Geochemistry of critical minerals in mine wastes at Hillsboro and Steeple Rock, New Mexico

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ABSTRACT

There are tens of thousands of inactive or abandoned mine features in 274 mining districts in New Mexico (NM) (including coal, uranium, metals, and industrial minerals districts) with about 15,000 abandoned legacy mine features varying from shallow prospect pits to deep mine shafts in the state. There is a need to classify these wastes or "abandoned deposits" to understand their composition, properly estimates the quantity and evaluate the potential economic value. Since most of the earlier operations and exploitation was focused on heavy metals, it would be good to now turn our attention to examine these wastes for potential critical minerals. Hence this project seeks to 1) characterize and estimate the critical mineral endowment of mine wastes in three mining districts in New Mexico (Copper Flat at Hillsboro, Black Hawk in Burro Mountains, and Carlisle-Center mines in Steeple Rock district) and 2) "beta-test" USGS procedures and provide feedback. Potential critical minerals at these deposits include As, Bi, Te, Zn, Co, Ni, Mg, Mn, and fluorite.

It is necessary to perform paste pH test and particle size analysis on samples collected since these factors can affect weathering and the migration of heavy metals. Also, acid rock drainage (ARD) is a huge concern for mine waste management and soil pH is an effective indicator for ARD. Paste Ph conducted on samples collected from the waste rock piles ranged from 3.66 to 5.67 and are mostly indicative of fine-grained pyrite or sulfide oxidation. The samples collected from the tailings however showed a slightly different pattern in pH, ranging from 6.30 to 8.62 probably due to the presence of carbonates. Difference in particle size fractions and its distribution along the slope are generally influenced by natural occurrences (e.g., gravity and pre-mining hydrothermal alteration) and operational activities such as material piling or dumping. This in turn also affects the general slope stability and possibly mineralogy distribution within the waste dump.

The benefits of this project are to ensure prospects for critical minerals in the New Mexico state are not lost to urbanization, settlement or other land use. This project would ensure that there are data and archived samples for future studies and advance research as these mine features may not be accessible after reclamation. Future mining of mine wastes that potentially contain critical minerals will directly benefit the economy of New Mexico. Possible re-mining of mine wastes could clean up these sites and pay for reclamation.

INTRODUCTION

Critical minerals are those that are essential to the nation's economic and national security. The majority of our electronic equipment, such as smartphones, laptops, computer chips, wind turbines, hybrid and electric cars, etc., depend on these rare earth elements (REE) and other critical minerals. This coupled with the anticipated rise in demand for critical minerals and the potential shortage of production capacity from China and other nations has made it necessary to examine and evaluate the NM mine wastes for its critical mineral and future mining potential. The NM Mines Database lists more than 9,000 mines, of which more than 7,000 are inactive or abandoned. While the actual mineral production was typically for precious and base metals rather than critical minerals, the majority of these mines have existed mine wastes that were generated during mineral production and may have potential for critical minerals. As a result, any essential minerals discovered in a mineral deposit would also be present in the mine wastes (mine waste dumps, tailings, etc.) Although the main focus of this project is the critical mineral endowment of mine wastes, we also intend to assess the stability of the mine features and typical environmental characteristics of the mine wastes (acid base accounting, pH, leaching tests, etc.), considering that these assessments are necessary to secure a safe working environment during mining, reclamation, and/or waste processing.

PURPOSE

- Determine the acid generating potential of mine waste in NM
- Characterize and estimate the critical minerals endowment of mine wastes in two mining districts in NM (i.e., Copper Flat at Hillsboro and Carlisle-Center mines in Steeple Rock district).
- "beta-test" USGS procedures for sampling mine wastes. Future mining of mine wastes that potentially contain critical minerals can help pay for reclamation and clean up these sites.

