UTILIZATION OF MINE DUMPS IN THE BLACK HILLS, SOUTH DAKOTA CARBONATE CAMP, SPOKANE, AND GALENA DISTRICTS

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ABSTRACT

A study of eight lead-silver-zinc mine dumps was conducted between April 1968 and March 1969 to determine the economic feasibility of recovering additional values from mine wastes in the region and to determine elements and minerals present in the dumps. Properties selected for investigation were the Iron Hill mine at Carbonate Camp, the Spokane mine near Keystone, and the Silver Queen, Horseshoe-Comet, Cora, St. Anthony, Galena Placer, and El Refugio mines at Galena, South Dakota.

Thirty samples from the Iron Hill mine, twenty-two samples from the Spokane mine, and fifty samples from six mine dumps at Galena were analyzed. Two previously unreported minerals, corkite and descloizite, were identified from the Silver Queen mine dumps; corkite also was found to be a component of the Iron Hill mine dumps.

Beneficiation studies of samples from the Carbonate Camp, El Refugio, and Silver Queen mine dumps were performed on a limited scale.

INTRODUCTION

The project "Utilization of Mine Dumps in the Black Hills, South Dakota" is a study to test the economic feasibility of recovering additional values from mine wastes in the region. The South Dakota Engineering and Mining Experiment Station received a research grant from the United States Bureau of Mines, under the provisions of the Solid Waste Disposal Act of 1965, to conduct this study.

This is the third paper of a series describing mine dumps and recovery methods. It pertains to the Iron Hill mine and adjacent properties located at Carbonate Camp, in the NW¼ of Section 15, T 5 N, R 2 E, Lawrence County; to the Spokane mine, located at Spokane, in the SW¼ of SW¼ of Section 26, T 2 S, R 6 E, Custer County; and to the El Refugio, Silver Queen, Cora, Horseshoe-Comet, Galena Placer, and St. Anthony mines, located at Galena, in Sections 4 and 9, T 4 N, R 4 E, Lawrence County, South Dakota.

The study, which included surveying, mapping, trenching, sampling, analytical work, and extraction experiments, was conducted between April 1968 and March 1969. Field and laboratory assistance was provided by two graduate students and one undergraduate student.

CARBONATE CAMP

History

In 1886 silver-lead ores were found near Carbonate, the discovery of lead carbonate on the West Virginia claim giving the camp its name. Large bodies of rich cerargyrite, galena, and cerussite ores were discovered in the Iron Hill mine and on adjacent properties during the same year. The mines were in production between 1886 and 1891, with ore being processed at the Iron Hill smelter and chloridizing plant. The properties were acquired and consolidated by the New Iron Hill Mining Company of Deadwood, South Dakota, in 1900; portions of the dumps were reworked by this company between 1901 and 1911. Ownership was transferred to the Carbonate Consolidated Mining Company in 1937, and leased by them to the Richmond Hill Mining Company in 1939; the latter company engaged in considerable mine and dump sampling, but no development work was undertaken. The properties are currently under lease to the Congo Uranium Corporation, who is formulating plans for an extensive exploration and development program.

Mineral Deposits and Production

Mineral of economic value produced from the Carbonate Camp properties investigated are galena, cerussite, pyromorphite, mimetite, vanadinite, cerargyrite, and gold. Other minerals that have been identified, some of which undoubtedly contributed to early-day production figures, are anglesite, aragonite, atacamite, calcite, corkite, goethite (limonite), matlockite, plattnerite, pyrolusite, quarts, and wulfenite. Scott (1897) also reported the questionable occurrence of pyrargyrite.

Production from the Iron Hill mine is reported for 1886-1888 and 1891 as $667,218, apparently representing total values in silver, lead, and gold. Between 1901 and 1911 portions of the Iron Hill dumps were reworked, with a total recovery of 82.91 ounces gold, 18,511 ounces silver, and 183,191 pounds lead.

All ore processed has been mined from a vertical fracture cutting the Pahasapa limestone. The fractures may be traced on the surface for at least 2,700 feet and vary in width from about 2 to 20 feet. Mineralization is associated with the intrusion of porphyry dikes and sills.

Methods

The dumps of the Iron Hill and Seabury-Calkins mines and three adjacent prospects were surveyed by transit and tape methods to establish the present configuration of the dumps. A preliminary map incorporating a proposed trenching pattern was prepared.

Thirty trenches with a total length of 300 feet, an average depth of 5 feet, and width of 3 feet were excavated with a truck-mounted back-hoe. Thirty samples, each weighing approximately one ton, were removed from the trenches, crushed at the site with a mobile jaw-crusher to minus two-inch size, split by quartering to 100-pound samples, bagged, labeled, and then transported to the Experiment Station for further processing and analyses.

