

# LESSONS LEARNED FROM ABANDONED/INACTIVE MINES STUDIES AT THE NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES

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## Introduction

Scientists at the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) have studied the effects of mining-influenced waters (MIW), acid drainage, and other environmental issues at abandoned or inactive mines and mills since it was created in 1927. As our population is expanding into rural areas, often near or adjacent to mining districts or other mineralized areas in New Mexico, there is a need to understand the distribution and migration of elements, especially uranium, that are potentially harmful to human population and the ecosystem in general. With new developments in statistical and GIS software, new interpretations of regional geochemical data, including the NURE (National Uranium Resource Evaluation) data, can provide new insights into mineral exploration, evaluation of mineral resource potential, environmental studies, and general geochemical mapping of the state. Geochemical databases are available for selected mining districts in areas where NMBGMR scientists have had projects (Hillsboro, Pecos, Red River, Questa, Española Basin, etc.). The purpose of this paper is to summarize some of the lessons learned from these studies.

## Summaries of selected abandoned/inactive mine studies in New Mexico

(1) Several uranium mines and occurrences are found in the Tesuque Formation in the San Jose district, in the Española Basin in Santa Fe County (Fig. 1; McLemore et al., 2011) and are associated with geochemical uranium anomalies in both water and NURE stream-sediment samples. Residents in the Española Basin locally have high concentrations of uranium and radon in their drinking water (McLemore et al., 2011). The geochemical uranium anomalies found in groundwaters used for drinking are most likely a result of weathering of uranium from these uranium mines and occurrences as well as from weathering of uranium-rich rocks in the adjoining Sangre de Cristo Mountains and subsequent migration of uranium and radon in the groundwater (Fig. 2). This area warrants continued examination to understand the significance of these geochemical anomalies and to determine if public health is at risk.

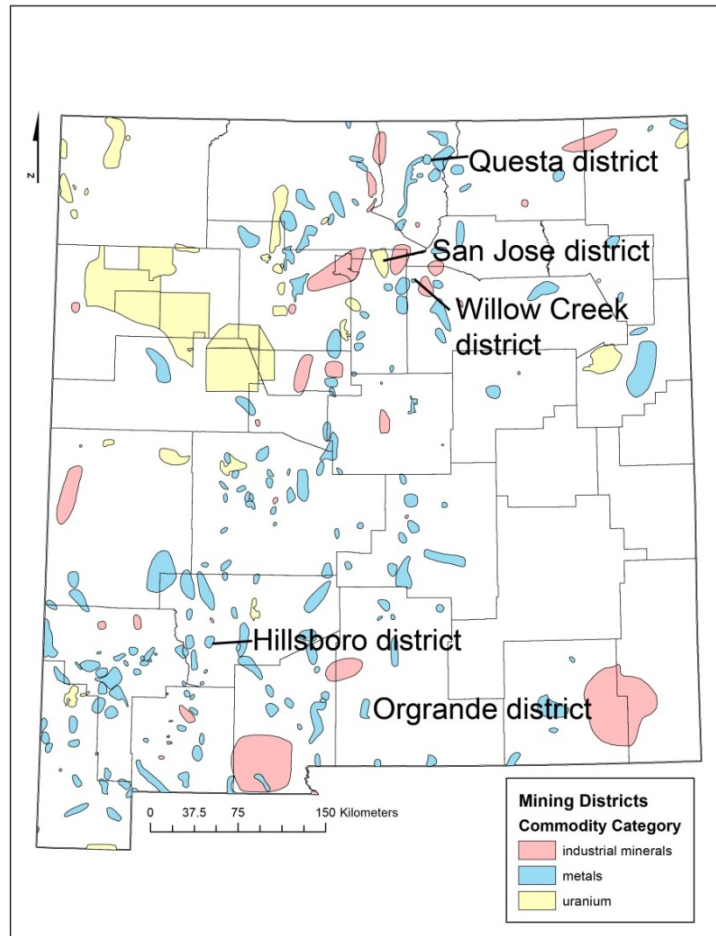


Figure 1. Map showing mining districts in New Mexico discussed in this report.