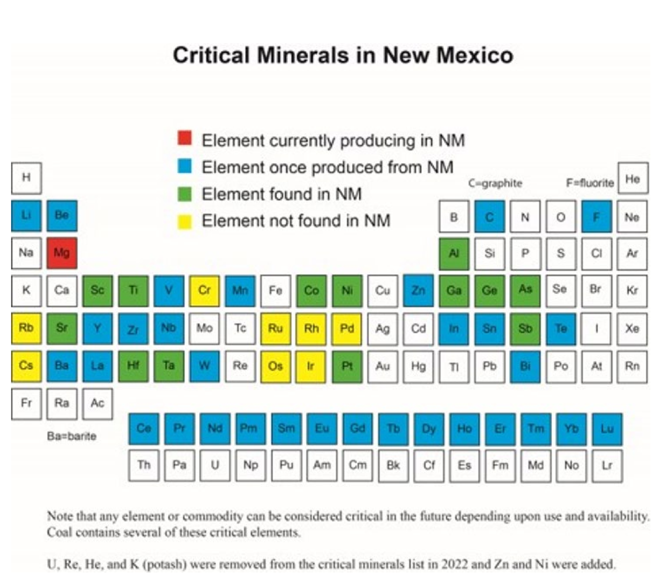


FIGURE 1: Critical minerals found in New Mexico

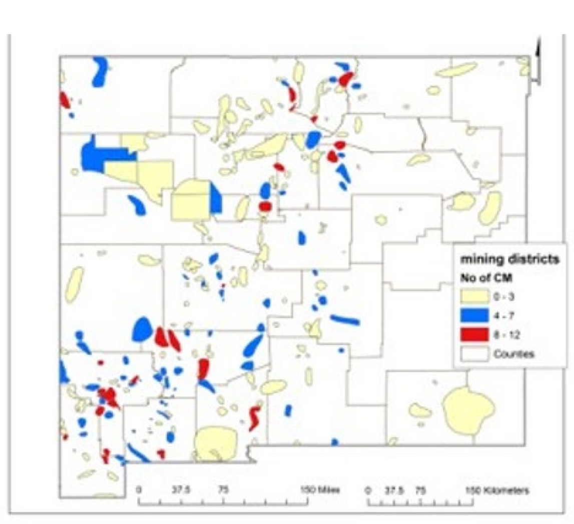


FIGURE 2: Mining districts in NM with critical minerals

FIGURE 3: Mine rock pile (left) and pit lake (right) at Copper Flat mine.