Each 100-pound sample was mixed thoroughly and divided into two equal portions; one portion was prepared for laboratory analyses by crushing to minus ½-inch size, splitting to obtain a representative sample, and pulverizing to minus 200 mesh size; the other 50-pound samples were used for concentration and extraction studies.

Qualitative x-ray and emission spectrographic analyses were made of all pulverized samples to determine elements present.

Quantitative lead and zinc analyses were made utilizing x-ray spectrographic techniques; silver analyses were made by fire assay and atomic absorption methods.

Beneficiation studies of a composite sample of the ore were conducted in the metallurgical laboratories at the South Dakota School of Mines and Technology.

Analytical Results

Qualitative x-ray spectrographic analyses of the thirty trench samples disclosed a wide variation of elements present, as shown in Table 1, which are distributed very unequally in the dumps.

Table 1. Qualitative X-ray Analyses – Carbonate Camp

Trench Number	Mn	Fe	Cu	Zn	Pb	As	Sr	Zr	Mo	Ag	Cd	Ba	Au	Rb	Sb
1	Tr	Hi		Tr	Tr	Tr	Lo	Tr		Tr		Tr		Tr	
2	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr	Tr	Lo		Tr		Tr	Tr
3	Tr	Hi	Tr	Tr	Hi	Tr	Tr	Tr	Tr	Tr		Tr		Tr	Tr
4	Tr	Hi	Tr	Tr	Hi	Tr			Tr	Hi		Tr			Tr
5		Lo		Tr	Tr	Tr	Lo	Lo				Tr		Tr	
6	Tr	Hi		Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr		Tr	Tr
7	Tr	Lo		Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr		Tr	Tr
8	Tr	Lo	Tr	Tr	Tr	Tr	Lo	Tr		Tr		Tr			
9	Tr	Hi	Tr	Lo	Lo	Tr	Lo	Lo	Tr	Lo		Tr		Tr	Tr
10	Lo	Hi	Tr	Lo	Lo	Tr	Lo	Tr	Tr	Lo		Tr		Tr	Tr
11	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr	Tr	Tr		Tr		Tr	Tr
12	Lo	Hi	Tr	Lo	Hi	Tr	Tr	Tr		Tr	Tr	Tr			Tr
13	Lo	Hi	Tr	Tr	Hi	Tr	Tr	Tr		Tr		Tr			Tr
14	Lo	Hi	Tr	Tr	Hi	Tr	Tr	Tr	Tr	Lo		Tr			Tr
15	Lo	Hi	Tr	Lo	Hi	Tr	Tr	Tr	Tr	Lo		Tr		Tr	Tr
16	Lo	Hi	Tr	Lo	Hi	Tr	Tr	Tr	Tr	Lo		Tr		Tr	Tr
17	Lo	Hi	Tr	Lo	Hi	Tr	Tr			Tr		Tr		Tr	Tr
18	Lo	Hi	Tr	Lo	Hi	Tr	Tr	Tr	Tr		Tr			Tr	Tr
19	Tr	Hi	Tr	Tr	Lo	Tr	Tr		Tr	Tr		Tr			Tr
20	Tr	Lo	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr		Tr	Tr
21	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr				Tr			Tr
22	Lo	Hi	Tr	Lo	Hi	Tr	Tr	Tr	Tr	Tr		Tr			Tr
23	Tr	Hi	Tr	Lo	Lo	Tr		Tr	Tr			Tr		Tr	
24	Tr	Hi	Tr	Lo	Lo	Tr						Tr		Tr	Tr
25	Tr	Hi	Tr	Hi	Hi	Lo	Tr					Hi			Tr
26	Hi	Hi	Tr	Lo	Hi	Tr	Tr	Tr	Tr	Lo		Lo			Tr
27	Lo	Hi	Tr	Lo	Lo	Tr	Tr	Tr		Tr					
28	Tr	Hi	Tr	Lo	Lo	Tr		Lo	Tr					Lo	
29	Lo	Hi	Tr	Lo	Lo	Tr	Tr	Tr	Tr	Tr		Tr		Tr	
30	Tr	Hi	Tr	Lo	Lo	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr		

Lead values, obtained by quantitative x-ray fluorescence analyses, range from a low of 0.02% in sample 1 to a high of 2.65% in number 25; a composite sample from all thirty trenches disclosed a lead content of 0.89%. Zinc values, also obtained by x-ray fluorescence analyses, range from a mere trace in sample 1 to a high of 0.31% in number 25; a composite sample from all thirty trenches gave a zinc content of 0.08%. Fire assay results showed no traces of silver in samples from trenches 5, 18, 21, 23, 24, 25, and 28; values from the other twenty-three trenches range from a trace to a high of 52.16 ounces per ton in sample 4. A composite sample from the dumps of the eighteen trenches confined to just the Iron Hill mine property (samples 1 to 18 inclusive) was fire assayed and showed 5.74 ounces silver and 0.02 ounces gold per ton.

