UTILIZATION OF MINE DUMPS IN THE BLACK HILLS, SOUTH DAKOTA, INGERSOLL AND TIN MOUNTAIN MINES

W. L. Roberts and Joseph H. Cope
South Dakota School of Mines and Technology
Rapid City, South Dakota

ABSTRACT

A study of two pegmatite mine dumps was conducted between October 1966 and March 1968 to evaluate the possible economic recovery of additional values from mine wastes in the region and to determine elements and minerals present in the dumps. Properties selected for investigation were the Ingersoll mine near Keystone and the Tin Mountain mine near Custer, South Dakota.

Sixty-one samples from the Ingersoll mine and thirty-one samples from the Tin Mountain mine were analyzed. Five previously unreported mineral species (bismuthinite, bismutite, fairfieldite, scorodite, sphalerite) were identified from the Ingersoll mine dumps, and four (aurichalcite, chalcocite, hemimorphite, smithsonite) from the Tin Mountain mine.

X-ray spectroscopy studies of 91 samples from the two mines disclosed a marked similarity for all elements detectable by this technique, with the exception of an appreciably higher concentration of rubidium and cesium in samples from the Tin Mountain mine than from the Ingersoll mine.

Methods for the recovery of microlite from selected ore from the Tin Mountain mine dumps were investigated and included table, jig, flotation, and electrostatic separation experiments. Results of the experiments disclosed that flotation, combined with preliminary electrostatic separation of feldspar and quartz, is the most practical method of concentration.

A hand-sorting study of samples recovered from the Ingersoll mine indicate that 17.92 percent of the dumps can be recovered by this method. Economic minerals that can be recovered are: quartz, albite, microcline, scrap mica, lepidolite, amblygonite, beryl, spodumene, and cassiterite.

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 paper is one of a series describing mine dumps and recovery methods. It pertains to the Ingersoll mine, located two miles northwest of Keystone, in the NE¼ NW¼ of Section 6, T2S, R6E,

Pennington County, and to the Tin Mountain mine located seven miles west of Custer, in the SE¼ NE¼ of Section 35, T3S, R3E, Custer County, South Dakota.

The study, which included surveying, mapping, trenching, sampling, and analytical work, was conducted between October 1966 and March 1968. Field and laboratory assistance was provided by two undergraduate students and one graduate student.

INGERSOLL MINE

History

The Bob Ingersoll claim was located April 27, 1881 by H. J. McKee and W. W. Challis as a mica prospect. The Harney Peak Tin Company acquired the property in 1884, together with the adjacent Ben Butler and Horace Greeley claims. All three claims were subsequently patented by the Harney Peak Tin Company. From 1895 until 1917 the property was owned by the Pa-Ha-Sa-Pa Mining Company. W. S. Dewing and Dennis Henault were the owners from 1917 to 1933. The mine has been owned by the Black Hills Keystone Corporation from 1933 to the present, and has been operated intermittently by several leasees under the supervision of A. I. Johnson as Resident Manager.

Mineral Deposits and Production

Minerals of economic value produced from the Ingersoll property are microcline-perthite, albite (cleavelandite), muscovite, amblygonite, beryl, lepidolite, spodumene, microlite, columbite-tantalite, cassiterite, quartz, tourmaline, and uraninite. Other minerals that have been identified are almandite, autunite, becquerelite, biotite, ferri-sicklerite, fluorapatite, fourmarierite, heterosite, kaolinite, kasolite, limonite, loellingite, staurolite, triphylite, uranophane, vandendriesscheite, and zircon.

During the course of this study the following additional mineral species, all from the dumps of Dike No. 1, were identified by utilizing x-ray diffraction and spectroscopy techniques; specimens of each type have been deposited in the Museum of Geology at the South Dakota School of Mines and Technology.

Bismuthinite—Occurs very sparingly as gray fibrous aggregates up to four inches in length, almost entirely altered to bismutite, associated with cleavelandite, quartz, and excellent euhedral cassiterite crystals.

Bismutite—Straw-yellow earthy masses occur as an alteration product of bismuthinite.

Fairfieldite—Minute white crystal aggregates are found in vugs in altered triphylite associated with several unidentified secondary phosphate minerals. Identification was confirmed by x-ray diffraction.

Scorodite—Found as yellowish-green earthy incrustations in cracks and on crystals of loellingite.

Sphalerite—Brown masses, exhibiting good cleavage, are found up to one inch by one inch in size associated with feldspar. The occurrence is very uncommon.