THE STUDY AREA

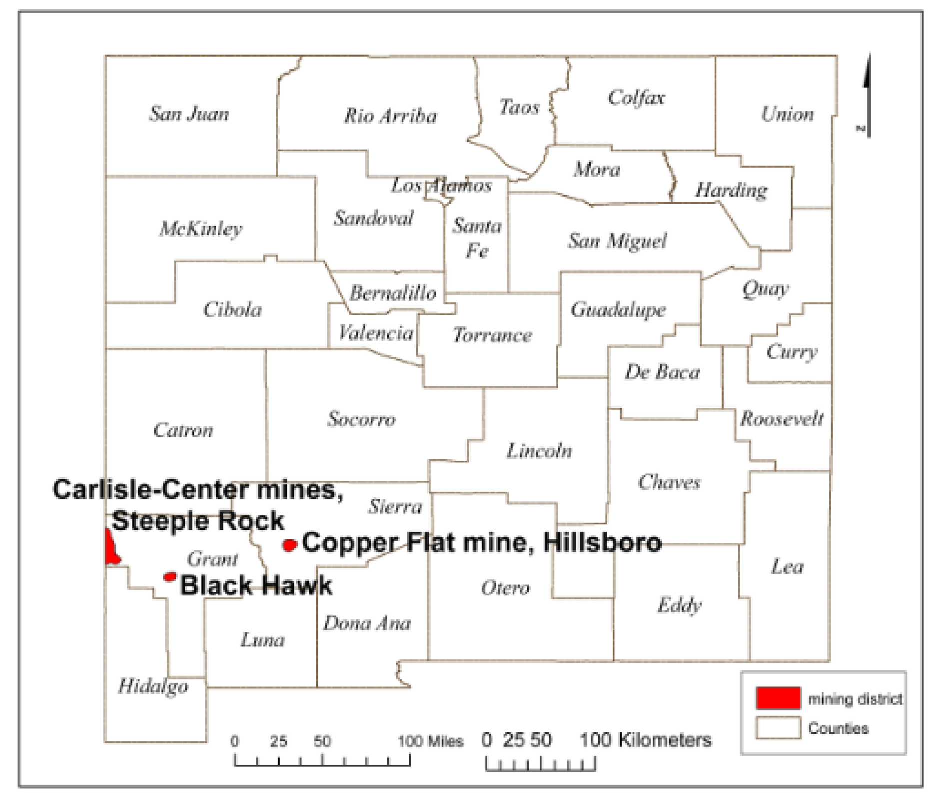


FIGURE 4: Location of the Copper Flat at Hillsboro, Black Hawk in Burro Mountains, and Carlisle-Center mine in Steeple Rock areas, southwestern NM.

TABLE 1. Shows location of mine sites (in decimal degrees, NAD27), prominent geologic features and known critical minerals

Mine Name	Carlisle-Center	Copper Flat
DISTRICT	Steeple Rock	Hillsboro
Latitude	32.852103, 32.8491178	32.968933
Longitude	-108.963512, -108.9600555	-107.533257
Prominent Geologic Features	This site has a volcanic-epithermal system with little sulfidation and has Au-Ag veins. There are also two groups of alteration assemblages: acid-pH (alunite, kaolinite, quartz, or acid-sulfate) and neutral-pH (propylitic to sericitic). Six different types of mineral deposits can be found in the district; base-metal (Ag, Au), Au-Ag (base metals), Cu-Ag, fluorite, Mn, and high-sulfidation disseminated Au deposits (McLemore, 1993, 1996, 2000).	The district's core is dominated by a quartz monzonite stock (74.930.66 Ma) with a breccia pipe, and latite dikes extend outward from it. Quartz veins with Cu, Au, Mo, and Ag disseminations make up the Copper Flat porphyry copper deposit. Many of the latite dikes are host to Laramide veins that radiate outward from the Copper Flat porphyry.
Known Critical Mineral	As, Bi, Te, fluorite and Zn	Te, As, Bi, Mg, Mn, and Zn
Mining History	Exploration in the district began about 1860, but it wasn't until 1880 that production occurred. Between 1880 and 1994, the district produced metals worth an estimated $10 million, primarily from the Carlisle and Center mines (McLemore, 1993).	In the town of Hillsboro, the first copper smelter was built in 1892. In the 1950s and 1960s, Bear Creek Mining Company and Newmont Mining Company conducted exploration. Additionally, the mine ran for three months in 1981. New Mexico Copper Corp. is applying for permits to begin mining.

METHODS

- The use of sampling techniques developed by USGS staff, the BLM (Bureau of Land Management, 2014), USGS, and EPA.
- Preparation of a Site Health and Safety Plan (HASP).
- General geologic mapping (GIS), sampling of waste and rock piles.
- Laboratory studies; Geochemistry, Petrography, Electron Microprobe analyses, XRD
- The use of geologic and geochemical data to determine potential of acid production within the wastes, estimation of the volumes and tonnages of waste and rock piles.
- Particle size analysis.

FIGURE 5: Sampling of waste rock pile (left) and tailings(right) at Hillsboro District