Results of emission spectrographic analyses of a composite sample from the thirty trenches are set forth in the following table:

Table 2. Emission Spectrographic Analysis of Composite Sample – Carbonate Camp

Element	Percent
Silicon	>10.0
Magnesium	>10.0
Calcium	>10.0
Aluminum	>1.0
Iron	>1.0
Manganese	>1.0
Lead	>0.1
Zinc	<0.1
Silver	<0.1
Copper	<0.1
Titanium	<0.1
Vanadium	<0.1

SPOKANE MINE

History

Although located in the 1880's and under development in the early 1890's, no production of ore was reported from the Spokane mine until 1898. Since discovery, the property has been owned and operated by numerous companies; initial production was made by the Crown Point Mining Company which produced a significant amount of silver and lead during the years 1898-1900. They were followed by the Spokane Silver and Lead Company which made shipments of concentrates during the years 1917-1919 and in 1927. Early in 1928 the power house of the company burned, and the property remained idle until taken over by the Iron Mountain Development Company of Cleveland, Ohio, which did some sampling, a minor amount of development work, and made small shipments of ore. The property is currently owned by Fillmore and Beardshear of Spearfish, South Dakota, who are in the process of negotiating a purchase agreement with Congo Uranium Corporation.

Mineral Deposits and Production

Minerals of economic value produced from the Spokane mine are galena, sphalerite, cerussite, argentite, and gold. Other minerals identified during the course of this investigation are calcite, chalcopyrite, goethite (limonite), microcline-perthite, muscovite, pyrite, quartz, and tourmaline. Early reports by Scott (1897) and Ziegler (1914) mention the occurrence of anglesite, cerargyrite, pyrargyrite, pyromorphite, native silver, vanadinite, and wulfenite in the oxidized ore near the surface of the mine; none of these minerals, however, have been preserved for reference.

Production from the Spokane mine has been very erratic, and very few production records are now available. The U.S. Bureau of Mines (1955) reports that two carloads of ore valued at $23.00 per ton were shipped in 1898 by the Crown Point Mining Company. In 1899, twenty-three additional cars were shipped. The Spokane Lead and Silver Company shipped several carloads of concentrates in 1917-1919. The Spokane Silver and Lead Company produced 297 tons of concentrates valued at $8,586.07 (net smelter returns) from 9,000 tons of ore in 1927. The Iron Mountain Development Company shipped 122 tons of broken ore to the Helena smelter in 1940. There has been very little activity on the property since that date.

The ore was mined from a fissure vein which varied in thickness from a few inches at the surface to over 25 feet and may be traced on the surface for 723 feet. Three ore shoots have been found and the mine has been developed to the depth of 300 feet. The ore vein cuts one small pegmatite and several additional pegmatites outcrop on the property.

Methods

Twenty-two excavation sites were established on the dumps and tailings ponds at the Spokane mine by transit and tape survey methods. Seventeen trenches with an aggregate length of 234 feet and average depth of 7 feet, and five trenches with an aggregate length of 60 feet and average depth of 3 feet were excavated with a back-hoe. Twenty-two samples, each weighing approximately one ton, were transported from the trenches to a mobile jaw-crusher by means of a front-end loader. Each sample was crushed to minus two-inch size, split by quartering to 100-pound samples, bagged, labeled, and then transported to the Experiment Station for further processing and analyses.

Each 100-pound sample was mixed thoroughly and divided into two equal portions; one portion was prepared for laboratory analyses by crushing to minus ½-inch size, splitting to obtain a representative sample, and pulverizing to minus 200 mesh size; the other 50-pound samples were reserved for beneficiation studies.

Qualitative x-ray and emission spectrographic analyses were made of all pulverized samples to determine elements present.

Quantitative x-ray fluorescence analyses were made for lead and zinc.

Tenor of dump material was determined to be two low for relevant beneficiation studies.

Analytical Results

Qualitative x-ray spectrographic analyses of the twenty-two trench samples disclosed a marked similarity in elements present; relative concentrations of elements were quite uniform, with the exception of lead, as shown in Table 3:

Table 3. Qualitative X-ray Analyses - Spokane Mine

Trench Number	Mn	Fe	Cu	Zn	Pb	As	Sr	Zr	Mo	Ag	Cd	Ba	Rb	Sb	Sn
1	Tr	Hi	Tr	Lo	Hi	Tr	Tr	Tr	Tr	Tr	Tr		Tr	Tr	
2	Tr	Hi	Tr	Tr	Tr	Tr	Tr	Tr	Tr			Tr	Tr		
3	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr	Tr	Tr	Tr		Tr		
4	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr	Tr	Tr		Tr	Tr		
5	Tr	Hi	Tr	Lo	Lo	Tr	Tr	Tr	Tr	Tr		Tr	Tr		
6	Tr	Hi	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr	Tr		
7	Tr	Hi	Tr	Lo	Hi	Tr	Tr	Tr					Tr		
8	Tr	Hi	Tr	Lo	Lo	Tr	Tr	Tr				Tr	Lo		Tr
9	Tr	Hi	Tr	Lo	Lo	Tr	Tr	Tr				Tr	Tr		
10		Hi	Tr	Lo	Lo	Tr	Tr	Tr	Tr	Tr		Tr	Tr		
11	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr	Tr	Tr			Tr		
12	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr	Tr	Tr		Tr	Tr	Tr	
13	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr		Tr		Tr	Tr		
14	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr	Tr			Tr	Tr		
15	Tr	Hi	Tr	Tr	Tr	Tr	Tr	Tr		Tr		Tr	Tr		
16		Hi	Tr	Tr	Tr	Tr	Tr	Tr		Tr		Tr	Tr		
17	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr		Tr		Tr	Tr		
18	Tr	Hi	Tr	Lo	Tr	Tr	Tr	Tr		Tr	Tr	Tr	Tr		
19		Hi	Tr	Tr	Hi	Tr	Tr	Tr		Tr		Tr		Tr	
20	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr		Tr		Tr	Tr		
21	Tr	Hi	Tr	Tr	Tr	Tr	Tr	Tr		Tr		Tr	Tr		
22	Tr	Hi	Tr	Lo	Lo	Tr	Tr	Tr	Tr	Tr		Tr			

Results of emission spectrographic analyses of a composite sample from the twenty-two trenches sampled are shown in the following table:

Table 4. Emission Spectrographic Analysis of Composite Sample – Spokane Mine

Element	Percent
Silicon	>10.0
Aluminum	>1.0
Magnesium	>1.0
Iron	>1.0
Calcium	>0.1
Manganese	>0.1
Titanium	>0.1
Lead	>0.1
Zinc	<0.1
Copper	<0.1

Lead values, as determined by quantitative x-ray fluorescence, range from a low of 0.05% to a high of 2.37%; a composite sample from all trenches sampled disclosed a lead content of 0.41%. Zinc values range from a low of 0.01% to a high of 0.19%; a composite sample from all trenches showed a zinc content of 0.04%.

GALENA DISTRICT

History

Lead-silver ores were discovered in the Bear Butte Mining District, more popularly referred to as the Galena district, in 1876; and the principal claims were located in 1877 before the advent of railroads into the Black Hills. Connolly (1927) described the early history as follows:

"Wagon freighters bringing supplies from Missouri River points carried back the high-grade silver ores on their return trip. These ores were transferred at the river to steam boats and taken to the Omaha and Grant smelting plant at Omaha, now a part of the American Smelting and Refining Company. With a wagon haul of 250 miles, river shipment of over 500 miles, and smelter charges added, costs were necessarily high and only the highest grade ore could be taken out. The lower graded material was either left in the mines or stored on the dumps. Later a small smelter and an old style pan-amalgamation silver mill were erected, but these proved very expensive to operate as salt was hauled 75 miles by wagon and charcoal was used in the smelter. Transportation charges on coke were prohibitive. The greatest production in the district appears to have been during the years 1881, 1882, and 1883, during which time something over $750,000 in silver and lead were produced. From the very beginning some controversies were aroused over the apex question, and in July 1883 the principal companies carried their differences to the courts. This litigation lasted over a period of sixteen years and production from the larger holdings practically ceased. By the time the matter was settled, silver had gone to a low figure. Considerable development work has been done since that time but production has been very small."

At the present time, extensive exploration and development programs are being conducted in the district by the Homestake Mining Company; and plans to re-open the Silver Queen mine, with consideration being given to re-working the mine dumps, are being formulated by a mining group based at Pierre, South Dakota.

Mineral Deposits and Production

Few production figures for lead, zinc, silver, or gold from the properties sampled are now available. Old-time local residents have volunteered information pertaining to production but, in most instances, the figures are grossly exaggerated. Incomplete reports indicate the production of $125,000 in silver from the Silver Queen mine during a four-year period in the early days of the camp, and there has been intermittent production up to the present time. The Horseshoe-Comet mine operated both as a silver producer and as a source of smelter pyrite. It was operated in the 1880's, is recorded as shipping to the Deadwood smelter in the early 1900's, and was finally shut down in 1918. Irving (1904) lists the Cora mine as the sixth most important silver producer in the Galena district before 1904 and described the El Refugio mine as a small producer of silver ore.