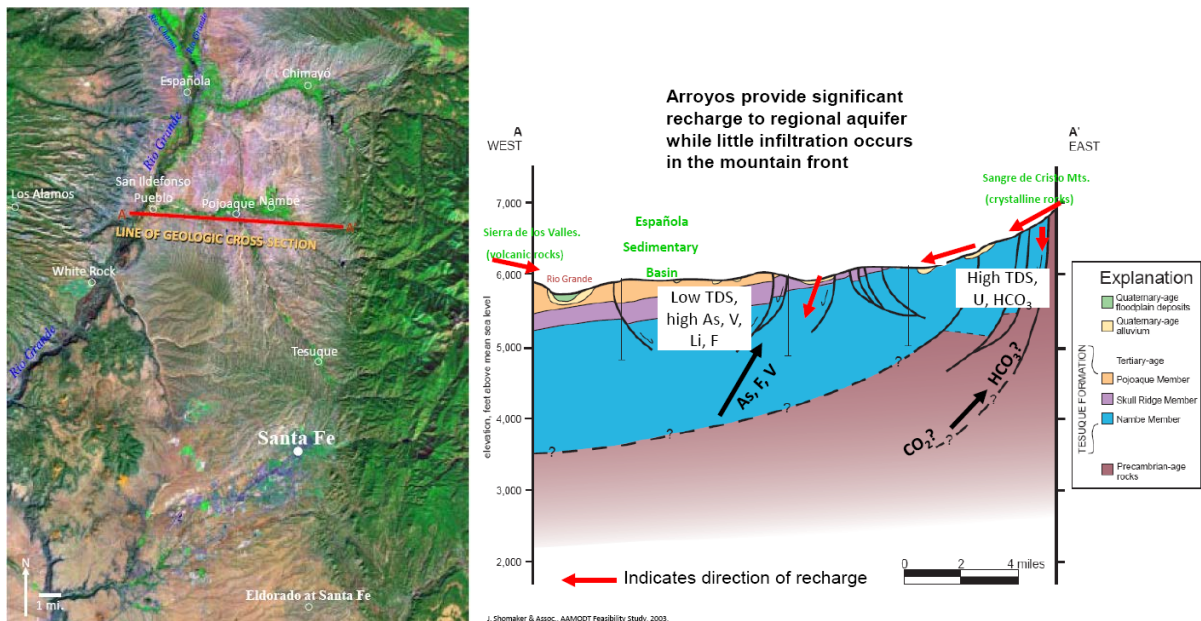
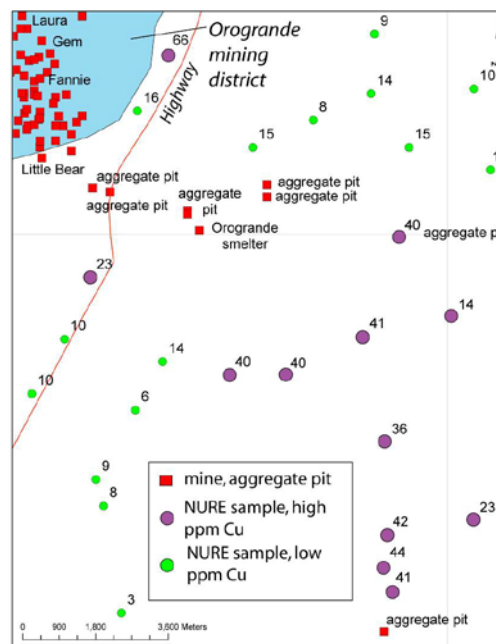


Figure 2. Uranium in the San Jose district in the Española Basin migrated in the groundwater down dip and precipitated from the groundwaters to form the uranium deposits. Uranium precipitated at reduced zones formed by clay, organic material, and possibly at the interface of reduced basin waters.

**Continued leaching of uranium from these sources and from older uranium deposits in the Tesuque Formation then formed the modern geochemical anomalies found today in the groundwater.**

(2) The area southeast of the Orogrande district, Otero County (Fig. 1) exhibits anomalous copper concentrations in stream-sediment samples (23-41 ppm). No mineralized areas were identified during field examination and no other geochemical anomalies were observed (Fig. 3). The most likely source for this copper anomaly is the abandoned copper smelter located in the northern part of the town of Orogrande (New Mexico Bureau of Mines and Mineral Resources et al., 1998; McLemore, 2014).



