# New Mexico Abandoned Uranium Mines Study: Jeter, Lucky Don, and Little Davie mines, Socorro County, New Mexico

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## Abstract

Mining has aided in the economic and social development of New Mexico as early as the 1500's. One of the earliest gold rushes in the West was in the Ortiz Mountains (Old Placers district) in 1828, 21 years before the California Gold Rush in 1849. Many of these mines were immediately abandoned when insufficient minerals were found, others were abandoned later when poor economics of the commodity made mining unprofitable. Miners operating on federal lands had little to no requirement for environmental protection until the 1960s and 1970s, although the dumping of mine wastes and mill tailings directly into the nation's rivers was halted by an Executive Order in 1935. Irrespective of the remarkable contribution of mining to the development of New Mexico, it has to be admitted that the after effects of mining operations in the state has resulted in thousands of abandoned/inactive mine features in 274 mining districts and prospect areas. Reclamation efforts have not examined the long-term chemical effects from these legacy mines and there is still potential for environmental effects long after remediation of the physical hazards, as found in several areas in New Mexico including Jackpile mine, Laguna subdistrict. Some of these observations only come from detailed electron microprobe studies.

The purposes of this study were to characterize and determine the mineralogical and geochemical composition of waste rock piles in uranium mines in Jeter uranium mine, Ladron Mountains, Lucky Don and Little Davie uranium mines, Socorro County. Waste rock piles were sampled in order to maximize surface area coverage, ensuring statistically representative sampling, and obtaining homogeneous samples.

In this study, about 100,000 $ft^3$ volume of waste rock pile material were estimated at Jeter mine, and 32,000 $ft^3$ volume of waste rock pile estimated at Lucky Don mine. Waste rock piles from the uranium mines have pH values 7.5-8.2. This study found elevated radioactivity from scintillometer measurements (50 times background). Backscattered electron images of samples showed pristine secondary uranium, vanadium and $CaCO_3$ grains from Lucky Don mine samples, while uranium and vanadium grains from Little Davie samples appeared to be partially dissolved. Waste rock pile samples from all uranium mines plotted in the non-acid forming zone on the Acid Rock Drainage (ARD) classification plot.

It is recommended that waste rock piles with elevated radioactivity from scintillometer should be covered. A stream sediment survey is needed to determine the leachability of uranium, vanadium and other trace elements in the environment near the uranium mines.

## Acknowledgements

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TABLE OF CONTENTS

TABLES



FIGURES

## APPENDICES

## 1.0 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 of water from the Gold King mine 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, including past uranium mines (http://geoinfo.nmt.edu/staff/mclemore/projects/environment/home.html). There are approximately 300 inactive or abandoned uranium mine features in approximately 40 mining districts in New Mexico (McLemore, 1983; 2017), however many of them have not been prioritized for reclamation.

Most of these uranium 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 EPSCoR 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 uranium and other mine features in New Mexico. This project will inventory, characterize, and prioritize for remediation the mine features at three sites in New Mexico: Jeter, Lucky Don, and Little Davie mines. The project involves field examination of the mines 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, and prioritization for remediation, including hazard ranking.

The purpose of this project is to provide an assessment on the current state of Jeter uranium mine, Ladron Mountains district, Little Davie, and Lucky Don uranium mines, Socorro mining district, Socorro County.

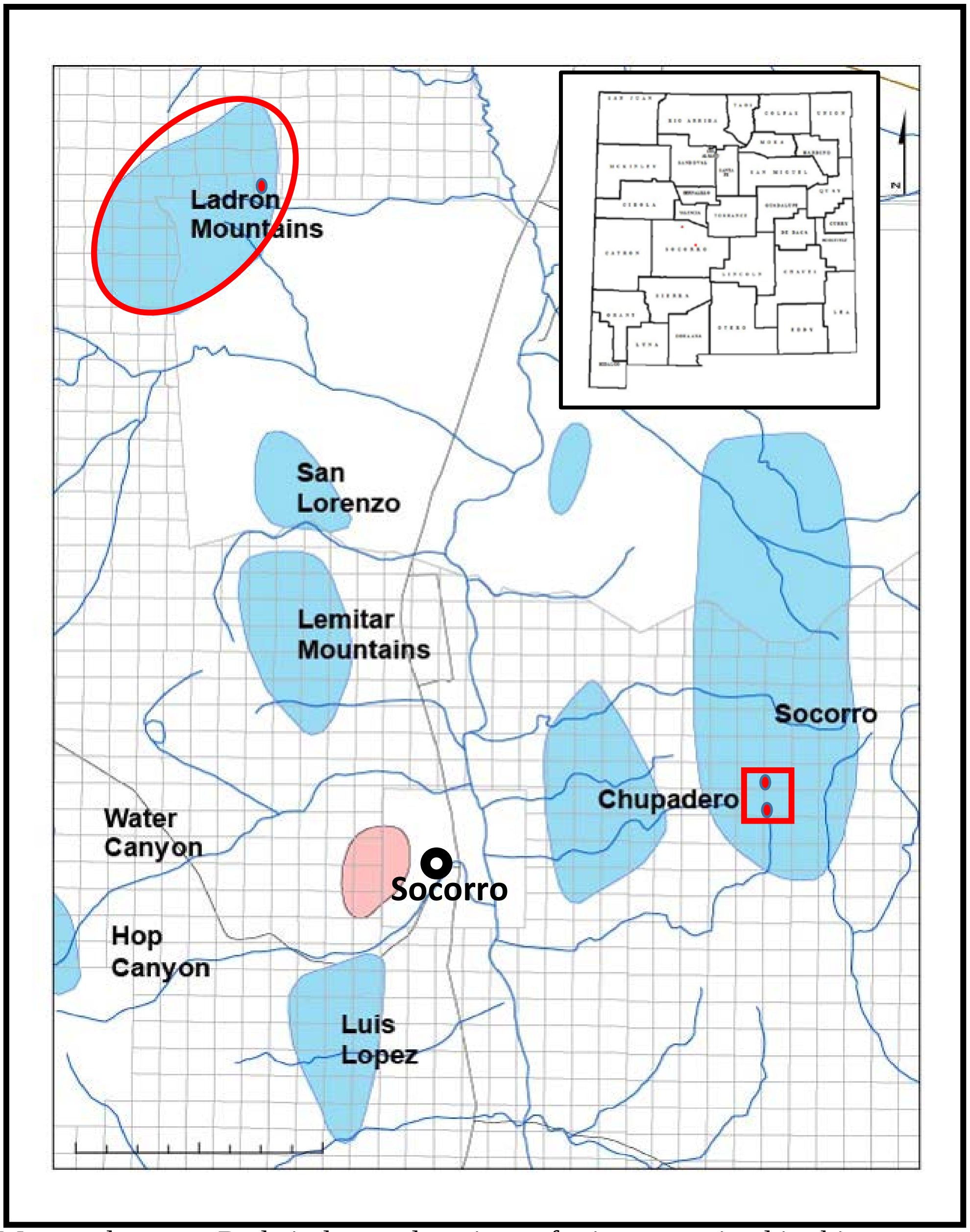



Figure 1. Map study areas. Red circles are locations of mines examined in this report

# 2.0 METHODS

## 2.1 FIELD WORK

### 2.1.1 Inventory

A field inventory form (Appendix C) was designed to collect data during the inventory, and record all significant mine features, which were later entered into the New Mexico Mines Database. This included collecting data including, mining history, and compiling data from other agencies, mine files, and literature.

### 2.1.2 Sampling

Legacy mines in the study areas have been mined either by surface and/or underground methods from pits, shafts and/or adits, and waste rock piles are located around or near the openings of these features. Waste rock pile locations were acquired using a handheld GPS.

Composite samples of waste rock piles were collected (Fig 2). Evenly spaced metal pegs with flagging tapes were positioned across an entire rock pile at each site marking a subsample location. Subsamples are collected with a small stainless hand trowel or shovel and sieved using 0.5 mm mesh into a 5-gallon bucket. About two shovels full of material was taken from each marked location on the waste pile. Subsamples are then mixed thoroughly. Equipment for sampling are brushed and cleaned after sampling each waste pile. A subsample of the homogenized, composite sample was split for petrographic, mineralogic, and geochemical analyses.

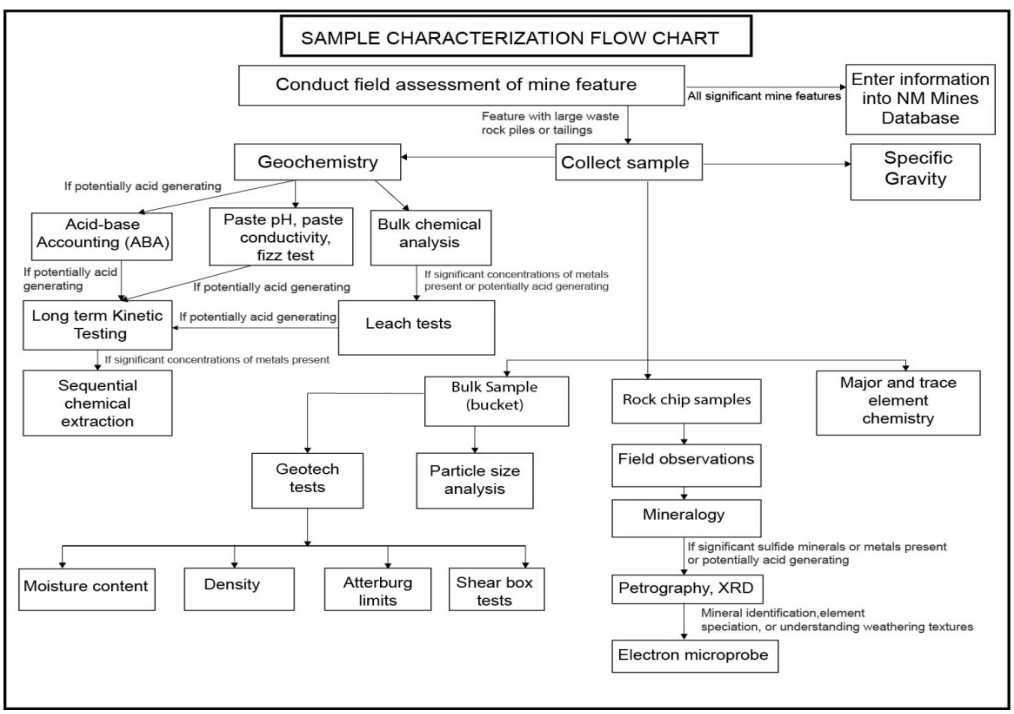



Figure 2. Sample characterization flow chart

## 2.2 LABORATORY ANALYSES

### 2.2.1 Paste pH and paste Conductivity

Paste pH and paste conductivity were determined to predict geochemical behavior of waste rock materials subjected to weathering under field conditions and to estimate or predict the pH and conductivity of the pore water resulting from dissolution of secondary mineral phases on the surface of oxidized rock particles. The paste conductivity values were converted to total dissolve solids (TDS) using standard procedures (http://www.chemiasoft.com/chemd/TDS).

### 2.2.2 XRD Technique

X-ray diffraction analysis was conducted on composite waste rock samples to determine the mineralogy. Samples were grinded into a well homogenized material with mortal and pestol to form a fine powder (~75µ/0029 mesh), poured into aluminum sample holder and mounted with the silicon standard in the XRD instrument. A five minute absolute scan analysis was run. Sample analyses was performed using appropriate software program. More details are found at Bureau website (https://geoinfo.nmt.edu/labs/x-ray/home.html)

### 2.2.3 Total whole Rock Chemistry

Sample were sent to ALS laboratory in Reno, Nevada for whole rock by fusion, ICP-MS, Leco and ICP-AES. Reference material (internal standard) and duplicate samples were included to monitor the precision of the analytical method and for quality assurance and quality control (QA/QC). ALS laboratory also performed its own QA/QC. More details are found at ALS (https://www.alsglobal.com/myals/downloads?keywords=Geochemistry+Fee+Schedule&category=b5b5208b58bc4609bd2fa20f32d820f8).

### 2.2.4 Electron Microprobe Analyses

Composite samples from waste rock piles were mounted in epoxy and polished to prepare polish sections. These polish sections are then coated with carbon and analyzed using the electron microprobe. Qualitative and quantitative method of analyses was conducted using the Cameca SX681 Electron Microprobe Spectrometer on the samples. More details are found at NMBGMR website (https://geoinfo.nmt.edu/labs/microprobe/description/home.html). Minerals were first viewed in backscatter electron image (BSE). Quantitative and qualitative analyses were used to determine textures and chemical composition of the minerals.

# 3.0 DESCRIPTION OF MINES

## 3.1 JETER MINE

### 3.1.1 MINING HISTORY

Jeter mine is one of the largest uranium mines outside the San Juan Basin area (McLemore, 1983). Early prospecting and discovery activities in the Ladron Mountains have been summarized by Chamberlin et al. (1982). Mineral prospecting in the Ladron Mountain occurred during and after the Civil War. Hanson (an American prospector) made the first mineral discovery in 1868 at the Ladron Mountains. Franscisco Armijo in 1866 located a “Lardoness mine” in the Sabinal district. The first mining claim in the Ladron Mountains appeared to have been the Santa Iduvigen Lode by Domingo Jaramillo 1860. Prospecting in the Ladron Mountains in the early days was threatened by renegade Indians.

Mineral prospecting, prior to 1900 went through two periods: 1879-84 and 1895-97. Lew Wallace (Territorial Governor) in 1880 prospected for silver ores in the Ladron Mountains. Active prospecting activity in the Ladron Mountains intensified in late 1895 or early 1896 and resulted in the discovery of a lead vein. Prospecting efforts in the area were directed towards finding gold and silver minerals. Although small, hand-sorted gold-silver ore were shipped to local smelters during the early period. The need for manganese in 1940 resulted in several groups of claim in the Rio Salado on the southwest side of the Ladron Mountains.

One most productive mining venture in the Ladron Mountain was the Jeter mine. Prospecting and production ore occurred between 1954 to 1958. Jeter mine produced 8,826 tons of ore with an average grade of 0.33% $U_3O_8$ during its life time (Table 1). The mine is credited with production of 58,562 pounds of $U_3O_8$ and 3,202 pounds of $V_2O_5$, this is equivalent to over $5000,000 worth of uranium.

Table 1. Production from the Jeter mine (from U.S. Department of Energy files).

| Period | Mill | Shipper | Tons | $U_3O_8$ (%) | $V_2O_5$ | $CaCO_3$ |
|---|---|---|---|---|---|---|
| 3rd ¼ 1954 | B | C.P. Jeter | 47 | 0.13 | 0.04 | 1.80 |
| 1st ¼ 1955 | B | C.P. Jeter | 18 | 0.12 | 0.03 | 1.20 |
| 2nd ¼ 1956 | B | Socorro U Corp. | 297 | 0.33 | 0.05 | 2.18 |
| 3rd ¼ 1956 | B | Socorro U Corp. | 1854 | 0.19 | 0.03 | |
| 4th ¼ 1956 | Gr | Socorro U Corp. | 295 | 0.18 | 0.03 | 1.00 |
| 1st ¼ 1957 | Gr | UTCO Uranium Corp. | 701 | 0.36 | 0.03 | 1.17 |
| 2nd ¼ 1957 | G/P | UTCO Uranium Corp. | 3642 | 0.46 | 0.03 | 1.09 |
| 3rd ¼ 1957 | G/P | UTCO Uranium Corp. | 1042 | 0.27 | | 1.35 |
| 4th ¼ 1957 | G/P | UTCO Uranium Corp. | 690 | 0.22 | | 1.12 |
| 1st ¼ 1958 | G/P | UTCO Uranium Corp. | 239 | 0.18 | | 2.01 |
| **Total** | | | **8,825** | **0.33** | | **1-2%** |

### 3.1.2 SITE LOCATION AND DIRECTIONS

The Jeter mine is on Federal (Bureau of Land Management) land and it lies approximately 27 miles north and 8 miles west of Socorro in Section 35, Township 3 North, Range 2 West. The mine is located in Ladron Mountains, Socorro County. Jeter mine is located at latitude 34.43889°N and longitude 107.0111°W.

### 3.1.3 SITE GEOLOGY

The geology of Ladron Mountains is summarized from Chamberlin et al. (1982), Collins and Nye (1957), McLemore and North, (1984), and Hilpert (1969). The Ladron Mountains consist of Precambrian crystalline rocks that lie on the western border of the Rio Grande rift, an active zone of crustal extension. The mountains consist of a core of granite surrounded by gneiss and quartzite. The granite has been intruded by a host of fine-grained gray andesitic dikes. The mountain range is flanked on the west by west-dipping Carboniferous strata of the Magdalena Group, which include the Sandia Formation and the overlying Madera limestone. On the north, east and south, the mountains are bounded by Tertiary basin deposits, which were down-faulted against the Precambrian rocks along normal faults.

It is this Tertiary faulting on the east side of the Ladron Mountains that has controlled the uranium deposition in the Jeter mine. This deposition may have been derived from high-grade mineralization peripheral to the copper sulfides, or from vein-type deposits in granites, or from uranium-oxides disseminated in granite (Chamberlin et al., 1982). It is formed along a section of a low-angle fault, which follows the contact between Precambrian granite and overlying sedimentary rocks of the Tertiary age. The footwall zone is a highly altered granite, but in some places includes a variety of metamorphic rocks, predominantly schist. Overlying the granite in the fault zone is a layer of light gray to dark gray carbonaceous tuffaceous mudstone with thin interbedded quartzite. This carbonaceous layer is a very favorable host and contains most of the known ore at Jeter mine. The hanging wall of the fault is franglomerate and overlies directly on the red clay. It is a heterogeneous mixture of pebbles, cobbles and boulders of granite and schist in a coarse sandy matrix. Gruner (1957) identified coffinite as the primary uranium mineral at Jeter mine. A number of secondary uranium minerals were abundant along the fault zone at the mine. These include paraschoepite, meta-autunite, meta-torbernite, and soddyite. Associated with these minerals are tyuyamunite, malachite, azurite, barite, alunite, pitchblende, Fe-Mn oxides, clay, and manganese oxide (Chamberlin et al., 1982; Northrup, 1996; NMBGMR file data).