Ore from the Silver Queen mine occurs in the lower contact zone twenty feet above the base of the Deadwood formation. Mineralization has been described by Connolly (1927) as follows: "The ore in the Silver Queen occurs in flattened lenticular bodies comformable with the bedding. These bodies vary in thickness from less than an inch up to about two feet, and in diameter from a few inches to 15 or 18 feet. They are replacement bodies in a bed of somewhat dolomitic quartzite . . . . The ore itself is thoroughly oxidized, and little trace of primary minerals is left . . . . Assays . . . . show this material to contain much lead as well as high values in silver. They almost invariably show some vanadium, sometimes as high as five percent."

Minerals identified from the Silver Queen mine dumps during the course of this study are:

Calcite – Occurs as minute colorless crystals in cavities and coating fractures.

Cerussite – Observed as white to grayish-black crystalline masses up to four inches in diameter, with occassional small vugs lined with colorless twinned crystals as much as two millimeters in length.

Corkite – Found in abundance as extremely fine-grained pale yellowish ocherous masses associated with descloizite and vanadinite. Analyses and x-ray data are presented in a following section.

Descloizite – Superb yellowish-brown to brown transparent to translucent crystals up to two millimeters in size occur associated with vanadinite and corkite, and occassionally coating fractures and cavities in quartzite. (See Table 8 for x-ray data.)

Galena – Observed as cleavable masses up to one inch across, usually with thick alteration rims of cerussite.

Goethite (limonite) – Occurs as earthy to compact incrustations and cavity fillings and as an impregnation in almost all dump material.

Gypsum – Found in abundance as colorless transparent crystals with a maximum size of five millimeters coating a major portion of the unexposed dump material. It is quite evident that the crystals formed in the mine dumps and not in the mine.

Pharmacosiderite – Occurs very sparingly as emerald-green cubic crystals up to two millimeters across, often exhibiting typical diagonal striations, and a crystalline masses in rock composed primarily of granular pyrite and quartz.

Pyrite – Observed as minute grains disseminated in rock.

Pyromorphite – Found sparingly as dull grayish-green to bright yellowish-green crystals up to one millimeter in length incrusting cracks and lining small vugs in rock. Yellowish-green crystalline masses as much as five millimeters in thickness by two centimeters in diameter also have been observed.

Quartz – Occurs in minute grains as the major component of the gangue rock, and also observed as minute colorless transparent crystals lining small cavities in the ore.

Vanadinite – Excellent colorless transparent to opaque white crystals up to two millimeters in length, exhibiting prism, pyramid, and pinacoid faces, occur associated with descloizite crystals and corkite. (See Table 8 for x-ray data.)

Connolly (1927) also mentions the occurrence of scorodite and the probable presence of cerargyrite in the Silver Queen ore.

The El Refugio mine, located on the upper ore horizon of the Deadwood formation, has been developed by a series of small trenches, pits, and short drifts which follow vertical fractures. The highly oxidized ore occurs in lenticular masses conformable with the bedding.

During the course of this study, the following minerals were identified from the El Refugio mine dumps:

Azurite – Found sparingly as thin coatings on ore, associated with malachite and cerussite.

Calcite – Occurs as thin incrustations on wulfenite crystals, and as minute crystals in small vugs in the ore.

Cerussite – Solid masses of grayish color as much as six inches in diameter, often enclosing residual galena, occur in relative abundance on the mine dumps. Superb transparent crystals up to two millimeters in size, frequently twinned, occasionally are found implanted on quartz crystals in small vugs.

Covellite – Infrequently found in platey aggregates up to five millimeters across imbedded in solid masses of cerussite.

Galena – Cleavable masses as much as four inches in diameter, often partially altered to cerussite, are found sparingly in the dumps.

Goethite (limonite) – Occurs in abundance as earthy fillings and incrustations disseminated throughout most of the dump material.

Hemimorphite – White tabular crystals up to one centimeter or more in size occur sparingly in vugs in the ore.

Malachite – Occurs as green fine-crystalline to fibrous masses up to one centimeter in diameter erratically distributed in the dump rock, and rarely admixed with quartz forming light-blue compact aggregates as much as five millimeters in size, which resemble turquois both in color, luster, and hardness.

Mimetite – Found sparingly as minute yellow to yellowish-green prismatic crystals incrusting massive cerussite and associated with lemon-yellow to orange wulfenite crystals.

Pyromorphite – Observed in relative abundance as gray to yellowish gray prismatic crystals up to five millimeters in length in cavities and incrusting cracks in highly ferruginous rock. Crystal incrustations exceeding one square foot in area were observed on random pieces of dump material.

Quartz – Occurs in minute grains as the major component of the gangue rock and as minute crystals lining cavities in the ore.

Smithsonite – Found sparingly as one to two millimeter distorted crystals, white to pale greenish-white in color, lining cavities in rock.