The mine is noted for exceptionally large crystals and crystal aggregates. A columbite mass 20 inches by 20 inches by 74 inches in size, estimated to exceed 2,000 pounds in weight, was reported by Blake (1884, p. 340). One mass of beryl crystals containing about 100 tons and a single crystal 18 feet long and 6 feet in diameter, weighing approximately 40 tons, have been mined. Page, et al (1953, p. 77, 78, 81); Jahns (1953, p. 563); Johnson (1945, p. 82). Enormous masses of amblygonite ranging in size up to six feet in diameter, with one mass reported to be thirty feet in length and four feet in width, have been removed from the deposit. During this investigation, a mass of loellingite 25 by 18 by 12 inches in size, weighing 604 pounds, composed of well-formed intergrown prismatic crystals up to 2 by 12 inches in size, was encountered. It is quite evident that it represented but a portion of a considerably larger mass. These are the largest loellingite crystals and the largest mass of loellingite ever reported from a pegmatite.

Volumetric studies of the dumps of Dikes No. 1 and No. 2 indicate that they contain 58,600 tons of material, ranging in size from minute grains to masses several tons in weight.

Methods

The mine dumps of Dikes No. 1 and 2 were surveyed by transit and tape methods to establish the present configuration of the dumps, and to provide a foundation for making volumetric estimates. A contour map and an isopach map, on a scale of 1″ to 40′, were prepared. A proposed trenching pattern was established and incorporated on the contour map.

A truck-mounted back-hoe was utilized to excavate fourteen trenches with an aggregate length of 339 feet, an average depth of 5½ feet, and width of 4 feet. Thirty samples, each weighing approximately 1,000 pounds, were removed from the trenches, crushed with a jaw-crusher to minus two-inch size, split by quartering to 100 pound samples, and then transported to the Experiment Station for further processing and analyses. Thirty-one shallow pits were hand-excavated, and one twenty pound sample was removed from each pit. These samples were removed from areas inaccessible to the back-hoe.

Each 100 pound sample was thoroughly mixed and split 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 hand-sorting studies. The thirty-one hand-excavated samples were also split and pulverized to minus 200 mesh size.

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

Possible recovery methods were investigated and some consideration of these methods is included in the conclusions of this report.

Analytical Results

X-ray spectrographic analyses of the thirty trench samples and thirty-one hand-excavated samples resulted in essentially identical qualitative elemental constituents. Detectable concentrations of Fe, Rb, Sn, Nb, Sr, Cs, and Zn were identified; tin occurs in abnormally high concentrations in trenches A, B, C, D, E, F, G, and I, niobium in trenches A, B, D, and K, and rubidium in all trenches except E, G, and J (see Figure 1). Quantitative x-ray fluorescence analyses of samples from the abnormally high trenches disclosed a rubidium content ranging from 0.105% to 0.25%, tin from 0.90% to 1.65%, and niobium from 0.015% to 0.05%. Lithium was determined by flame photometric methods; analyses of the trench samples disclosed an average elemental composition of 0.14%.

Emission spectrographic analyses of the samples resulted in average elemental components as set forth in the following table:

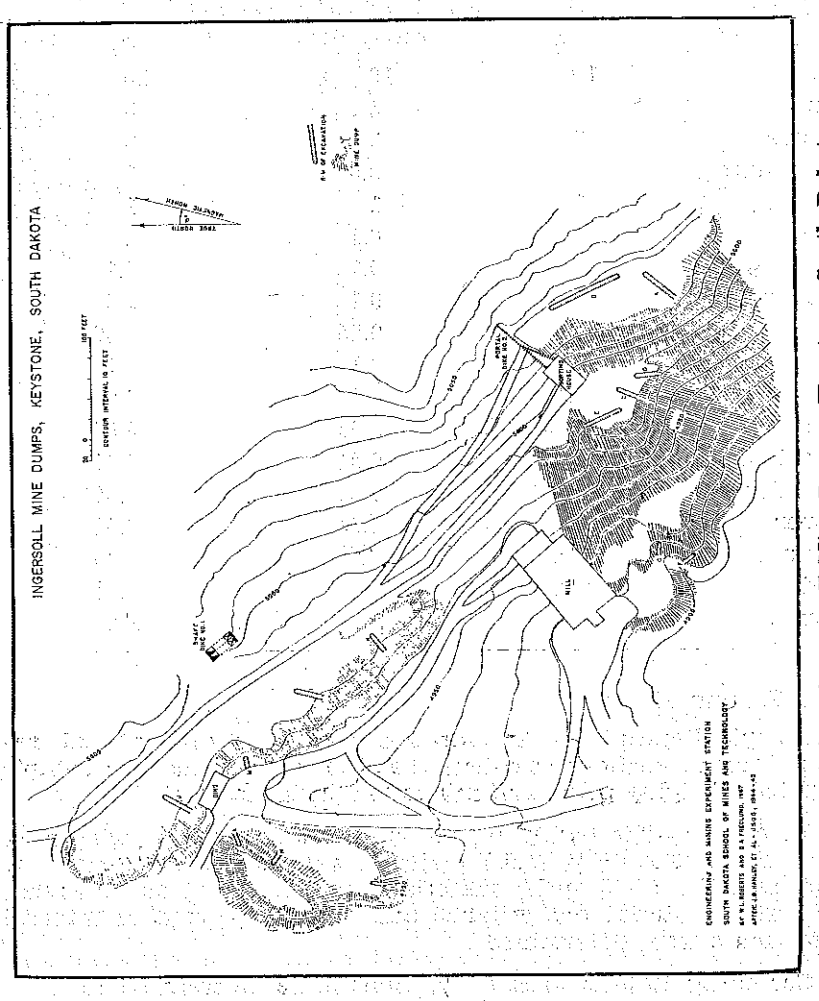

Figure 1. Map of Ingersoll Mine Dumps, Keystone, South Dakota.

TABLE I

Element	Ingersoll Mine (Trench Samples)	Ingersoll Mine (Hand-Excavated Samples)	Tin Mountain Mine (Hand-Excavated Samples)
	%	%	%
Silicon	10	10	10
Iron	5	5	5
Aluminum	5	5	5
Magnesium	1	0.5	1
Sodium	1	1	1
Boron	0.1	0.1	..
Phosphorus	0.1	0.1	0.1
Manganese	0.1	0.1	0.5
Tin	0.1	0.05	0.05
Titanium	0.1	0.1	0.1
Calcium	0.1	0.1	0.5
Zinc	0.05	0.05	0.05
Beryllium	0.01	0.01	0.01
Molybdenum	0.005	0.01	0.01
Copper	0.001	0.01	0.01
Niobium	Tr.	Tr.	0.05
Lead	Tr.	..	0.01
Arsenic	..	..	Tr.

Hand-Sorting Study

Sample Description—A composite sample of all material recovered from trenches was collected at the crusher site. The sample consisted of eighty pounds of minus two inch material.

Procedure—The eighty pound sample was screened with a ¼ inch screen. The (+ ¼ inch) material was washed and sorted by hand, and the (– ¼ inch) material was eliminated as undersize. The sorted material was weighed and relative percent of mineral constituents were determined.

Screening Results—The (+ ¼ inch) material weighed 30 pounds.
The (– ¼ inch) material weighed 50 pounds.
Total weight of original sample, 80 pounds.

TABLE II

Relative Percent of Mineral Constituents Recovered From Original Sample

Mineral	Percent Recovered from (+ ¼ inch) Material	Percent Recovered from Original Sample
Quartz	24.08	9.03
Albite	10.36	3.88
Microcline	7.45	2.79
Scrap Mica	2.12	0.80
Lepidolite	1.57	0.59
Amblygonite	1.47	0.55
Beryl	0.71	0.27
Spodumene	0.02	0.01
Cassiterite	0.01	0.00
Sub-Total	47.88	17.92
Gangue	52.21	19.58
Undersize	.....	62.50
Total	100.00	100.00

TIN MOUNTAIN MINE

History

Original location records of the Tin Mountain mine are not available, presumably having been lost when the county seat was moved from Hayward to Custer. D. P. Moore discovered tin ore (cassiterite) on the property in May 1885. A 50 ton mill was installed by H. W. Fowler and a small amount of concentrates were produced in 1887. The Harney Peak Tin Company applied for a patent to the property on June 24, 1889; the patent (M. S. 553) was granted in 1894. In 1927 the mine was purchased from H. W. Fowler by the Maywood Chemical Works and operated until 1930. The mine remained idle from 1930 until the early 1950's and was then worked intermittently until 1961 by James Koba and Consolidated Feldspar Corporation under lease agreements. The mine was purchased from Maywood Chemical Works by Walter Clifford and Roy Chord in 1961 and has been operated sporadically by them up to the present time.

Mineral Deposits and Production

Minerals of economic value produced from the Tin Mountain mine are beryl, microcline-perthite, amblygonite (montebrasite),

spodumene, pollucite, columbite-tantalite, cassiterite, microlite, muscovite, and quartz. Other minerals that have been identified are albite, autunite, azurite, biotite, bismuth, bismuthinite, calcite, chalcopyrite, ferri-sicklerite, fluorapatite, fourmarierite, garnet, kasolite, lepidolite, limonite, loellingite, malachite, montmorillonite, sphalerite, triphylite, tourmaline, uraninite, uranophane, vandendriesscheite, and zircon.