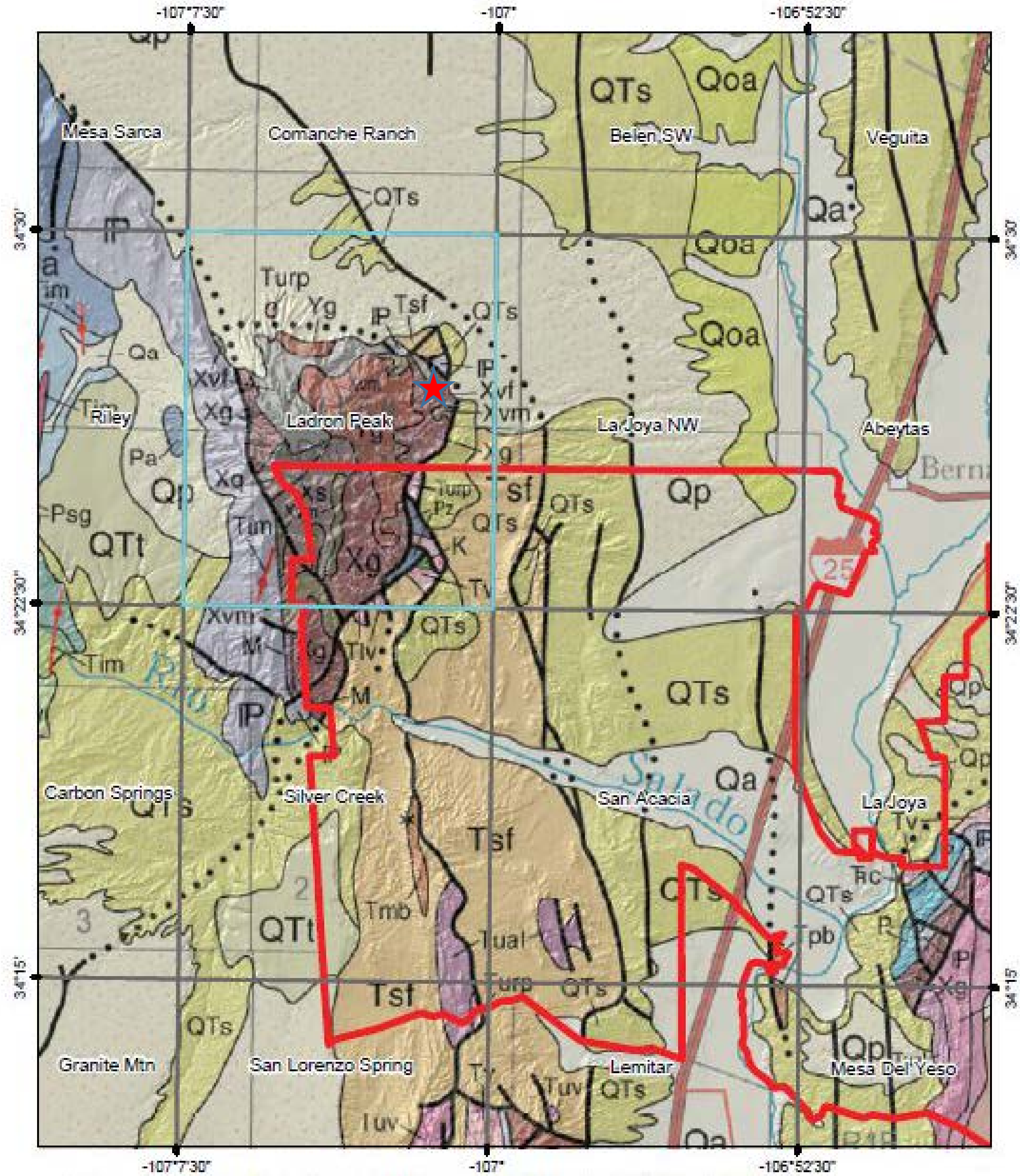



Figure 3. Geology of the Ladron Peak Quadrangle by Cather et al. (2007). Red star is the location of the mine.

### 3.1.4 SITE HYDROGEOLOGY

Generally subsurface waters flows to the south and west off the Ladron Mountains. Surface runoff at the mine discharges east-southeast into the gulch, eventually draining into ground. The site is located in the Middle Rio Grande Underground Water Basin. Three wells are in the vicinity of the mine (Fig. 2). Groundwater is approximately 160 ft deep.

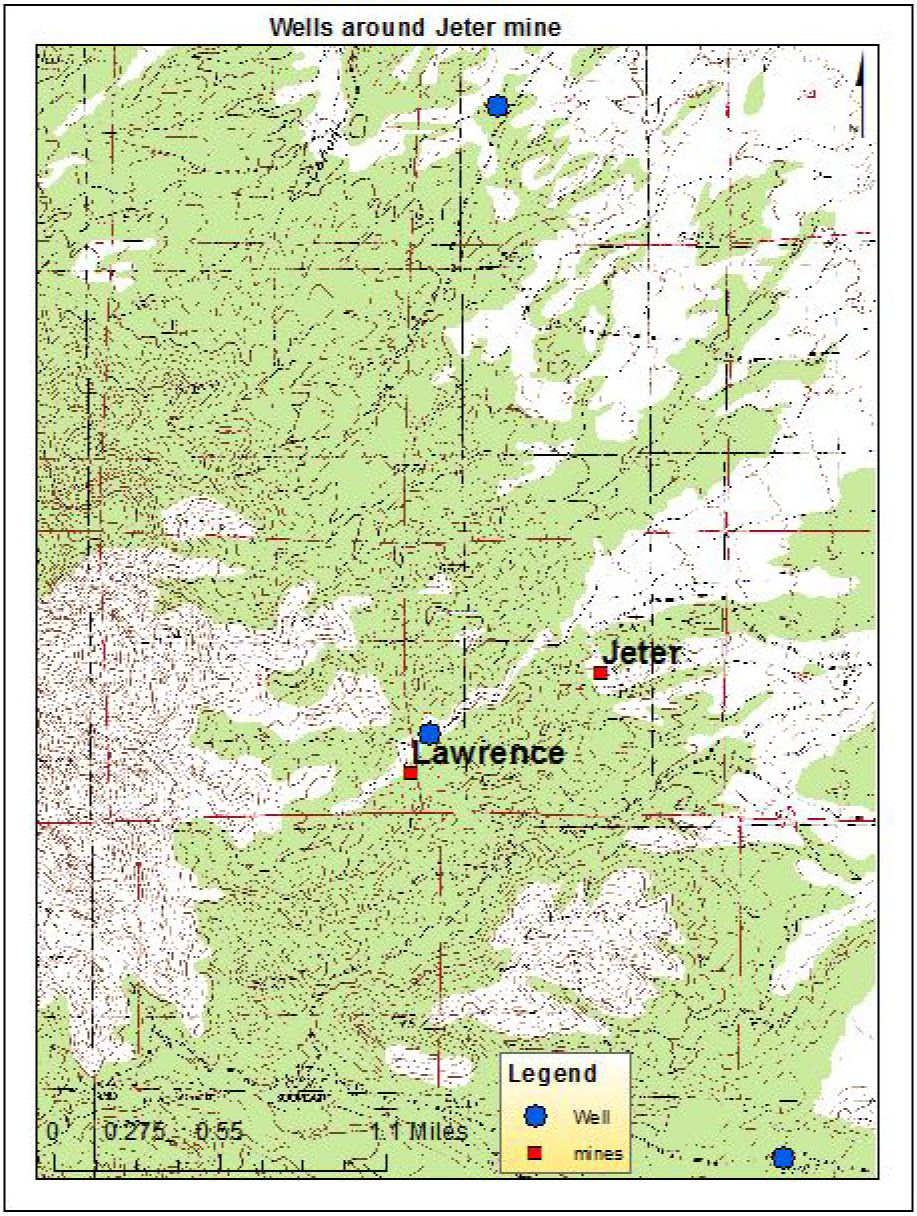



Figure 4. Map of well Locations around Jeter mine.

### 3.1.5 REGIONAL TOPOGRAPHY AND TERRAIN

Jeter mine is found on the Ladron Peak quadrangle 7.5 minute U.S. Geological Survey topographic map at an elevation of approximately 5700 ft. The mine is located on the east edge of the Ladron Mountains. Topography to the northwest of the mine slopes gently to the east.

### 3.1.6 MINE FEATURES

Mine features at Jeter mine include a decline (now caved), open pit, three waste rock piles, concrete platform, and two mine roads. A volume of about 100,000 $ft^3$ of waste rock pile was estimated at the mine. Please refer to Table A2 in Appendix A for a list of mine features at the site. Previous assessment by Chamberlin et al. (1982) indicates that the workings of the mine consist of an open pit and an inclined shaft descending at approximately $25^o$ in the easterly direction from the bottom of the pit along the Jeter fault. This decline was completely caved at the time of our visit.

Figure 5. Jeter adit in 1980 (Anderson, 1980)

Figure 6. Jeter adit in 2016


### 3.1.7 ARCHEOLOGICAL SITES

No archeological sites were identified at or near the Jeter mine.

### 3.1.8 SITE RADIATION READINGS

Background radiation measurements from scintillometer were between 10-30 counts per second (cps). Minimum radiation reading was 80 cps while the maximum radiation reading was 1,640 cps. Please see Table A3 in appendix for all of the radiation readings taken at the Jeter mine.

### 3.1.9 CURRENT LAND USES

The area is currently used for cattle grazing. Meadowlarks and other small birds were observed onsite. Rabbit droppings were identified. The area is adjacent to the Sierra Ladroness Wilderness Study Area.

### 3.1.10 NEARBY RESIDENTIAL, COMMERCIAL AND INDUSTRIAL STRUCTURES

No structures are within a mile of the Jeter mine.

### 3.1.11 NEARBY DOMESTIC WELLS

Three wells in have been identified in the vicinity of the mine (Fig. 4).

### 3.1.12 VEGETATION

Vegetation at the Jeter mine is moderate to sparse native, healthy, and dominated by pinon pines and cholla cactus.

### 3.1.13 EROSION

Surface runoff at the mine discharges into the open pit. There was water standing in the open pit.

**SKETCH MAP OF JETER MINE**

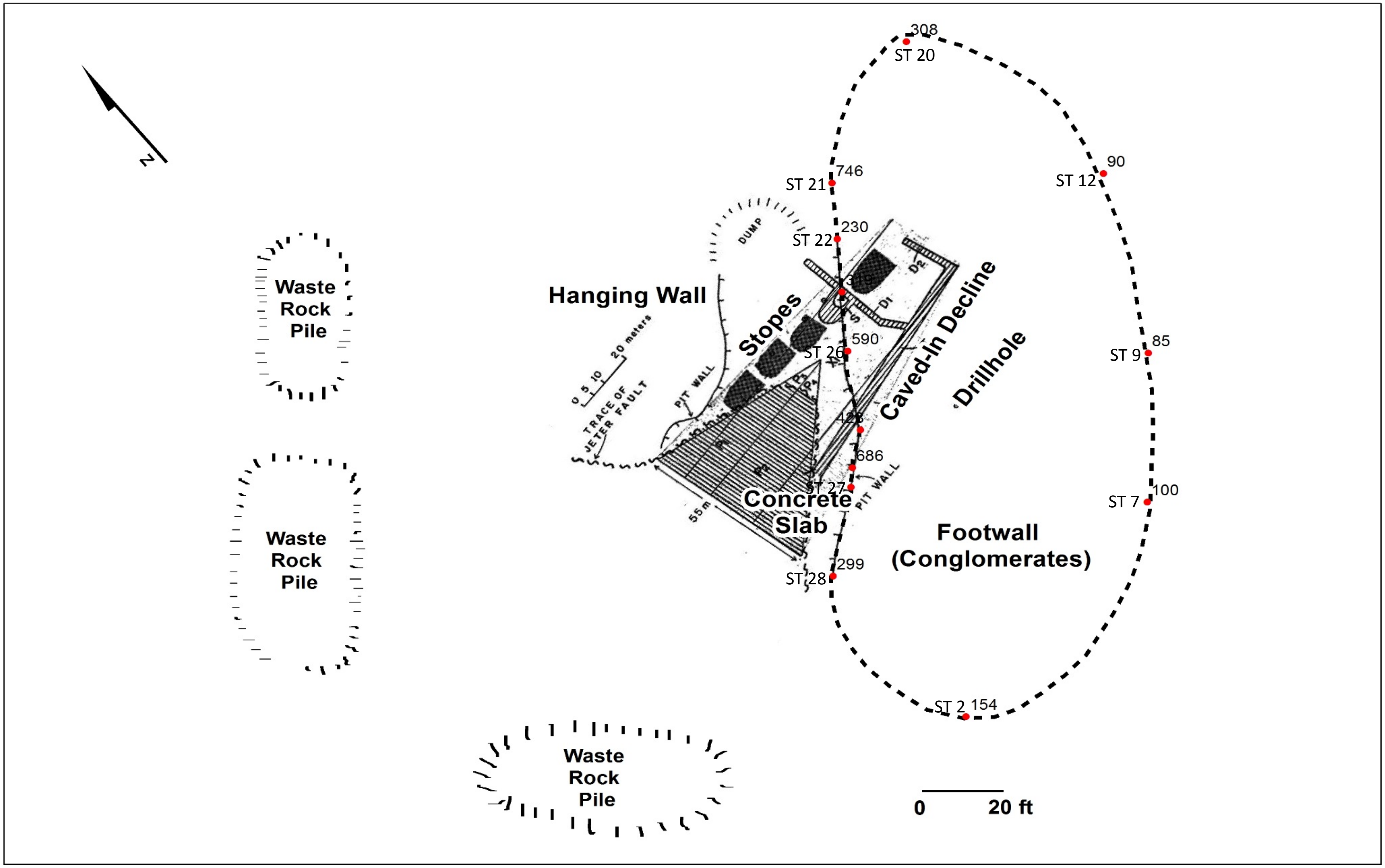



Figure 7: Sketch of Jeter mine

## 3.2 LUCKY DON AND LITTLE DAVIE MINES

### 3.2.1 MINING HISTORY

Lucky Don and Little Davie mines were discovered in the early 1950's. Little Davie mine was mined by Holly Uranium Corporation in 1955. Also known as the Bonanza mine, Lucky Don mine was active during 1955-1956 and again during 1960-1963 (Hilpert, 1969). Early mining activities have been summarized by Presley (1955). In July 1955, Holly Uranium Corporation filed an application for certification of the Lucky Don Group. A later application from the company was filed on November 1955 covering Little Davie mine. Uranium in the Little Davie and Lucky Don mine is hosted by the San Andres limestone. The lucky Don ore was up to 12 ft in thickness, quite spotty and largely autunite (Presley, 1955). An adit was driven through the San Andres Formation for about 30 to 40 ft at Lucky Don, and it was later blasted after the ore run out. Ore was blasted, hand sorted and trammed to a 15 to 20 ton ore chute on the side of the hill (Presley,1955). Ore from Little Davie was loaded into a pickup and hauled down to the ore chute at Lucky Don. Equipment used in mining included a 125 cubic ft per minute (cfm), jaeger compressor, jackhammer, wheelbarrows, and picks and shovels.

Table 2. Production from the Lucky Don mine (from U.S. Department of Energy files).

| Period | Shipper | Tons | $U_3O_8$ (%) | $V_2O_5$ | $CaCO_3$ |
|---|---|---|---|---|---|
| 1955 | McKedy Mining and Exploration Co | 48.39 | 0.34 | 0.32 | 50% |
| 1956 | Holly Uranium Corp | | | | |
| 1956 | Umino Co | 46 | | | |
| 1956 | Three Bear Mining | | | | |
| 1960 | McKedy Mining and Exploration Co | 27 | 0.16 | | |
| 1962 | R.H. Lummus | 50 | 0.50(?) | | |
| 1962 | Lummus and Muriel | | | | |
| 1963 | R.H. Lummus | 20 | | | |
| **Total** | | **964.94** | **0.23** | **0.43** | |

Table 3. Production from the Little Davie mine (from U.S. Department of Energy files).

| Period | Shipper | Tons | $U_3O_8$ (%) | $V_2O_5$ (%) | |
|---|---|---|---|---|---|
| 1955 | McKedy Mining and Exploration Co | 17 | 0.18 | 0.21 | |
| **Total** | | **17** | **0.18** | | |

### 3.2.2 SITE LOCATION AND DIRECTIONS

Lucky Don mine is located in the NE$^1/_4$ NE$^1/_4$ of section 35, Chupadera mining district, Socorro County. Little Davie mine is located about ¼ mile south-southwest of Lucky Don, in the SW$^1/_4$ NE$^1/_4$ of section 35, Chupadera mining district, Socorro County (Hilpert, 1969). Lucky Don is located at latitude 34.09778°N and longitude 106.6833°W, and Little Davie located at latitude 34.09167°N and longitude 106.6986°W. The mines are located in the Bustos Well 7.5 Quadrangle.

### 3.2.3 SITE GEOLOGY

The geology of Lucky Don and Little Davie is summarized by McLemore (1980), Hilpert (1969), Mathewson (1968), and Cather (). The mines lie in a complex faulted zone at the margin of the east side at the Rio Grande graben (McLemore et al., 2016). The rock formations mostly consist of the Permian Yeso Formation, Glorieta Sandstone, and San Andres Formation. These formations are considered to be interbedded continental and marine in origin and represent transgressions and regressions of the Permian seas. Lucky Don mine is hosted by the San Andres Formation, which consist primarily of beds of shale, siltstone, limestone and gypsum. Local rock types at the mine include orange to red, buff and yellow sandstones, gypsiferous siltstone, gypsum, siltstone and limestone. Ore minerals include tyuyamunite, carnotite, uraninite, Cu minerals, and uranophane. Carnotite-type mineralization occurs in the San Andres limestone near the contact of the underlying Glorieta sandstone. The mineralization appears to be localized by a northeast trending fault which parallels to the major fault lying immediately to the west. Uranium occurs as a fracture coating on the limestone, and some mineralization has been noted in the underlying sandstone. Ore minerals include tyuyamunite, carnotite, uraninite, Cu minerals and uranophane.