**Figure 3. Copper in stream-sediment samples in the Orogrande area, Otero County, New Mexico. Note the samples (larger circles) high in copper south and east of the Orogrande smelter (section 14, T22S, R8E) that are likely due to contamination from the smelter. Field examination of the area found only the smelter site and no mineralized outcrops.**

(3) Geochemical analyses of surface-water samples indicate that drainage from the Terrero (Pecos) mine, Willow Creek district (Fig. 4, 5) did not significantly affect the composition of the surface water in the area, except in the immediate vicinity of the Terrero mine and Alamitos mill site. Elevated concentrations of copper, lead, zinc, and cadmium occurred in stream sediments below both the Terrero mine and Alamitos Canyon mill sites, before reclamation began (Fig. 6). Collectively, multi-disciplinary studies suggest that copper, lead, zinc, cadmium, and other metals were eroded and leached from the Terrero mine waste rock pile and the tailings piles in Alamitos Canyon. The overall metal concentrations dramatically decrease in stream sediments below Pecos Village, mostly due to dilution of sediment derived from the red bed sedimentary units. Since reclamation of the Pecos mine, Alamitos Canyon

mill, campgrounds and roads began in 1990-1991, copper, lead, zinc, and cadmium concentrations have decreased overall (McLemore et al., 1993; 1995; 2001).

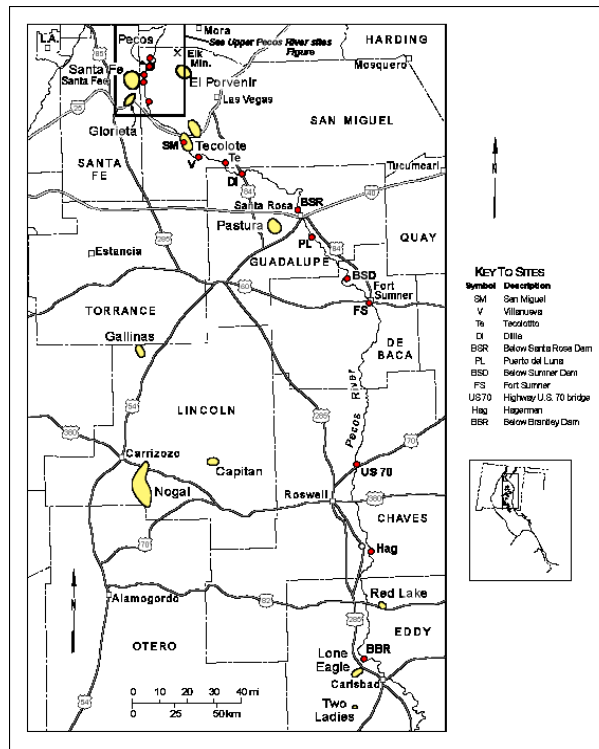


Figure 4. Location of sample sites and mining districts along the Pecos River, eastern New Mexico.

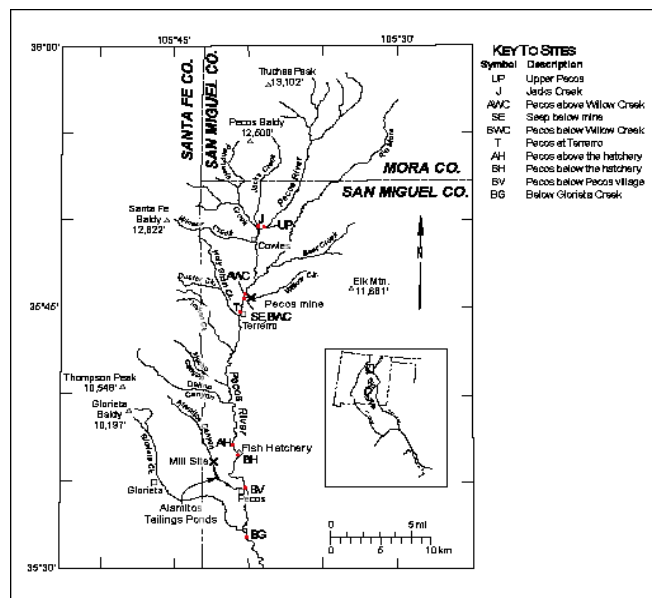
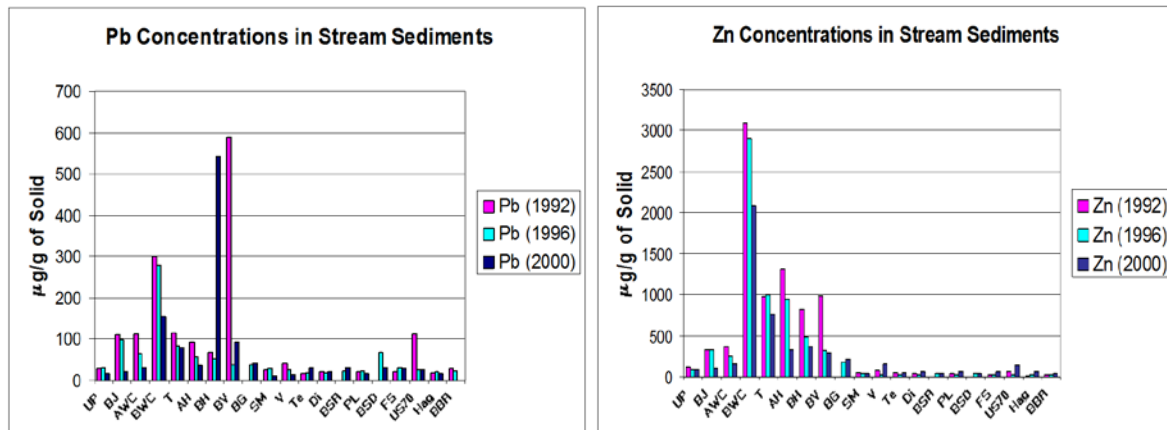