The following additional mineral species, collected from the mine dumps during this study, were identified by optical and x-ray techniques:

Aurichalcite—Drusy, light blue incrustations are found sparingly in vugs associated with euhedral cassiterite crystals, hemimorphite, smithsonite, chalcocite, and minute amounts of azurite.

Chalcocite—Observed as lead-gray masses up to ¼ inch in diameter imbedded in vuggy white quartz associated with cassiterite crystals and several secondary minerals.

Hemimorphite—Occurs as colorless, transparent, vertically striated prismatic crystals implanted on quartz crystals and associated with cassiterite crystals, aurichalcite, smithsonite, chalcocite, limonite, sphalerite, and minute grains of azurite.

Smithsonite—Pale green botryoidal incrustations occur sparingly in vugs associated with cassiterite crystals, aurichalcite, chalcocite, hemimorphite, and sphalerite.

The smithsonite and hemimorphite were probably derived from the alteration of primary sphalerite, and aurichalcite from the alteration of primary chalcocite. Specimens of the above described minerals have been deposited in the Museum of Geology at the South Dakota School of Mines and Technology.

Methods and Analytical Results

The mine dumps were surveyed by transit and tape methods to establish the present configuration. A sampling pattern was established and included on a preliminary map.

Thirty shallow pits were hand-excavated, and one twenty pound sample was removed from each pit. The samples were crushed with a jaw crusher to minus ½ inch size, split to obtain a representative sample, and pulverized to minus 200 mesh size.

X-ray spectrographic analyses of the thirty samples resulted in essentially identical qualitative elemental constituents. Detectable amounts of Fe, Rb, Cs, Sn, Nb, Sr, and Zn were identified; rubidium and cesium occur in abnormally high concentrations in all samples. Quantitative x-ray analyses disclosed a rubidium content ranging from 0.045% to 0.49%, and niobium from 0.017% to 0.75%.

Subsequent emission spectrographic analyses of the samples resulted in average elemental concentrations as set forth in Table I.

A 9620 gram sample of microlite-bearing pegmatite, consisting of approximately 50% mica, 35% feldspar, 10% quartz, and a 5% mixture of microlite, cassiterite, zircon, columbite-tantalite, and uraninite was collected from the east mine dumps. The sample was crushed with primary and secondary jaw crushers and a roll-mill. Concentration experiments with a Wilfley table, jig, flotation cells, and electrostatic separators were conducted.

An 8 x 28 fraction of the crushed sample was concentrated by tabling and a 70% concentration was produced. The 28 x 65 fraction produced similar results, but the adjustments, particularly the flow-rate of water, were delicate.

Separation of an 8 x 28 fraction of the sample was attempted on a small jig with very poor results.

Electrostatic separation was attempted on a 28 x 65 fraction using a low intensity electrode, but the results were negative. Preliminary studies suggest the utilization of a high intensity electrode for the electrostatic separation of quartz and feldspar from the microlite ore as a supplement to flotation.

Flotation experiments were performed on the 28 x 65 fraction. Coco amine acetate, Aero Promoter 801, and amine D acetate were used as collectors in the mica and feldspar flotation experiments. Aero Promoter 801 and amine D acetate provided very poor separation. A 99.9% mica concentrate and a 52% feldspar concentrate was obtained with coco amine acetate.

An analysis was made of a hand-picked sample of microlite from the 8 x 28 fraction of the table concentrate containing minor admixed cassiterite, columbite-tantalite, uraninite, and zircon. Na_2O was determined by flame photometric methods, fluorine by the colormetric method, and all other elements by x-ray spectrographic analysis.

A qualitative x-ray analysis of the sample indicated the presence of Ta, Nb, Sn, Ca, U, Pb, and Zr. Quantitative x-ray analysis was performed on the elements Ta, Nb, Sn, and U. No attempts were made to separate cassiterite or other minor minerals from the sample. The results of the analysis (1) are set forth below, together with an analysis (2) of pure microlite from the same locality by Rapp (1962):

	(1)		(2)
Na_2O	1.9	Na_2O	2.0
CaO	n.d.	CaO	10.4
UO_2	1.1	UO_2	5.0
Ta_2O_5	56.0	Ta_2O_5	70.6
Nb_2O_5	5.8	Nb_2O_5	6.1
SnO_2	6.0	SnO_2	n.d.
F	0.8	F	1.7
OH	n.d.	OH	n.d.
			95.8
		O = F	.8
			95.0

X-ray analysis indicated that the elements Zr and Pb are present only in trace amounts. The Pb probably originates from the decay of U, and Zr from the small amount of zircon in the concentrate.