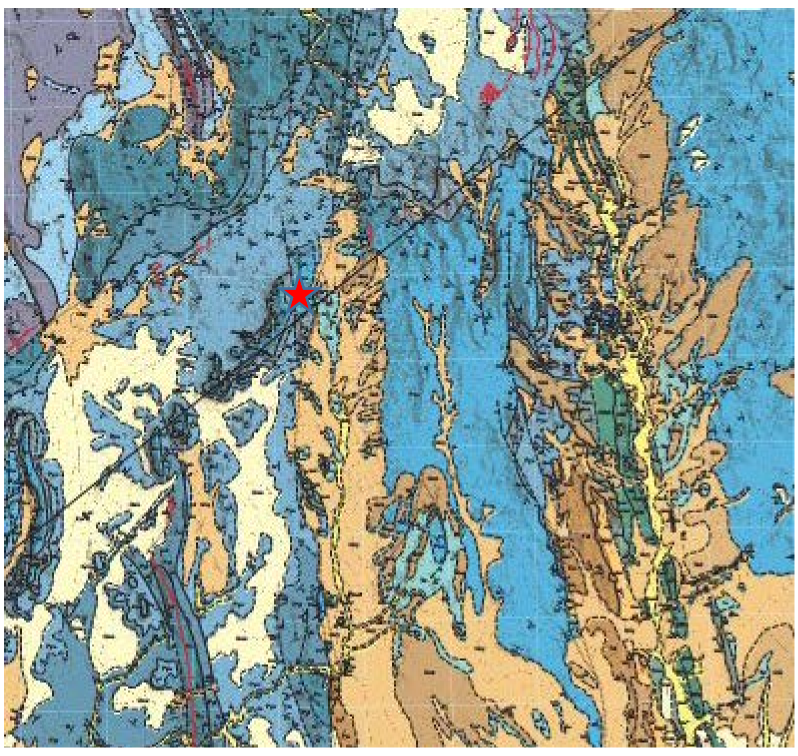


Figure 8. Geology of the Bustos Well Quadrangle by Cather et al, (2014). Red star is the location of the mines.

### 3.2.4 SITE HYDROGEOLOGY

The surface runoff at both Lucky Don and Little Davie mines discharge west-northwest down slope into the valley and eventually draining into ground. The sites are located in the Middle Rio Grande Underground Water Basin. The mines are found in the alluvium aquifers near the San Mateo Creek. Two wells have been identified in the vicinity of the mines; about 1.5 miles southeast and 2 miles southwest of Little Davie mine (Fig. 9).

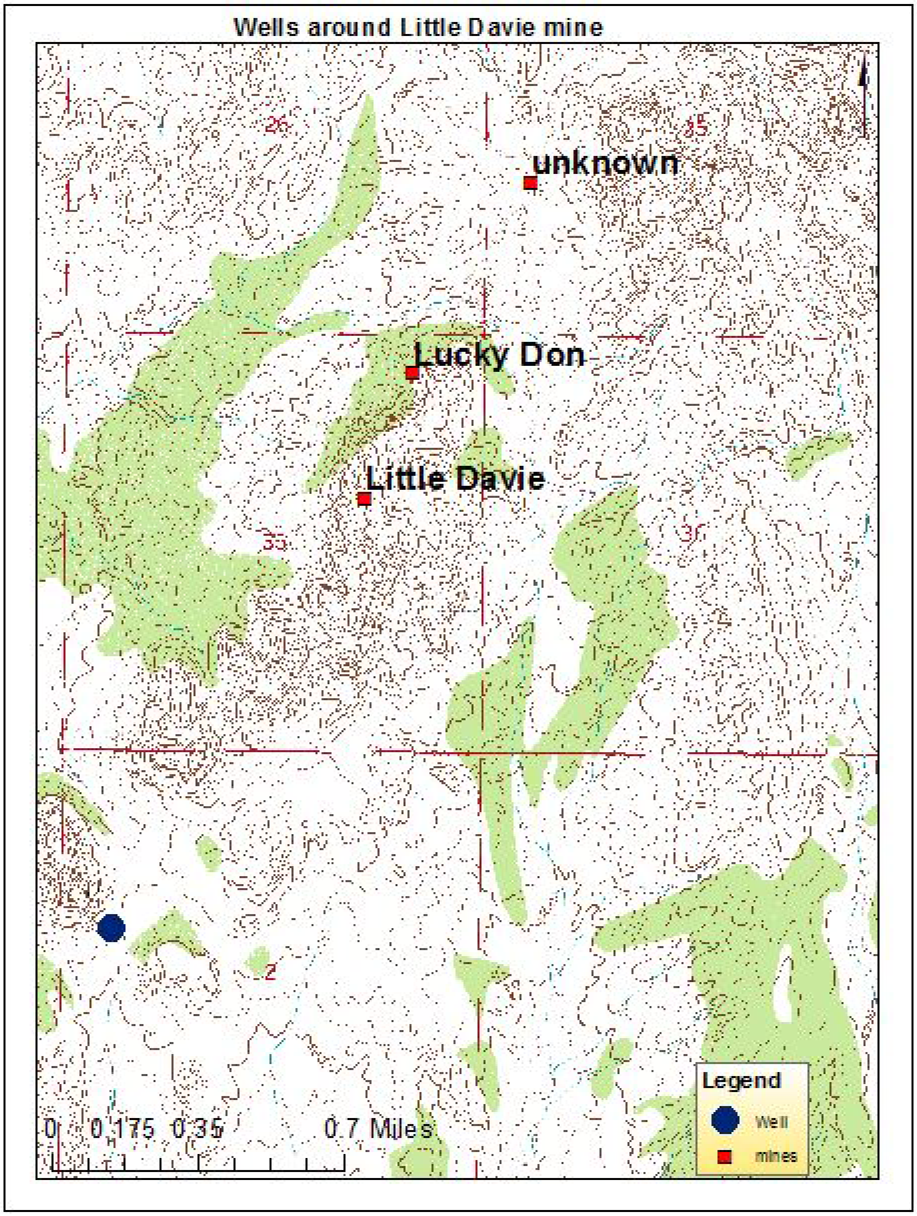



Figure 9. Map of Well Locations around Lucky Don and Little Davie mines

### 3.2.5 REGIONAL TOPOGRAPHY AND TERRAIN

Lucky Don and Little Davie mines are found on the Bustos Well 7.5 Quadrangle. Lucky Don is in Township 2S, Range 2E and section NE$^{1}/_{4}$ NE$^{1}$/35 at an elevation of approximately 6035 ft above mean sea level, while Little Davie is in Township 2S, Range 2E and section SW $^{1}/_{4}$ NE$^{1}$/35 at an elevation of about 6100 ft above mean sea level. Groundwater is at 55 ft depth.

### 3.2.6 MINE FEATURES

Mine features at the Lucky Don mine include a cut face of about 170 ft long, 4 stub adits in the cut face, a wooden loading bin and three waste rock piles with a volume of about 32,000 ft$^3$. Mine features at Little Davie mine include 6 ft deep pit, face cut and a waste rock pile. At the time of our visit an exploration pit of 8 ft x 12 ft and 6 ft deep was found. Lucky Don has a cut face of approximately 170 ft long with 4 stub adits located in the cut face.

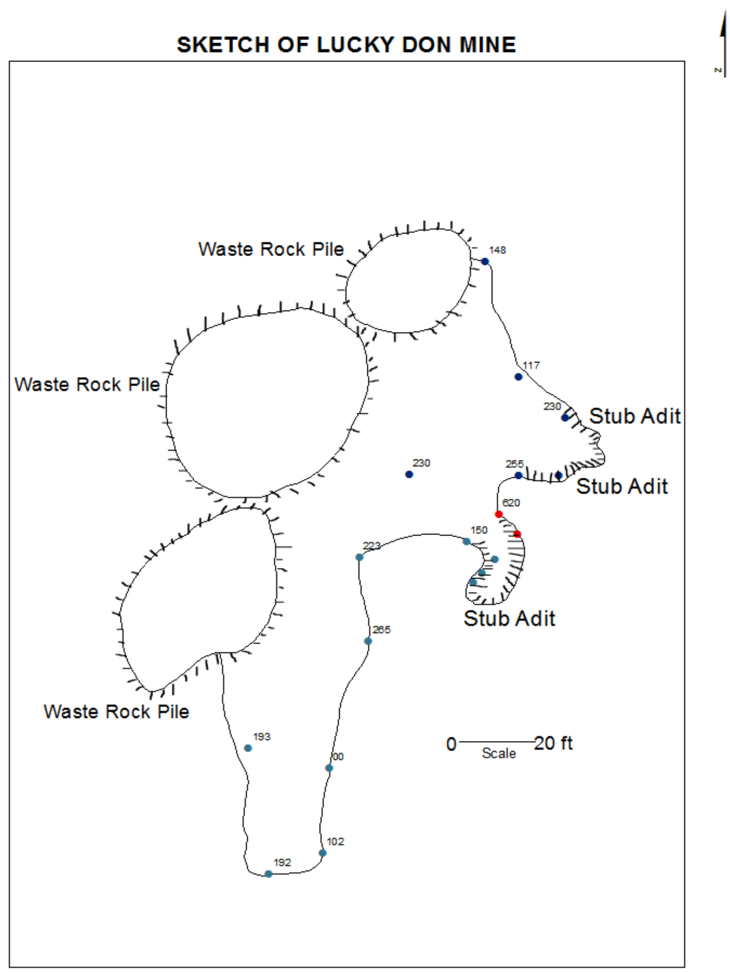



Figure 10. Sketch of Lucky Don mine (2016)

### 3.2.7 ARCHEOLOGICAL SITES

No archeological sites were identified at or near the sites.

### 3.2.8 SITE RADIATION READINGS

Background radiation measurements from scintillometer were between 20-50 counts per second (cps). Minimum radiation reading at Lucky Don mine was 100 cps while the maximum radiation reading was 4,435 cps. Also minimum radiation reading at Little Davie mine was 120 cps and the maximum radiation reading was 1,640 cps.

### 3.2.9 CURRENT LAND USES

The area is currently used for cattle grazing. Meadowlarks and other small birds were observed onsite. Rabbit droppings were identified.

### 3.2.10 HUMAN ACTIVITY AND RECREATIONAL SITE USE

Footprints and dung of cows were seen along the access route to the mines.

### 3.2.11 VEGETATION

Vegetation at the sites are sparse, native, healthy and dominated by pinon pines and cholla cactus.

### 3.2.12 EROSION

Surface runoff discharge downslope from both mines.

## 4.0 RESULTS

### 4.1 Description of Waste Rock Piles

Waste rock piles samples from mines examined are described in Table 4 below.

Table 4. Waste rock pile description

| Waste Rock Pile | Description | Texture | Lithology |
|---|---|---|---|
| Jeter1 | Dark brown sediments, ranging from sand to gravel | Angular to sub-angular | Conglomerates and limestones |
| Jeter29 | Dark brown sediments, ranging from sand to gravel | Angular to sub-angular | Conglomerates and limestones |
| Jeter31 | Dark brown sediments, ranging from sand to gravel | Angular to sub-angular | Conglomerates and limestones |
| Little Davie | Light brown material with approximately 60% covered by cobbles or larger sized rock | Angular | Sandstones, siltstones, limestones |
| Lucky Don | Light brown material with approximately 60% covered by cobbles or larger sized rock | Angular | Sandstones, siltstones, limestones |

**4.2 Paste pH and paste Conductivity Results**

Paste pH and paste conductivity results are presented in Table 5 below. Average pH values of the mines ranges between 7.5-8.24. The pH results indicate moderately alkaline waste rock piles. Total dissolved solids (TDS) values calculated provide an indication of the level of dissolved solids in the stream or lakes closer to the waste rock piles. TDS values of 1 to 500 mg/L are typical of lakes and streams.

Table 5. Summary of paste pH and paste conductivity results for waste rock piles.

| Waste Rock Pile | Average paste pH | Average Conductivity | TDS (mg/L) |
|---|---|---|---|
| Jeter1 | 7.77 | 1.25 | 1 |
| Jeter29 | 7.85 | 1.278 | 1 |
| Jeter31 | 7.50 | 814.6 | 428 |
| Little Davie | 8.24 | 193.2 | 98 |
| Lucky Don | 8.16 | 181.5 | 92 |

### 4.3 Chemistry and Mineralogy Results

Results of total whole rock chemistry are presented in Tables A3-A7 in Appendix A. Total whole rock analyses were done on all 5 waste rock piles from the studied area. Table 6 below shows a comparison of total whole rock chemistry values for uranium, vanadium, arsenic and copper from the study areas to the Environmental Protection Agency's (EPA) Regional Screening Levels (2016). Uranium, vanadium and copper concentrations in the waste rock piles are below the resident soil levels. However, arsenic concentrations from the mines examined are greater than the industrial soil levels. The National Uranium Resource Evaluation (NURE) data collected in 1980 and results from Ladron sediment survey were also compared to total whole rock chemistry values. Uranium and copper concentrations in the Jeter mine were greater than NURE's range in common soil, but vanadium concentrations are within NURE's range in common soil. However uranium, vanadium and copper concentrations from Little Davie and Lucky Don waste rock piles are greater than NURE's range in common soils.

Table 6. Chemistry of mine waste rock samples, EPA Regional Screening Levels and National Uranium Resource Evaluation data.

| Sample | U (ppm) | V (ppm) | As (ppm) | Cu (ppm) |
|---|---|---|---|---|
| Jeter1 | 23.7 | 93 | 6.1 | 537 |
| Jeter29 | 75.1 | 101 | 5.1 | 223 |
| Jeter31 | 138 | 74 | 7.5 | 290 |
| Little Davie | 160.5 | 457 | 50 | 9 |
| Lucky Don | 126.5 | 563 | 241 | 11 |
| NURE, Range in common soil[1] | 0.6-4.8 | 15-250 | | 10-100 |
| NURE, Range in Ladron soil[1] | 1.93-6.62 | 34-358 | | 11-163 |
| EPA Resident soil (mg/kg)[2] | 230 | 460 | 0.68 | 3,100 |
| EPA Industrial soil (mg/kg)[2] | 3,500 | 380,000,000 | 3 | 47,000 |

[1]From Chamberlin et al, (1982)
[2]From EPA (https://www.epa.gov/sites/production/files/2016-06/documents/master_sl_table_run_may2016.pdf)

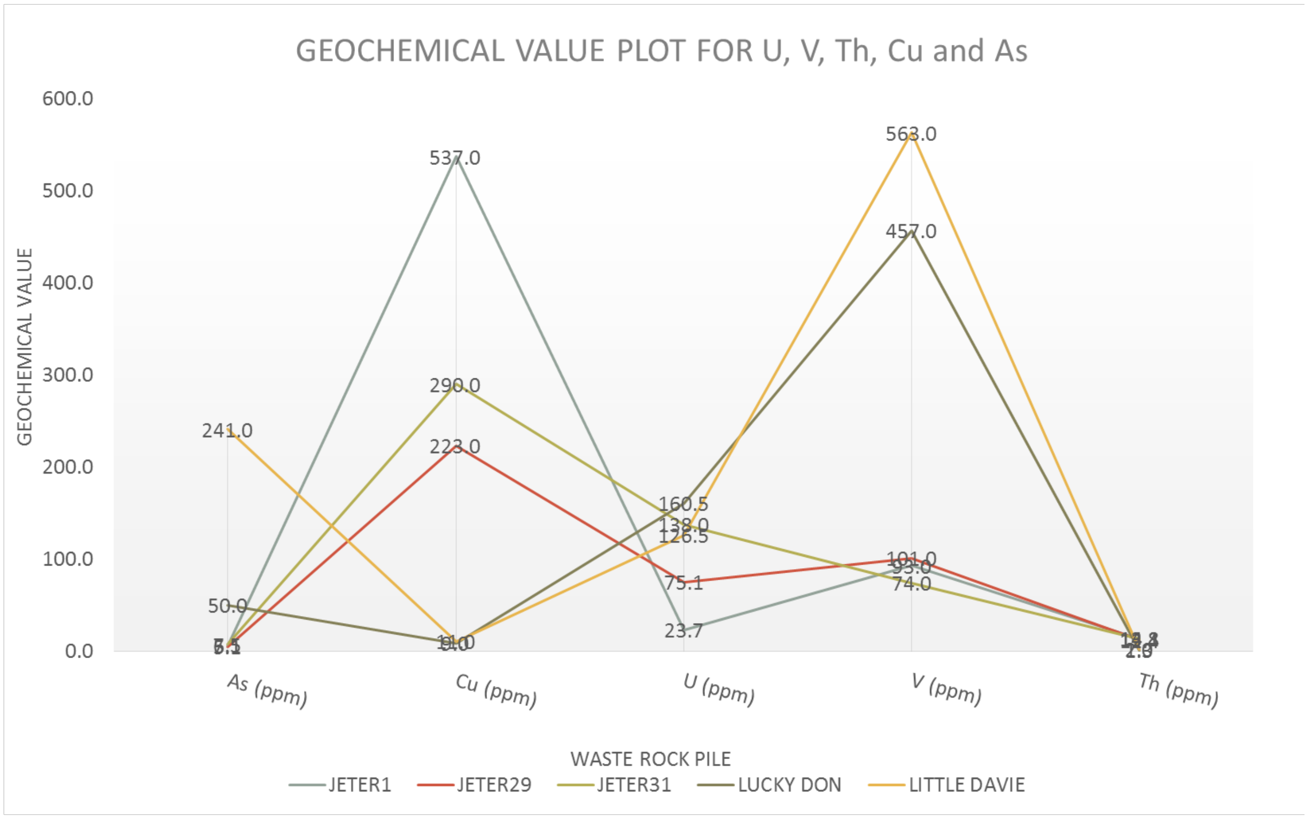



Figure 11. Geochemical value plot for arsenic, copper, uranium, vanadium and thorium. Analyses are in Appendix A.

### 4.3.1 Acid Rock Drainage (ARD) Classification

Acid rock drainage is formed when sulfide minerals are exposed to oxidizing conditions such as weathering. Field characteristics of potential ARD waste rock piles include, identification of pyrite and/or jarosite and low pH. The rate of sulfide oxidation depends on reactive surface area of sulfide, oxygen concentration and solution pH. ARD can be determined by Acid Base Accounting (ABA) and Net Acid Generation (NAG) Tests.