Vanadinite – Lustrous reddish-orange crystals, less than one millimeter in size, occur sparingly in vugs associated with wulfenite crystals and calcite.

Wulfenite – Superb, nearly equant lemon-yellow to orange crystals, exhibiting a variety of forms and ranging from one to two millimeters in size, occur with mimetite incrusting massive cerussite. Thin orange to reddish-orange tabular crystals up to one centimeter across occur sparingly, often with a thin coating of calcite and associated with minute vanadinite crystals, in cracks and cavities in rock.

The Horseshoe-Comet, Cora, St. Anthony, and Galena Placer mines are all located on the lower ore horizon of the Deadwood formation. Mineralization at each mine has been controlled by vertical fractures, and most of the ore is unoxidized.

Minerals identified in dump material during the course of this program are chalcopyrite, galena, pyrite, quartz, sphalerite, and tetrahedrite. Frazer (1897) reported argentite as one of the major silver minerals produced from these mines during the early history of the district; Connolly and O'Harra (1929) suggest that cerargyrite is a probable constituent of the ore; and old mine reports indicate an abundance of native silver in the richer ore pockets encountered in the early-day workings at these mines. Although diligently sought, none of the three aforementioned minerals were identified in dump material during this investigation.

Methods

Trenching patterns at the six mine dumps sampled were established in early winter of 1968 under adverse weather conditions. Frozen ground and heavy snowfall restricted hand sampling, mapping, and other proposed work.

Approximately 300 linear feet of trenches, ranging from 3 to 8 feet in depth, were excavated with a truck-mounted back-hoe; and approximately 160 feet of trenches, averaging 3 feet in depth, were excavated with a bulldozer and front-end loader. Fifty samples, each weighing about 500 pounds, were removed from the trenches, transported to a centrally located jaw-crusher site, and crushed to minus two-inch size. Eighteen samples were obtained from the Silver Queen mine dumps, six from the El Refugio, ten from the Horseshoe-Comet, eight from the Cora, three from the St. Anthony, and five from the Galena Placer.

After crushing, each of the fifty samples was split by quartering to 100-pound size, bagged, labeled, and then transported to the Experiment Station for additional processing, analyses, and extraction studies.

At the Experiment Station each 100-pound sample was mixed thoroughly and divided into two equal portions. One portion was prepared for laboratory analyses by crushing to minus ½-inch size, splitting to obtain a representative sample, and pulverizing to minus 200 mesh size; the other 50-pound samples were used for metallurgical experiments.

Qualitative x-ray and emission spectrographic analyses were made to determine elements present in each sample.

Quantitative lead and zinc analyses were made utilizing x-ray spectroscopy techniques; silver and gold analyses were accomplished by fire assay.

Mineral species were identified by utilizing x-ray diffraction and spectroscopy, emission spectroscopy, atomic absorption spectroscopy, standard wet chemical methods, and microscope examination.

Beneficiation studies were conducted on composite samples of ore from both the Silver Queen and El Refugio mines.

Analytical Results

Qualitative x-ray spectrographic analyses of the fifty trench samples from the Galena district mines disclosed a wide variation in elements present and relative concentrations as shown in Table 5.

