
avg	6.21	5.704	4.434	0.07	0.234	1.3	10.5	0.0075	3.95	537.2	27.6	1.55	219.7	202.8	85.6
std dev	0.579828	7.279	2.553	0.07	0.38	1.6	13.309	0.0035	0.3536	724.974	10.9225	1.5161	247	146.6	58.308
min	5.8	0.11	1.52	0.02	0.04	0.1	2.4	0.005	3.7	6	18	0.24	1.68	87	17
max	6.62	13.75	6.99	0.14	0.91	3.1	34	0.01	4.2	1390	40	3.25	549	459	141
North Magdalena, n=5															
avg		10.46	8.502	0.17	0.472	2.3	62.2	1.883	157.18	15441.8	499.6	25.352	5.92	253.6	1294.8
std dev		4.457	3.622	0.04	0.569	1	104.25	3.9967	224.5	21740.5	692.704	46.52	7.646	183.6	2061.1
min		2.84	5.79	0.14	0.04	0.6	6.5	0.005	3.7	949	39	3.13	1.68	132	136
max		13.75	14.83	0.22	1.27	3.1	248	9.03	530	50400	1705	108.5	19.5	566	4940
Rosedale, n=20															
avg	5.881667	0.296	1.477	0.22	0.011	0.3	14.21	0.5337	14.264	11.9	40.95	20.309	5.539	12.75	62.9
std dev	0.472805	0.216	0.342	0.36	0.003	0.4	8.0164	1.0241	22.415	12.1391	29.3911	29.9	1.231	4.529	25.16
min	4.92	0.09	0.95	0.03	0.01	0	2.9	0.001	0.5	2	22	0.57	3.7	7	36
max	6.67	0.97	2.3	1.3	0.02	2.1	34.6	3.61	72.7	47	119	126	8.15	23	121
Chupadera, Socorro, n=3															
avg	8.20	18.83	2.22	0.08	0.19	5.48	168.67	0.01		12.67	71.67	8.43	429.00	766.67	391.00
std dev	0.06	16.48	1.44	0.07	0.25	4.96	103.59	0.00		4.73	13.05	7.45	494.79	447.71	98.96
min	8.16	2.34	1.1	0.01	0.03	0.5	50	0.003	0	9	57	2.02	126.5	457	298
max	8.24	35.3	3.85	0.15	0.48	10	241	0.007	0	18	82	16.6	1000	1280	495
Jeter, n=4															
avg	7.71	1.14	3.78	0.15	0.10	0.29	5.03	0.02	0.70	294.50	73.00	0.40	83.85	107.75	148.50
std dev	0.18	0.98	0.77	0.06	0.09	0.31	2.61			174.80	48.63	0.36	47.76	38.53	42.59
min	7.5	0.4	2.85	0.08	0.05	0.1	1.4	0.015	0.7	128	39	0.09	23.7	74	96
max	7.85	2.58	4.55	0.22	0.24	0.8	7.5	0.015	0.7	537	143	0.91	138	163	200
Jicarilla, n=21															
avg	5.84	2.98	6.79	0.06	0.19	0.72	1.73	0.31	0.80	156.09	20.14	0.52	2.07	83.05	37.18
std dev	1.48	3.32	3.61	0.03	0.29	1.21	2.37	0.44	0.14	208.27	15.84	1.03	0.55	22.93	28.66
min	3.03	0.44	3.52	0.02	0.01	0.2	0.4	0.007	0.7	3	3	0.06	1.43	36	12
max	7.46	15.2	19.48	0.12	0.87	6	10.9	1.4	0.9	707	71	3.39	3.6	136	157



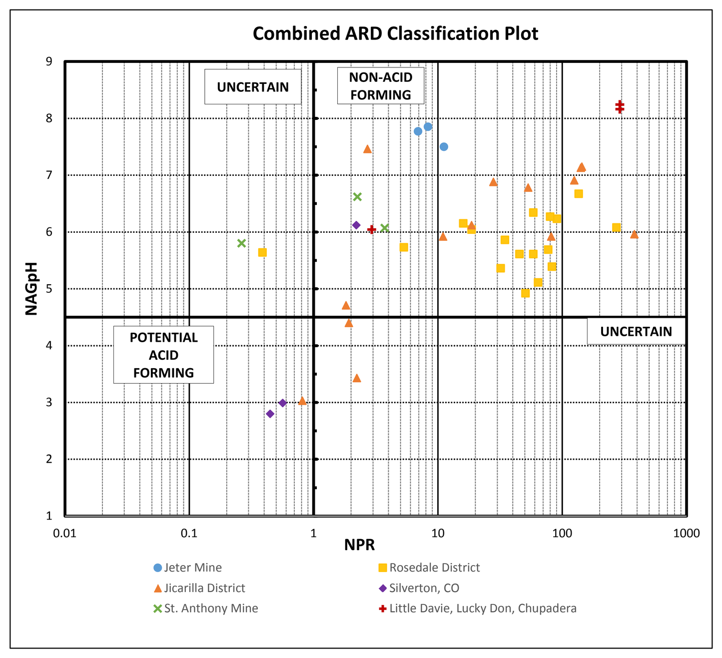




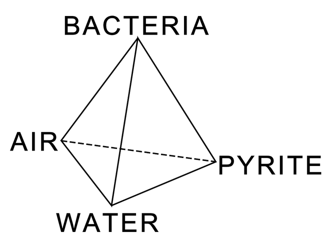




POTENTIAL FOR ACID ROCK GENERATION



The dissolution of pyrite during weathering is the predominant chemical reaction that results in potential acid forming rocks.



$$AP = S(\%) \times 31.25$$
$$NP = C(\%) \times 83.3$$
$$NNP = NP - AP$$
$$NPR = \frac{NP}{AP}$$

Acid Potential (AP)
Neutralization Potential (NP)
Net Neutralization Potential (NNP)
Net Potential Ratio (NPR)

MINERAL-RESOURCE POTENTIAL

There is very high potential for placer gold deposits in the Jicarilla district, high potential for lode gold in the Rosedale district and very high potential for uranium in the Laguna subdistrict of the Grants uranium district.

PRELIMINARY CONCLUSIONS

- Many mines, waste rock piles, tailings, and heap leach facilities examined are safe and have remained stable with little or no environmental impacts
- Reclamation has occurred at a few sites; monitoring for potential erosion is recommended
- However, a few sites examined have potential to generate acid drainage and additional sites are physically dangerous and require proper safe guarding
- Most of the waste rock piles surrounding the mine features are suitable for backfill material
- Weathering is the major geologic process involved
- Some areas have high potential for future mineral resources

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