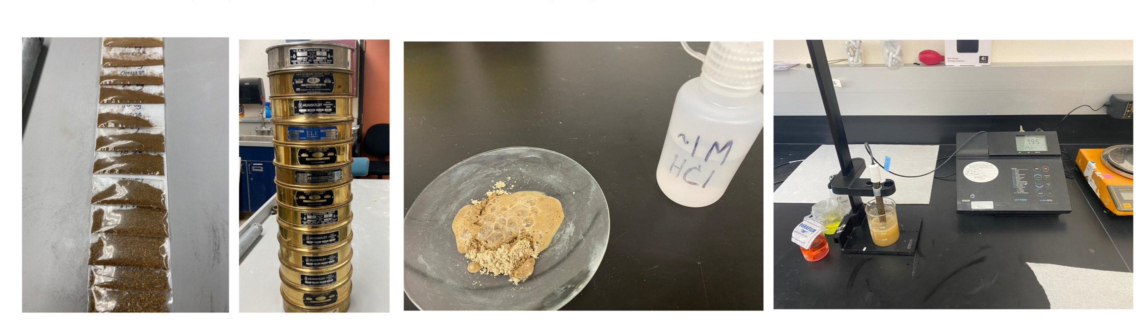
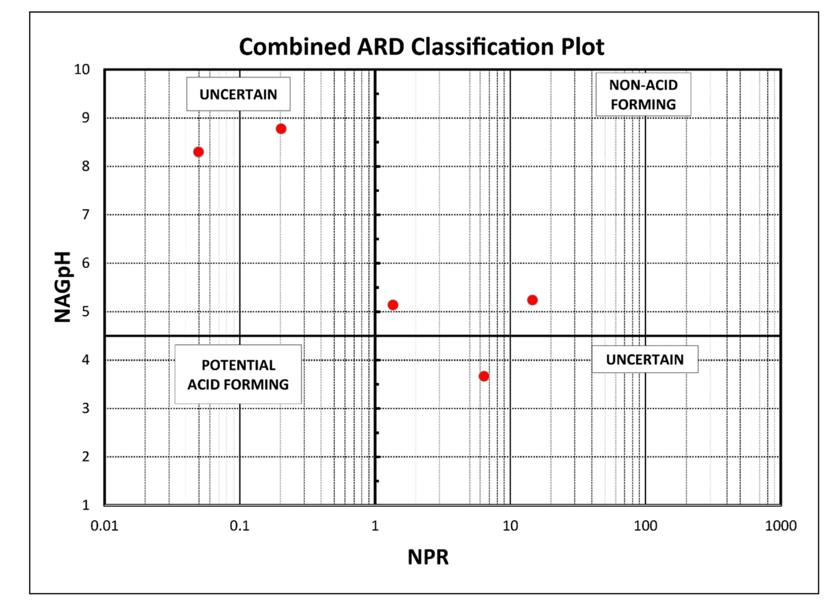


FIGURE 6: Laboratory test on sieved samples, Particle size analysis (left),Fizz test(middle) and Paste pH test(right)

PRELIMINARY RESULTS

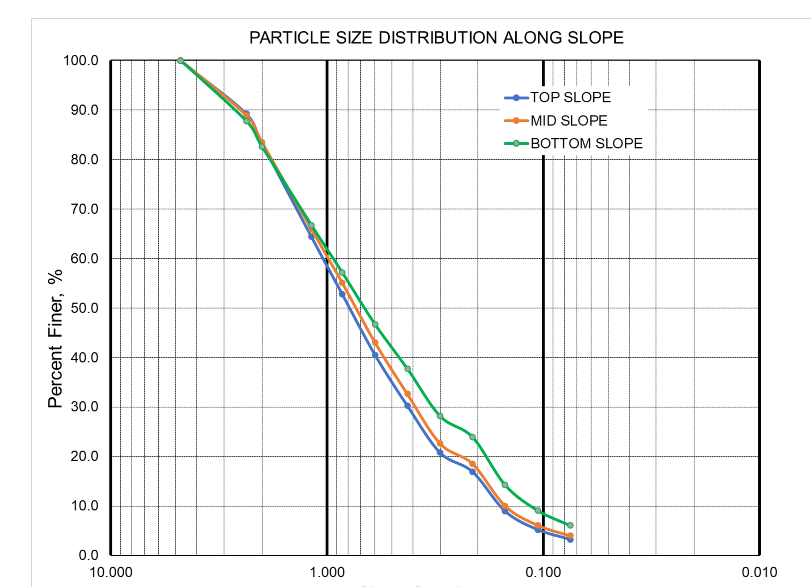
TABLE 2. Shows Legacy data of mine waste rock pile samples from Copper Flat, Hillsboro