#### 4.3.1.1 Acid Base Accounting (ABA)

The ABA procedure consists of two separate tests; the acid potential (AP) test and the neutralization potential (NP) test. ABA was calculated and plotted on the ARD classification plot for waste rock pile samples from the various mines. The assumption is that all C in the samples are as $CaCO_3$ (no organic carbon) and also the NAG pH is equals the measured paste pH of the sample.

Below are the formula used:

AP (Kg $CaCO_3$/tonnes) = 31.25 x S (%)

NP (total C) = C (%) x 83.3,

NNP = NP – AP,

NPR = NP/AP

Results of ABA are presented in Table 7 and Figure 12.

Table 7. Net Neutralization Potential (NNP)

| Waste Rock Pile | S (%) | C (%) | AP (Kg CaCO3) | NP (total C) | NNP | NPR | NAGpH |
|---|---|---|---|---|---|---|---|
| JETER1 | 0.05 | 0.13 | 1.56 | 10.82 | 9.27 | 6.95 | 7.77 |
| JETER29 | 0.24 | 0.75 | 7.48 | 62.47 | 54.99 | 8.35 | 7.84 |
| JETER31 | 0.05 | 0.21 | 1.56 | 17.49 | 15.93 | 11.23 | 7.49 |
| LITTLE DAVIE | 0.03 | 10.45 | 0.93 | 870.48 | 869.55 | 931.49 | 8.24 |
| LUCKY DON | 0.05 | 5.45 | 1.56 | 453.98 | 452.42 | 291.48 | 8.16 |

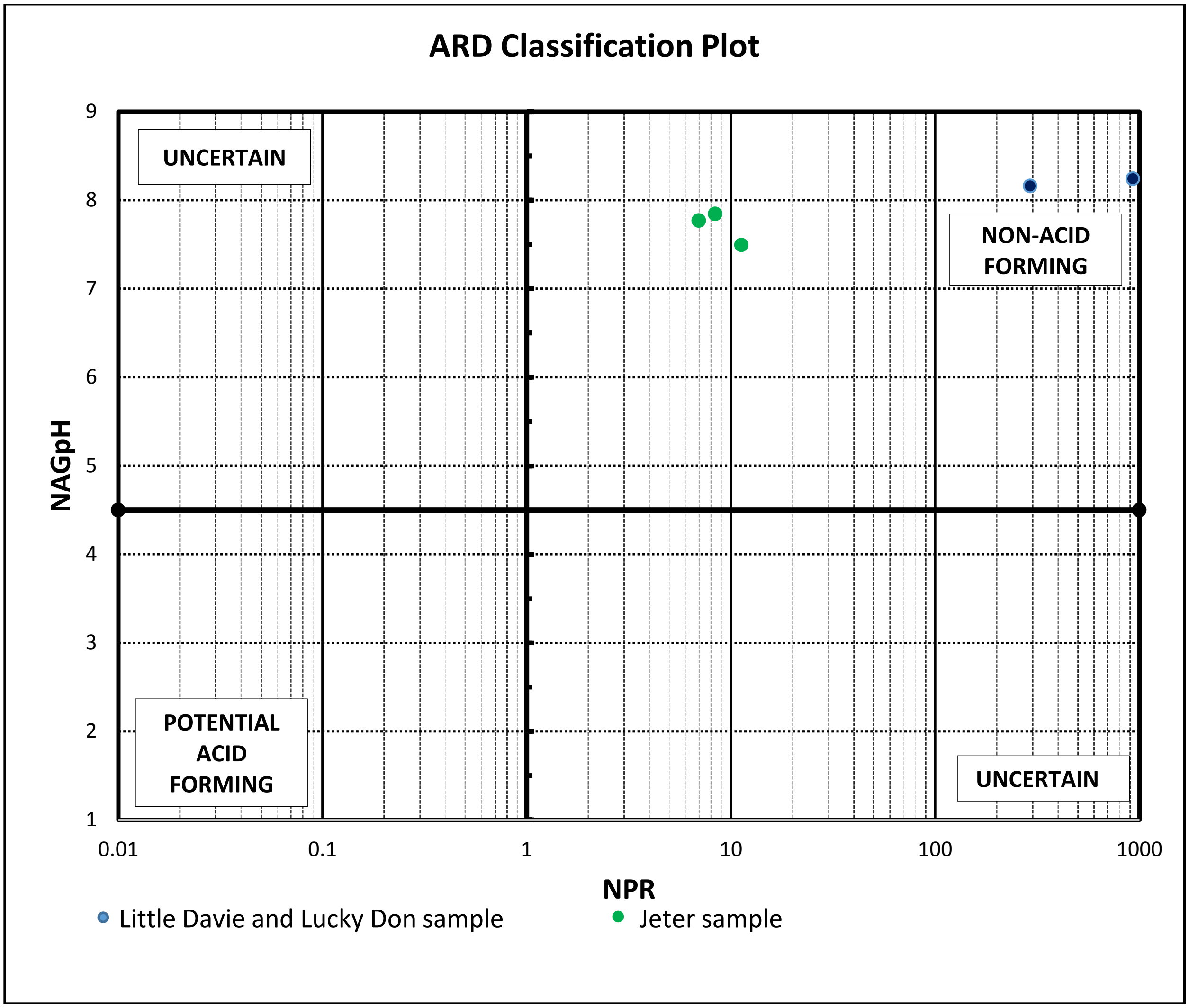



Figure 12. Acid Rock Drainage (ARD), waste rock pile classification Plot of mines.

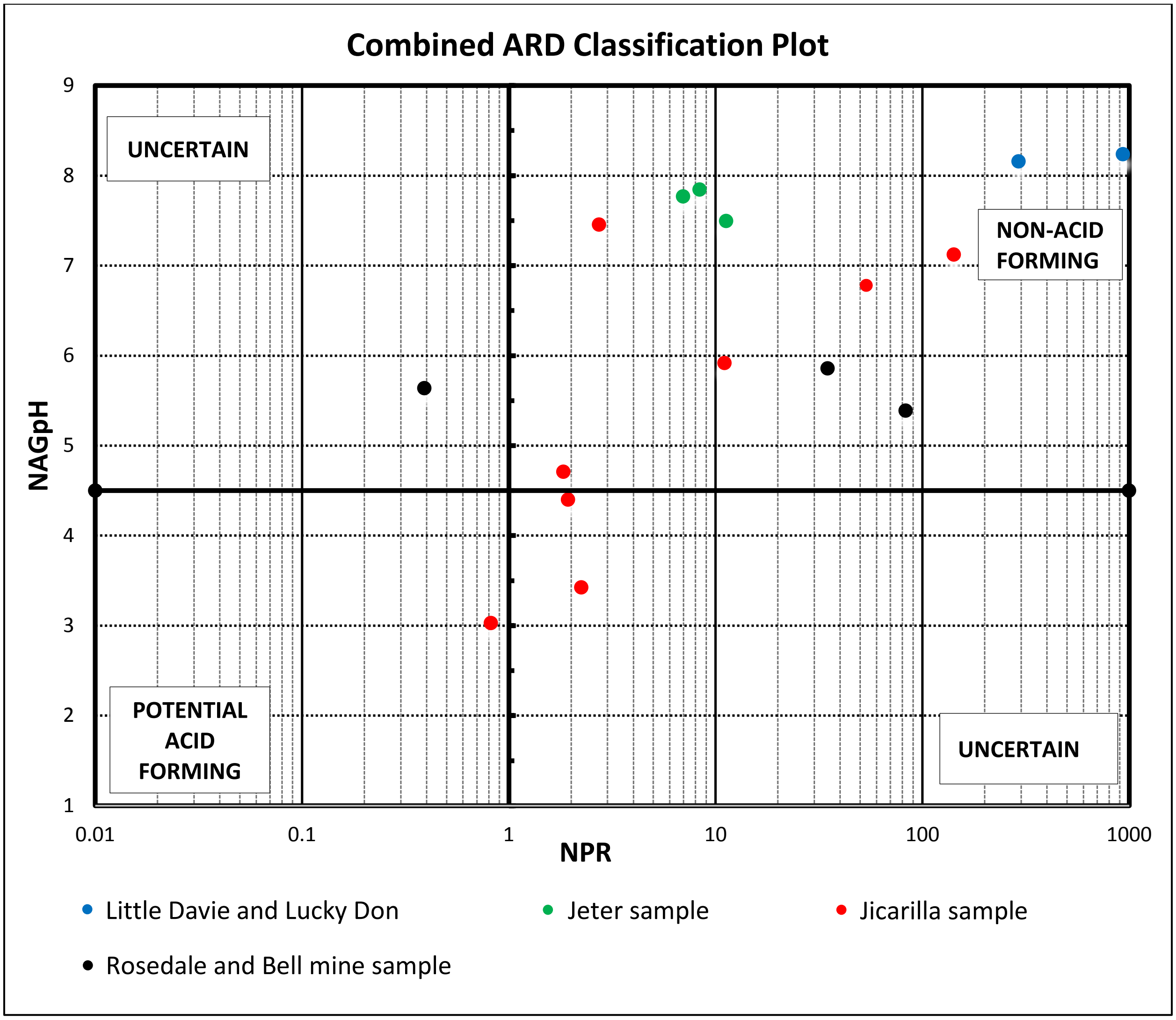



Figure 13. Acid Rock Drainage (ARD), waste rock pile Classification Plot of all working mines. The results for the gold waste rock piles from the Jicarilla Rosedale and Bell mines are shown for comparison (unpublished work in progress). Jicarilla mines are in the Jicarilla district in Lincoln County. Rosedale and Bell mines are in the Rosedale district in Socorro County. Results of these mines will be published in a future report.

### 4.4 Particle Size Analysis

Plots of particle size analyses for waste rock piles are presented in Figures 14 to 18. Particle size distribution curves obtained were generally poorly graded soil. Waste rock piles were sieved with 0.5 mm mesh in the field during sampling to eliminate gravel to cobble size particles from samples, which are not indicated in Figures 14-18. Samples plot mainly in the sand zone. Total fines were less than 30% of the sieved sample. From visual inspection in the field, waste rock piles are generally stable.