Figure 5. Location of sample sites, Pecos mine, Alamitos Canyon mill, and Lisboa Springs Fish Hatchery along the upper Pecos River, northeastern New Mexico.



**Figure 6. Lead and zinc concentrations in stream sediments along the Pecos River from the Pecos mine to Carlsbad. Sample locations shown in Figure 5.**

(4) Copper Flat in the Hillsboro district (Fig. 1), approximately 23 miles southwest of Truth or Consequences, is a porphyry copper deposit with associated gold, silver, molybdenum, and sulfide minerals. The stock consists of a 75 million-year-old quartz monzonite breccia pipe forming the center of an eroded andesite stratovolcano. Quintana Minerals Corporation mined the property for three months in 1982 producing 7.4 million pounds of copper, 2,306 ounces of gold, and 55,966 ounces of silver. Mining activities ceased because of low copper prices. The mining equipment was dismantled and sold. Currently, THEMAC Resources Group, Ltd. is applying for mining permits to resume operations at the mine, with updated measured and indicated reserves of 194 million short tons at 0.26% Cu, 0.008% Mo, 0.002 oz/short ton Au, and 0.05 oz/ short ton Ag and inferred resources of 8 million short tons of ore with a reported grade of 0.23% Cu, 0.004% Mo, and 0.01 oz/short ton Ag.

Since no mining activities have occurred since 1982, the site provided an excellent field laboratory for studying the behavior of metals and sulfide minerals exposed in waste rock piles and tailings in the arid southwest. There is a 12.8-acre pit and pit lake on site that is located near the center of the breccia pipe.

Munroe et al. (1999, 2000) examined the effects of weathering in the waste rock piles. A second study by Raugust (2003, Raugust and McLemore, 2005) focused on the potential impact of the pit lake, the waste rock piles, and the tailing impoundment on the local surface and groundwater quality.

A geochemical and mineralogical study was implemented for five waste rock piles, some of which contained sulfide minerals, in the Hillsboro district. Chemical and physical characteristics of mineral grains and their secondary mineral oxidation rinds were examined with the electron microprobe. Minerals found in the polymetallic vein waste rock piles were more reactive than other types of deposits in the district. Pyrite and chalcopyrite appear to be the most reactive to oxidizing conditions (Munroe et al. 1999, 2000). Some mineral grains like galena were oxidized during late hydrothermal fluid oxidation (pre-mining) and formed a rind of cerussite