Table 5. Qualitative X-ray Analyses – Galena District

Trench Number	Mn	Fe	Cu	Zn	Pb	As	Sr	Zr	Rb	Mo	Ag	Cd	Sb	Ba	Au
1-SQ	Tr	Hi	Tr	Hi	Hi	Tr	Tr	Tr			Lo				
2-SQ	Tr	Hi	Tr	Hi	Hi	Tr	Lo	Tr			Hi		Tr	Tr	
3-SQ	Tr	Hi	Tr	Lo	Hi	Tr	Lo	Lo	Tr		Tr		Tr		
4-SQ	Tr	Hi	Tr	Lo	Hi	Tr	Tr	Tr			Lo		Tr	Tr	Tr
5-SQ	Tr	Hi	Tr	Lo	Hi	Tr	Tr	Tr			Lo		Tr	Tr	Tr
6-SQ	Tr	Hi	Tr	Lo	Hi	Tr	Tr	Tr			Lo		Tr	Tr	
7-SQ	Tr	Hi	Tr	Tr	Hi	Tr	Lo	Tr			Tr		Tr		
8-SQ	Tr	Hi	Tr	Hi	Hi	Tr	Tr	Tr			Lo	Tr	Tr	Tr	Tr
9-SQ	Tr	Hi	Tr	Lo	Hi	Tr	Lo	Tr			Lo		Tr		
10-SQ	Tr	Hi	Tr	Lo	Hi	Tr	Tr	Tr			Lo		Tr		
11-SQ	Tr	Hi		Hi	Lo	Tr	Tr	Tr			Tr		Tr	Tr	
12-SQ	Tr	Hi	Tr	Lo	Hi	Tr	Tr	Tr			Lo		Tr	Tr	Tr
13-SQ	Tr	Hi	Tr	Lo	Hi	Tr	Tr	Tr			Hi		Tr	Tr	
14-SQ	Tr	Hi	Tr	Hi	Hi	Tr	Tr	Tr			Tr		Tr		
15-SQ	Tr	Hi	Tr	Lo	Lo	Tr	Tr	Tr			Tr				
16-SQ	Tr	Hi	Tr	Hi	Hi	Tr	Tr	Tr			Lo		Tr	Tr	
17-SQ	Tr	Hi	Tr	Hi	Hi	Tr	Tr	Tr			Hi		Lo		
18-SQ	Tr	Hi	Tr	Lo	Tr	Tr	Tr	Tr	Tr		Tr				
1-HC	Tr	Hi	Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr				
2-HC		Hi	Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr				
3-HC	Tr	Hi		Tr	Tr	Tr	Hi	Tr	Tr		Tr			Lo	Tr
4-HC		Lo	Tr	Tr	Tr	Tr	Tr	Tr			Tr				
5-HC		Lo	Tr	Tr	Tr	Tr	Tr	Tr	Tr						Tr
6-HC		Hi		Tr	Tr	Tr	Tr	Tr	Tr		Tr		Tr		
7-HC		Lo	Tr		Tr	Tr	Tr	Tr	Tr		Tr				
8-HC		Hi	Tr	Tr	Tr	Tr	Tr	Tr	Tr						
9-HC	Tr	Hi		Tr	Tr		Tr	Tr	Tr		Tr				
10-HC		Hi	Tr	Tr	Tr		Tr	Tr					Tr	Tr	
1-ER	Tr	Hi	Lo	Hi	Hi	Lo	Tr	Tr		Tr	Tr	Tr	Tr		
2-ER	Tr	Hi	Lo	Hi	Hi	Lo		Tr		Lo	Tr	Tr	Tr		
3-ER	Tr	Hi	Lo	Hi	Hi	Lo		Tr		Tr	Tr	Tr	Tr	Tr	
4-ER	Tr	Hi	Tr	Hi	Hi	Lo	Tr	Tr		Tr	Tr	Tr	Tr		
5-ER	Tr	Hi	Tr	Hi	Hi	Lo		Tr		Tr	Tr		Tr		
6-ER	Tr	Hi	Tr	Hi	Hi	Lo		Tr		Tr	Tr	Tr	Tr		
1-C		Hi	Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr				Tr
2-C		Lo	Tr		Tr			Tr							
3-C		Lo	Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr				
4-C		Lo	Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr				
5-C		Lo	Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr				
6-C		Lo	Tr	Tr	Lo	Tr	Tr	Tr	Tr		Tr				
7-C		Lo	Tr	Tr	Lo	Tr	Tr	Tr	Tr						
8-C		Lo	Tr		Tr	Tr	Tr	Tr	Tr		Tr				Tr
1-SA	Tr	Hi	Tr	Lo	Hi	Lo	Tr	Tr			Tr				
2-SA	Tr	Hi	Tr	Tr	Hi	Hi	Tr	Tr			Lo		Tr		Tr
3-SA		Hi		Tr	Lo	Tr	Tr	Tr			Tr				Tr
1-GP	Tr	Hi	Tr	Lo	Tr	Tr	Tr	Tr	Tr					Tr	
2-GP	Tr	Hi	Tr	Lo	Lo	Tr	Tr	Tr	Tr					Tr	
3-GP	Tr	Hi	Tr	Tr	Lo	Tr	Tr	Tr	Tr		Tr	Tr		Tr	
4-GP	Tr	Hi	Tr	Tr	Tr	Tr	Tr	Tr	Tr		Tr			Tr	
5-GP		Hi	Tr	Hi	Hi	Tr		Tr			Lo	Tr	Tr		

Abbreviations: SQ=Silver Queen mine; HC=Horseshoe-Comet mine; ER=El Refugio mine; C=Cora mine; SA=St. Anthony mine; GP=Galena Placer mine.