Figure 14. Particle Size Distribution curve for sample Jeter1

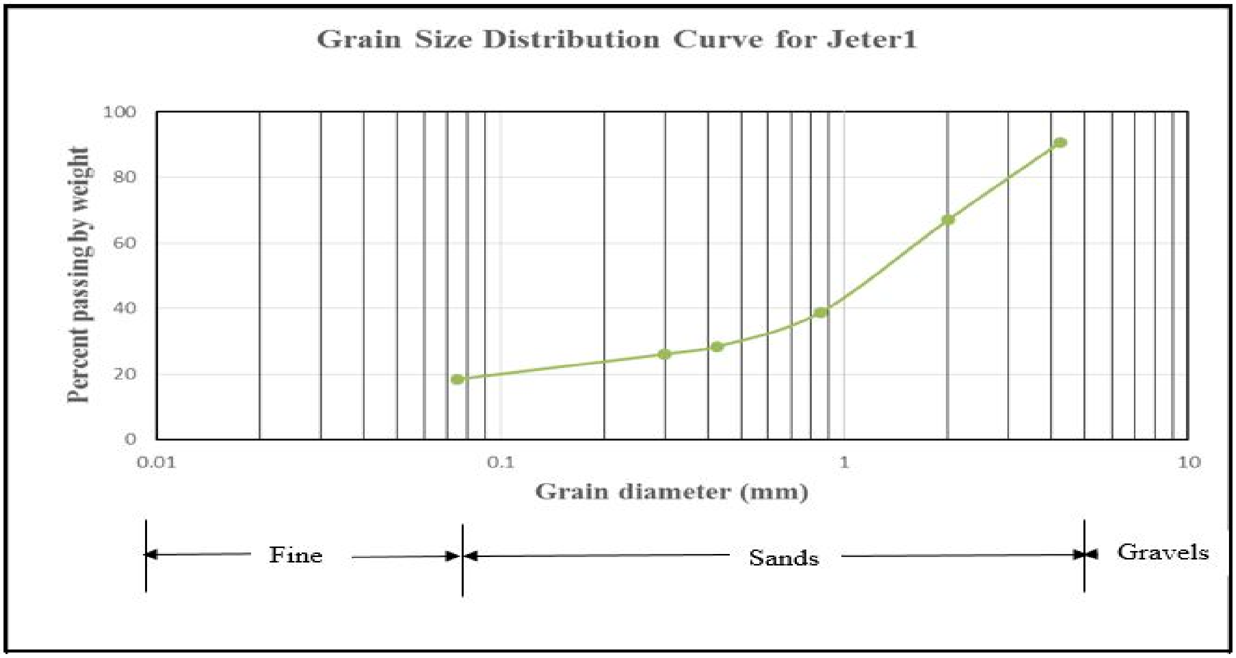



Figure 15. Particle Size Distribution curve for sample Jeter29

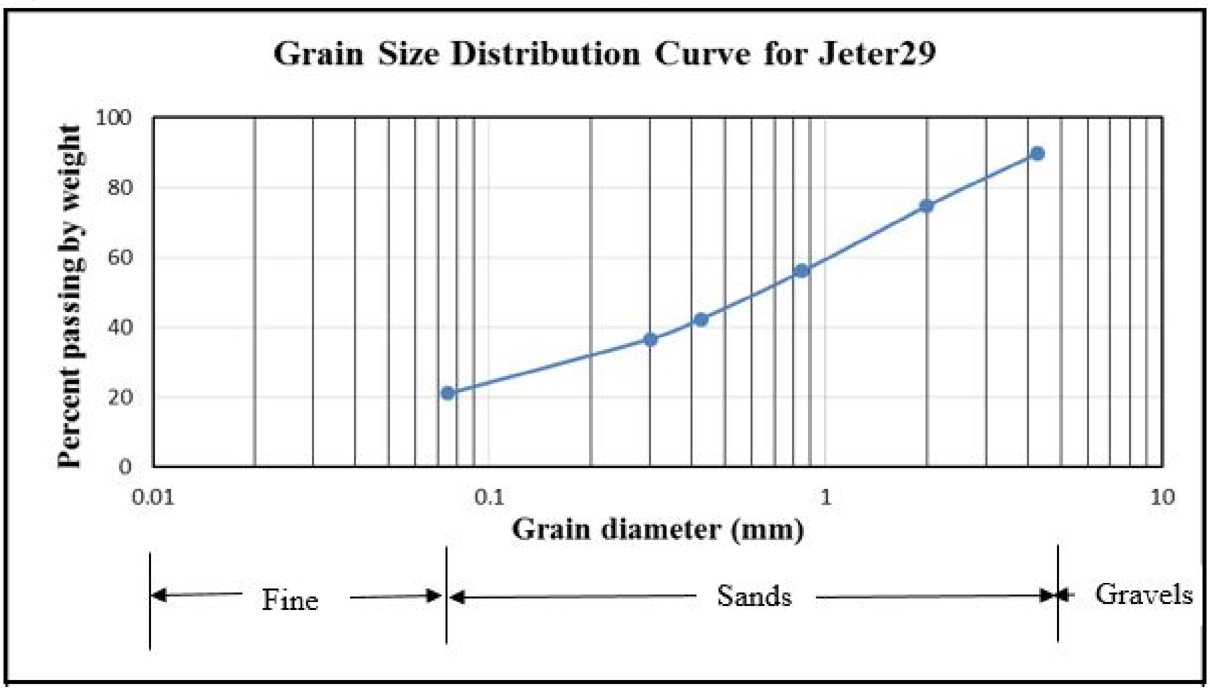


Figure 16. Particle Size Distribution curve for sample Jeter31

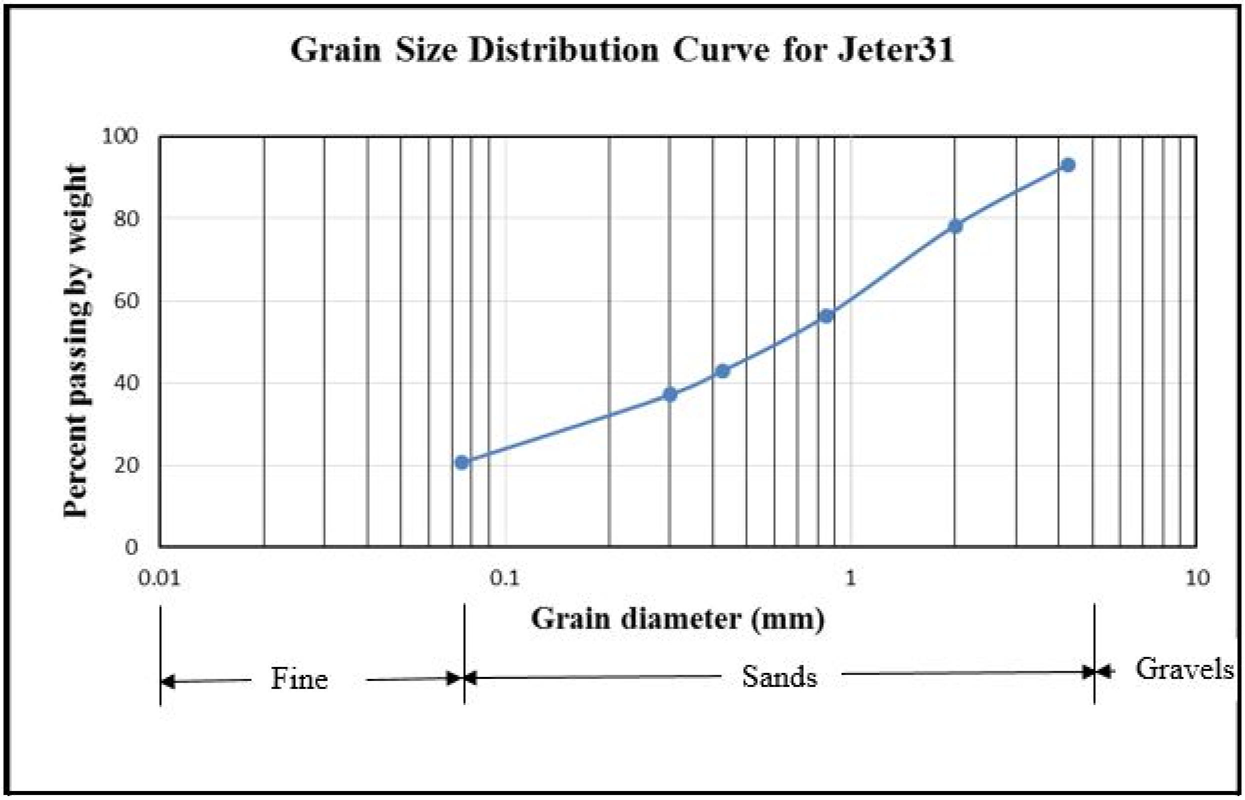



Figure 17. Particle Size Distribution curve for sample Lucky Don

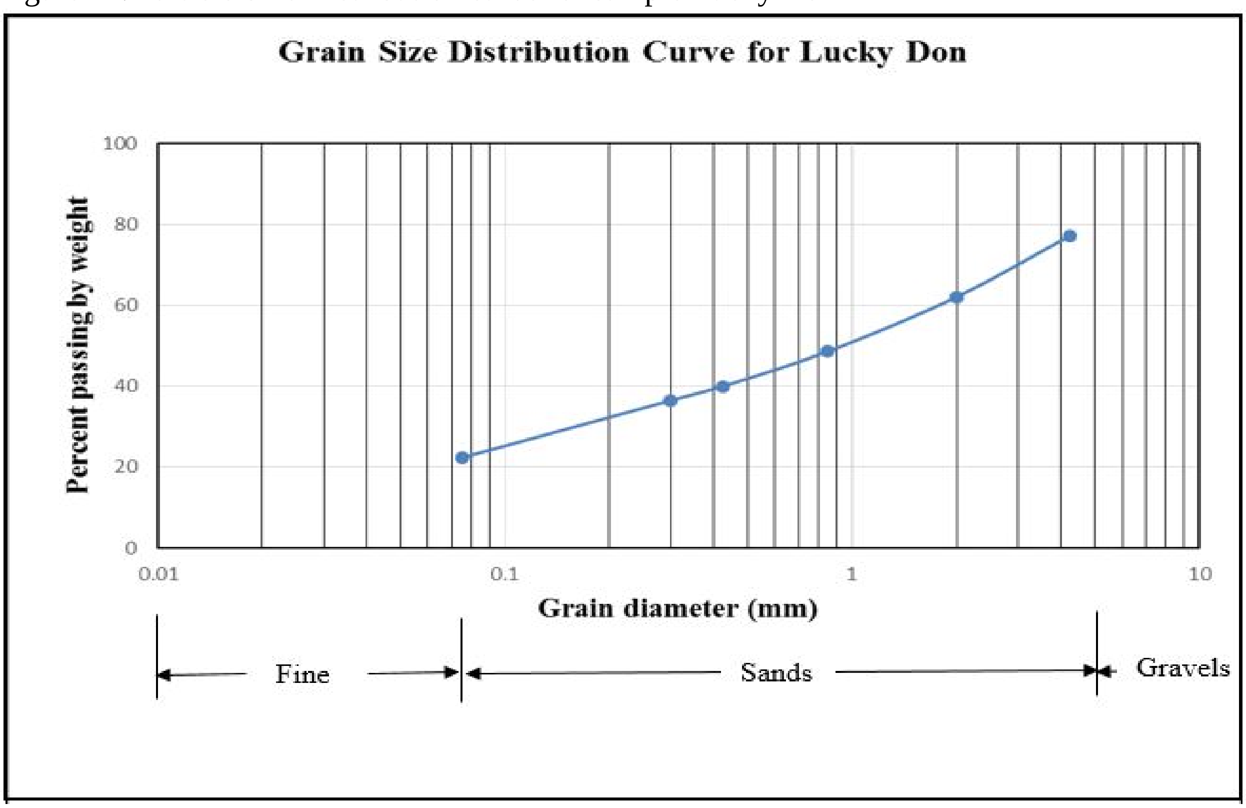
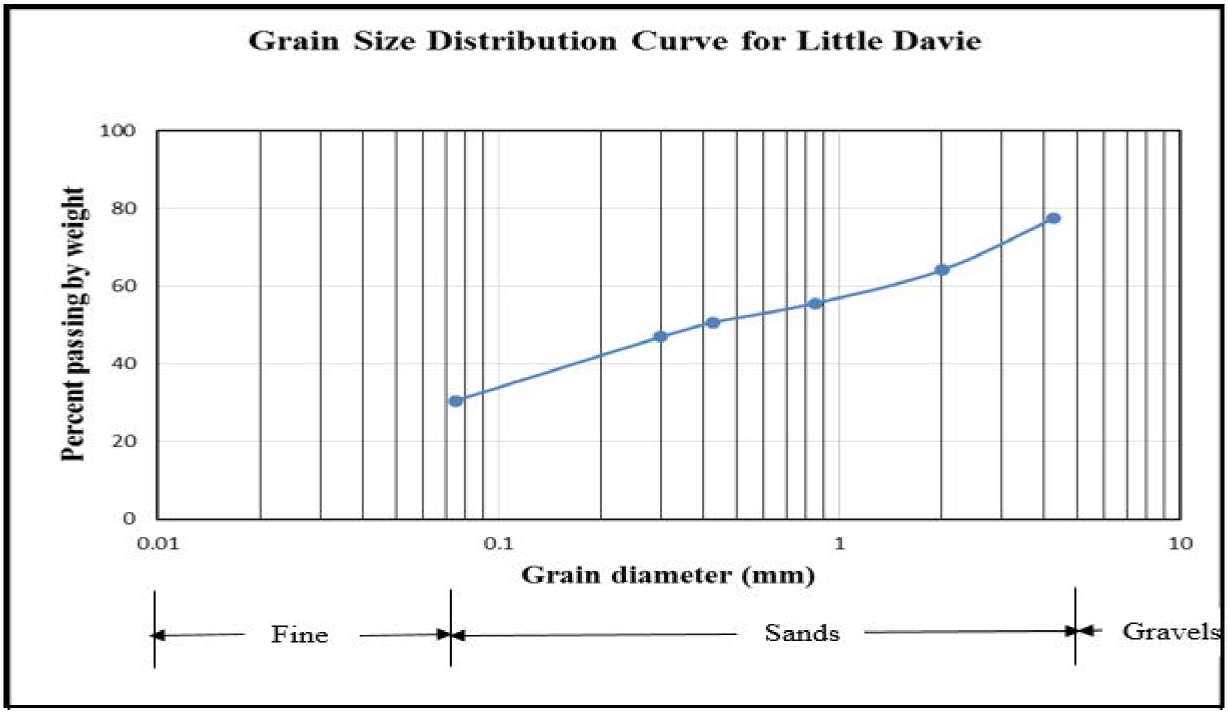


Figure 18. Particle Size Distribution curve for sample Little Davie




## 4.5 Electron microprobe

Figures 19-25 are the backscattered electron (BSE) images of rock chips found in the various waste rock piles. BSE images included pristine uranium, vanadium and $CaCO_3$ grains. Dissolved uranium and vanadium grains were also identified in some samples

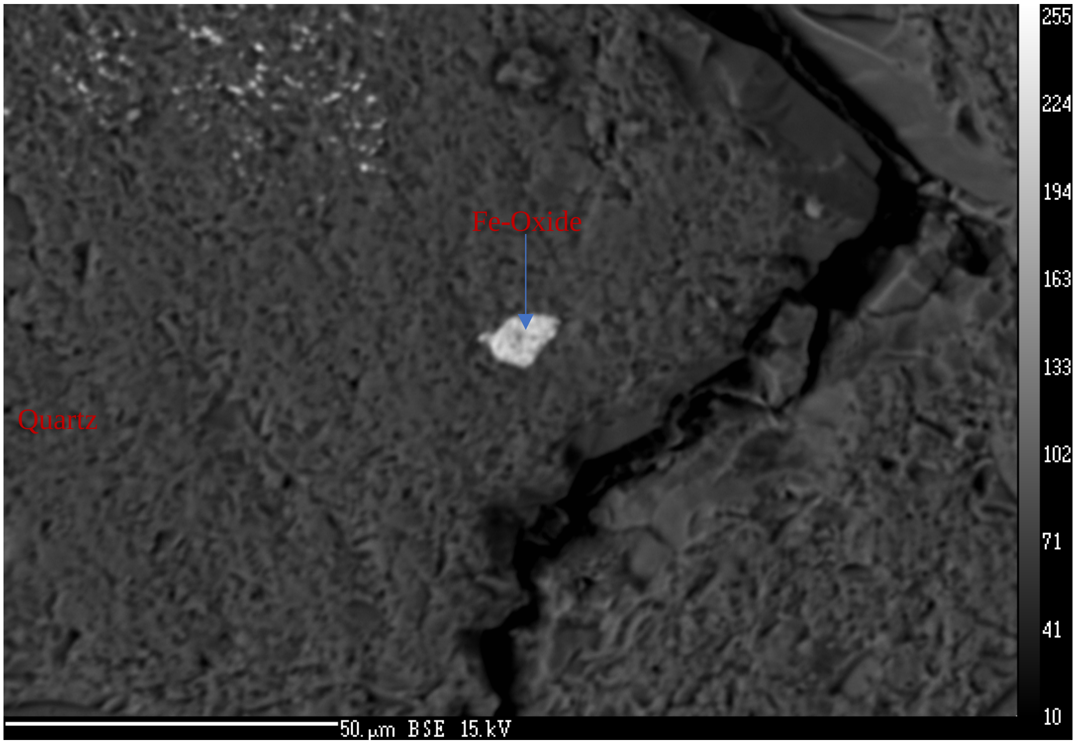



Figure 19. Backscattered electron image (BSE) of Fe-Oxide and Quartz grains - Jeter1. Source of iron oxide grain is interpreted as from surficial weathering.

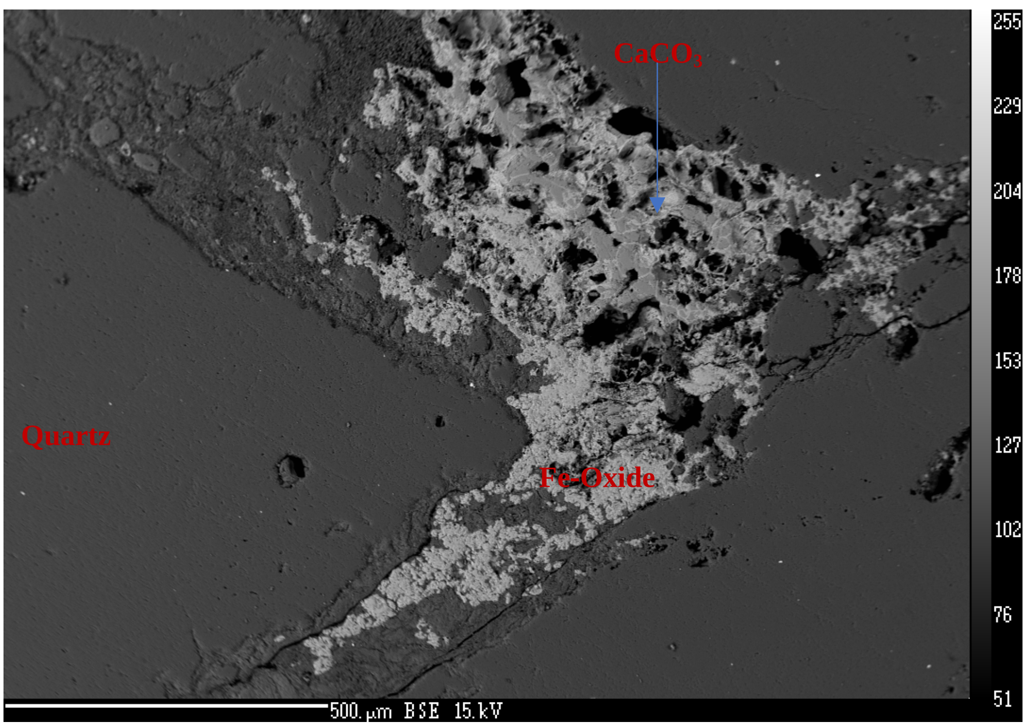



Figure 20. Backscattered Electron Image (BSE) of Fe-oxide, quartz and $CaCO_3$ grains, sample Jeter29. Though pyrite was not identified in from field investigations, the present of $CaCO_3$ grain is interpreted as neutralizing any possible acid producing minerals in the waste rock pile.

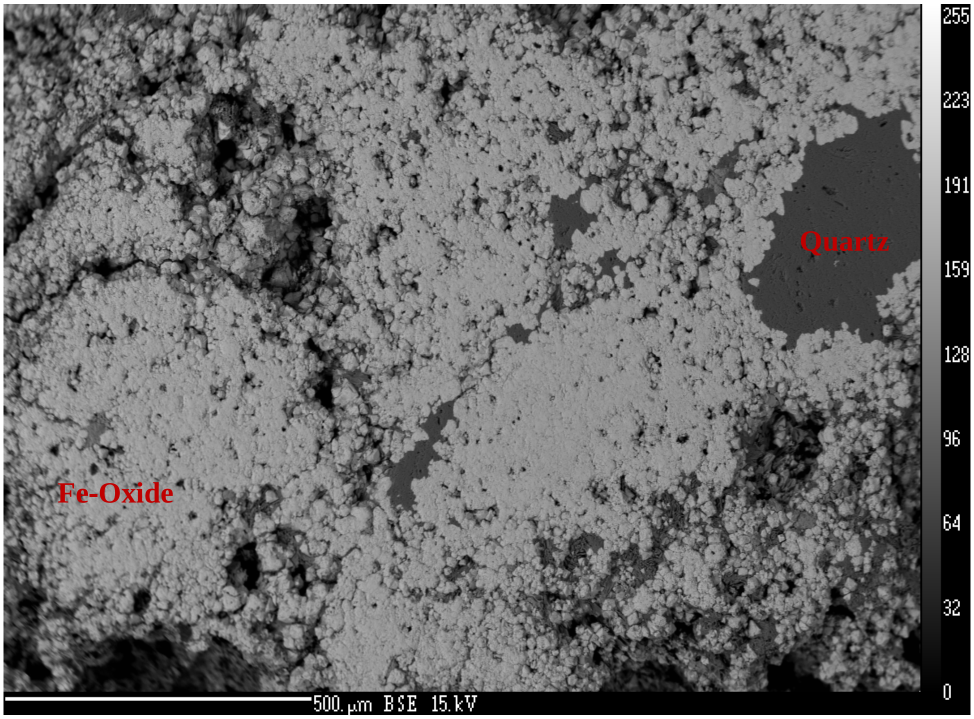



Figure 21: Backscattered Electron Image (BSE) of Fe-oxide and quartz grains, sample Jeter31. Source of iron oxide grain coatings is interpreted as from surficial weathering.

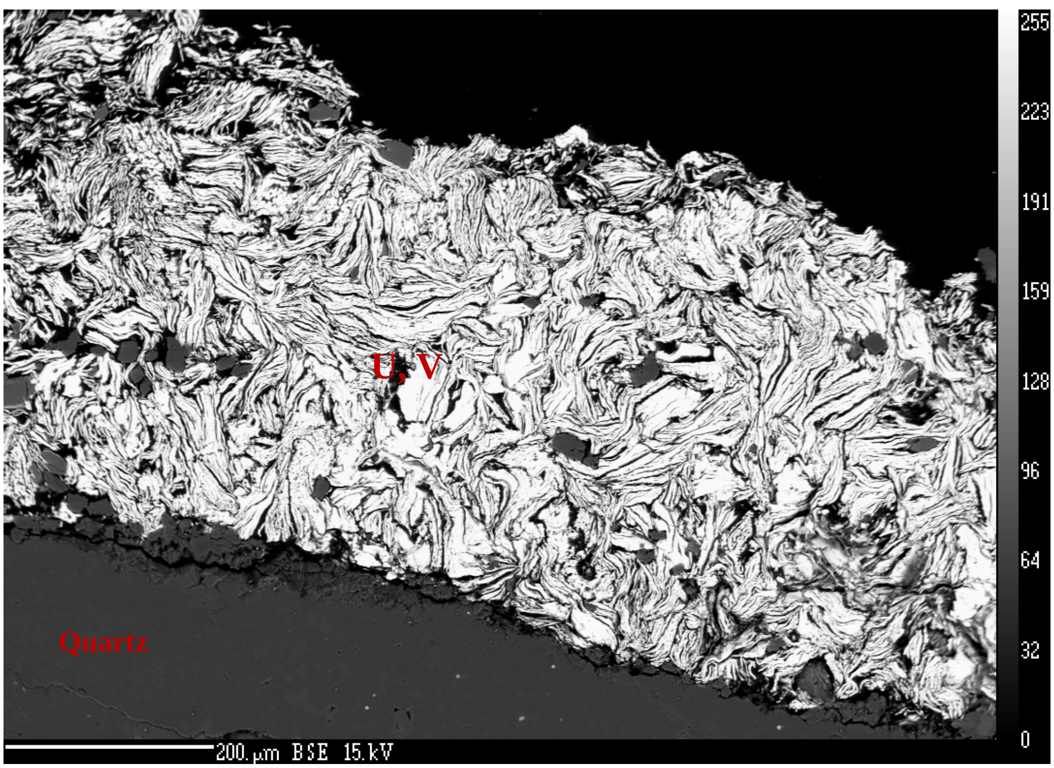



Figure 22: Backscattered electron image (BSE) of pristine uranium and vanadium grains, sample Lucky Don mine. Pristine mineral grains is interpreted as uranium and vanadium minerals in the waste rock pile had not dissolve, hence are not leaching into the environment.