SAMPLE	Paste pH	S%	C%	AP (Kg CaCO3)	NP (total C)	NNP	NPR
Hill1000	5.24	17.85	0.46	557.81	38.32	519.49	14.56
Hill1002	3.67	0.51	0.03	15.94	2.50	13.44	6.38
Hill1003	5.14	0.47	0.13	14.69	10.83	3.86	1.36
Hill5500T	8.3	0.12	0.91	3.75	75.80	-72.05	0.05
HillWicks/Compromise	8.78	0.14	0.26	4.38	21.66	-17.28	0.20



None of the samples have a potential to generate acid drainage though some samples were slightly acidic when a paste pH test was done.

FIGURE 8: Acid Rock Drainage(ARD) plot of waste rock pile at mines at Copper Flat mine.



Fine Particle fractions are evenly distributed along slope

FIGURE 9:A plot of particle size distribution along rock pile slope at Copper Flat mine.

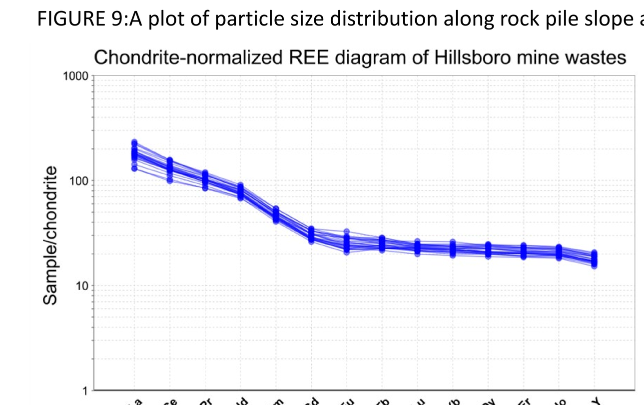


FIGURE 11:A chondrite REE plot of samples from Copper Flat mine.

TABLE 3. Shows a summary of geochemistry of critical minerals in mine waste at Copper Flat mine.

	As (ppm)	Bi (ppm)	Cd (ppm)	Cu (ppm)	Ni (ppm)	Te (ppm)	TREE (ppm)
Count Numeric	25	25	25	25	25	25	25
Unique Values	3	20	9	25	12	22	25
Minimum	2.5	0.7	0.2	346	2.5	0.22	161.1
Maximum	14	8.1	1.3	3303	43	1.64	232.9
Mean	3.7	2.9	0.5	1725	12.3	0.6	197.9
Median	2.5	1.9	0.3	2072	11	0.48	194.2
Range	11.5	7.4	1.1	2957	40.5	1.42	71.8
Standard Deviation	3.4	2.1	0.3	1041	8.5	0.4	19.5

PRELIMINARY CONCLUSIONS

- Two samples fall within the non-acid forming field, and that some material would likely be suitable for backfilling.
- Samples show the waste rock pile is poorly sorted with even distribution of particle fractions along the slope, accounting for low permeability of the rock pile and potential high retention of critical minerals.
- The large amount of relatively course and sand fractions accounts for very loose material and hence makes the slope susceptible to failure or unstable.
- Geochemistry results shows light REE enrichment of up to 200 times chondritic values, however this does not make it attractive for recovery.
- Tellurium values also ranges as high as 1.64ppm.

FUTURE WORK

- More samples to be collected, analyzed and archived from mine waste rock piles in the two mining districts.
- Samples to be analyzed for S and C concentration to determine acid drainage potential of the waste rock piles at Steeple rock district, NM and confirm earlier results and provide insights on the geochemistry of the mine waste in the Copper Flat mine.
- Geochemistry on different particle fractions would be analyzed.

ACKNOWLEDGEMENTS

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