CONCLUSIONS

Hand-sorting the total volume of dump material from the two mines studied appears to be economically marginal at the present time. Installation of a jaw-crusher, screens, washer, and picking belt would permit the recovery of 17.92 percent of the volume of the dumps at the Ingersoll mine. Quartz, microline, albite, scrap mica, lepidolite, amblygonite, beryl, spodumene, cassiterite, and small amounts of green tourmaline in muscovite, and columbite-tantalite can be recovered by this method. The gangue and undersize material can be marketed locally for road gravel and highway construction purposes; the green tourmaline in muscovite can be sold to mineral supply companies and local mineral shops; all other recoverable economic minerals have well-established markets.

If a custom treatment plant was available in the district, a small but significant amount of cassiterite and columbite-tantalite could be recovered from hand-sorted ore from the Ingersoll mine, and a small amount of microlite, cassiterite, and columbite-tantalite from the dumps of the Tin Mountain mine.

Substantial reserves of rubidium and cesium are present in the dumps of the two mines. If an increased demand for rubidium or cesium should occur, reserves are large enough to warrant investigation and development of suitable extraction methods.

ACKNOWLEDGMENTS

The authors wish to acknowledge the financial support of the United States Bureau of Mines for part of the funds used in carrying out this investigation. A. I. Johnson, Merle Chase, and Walter Clifford generously gave permission to conduct extensive sampling programs at the Ingersoll and Tin Mountain mines. Students Joseph Kovarik, Olav Hatlegjerde, and John Steichen provided helpful assistance throughout all phases of this project. Dr. Amos Lingard, Prof. David Garske, students Bruce Ballard and James Kernaghan contributed assistance in collecting specimens and performing many analyses. The excavation and sample recovery program was contracted to Earth Science Consulting of Rapid City under the supervision of Daniel A. Fredlund.

BIBLIOGRAPHY

Blake, W. P., 1884, Columbite in the Black Hills of Dakota: Am. Jour. Sci., 3rd ser., vol. 28, pp. 340-341.

Connolly, Joseph P. (and O'Harra, Cleophas C.), 1929, The mineral wealth of the Black Hills: SDSM Bull. 16, 418 pp.

Guiteras, Jos. R., 1940, Mining of feldspar and associated minerals in the southern Black Hills of South Dakota: U. S. Bur. Mines Inf. Circ. 7112, 104 pp.

Hess, Frank L. (and Fahey, J. J.), 1932, Cesium biotite from Custer County, S. Dak.: Am. Mineralogist, vol. 17, no. 5, pp. 173-176.

Jahns, Richard H., 1953, The genesis of pegmatites. I. Occurrence and origin of giant crystals: Am. Mineralogist, vol. 38, nos. 7-8, pp. 563-598.

Johnson, Arthur I., 1945, Beryl found in large crystals at the Ingersoll mine in the Black Hills of South Dakota: Pit and Quarry, vol. 38, no. 5, pp. 82-83.

Page, Lincoln R. (and others), 1953, Pegmatite investigations, 1942-1945, Black Hills, South Dakota: U. S. Geol. Survey Prof. Paper 247, 228 pp.

Rapp, George, Jr., 1962, Microlite from the Tin Mountain pegmatite, South Dakota: S. D. Acad. Sci. Proc., vol. 41, pp. 44-45.

Roberts, Willard Lincoln (and Rapp, George, Jr.), 1965, Mineralogy of the Black Hills: SDSM&T Bull. 18, 268 pp.

Schwartz, G. M., 1930, The Tin Mountain spodumene mine, Black Hills, S. D.: Econ. Geology, vol. 25, no. 3, pp. 275-284.

Smith, Arthur E., Jr. (and Roberts, W. L.), 1964, Tin Mountain pegmatite mine, Custer County, South Dakota: Rocks and Minerals, vol. 39, nos. 11, 12, pp. 565-568.

Staatz, Mortimer Hay (and others), 1963, Exploration for beryllium at the Helen Beryl, Elkhorn and Tin Mountain Pegmatites, Custer County, South Dakota: U.S.G.S. Prof. Paper 297-C, pp. 129-197.

Tullis, Edward Langdon, 1952, Beryl resources of the Black Hills, S. Dak.: U. S. Bur. Mines Rept. Invest. 4855, 19 pp.

United States Bureau of Mines, 1955, Black Hills mineral atlas, South Dakota, Pt. 2: U. S. Bureau of Mines Inf. Circ. 7707, 208 pp.