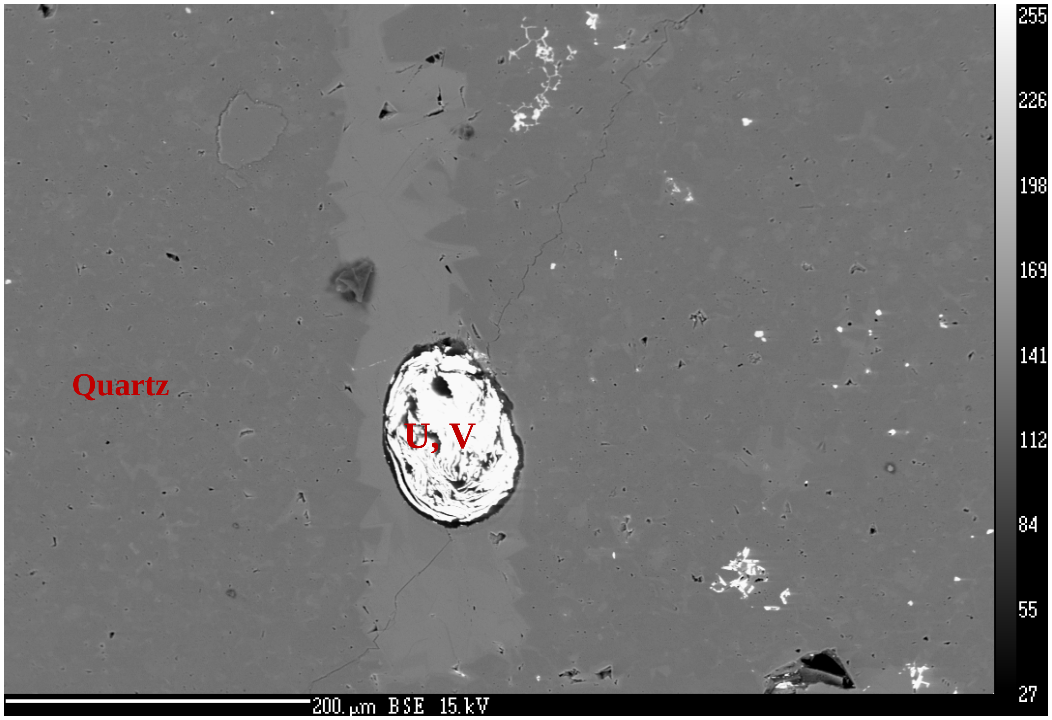


Figure 23: Backscattered electron image (BSE) of pristine uranium and vanadium grains, sample Lucky Don mine. Pristine mineral grains is interpreted as uranium and vanadium minerals in the waste rock pile had not dissolve, hence are not leaching into the environment.

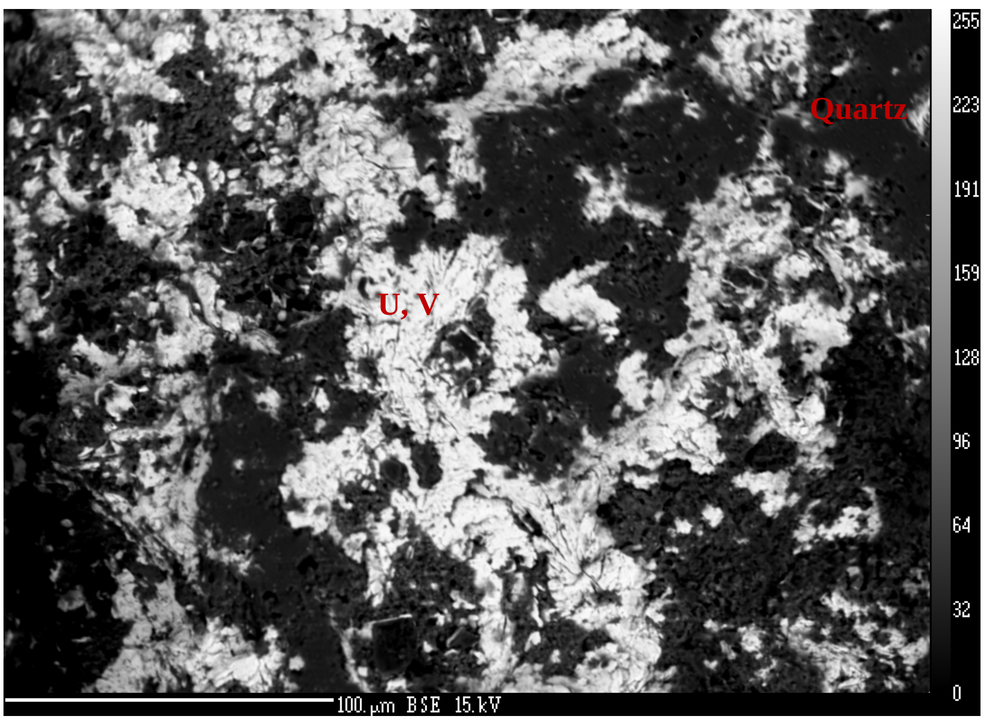


Figure 24: Backscattered Electron Image (BSE) of dissolved uranium and vanadium grains, sample Little Davie mine. Dissolved mineral grains is interpreted as possible leaching of uranium and vanadium minerals from waste rock pile.

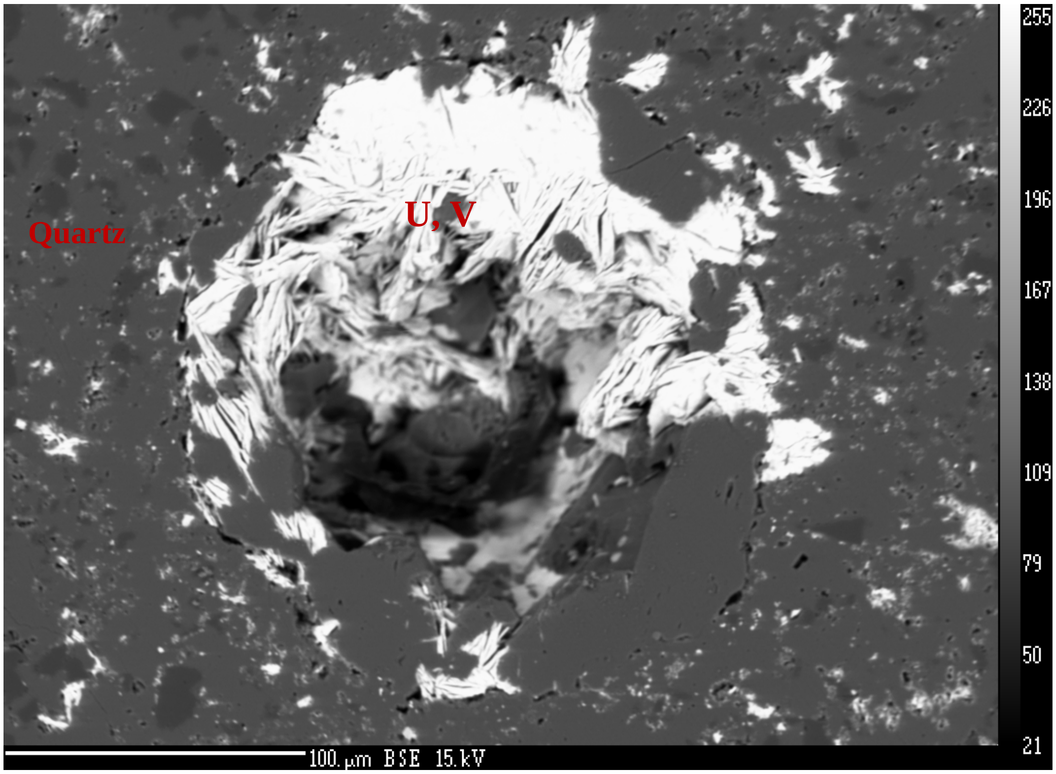



Figure 25: Backscattered Electron Image (BSE) of dissolved uranium and vanadium grains, sample Little Davie mine.

## 5.0 Discussions

The overall purpose of the study was to determine mineralogic and geochemical composition of wastes rock pile, their possible release of trace elements into the environment, and their acid/ neutralizing potential. In this manner, the study sought to develop a quick and inexpensive approach to inventory and characterizing waste rock piles. The assumptions of this study was that a quick and inexpensive procedure to characterizing waste rock piles could provide a key input into policy decisions on future reclamation activities.

Many studies have characterized mine waste. Brodie (1991) developed a conceptual model for classifying waste rock management and a laboratory method for predicting acid rock drainage from waste rock piles. Previous mine waste characterization studies (Techie-Menson 2006; McLemore et al 2001; McLemore et al 2009a; McLemore et al 2010; McLemore and Herring 2002; McLemore and Morkeh 2012; Munroe 1999) in New Mexico, have characterized and examined mine waste from the Questa mine or other mining district, including particle size analyses, geology, mineralogy, textures, geochemistry, and acid/neutralization potential.

This study is significant because it characterizes uranium mines in different mining districts using relatively quick and inexpensive procedures (like paste pH), determined the acid/ neutralizing potential, and the suitability for use of waste rock piles for backfill.

## 6.0 CONCLUSIONS AND RECOMMENDATION

In this study, a volume of about 100,000 $ft^3$ of waste rock pile material were estimated at Jeter mine, and volume of about 32,000 $ft^3$ of waste rock pile was estimated at Lucky Don mine. Waste rock piles from mines examined had no evidence of potential acid drainage. Their pH values ranges between 7.5-8.2. The study found elevated radioactivity from scintillometer readings in the waste rock piles, backscattered electron images of pristine secondary uranium, vanadium and $CaCO_3$ grains from Lucky Don mine, while uranium and vanadium grains from Little Davie mine appeared to be dissolved. Waste rock piles from studied areas plotted in the non-acid forming zone on the Acid Rock Drainage (ARD) classification plot. It is recommended that waste piles with high radioactivity from scintillometer should be covered, also sediment survey should be conducted to determine the leachability of uranium, vanadium and other trace elements in the environment.

## 7.0 REFERENCES

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# APPENDIX A

Table A1. GPS Location Coordinates of waste rock piles

| Mine | Sample_ID | Latitude | Longitude |
|---|---|---|---|
| JETER | JETER1 | 34.442219 | -107.017 |
| JETER | JETER29 | 34.442447 | -107.017 |
| JETER | JETER31 | 34.442592 | -107.016 |
| LITTLE DAVIE | LD001 | 34.094326 | -106.701 |
| LUCKY DON | SOC2 | 34.098682 | -106.699 |

Table A2. Stations of scintillometer readings - Jeter mine

| Station | UTM_East | UTM_North | Radiation (cps) |
|---|---|---|---|
| Station 1 | 314714 | 3812839 | 120 |
| Station 2 | 314716 | 3812832 | 154 |
| Station 3 | 314721 | 3812803 | 110 |
| Station 4 | 314728 | 3812795 | 104 |
| Station 5 | 314760 | 3812794 | 102 |
| Station 6 | 314782 | 3812785 | 92 |
| Station 7 | 314809 | 3812785 | 100 |
| Station 8 | 314835 | 3812786 | 95 |
| Station 9 | 314835 | 3812791 | 90 |
| Station 10 | 314801 | 3812796 | 95 |
| Station 11 | 314955 | 3812822 | 88 |
| Station 12 | 314971 | 3812836 | 85 |
| Station 13 | 314978 | 3812857 | 82 |
| Station 14 | 314957 | 3812874 | 80 |
| Station 15 | 314937 | 3812876 | 85 |
| Station 16 | 314903 | 3812870 | 85 |
| Station 17 | 314885 | 3812888 | 93 |
| Station 18 | 314890 | 3812940 | 97 |
| Station 19 | 314866 | 3812905 | 113 |
| Station 20 | 314832 | 3812897 | 308 |
| Station 21 | 314822 | 3812889 | 746 |
| Station 22 | 314786 | 3812870 | 230 |
| Station 23 | 314781 | 3812857 | 319 |
| Station 24 | 314766 | 3812850 | 423 |
| Station 25 | 314762 | 3812842 | 590 |
| Station 26 | 314735 | 3812843 | 1640 |
| Station 27 | 314721 | 3812840 | 686 |
| Station 28 | 314730 | 3812830 | 299 |

Table A3. Total whole chemistry data

| Sample_ID | Au (ppm) | Al2O3 (%) | BaO (%) | CaO (%) | Cr2O3 (%) | Fe2O3 (%) | K2O (%) | MgO (%) | MnO (%) | Na2O (%) | P2O5 (%) | SiO2 (%) | SrO (%) | TiO2 (%) | LOI 1000 (%) | Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JETER1 | 0.015 | 14.7 | 0.12 | 0.7 | 0.02 | 4.55 | 3.4 | 1.16 | 0.16 | 0.64 | 0.15 | 69.85 | 0.02 | 0.57 | 3.86 | 100.2 |
| JETER29 | <0.001 | 14.75 | 0.1 | 2.58 | 0.01 | 4.26 | 3.27 | 1.54 | 0.13 | 1.7 | 0.24 | 63.33 | 0.02 | 0.8 | 5.74 | 99.14 |
| JETER31 | <0.001 | 14.02 | 0.08 | 0.88 | 0.01 | 3.45 | 3.6 | 0.74 | 0.22 | 1.54 | 0.18 | 70.91 | 0.01 | 0.51 | 3.15 | 99.54 |
| LD001 | <0.001 | 1.33 | 0.02 | 35.3 | <0.01 | 1.1 | 0.29 | 7.86 | 0.15 | 0.11 | 0.12 | 15.65 | 0.02 | 0.08 | 37.2 | 99.47 |
| SOC2 | 0.003 | 2.49 | 0.02 | 18.85 | <0.01 | 1.71 | 0.72 | 4.89 | 0.07 | 0.03 | 0.07 | 50.55 | 0.01 | 0.12 | 20.27 | 100.15 |

Table A4. Total whole chemistry data

| Sample_ID | Ba (ppm) | Ce (ppm) | Cr (ppm) | Cs (ppm) | Dy (ppm) | Er (ppm) | Eu (ppm) | Ga (ppm) | Gd (ppm) | Ge (ppm) | Hf (ppm) | Ho (ppm) | La (ppm) | Lu (ppm) | Nb (ppm) | Nd (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JETER1 | 1180 | 72.4 | 60 | 67.7 | 5.54 | 3.41 | 1.2 | 18.7 | 5.34 | <5 | 5.3 | 1.11 | 35 | 0.52 | 17.6 | 30.5 |
| JETER29 | 982 | 74.3 | 80 | 16.2 | 6.06 | 3.34 | 1.38 | 18.6 | 6.09 | <5 | 4.9 | 1.27 | 35.8 | 0.49 | 24.1 | 33.1 |
| JETER31 | 755 | 69.5 | 70 | 32.3 | 5.43 | 3.28 | 1.16 | 17.9 | 5.69 | <5 | 4.6 | 1.14 | 33.6 | 0.46 | 18.5 | 30.3 |
| LD001 | 230 | 9.3 | 20 | 0.91 | 1.04 | 0.66 | 0.19 | 2.4 | 0.8 | <5 | 1.4 | 0.22 | 4.5 | 0.17 | 2 | 4.3 |
| SOC2 | 150.5 | 13.5 | 30 | 2.44 | 0.94 | 0.62 | 0.29 | 4 | 1.1 | <5 | 1.5 | 0.18 | 6.7 | 0.09 | 2.8 | 6.1 |

Table A5. Total whole chemistry data

| Sample_ID | Pr (ppm) | Rb (ppm) | Sm (ppm) | Sn (ppm) | Sr (ppm) | Ta (ppm) | Tb (ppm) | Th (ppm) | Tm (ppm) | U (ppm) | V (ppm) | W (ppm) | Y (ppm) | Yb (ppm) | Zr (ppm) | Ag (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JETER1 | 8.58 | 252 | 6.71 | 2 | 212 | 1.6 | 0.91 | 14.1 | 0.52 | 23.7 | 93 | 3 | 32.8 | 3.07 | 198 | 0.7 |
| JETER29 | 8.77 | 180 | 7.3 | 2 | 253 | 2 | 0.98 | 12.4 | 0.53 | 75.1 | 101 | 2 | 34.5 | 3.32 | 179 | <0.5 |
| JETER31 | 8.13 | 222 | 6.46 | 2 | 139 | 1.8 | 0.93 | 13.8 | 0.48 | 138 | 74 | 3 | 32.9 | 3.27 | 175 | <0.5 |
| LD001 | 1.15 | 13 | 0.82 | <1 | 164.5 | 0.1 | 0.15 | 1.32 | 0.13 | 160.5 | 457 | 4 | 7.2 | 0.83 | 56 | <0.5 |
| SOC2 | 1.67 | 28.7 | 1.37 | 1 | 78.3 | 0.1 | 0.15 | 1.96 | 0.1 | 126.5 | 563 | 3 | 5.5 | 0.64 | 56 | <0.5 |

Table A6. Total whole chemistry data

| Sample_ID | Cd (ppm) | Co (ppm) | Cu (ppm) | Li (ppm) | Mo (ppm) | Ni (ppm) | Pb (ppm) | Sc (ppm) | Zn (ppm) | As (ppm) | Bi (ppm) | Hg (ppm) | In (ppm) | Re (ppm) | Sb (ppm) | Sc (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JETER1 | <0.5 | 15 | 537 | 30 | 3 | 34 | 143 | 10 | 153 | 6.1 | 0.46 | 0.117 | 0.023 | 0.003 | 0.91 | 4.2 |
| JETER29 | 0.5 | 19 | 223 | 30 | 3 | 40 | 39 | 11 | 145 | 5.1 | 0.4 | 0.302 | 0.022 | 0.008 | 0.3 | 4.2 |
| JETER31 | 2.2 | 31 | 290 | 20 | 4 | 43 | 69 | 10 | 200 | 7.5 | 0.89 | 0.155 | 0.024 | 0.008 | 0.29 | 3.6 |
| LD001 | 2.8 | 9 | 9 | <10 | 11 | 68 | 76 | 1 | 380 | 50 | 0.03 | 0.253 | 0.006 | 0.016 | 6.68 | 0.6 |
| SOC2 | 2.6 | 3 | 11 | 10 | 6 | 22 | 82 | 2 | 495 | 241 | 0.05 | 0.093 | 0.008 | 0.008 | 2.02 | 1 |

Table A7. Total whole chemistry data

| Sample_ID | Se (ppm) | Te (ppm) | Tl (ppm) | S (%) | C (%) |
|---|---|---|---|---|---|
| JETER1 | 0.6 | 0.01 | 0.21 | 0.05 | 0.13 |
| JETER29 | 2.1 | 0.01 | 0.11 | 0.24 | 0.75 |
| JETER31 | 0.5 | 0.02 | 0.17 | 0.05 | 0.21 |
| LD001 | 1.7 | 0.02 | 6.6 | 0.03 | 10.45 |
| SOC2 | 3.2 | 0.01 | 1.11 | 0.05 | 5.45 |

**APPENDIX B**

*JETER MINE PHOTOS*

Figure 26. Cut face of Jeter mine

Figure 27. Jeter mine with concrete platform

Figure 28. Jeter mine looking southwest

Figure 29. Jeter mine looking west

*LUCKY DON AND LITTLE DAVIE MINES PHOTOS*


Figure 30. Ore chute at Lucky Don

Figure 31. Cut face with stub adits - Lucky Don mine


Figure 32. GPS/ Scintillometer mapping at Lucky Don

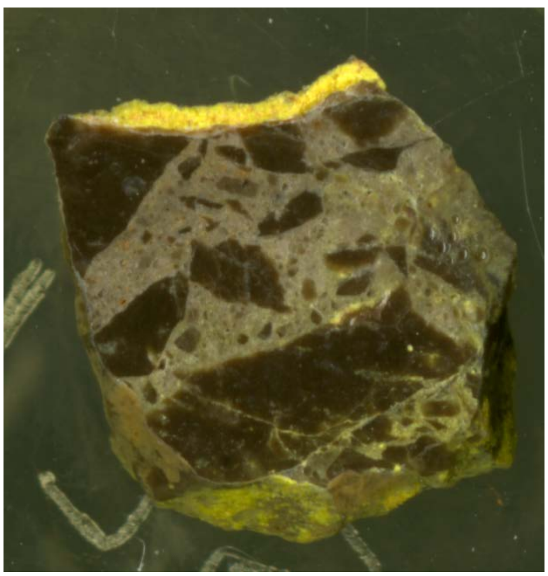


Figure 33. Mineralized Sample

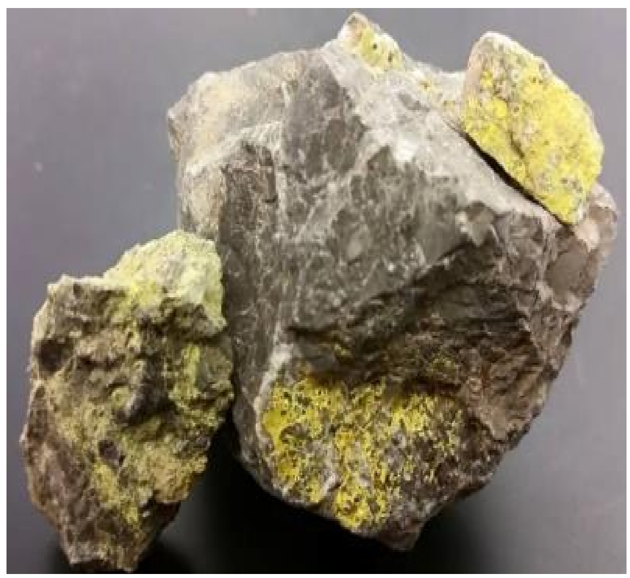


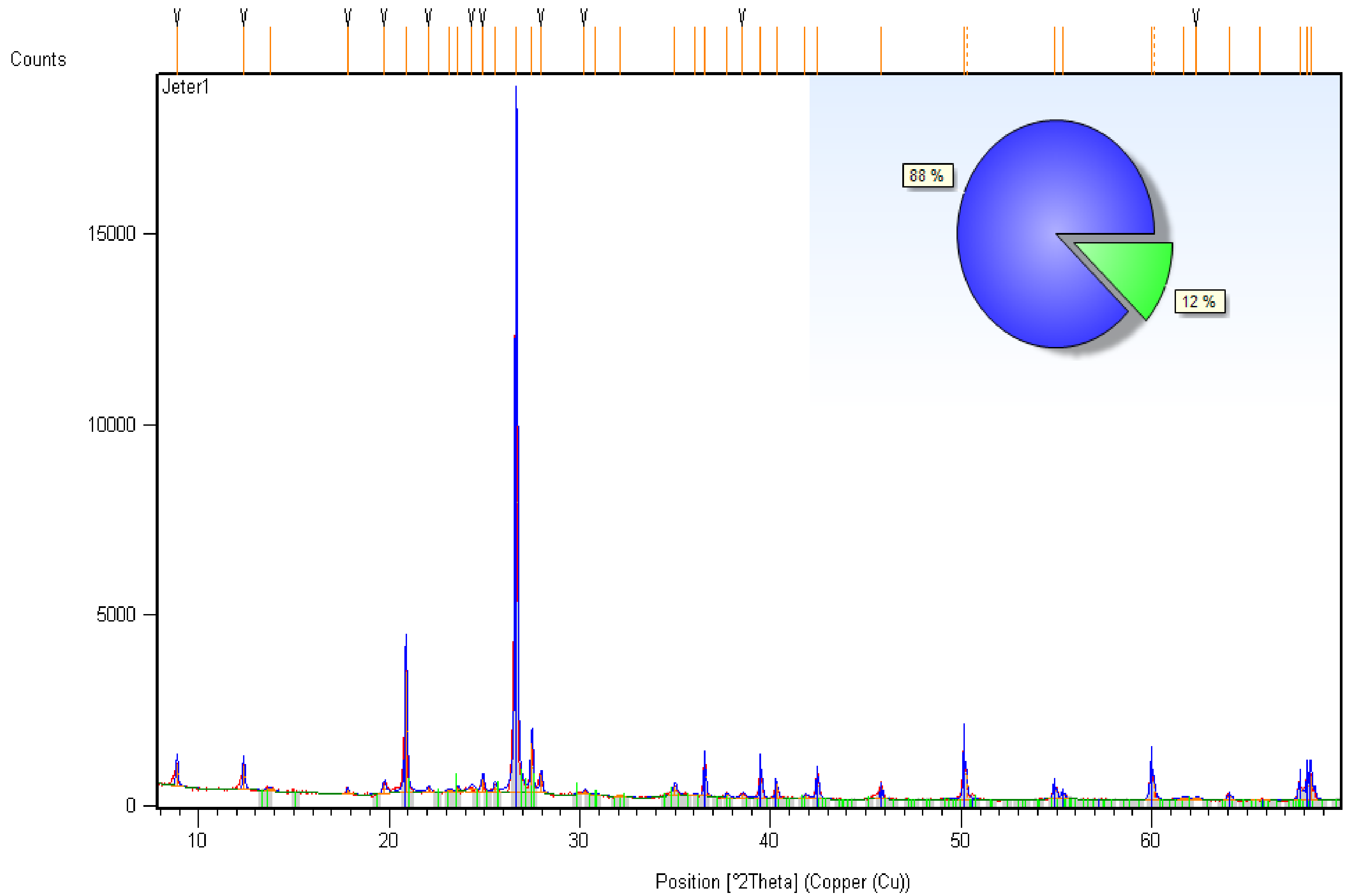
Figure 34. Mineralized Sample

Figure 35. Little Davie mine looking north

Figure 36. Little Davie mine looking south

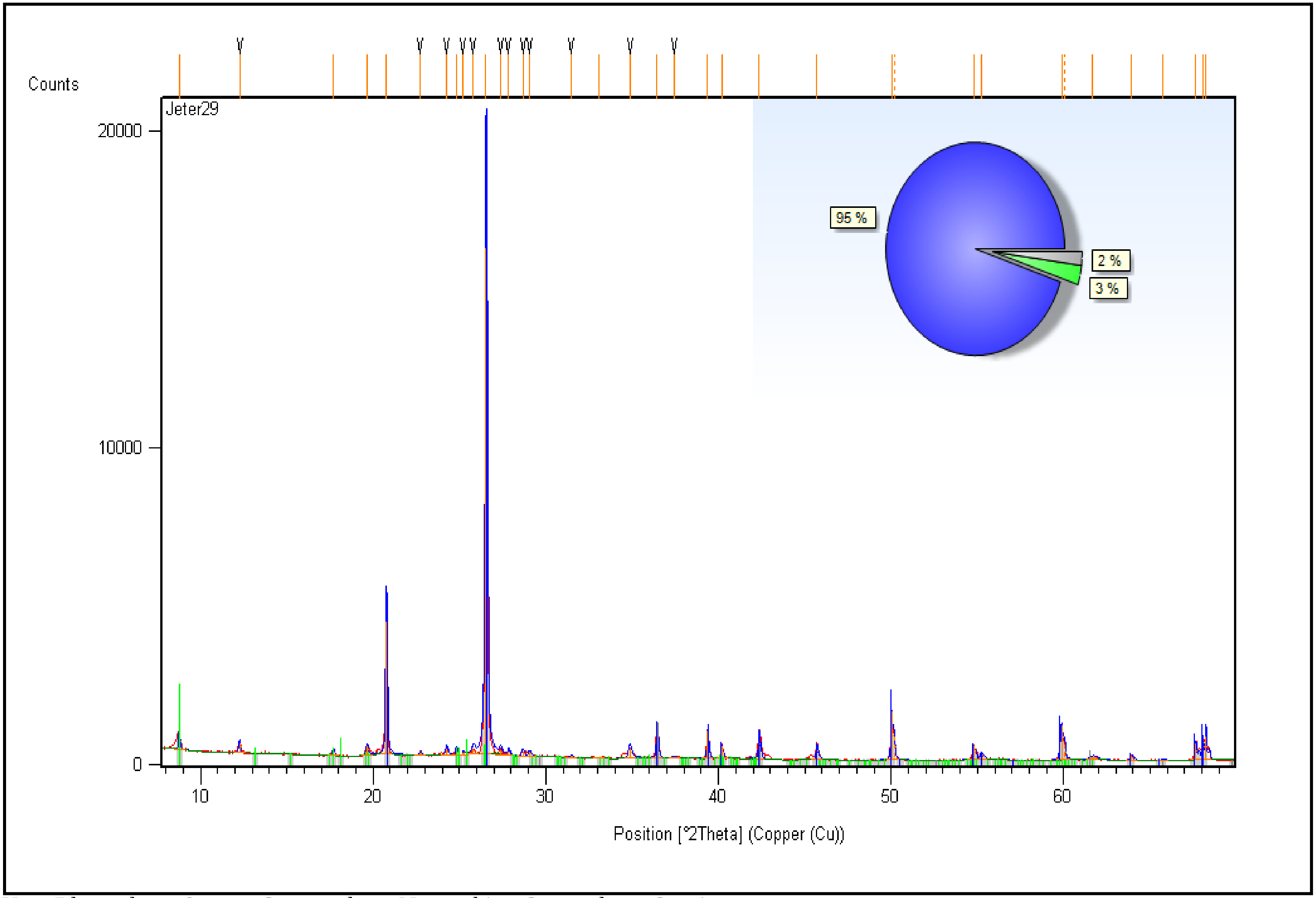
Figure 37. Little Davie pit

*X-RAY DIFFRACTION (XRD) IMAGES*

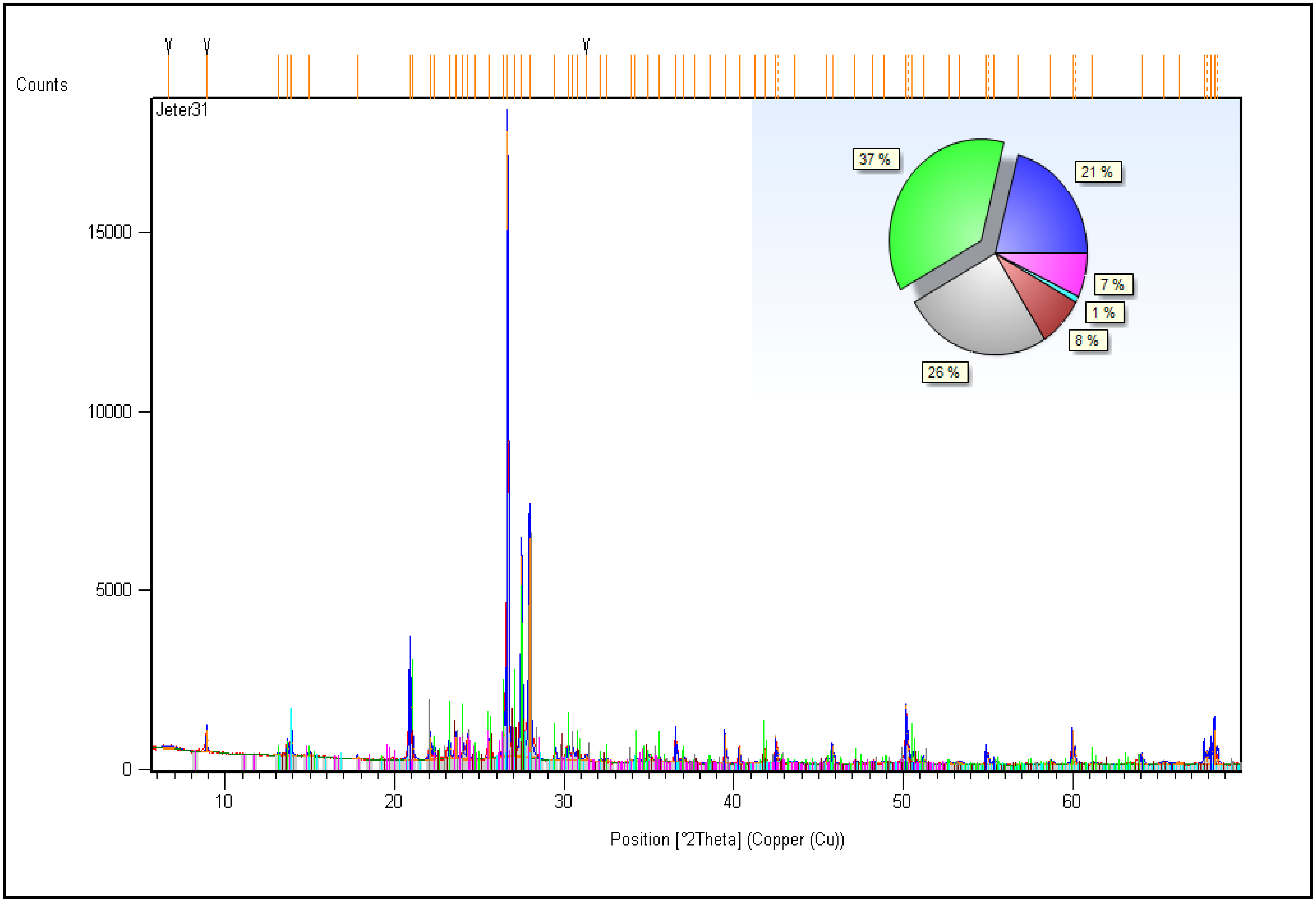



The percentage shows the approximate amount of minerals in the sample. Key: Blue color – Quartz, Green color – Orthoclase

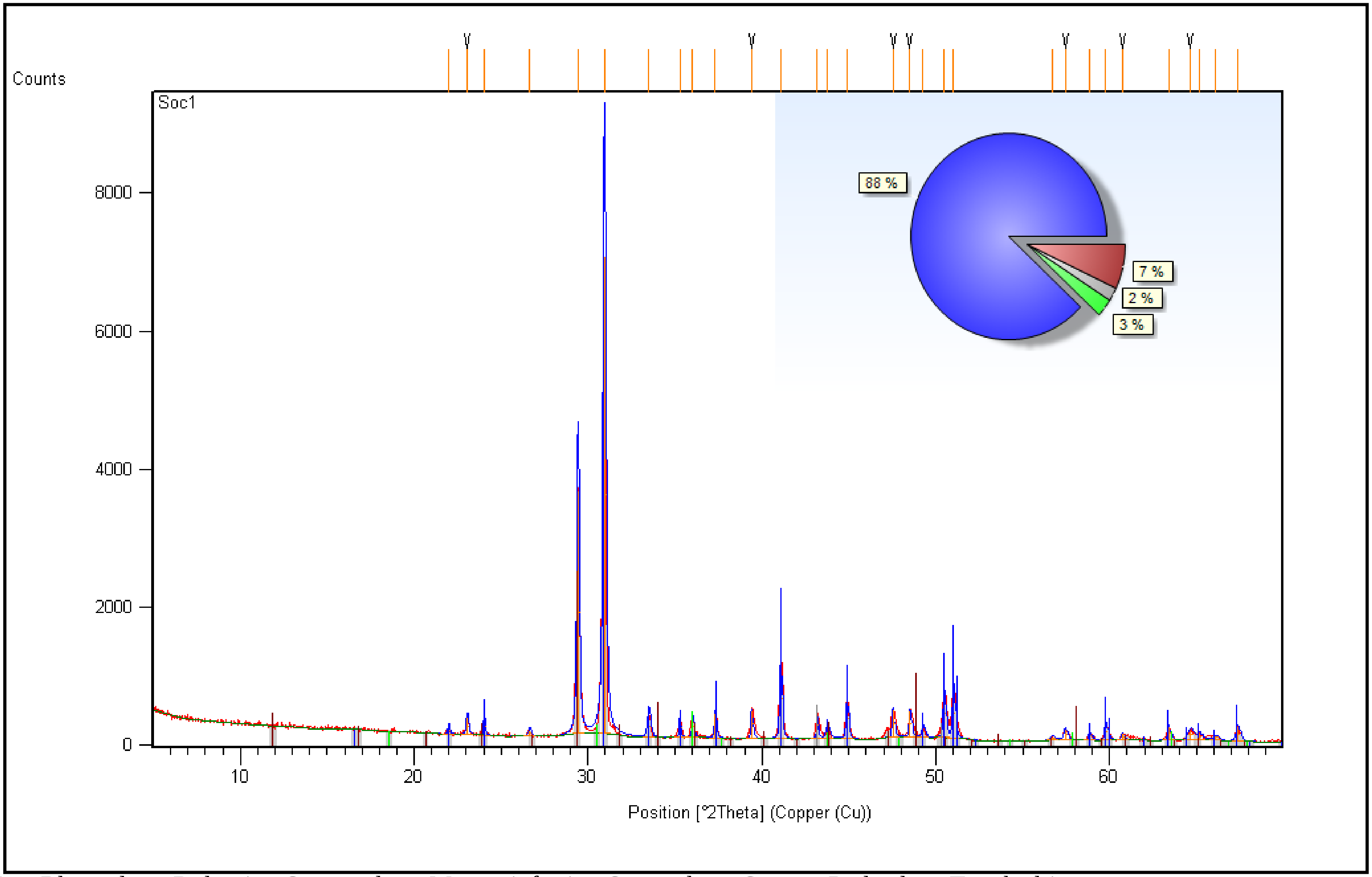
Figure 38. XRD Image of Jeter1 Sample – Jeter Mine




Key: Blue color – Quartz, Green color – Novacekite, Gray color – Cuprite
Figure 39. XRD Image of Jeter29 Sample – Jeter mine

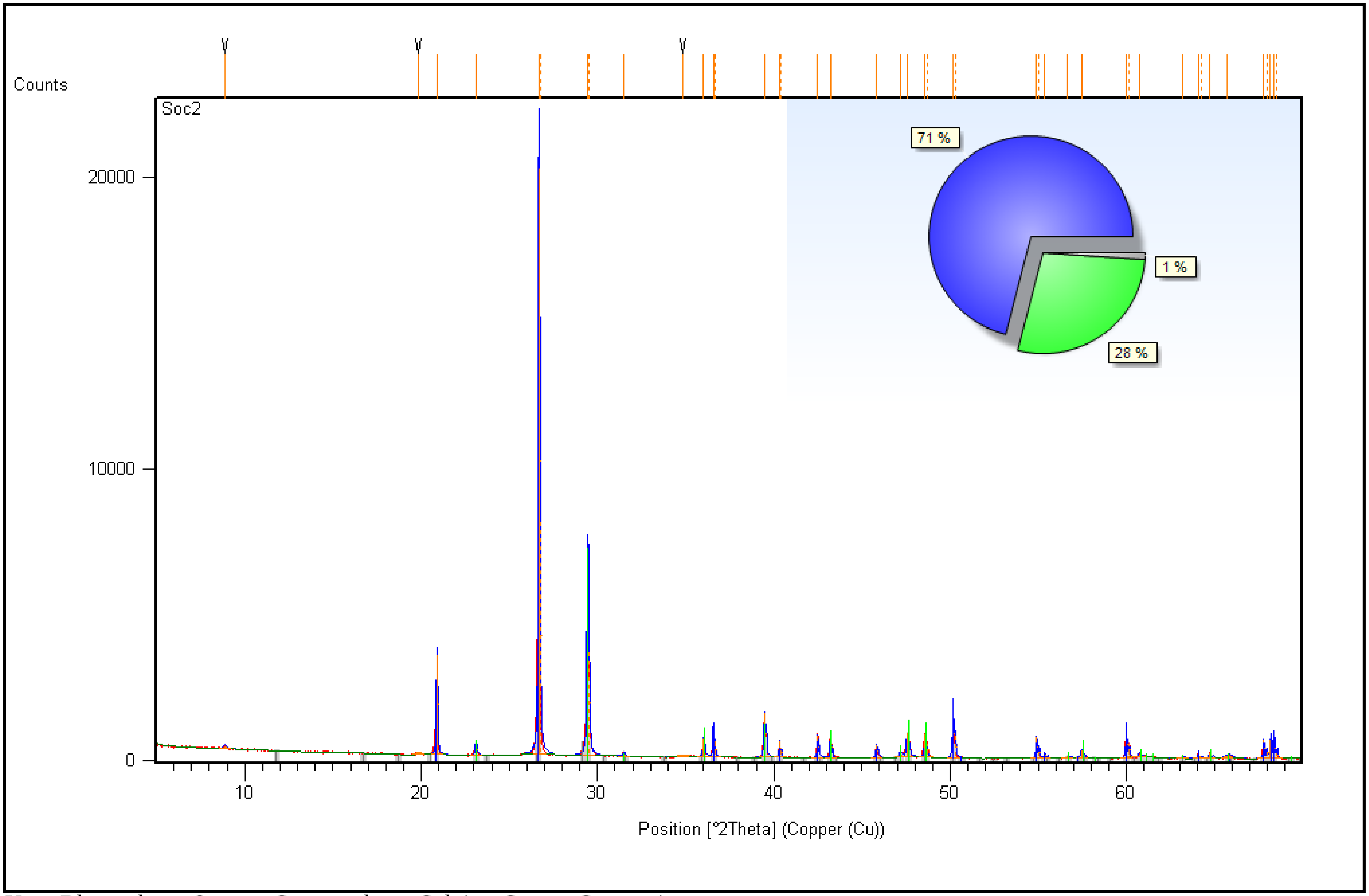



Key: Blue color – Quartz, Green color – Microcline, Gray color – Albite, Red color -Orthoclase, Light blue color – Iriginite
Figure 40. XRD Image of Jeter31 Sample – Jeter mine



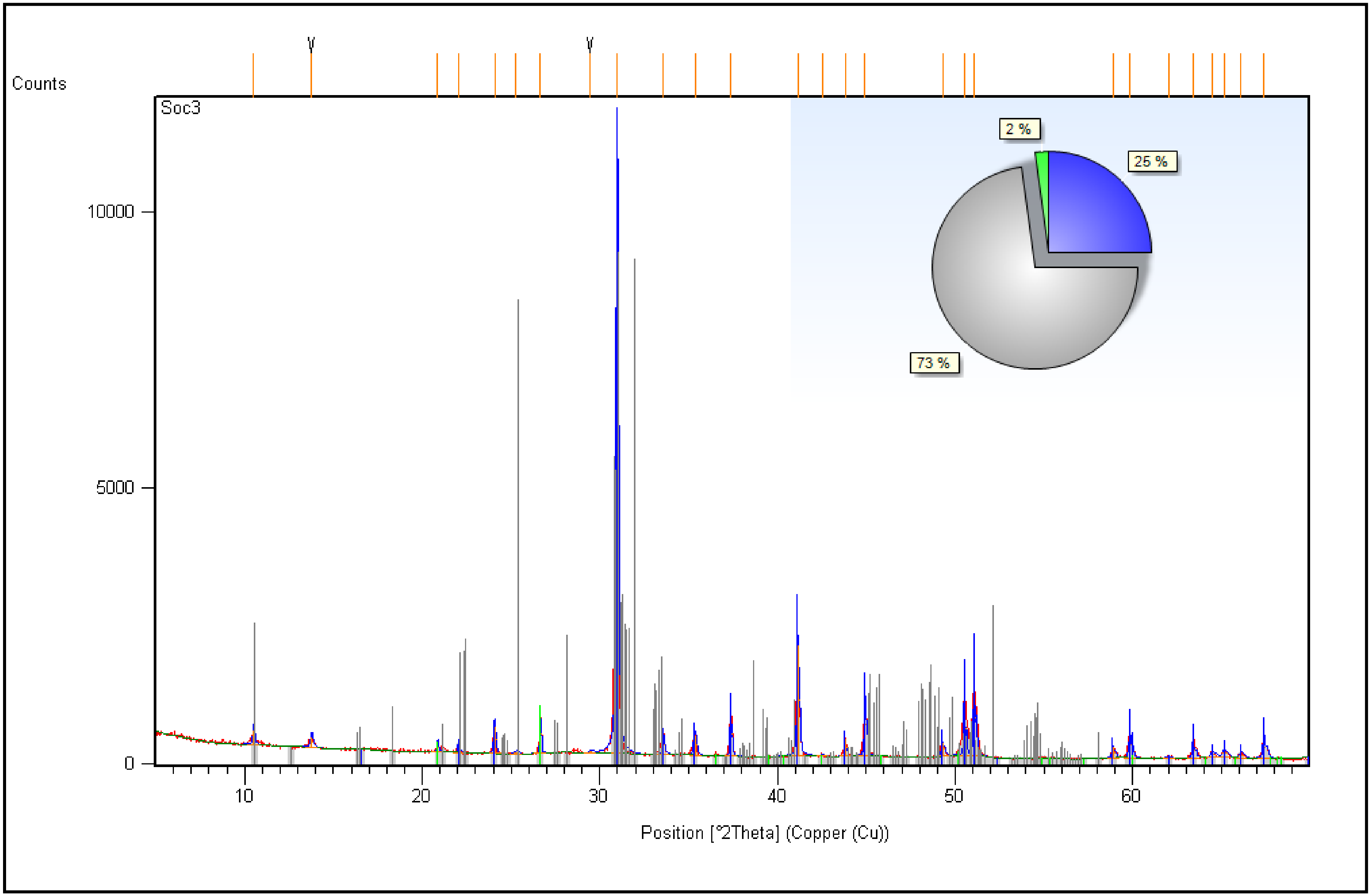

Key: Blue color – Dolomite, Green color – Magnesioferrite, Gray color – Copper, Red color -Tetrahedrite

Figure 41. XRD Image of Soc1 Sample – Lucky Don mine

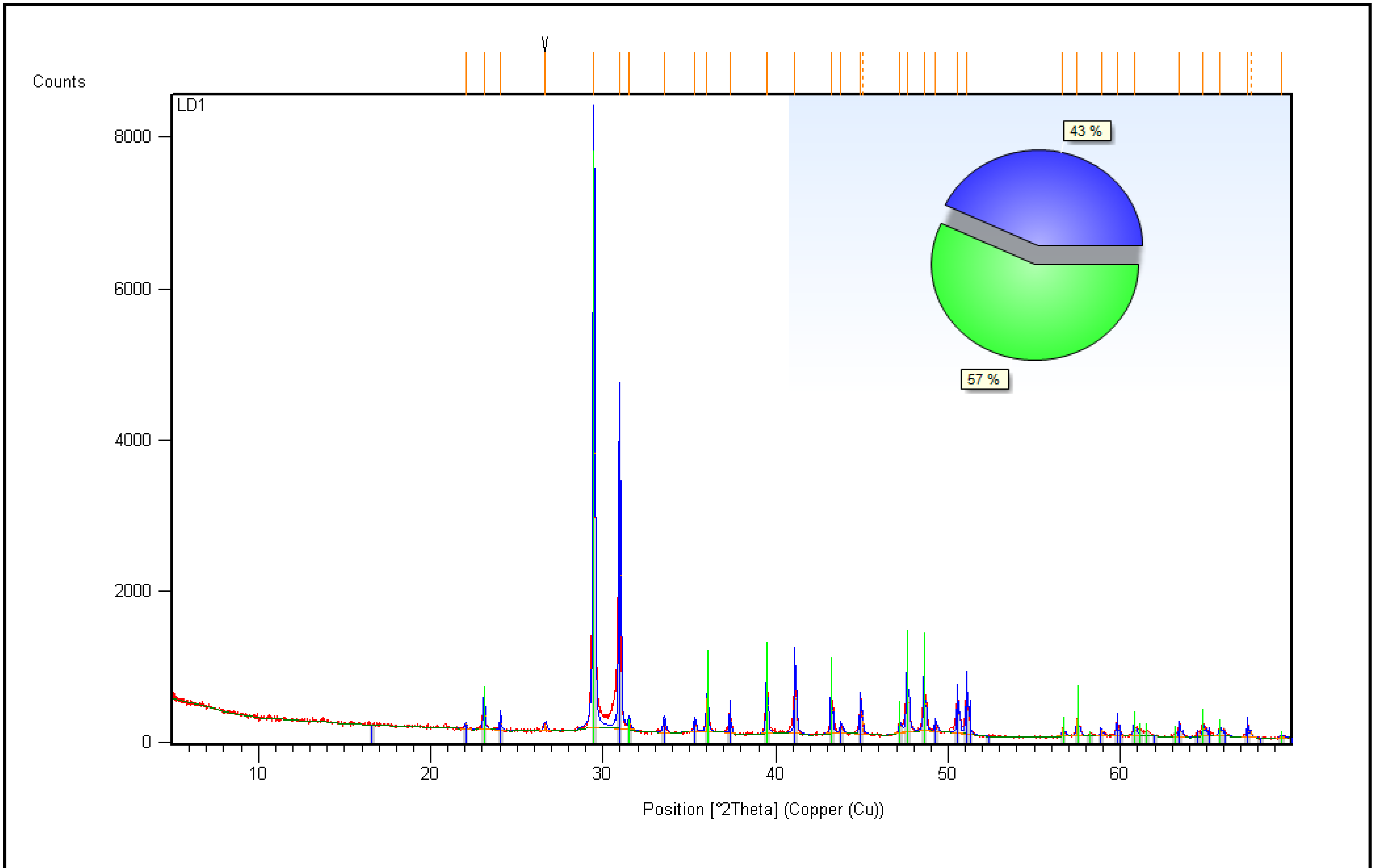



Key: Blue color – Quartz, Green color – Calcite, Gray – Germanite

Figure 42. XRD Image of Soc2 Sample – Lucky Don mine

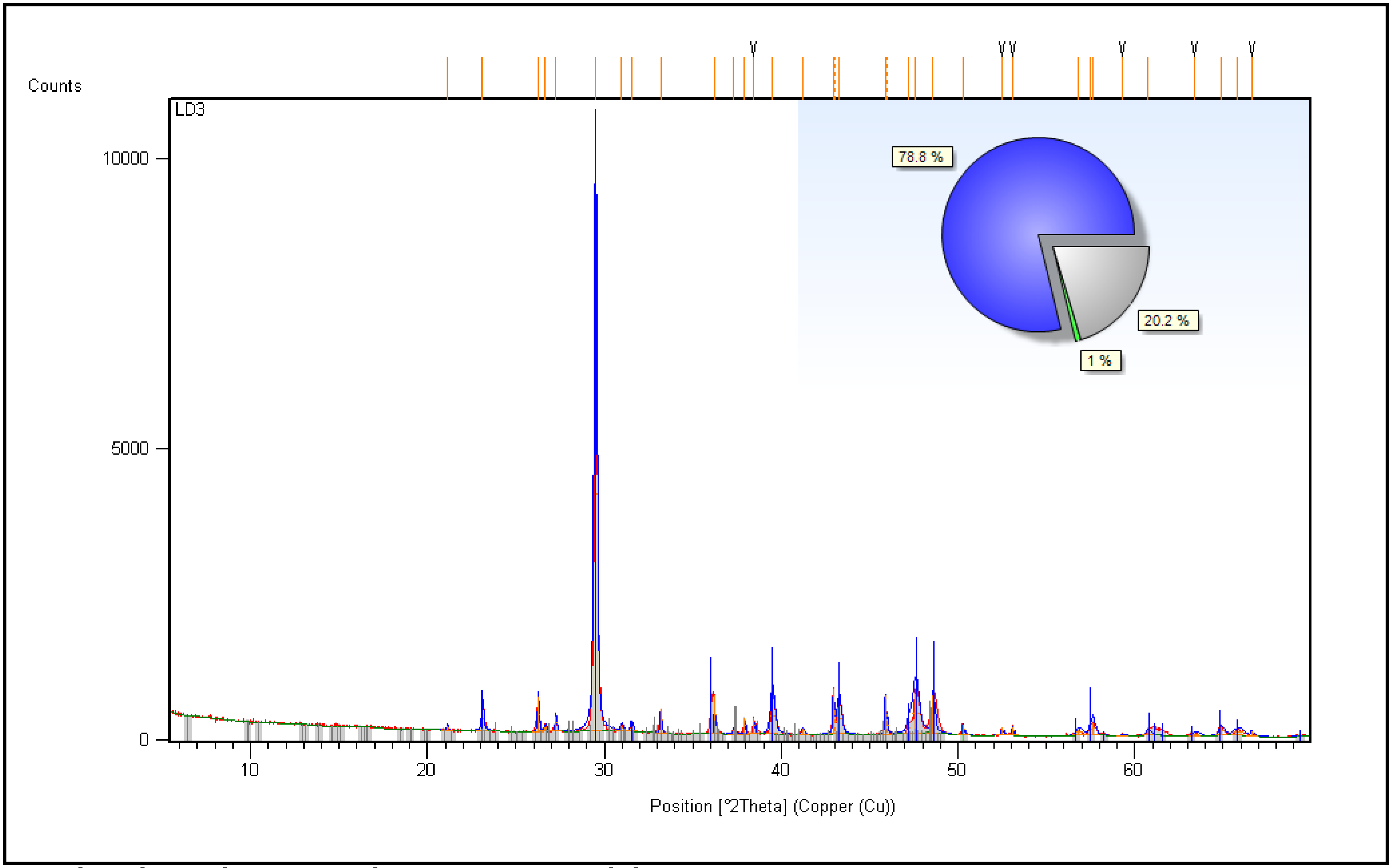



Key: Blue color – Dolomite, Green color – Quartz, Gray – Fluorapatite
Figure 43. XRD Image of Soc3 Sample – Lucky Don mine




Key: Blue color – Dolomite, Green color – Calcite

Figure 44. XRD Image of LD1 Sample – Little Davie mine




Key: Blue color – Calcite, Green color – Copper, Gray – Chalcocite

Figure 45. XRD Image of LD3 Sample – Little Davie mine

# APPENDIX C

## Field Inventory Forms

Mine id | Mine name | County

District id | District | Mines Aliases

Subdistrict id

Township | Latitude | UTM easting

Range | Longitude | UTM northing

Section | Subsection | UTM zone | Coor system

Location assurance | Point of location reference | ☐ Active claim

Location Notes | Year of Discovery

Production category | Year of initial production | Year of last production

☐ Significant Deposit (if checked, see table below) | Visibility | Recent mineral activity

Commodity category | Development | ☐ Potential for future potential

Commodities produced | Commodities present not produced

Comments on production | Operating status | Access

Depth of workings | Length of working | Disturbed area acres | Reclaimed acre

Mining methods | Mine feature

Surface land status | Minerals land status | Ownership

Primary company | Mining history

Cultural resources | Condition mine feature | General slop

Host formation | Age of host rock | Age of mineralization

Geology | Stability | Rock type

Mineralogy | Size of deposit

Alteration | Type of dep osit

USGS quadrangle | Elevation | Method of obtaining elevation

Type of terrain | ☐ Is water present? | ☐ Is waste rock present? | Soils

Land use | Receiving stream | Recent human use

Hydrology | Water drainage | Aquatic life | Color of water

Vegetation | Vegetation density | Vegetation type

Animals | Animal rating | ☐ Are bats present? | Air quality/condition

Erosion | Evidence of potential acid drainage | Radiation readings

Mitigation status | Reclamation

Floodplain

Sensitive environments

Danger level

Potential hazardous materials

Comments

Chemistry

Recommendations

References

web site

date web sit

Data reliability field

Patented Mines

Inspected by

Verified by

Date inspected

Date of last modification

Archeology site no

USGS Deposit Id number

NMMMD number

Other agency number

Sample number

MAS number

BLM amlis number

USFS number

MRDS number

Cata-logue ID

Mine ownership:

Photographs subform