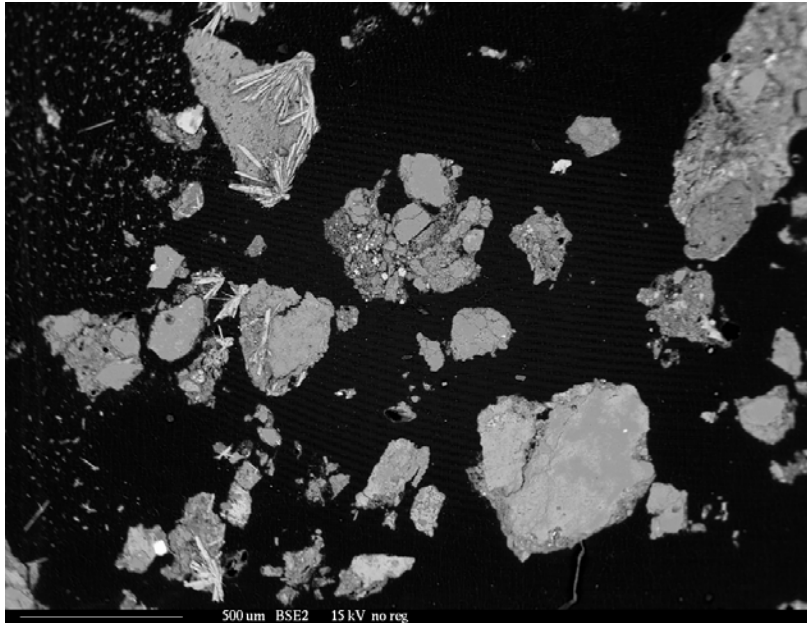


surrounding the galena, thereby preventing further oxidation by weathering (post mining). This armoring leads to a decrease in lead concentration available for chemical mobility during pre-mining weathering of the waste rock piles (Munroe et al. 1999, 2000).

The pit lake at Copper Flat was sampled at least 65 times between 1989 and 1997 (Raugust, 2003; Raugust and McLemore, 2005). The pH of the lake is typically neutral to alkaline, except in 1992 and 1993, when the pH dropped as low as 4.4. At least one intermittent seep from the pit wall has been sampled and the results reported a pH of 2.64, a total dissolved solid concentration (TDS) of 12,770 milligrams per liter (mg/L), and a sulfate concentration of 790 mg/L. The andesitic host rocks surrounding the ore body and groundwater inflow have a high acid buffering capacity as shown by the partial dissolution of calcite and the precipitation of gypsum and goethite. The alkalinity of the groundwater and host rocks quickly neutralizes and dilutes acidic discharges into the pit lake. Groundwater samples collected from monitoring wells located down gradient from the pit lake indicate groundwater chemistry is similar before and after the excavation of the pit.

(6) Multidisciplinary studies of the Questa rock piles, Taos County (Fig. 1) indicates that predominant weathering reactions in the GHN mine waste rock pile involve the oxidation of pyrite, dissolution of carbonate, and formation of sulfate minerals, mainly gypsum, jarosite, and soluble, efflorescent salts, depending on pH (Fig. 7; McLemore et al., 2009, 2010). The chemical composition of waters from the Questa rock piles (i.e., seeps and runoff waters from the rock piles, chemistry of leachate waters) imply that silicate dissolution is occurring within the rock piles.

Little if any clay minerals are forming as a result of weathering. There are five principal lines of evidence that the clay minerals in the Questa waste rock piles are predominantly formed from the hydrothermal alteration of the host lithologies prior to excavation and emplacement into the rock piles and not formed by weathering of silicate minerals: (1) the unweathered drill core and samples from GHN rock pile have similar types and abundances of clay mineral groups based on XRD analyses, (2) textural evidence gathered from electron microprobe examination suggests that the clay minerals did not form in situ, (3) the contacts between the sand-size rock fragments and mineral grains within the fine-grained soil matrix within the rock piles are sharp and do not indicate the in-situ formation of the clay minerals into the fine-grained soil matrix, (4) chemical analyses from electron microprobe analysis reveal similar chemical compositions for the clay minerals from the two environments (unweathered drill core vs. weathered rock-pile material), (5) tritium content of clays within the waste rock piles indicate formation by hydrothermal processes, not weathering (Marston et al., 2012). Instead the clays are formed during the hydrothermal alteration of the host lithologies prior to excavation and emplacement before mining (Donahue et al., 2009; McLemore et al., 2009).



**Figure 7. Backscattered electron image of rock pile sample from unit I, GHN. Bladed, prismatic crystals are authigenic gypsum formed during weathering in the rock pile. It is unlikely that these delicate crystals would survive blasting, haulage, and dumping, therefore, these are weathered gypsums.**

## **Lessons learned**

In conclusion, these and other studies indicate that the differences in chemistry of MIW and other environmental effects due to mining within the various mining districts in New Mexico are due to differences in geology, mineralogy, type of mineral deposits, and pre-mining hydrothermal alteration and post-mining weathering. Each area is site-specific and must be examined in detail and over a period of time to determine the cause of the adverse MIW and other environmental effects. However, as more people are building houses in and near mining districts, even natural geochemical anomalies could become a health problem and may have to be addressed in some manner.

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