Results of emission spectrographic analyses of composite samples from each of the mine dumps sampled are shown in the following table:

Table 6. Emission Spectrographic Analyses of Composite Samples – Galena District

Element	Silver Queen	El Refugio	Horseshoe-Comet	Cora	St. Anthony	Galena Placer
Silicon	>10.0%	>10.0%	>10.0%	>10.0%	>10.0%	>10.0%
Aluminum	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
Calcium	>1.0	>1.0	>1.0	>0.1	>0.1	>1.0
Magnesium	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1
Iron	>1.0	>10.0	>1.0	>1.0	>1.0	>10.0
Manganese	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1
Titanium	<0.1	>0.1	>0.1	>0.1	>0.1	>0.1
Zinc	<0.1	>0.1	<0.1			<0.1
Silver	<0.1	<0.1		<0.1	<0.1	<0.1
Copper	<0.1	>0.1	<0.1	<0.1	<0.1	<0.1
Lead	>0.1	>0.1	<0.1	<0.1	>0.1	>0.1
Vanadium	<0.1	>0.1			<0.1	<0.1
Molybdenum		<0.1				

Quantitative x-ray analyses were made for lead and zinc from each mine dump; silver and gold were determined by fire assay on composite samples from the Silver Queen and El Refugio mines. Results obtained are set forth in the following table:

Table 7. Quantitative X-ray and Fire Assay Analyses of Dump Samples – Galena District

Mine	Lead %			Zinc %			Silver Oz/T			Gold Oz/T
	Low	High	Comp	Low	High	Comp.	Low	High	Comp.	Composite
Silver Queen	0.10	4.51	1.20	0.02	0.40	0.17	Tr	23.1	5.06	0.02
El Refugio	1.53	4.61	2.67	0.33	2.38	1.04			2.68	0.08
Horseshoe-Comet	Tr	0.16	0.06	Tr	0.01	Tr				
Cora	0.02	0.19	0.14	Tr	Tr	Tr				
St. Anthony	0.43	2.81	1.10	Tr	0.20	0.06				
Galena Placer	0.11	1.67	0.66	0.02	0.64	0.20				

Corkite, Descloizite, and Vanadinite

Connolly (1927) noted the abundant occurrence of a soft, yellow, ocherous material at the Silver Queen mine, referred to as "carbonate ore" by the miners of the district. He described the material in the following manner:

"The exact mineralogical nature of this material remains in doubt. In spite of its popular name it actually contains very little lead carbonate. Separation of the material by washing and use of heavy solutions gives a heavy concentrate which is a mixture of several minerals, not further separable and as yet not positively identified. One of them is a greenish yellow mineral containing lead, vanadium, and chlorine. The rest of the material is a dense, nearly opaque mineral, isotropic or amorphous, impossible to identify with the microscope. It contains a high percentage of lead as shown by qualitative blowpipe tests, but no sulphur or carbonate. Some of this material was submitted to Mr. E. S. Larsen who made the following report:

> 'The yellow mineral that makes up most of specimen 2835-B has the following optical properties: 2V near 90°, so large that I could not determine the optical character from a fair interference figure. Beta (Li) equals 2.24, alpha about 2.15. It probably has a perfect cleavage normal to Z. These data, except the cleavage, indicate descloisite (sic) but the presence of chlorine cuts that out. It may be new and I recommend that you get as pure a sample as you can and analyze. Vanadinite is often biaxial but hardly like this.
>
> The main part of 2792-B is a clouded mineral that seems to be nearly opaque, (from its high index and inclusions of air) and apparently isotropic. It is one of those amorphous or sub-microscopic minerals that can best be determined by chemical tests. Some of the lead oxides are of this character.' (Letter dated July 29, 1922.)

Because of the lack of time for the laborious hand separation of enough of the minute grains for quantitative analysis, this has not yet been done."

During the course of this study, the soft, yellow, ocherous material was determined to be the mineral corkite, frequently associated with descloizite and vanadinite.

X-ray fluorescence analyses of the corkite disclosed the presence of Fe, Pb, Zn, Cu, As, Ag, Sb, and minute traces of Sr, Zr, and Ba. Emission spectrographic analysis provided the following results: Fe $>$ 10, Pb, $>$ 10, P $>$5, Ca$>$ 0.5, Al $>$0.5, As $>$0.5, Ag$>$ 0.1, Zn $>$0.1, Cu $>$0.05, Sr – Trace, V$>$ 0.1, Be – Trace, Ti $>$0.1, Si $>$ 1, Mg $>$0.5, Sb$>$ 0.5, Mn $>$ 0.1.

The following chemical analysis was made using standard titration methods and atomic absorption spectroscopy techniques:

	Silver Queen Mine	$PbFe_3(PO_4)(SO_4)(OH)_6$
PbO	37.3	33.41
Fe_2O_3	32.8	35.89
ZnO	0.3	
As_2O_3	0.5	
P_2O_5	8.8	10.63
SO_3	10.4	11.98
H_2O	7.8	8.09
Totals	97.9	100.00

The minor cations detected by x-ray fluorescence and emission spectroscopy were not determined by wet chemical methods which accounts, in part, for the low total.

X-ray diffraction studies of corkite, descloizite, and vanadinite specimens from the Silver Queen mine dumps afforded the following patterns which, for convenience, are compared with ASTM standards: