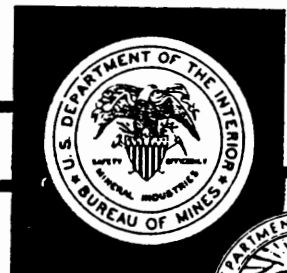


**Characterization of the Sheep
Creek Pb-Zn-Ag-Sn Prospect,
North-Central Alaska Range**

By W. K. O'Connor, D. C. Dahlin,
and J. D. Warner

BUREAU OF MINES



UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 9256

Characterization of the Sheep Creek Pb-Zn-Ag-Sn Prospect, North-Central Alaska Range

By W. K. O'Connor, D. C. Dahlin,
and J. D. Warner

UNITED STATES DEPARTMENT OF THE INTERIOR
Manuel Lujan, Jr., Secretary

BUREAU OF MINES
T S Ary, Director

Library of Congress Cataloging in Publication Data:

O'Connor, W. K.

Characterization of the Sheep Creek Pb-Zn-Ag-Sn prospect, north-central Alaska Range / by W. K. O'Connor, D. C. Dahlin, and J. D. Warner.

(Report of investigations; 9256)

Bibliography: p. 14

Supt. of Docs. no.: I 28.23:9256.

1. Mines and mineral resources--Alaska--Fairbanks North Star Borough.
2. Mines and mineral resources--Alaska--Alaska Range. I. Dahlin, D. C. (David Clifford), 1951- . II. Warner, J. Dean. III. Title. IV. Title: Sheep Creek Pb-Zn-Ag-Sn prospect, north-central Alaska Range. V. Series: Report of investigations (United States. Bureau of Mines); 9256.

TN23.U43 [TN25.F35] 622 s--dc19 [553'.09798'6] 89-600045

CONTENTS

	<i>Page</i>
Abstract	1
Introduction	2
Regional geology and location	2
Prospect history	2
Geology	4
Mineralogy	6
Channel samples	6
Core samples	7
Concentration products	8
Concentration tests	9
Sample preparation	9
Concentration procedure	10
Concentration results	10
Conclusions	14
References	14
Appendix.—Sample key	15

ILLUSTRATIONS

1. Location of Sheep Creek prospect	3
2. Geologic map of Sheep Creek prospect	4
3. Cross section of diamond drill hole DDH-SC1, drilled by Bear Creek Mining Co. in 1977	5
4. SEM backscatter electron photomicrograph of multiphase grain with pyrite, galena, and sphalerite	6
5. Backscatter electron image and element X-ray maps for Fe and Sn showing cassiterite inclusions in pyrite	7
6. Photomicrograph with pyrite and sphalerite present along edge of large quartz grain	8
7. Photomicrograph of massive pyrite and sphalerite	8
8. Backscatter electron image of galena grain, with X-ray element maps for Pb, Fe, and Ag	9
9. Concentration flowsheet for the three surface bulk samples and two drill-core samples	11

TABLES

1. Drill-hole geochemistry	5
2. Head analyses of Sheep Creek bulk and composite samples	10
3. Size distribution of minus 150- μ m feed to rougher shaking table	10
4. Concentration results on sample BS 1	12
5. Concentration results on sample BS 2	12
6. Concentration results on sample BS 3	12
7. Concentration results on sample BS 4	13
8. Concentration results on sample BS 5	13
9. Sulfide flotation on rougher table slime tailings from sample BS 5	13

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	μm	micrometer
ft	foot	pct	percent
ft ³ /st	cubic foot per short ton	ppm	part per million
in	inch	st	short ton
kg	kilogram	tr oz/st	troy ounce per short ton
lb	pound (mass)	wt pct	weight percent
lb/st	pound per short ton		

CHARACTERIZATION OF THE SHEEP CREEK Pb-Zn-Ag-Sn PROSPECT, NORTH-CENTRAL ALASKA RANGE

By W. K. O'Connor,¹ D. C. Dahlin,¹ and J. D. Warner²

ABSTRACT

The U.S. Bureau of Mines investigated the Sheep Creek prospect in the north-central Alaska Range to evaluate the Pb, Zn, Ag, and Sn resources. The studies included field investigations, mineralogical characterization, and concentration tests. Mineralization at Sheep Creek consists of disseminated, banded, and massive pyrite, sphalerite, and galena. Tin occurs as grains of cassiterite (SnO_2) in the quartz-mica matrix and within pyrite and sphalerite grains, and Ag occurs in solid solution within the galena.

Three bulk surface samples and two sets of core samples were collected at the Sheep Creek prospect for this study. Gravity concentration yielded products with up to 30 pct Sn, and the best result was a product that recovered 52 pct of the Sn at a grade of 22 pct Sn. Bulk sulfide flotation yielded products that recovered up to 89 pct of the Zn, 73 pct of the Pb, and 75 pct of the Ag, but grades were relatively low; selective flotation would significantly increase the grades.

¹Metallurgist, Albany Research Center, U.S. Bureau of Mines, Albany, OR.

²Geologist, Alaska Field Operations Center, U.S. Bureau of Mines, Fairbanks, AK (now with NERCO Minerals Inc., Vancouver, WA).

INTRODUCTION

As part of a program evaluating domestic resources of critical and strategic materials, the U.S. Bureau of Mines is doing research to characterize domestic resources of Sn. Tin occurrences in Alaska include both placer and lode deposits, with most of the State's production provided by the placer deposits on the Seward Peninsula. In a previous study, Warner (1)³ described many of the Sn, Ta, and Cb resources in Alaska. The Sheep Creek deposit described in this report is unique in that it contains Pb, Zn, and Ag in addition to Sn.

The exhaustion of the International Tin Council funds to support the price of Sn in late 1985 has had continued

repercussions on the Sn industry (2). Lower Sn prices have dictated a reduction in high-cost mining operations, such as the underground mines in Bolivia and the gravel pump operations in Malaysia. Substantially lower prices led to mine closures in Australia, Bolivia, Malaysia, Thailand, and the United Kingdom. As a result of these closures, Sn supplies will decrease and prices will increase, and consequently, domestic Sn resources will become more important. The purpose of this study was to provide additional information on domestic resources through evaluation of the Pb, Zn, Ag, and Sn resources at the Sheep Creek deposit in the north-central Alaska Range.

REGIONAL GEOLOGY AND LOCATION

Most of Alaska's Sn reserves and resources are of the lode type, which can be classified in five groups: greisen, vein, skarn, pegmatite, and volcanogenic massive sulfide. The Sheep Creek deposit, a volcanogenic massive sulfide type, occurs within a belt of Precambrian to Mississippian schists that contain numerous similar deposits (3). However, the Sheep Creek deposit is the only one within this belt that contains significant Sn. The form, alteration, mineralogy, and geologic setting indicate that this deposit is similar to stratiform massive sulfides mined elsewhere in the world.

The Sheep Creek deposit is in the north-central Alaska Range, approximately 65 miles southwest of Fairbanks and 15 miles northeast of Healy (fig. 1). The Sheep Creek prospect is specifically located in sections 34, 35, and 36, T. 11 S., R. 4 W., of the Healy D-3 quadrangle (fig. 2). The main exposures of the deposit occur from the flanks of Gossan Peak, just south and east from the northwest corner of section 35, to the northeast corner of section 35, with exposures along the banks of Sheep Creek. The region consists of rugged mountainous terrain that can be reached best by helicopter.

PROSPECT HISTORY

The Sheep Creek property was originally staked by Resource Associates of Alaska, Inc., Fairbanks, for Uran-gesellschaft U.S.A., Inc. (UG), Denver, CO. UG leased the property to Bear Creek Mining Co., a division of Kennecott Minerals Corp. (now British Petroleum Minerals, Salt Lake City, UT), in 1976. Bear Creek Mining conducted reconnaissance geologic mapping and geochemical rock sampling of the exposed mineralization in 1976 and drilled a 425-ft diamond drill hole (DDH-SC1) in 1977 to test the stratigraphic thickness, depth, and grade of the mineralization (4).

Bear Creek Mining subsequently leased the property to United States Borax and Chemical Corp., Los Angeles, CA, in 1979. During the 1979 field season, U.S. Borax blasted and geochemically sampled three sites selected

from the geochemical anomalies identified by Bear Creek Mining. The 1979 sampling failed to duplicate these anomalies. Additional geologic mapping and geochemical rock sampling were conducted along the Gossan Peak ridgeline to determine the Pb-Zn-Ag-Sn potential of the entire deposit. Several new outcrops, highly anomalous in base and precious metals, were located, but none appeared as extensive as the original exposure at Gossan Peak. U.S. Borax drilled two diamond drill holes on the northeast end of the Gossan Peak exposure in 1979, attempting to determine the depth and grade of the strata-bound deposit. U.S. Borax determined that the grade and tonnage needed for an economic Pb-Zn deposit did not appear to exist and so terminated its operations.

Based on geochemical data acquired by Bear Creek Mining and U.S. Borax, Bureau geologists sampled the Sheep Creek deposit in 1984. Samples of the core drilled by Bear Creek Mining in 1977 were also obtained for this study.

³Italic numbers in parentheses refer to items in the list of references preceding the appendix at the end of this report.

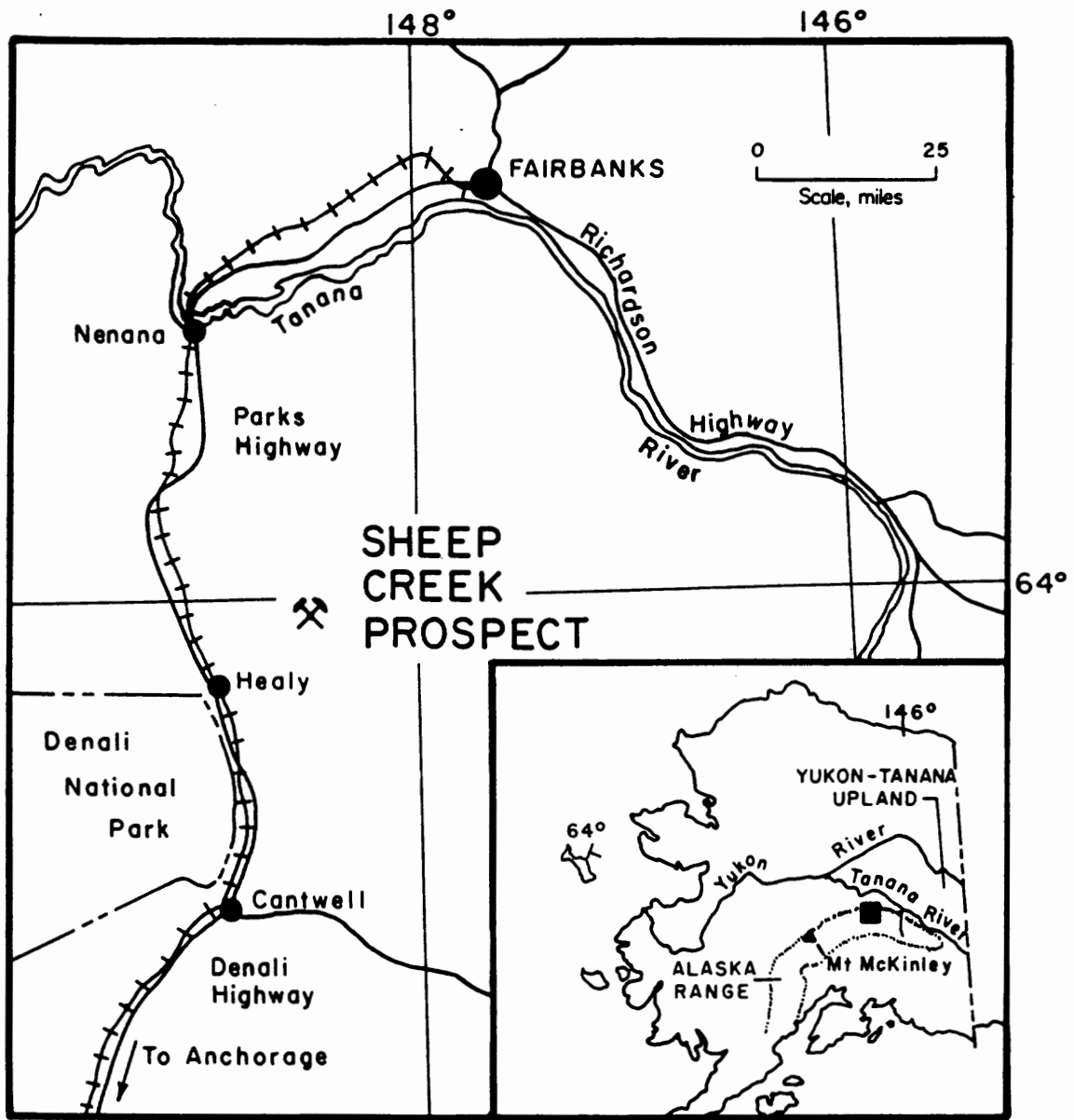
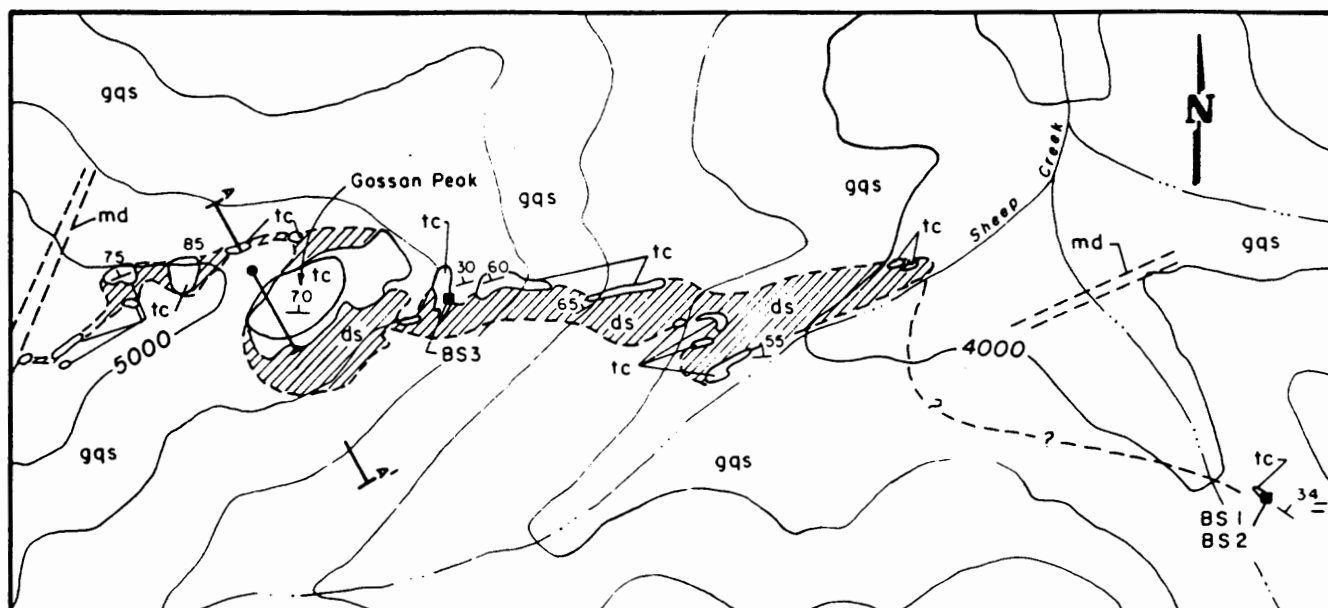
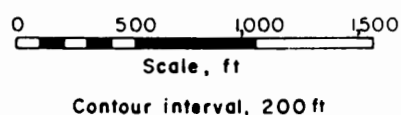


Figure 1.-Location of Sheep Creek prospect.



LEGEND



md	Mafic dike	Geologic contact, dashed where approximated, queried where projected
tc	Tuffaceous chert with disseminated sulfides	Strike and dip of bedding
ds	Sericite schist with mineralized chert interbeds	Diamond drill hole DDH-SCI
gqs	Graphite and quartz-sericite schist	Cross-sectional line
		Bulk sample site

Figure 2.—Geologic map of Sheep Creek prospect (based on map from Bear Creek Mining Co.).

GEOLOGY

Geologic mapping and geochemical sampling indicated the presence of a strata-bound massive sulfide deposit enclosing a mineralized 250- by 750-ft tuffaceous chert exposure at Sheep Creek. The deposit occurs within a quartz-sericite-graphite-chlorite schist horizon enclosed within graphitic and quartz-sericite schists of the Paleozoic Keavy Peak Formation (5-6). Irregular mineralization occurs along the strike of this chert horizon for a distance of over 10,000 ft (fig. 2).

The mineralization of the Sheep Creek deposit consists of disseminated to massive pyrite, sphalerite, and galena. The mineralized chert horizon has undergone complex folding and plastic deformation. The banded sulfides generally parallel the schistosity, with the more massive

occurrences apparently resulting from migration of the sulfides into fold crests.

Drilling of the 425-ft hole (DDH-SC1) by Bear Creek Mining in 1977 intersected a 350-ft-thick section of mineralized cherts and schists (fig. 3). Three zones with above-average-grade mineralization were intercepted by the drilling: zone 1 at the 48- to 125-ft interval, zone 2 at the 192- to 265-ft interval, and zone 3 at the 308- to 392-ft interval. Average grade for the hole was 1.4 pct Zn, 0.6 pct Pb, 0.035 pct Sn, and 0.3 tr oz/st Ag. This average includes a 6.5-ft interval near the bottom of the hole containing 4.5 pct combined Zn-Pb and 1.2 pct Sn. Complete drill-hole geochemistry is listed in table 1.

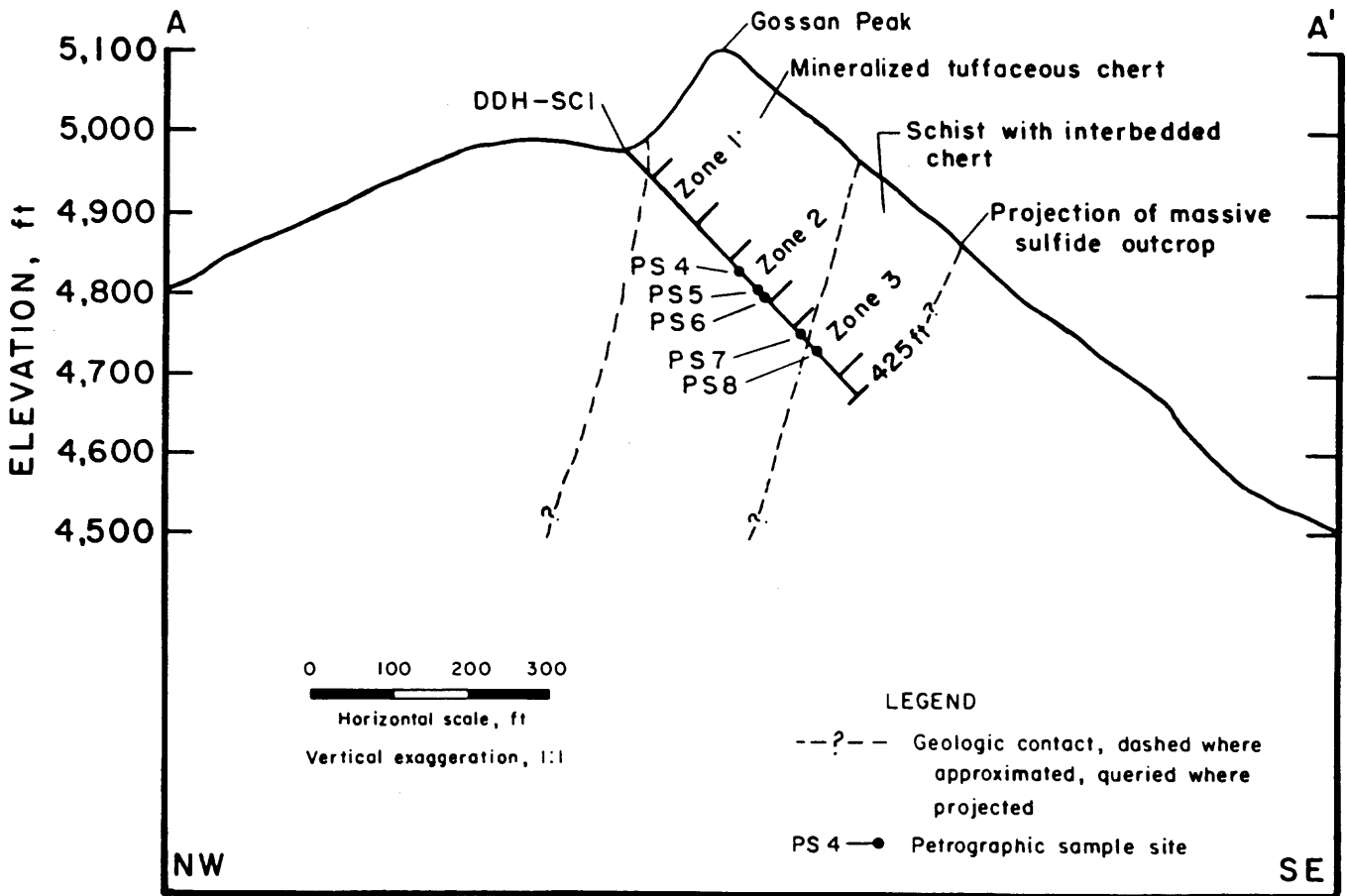


Figure 3.—Cross section of diamond drill hole DDH-SC1, drilled by Bear Creek Mining Co. in 1977, showing location of core samples described in text (based on map from Bear Creek Mining Co.).

Table 1.—Drill-hole geochemistry

	Ag, tr oz/st	Pb, pct	Sn, pct	Zn, pct
Zone 1, 77 ft	0.45	1.0	0.021	1.3
Zone 2, 73 ft . . . . .	.33	1.2	.025	2.5
Zone 3, 84 ft . . . . .	.30	.5	.127	2.5
Av for hole, 425 ft . . . .	.30	.6	.035	1.4
Av for zones, 234 ft . . .	.36	.9	.060	2.1

U.S. Borax drilled two diamond drill holes on the northeast end of the Gossan Peak exposure in 1979. The holes cut through the steeply, northerly dipping mineralized chert and schist horizon. Drill hole GP79-1 was an inclined hole (470 ft deep) drilled to test the stratigraphic thickness and grade of the mineralization. Six mineralized horizons totaling 95.2 ft thick over a total section of 305 ft were defined by the drilling. Average grade of the mineralized horizons was 2.17 pct Zn, 0.82 pct Pb, 0.042 pct Sn, and 0.36 tr oz/st Ag.

A second drill hole, GP79-2, was set up next to the first hole (GP79-1) and was drilled vertically. GP79-2 was

intended to intersect the mineralized zones downdip from GP79-1, thus defining the continuity of the strata-bound deposit. However, none of the mineralized horizons were encountered in GP79-2, indicating that the mineralization is not continuous downdip. Surface sampling indicated that the mineralization is laterally discontinuous as well, occurring in pods over a 10,000-ft strike length, generally less than 20 ft thick.

With a cross-sectional area similar to that shown in figure 3 (250-ft width, with an inferred downdip extension of 420 ft) and an estimated tonnage factor (cubic feet of ore per ton) of 10 ft³/st, this plunging ore shoot contains a potential for approximately 10.5 million st of mineralized rock per 1,000 ft of strike length. Although the inferred extensions have not been drill tested, a resource of approximately 5.5 million lb Sn (at an average grade of 0.035 pct Sn) is inferred within the 750-ft strike length of exposed mineralization.

MINERALOGY

This study concentrated on two sample groups from the Sheep Creek prospect. The first is a group of three channel samples collected by Bureau geologists as examples of the exposed mineralization. The second sample group consists of composited core materials from the Bear Creek Mining DDH-SC1 diamond drill hole drilled on Gossan Peak in 1977. Two of the three significant zones of mineralization, intercepted by the hole, were sampled and composited. Sample numbers and descriptions of both the petrographic samples (PS series) and bulk samples (BS series) are listed in the appendix.

Characterization by reflected-light and scanning electron microscopy and energy dispersive X-ray (EDX) microanalysis was conducted on both groups of ore samples. Concentration tests were conducted on each bulk sample. The products from these tests were then characterized using the same procedures utilized with the ore samples.

CHANNEL SAMPLES

Based on the geochemical anomalies determined by Bear Creek Mining and U.S. Borax, three channel samples were collected. The location of each sample site is shown in figure 2. Samples BS 1 and BS 2, collected from a creek exposure, are 9.3-ft and 10.3-ft channel samples, respectively, collected perpendicular to a N. 40° W.-trending, 45° NE.-dipping zone of mineralization. Sample BS 1 represents the footwall section and consists of sericite-quartz-graphite-sulfide schist with traces of sphalerite, galena, and pyrite. Sample BS 2 represents lower grade hanging-wall mineralization similar to that of BS 1 but lacking graphite and containing lower amounts of sulfides. Mineralization similar to that of BS 2 continues for 15 to 20 ft up section. Channel sampling by Bear Creek Mining and U.S. Borax showed 0.12 to 1.3 pct Sn to be present in this outcrop.

Sample BS 3, collected from the central portion of the mineralized horizon, approximately 3,500 ft west of samples BS 1 and BS 2, represents a 7-ft-channel hanging-wall and an 8-ft-channel footwall pyrite-sphalerite-galena mineralization that encloses a 62-ft-thick section of weakly mineralized massive quartz-sericite schist. Sampling by Bear Creek Mining and U.S. Borax in the vicinity of BS 3 indicated 125 to 3,900 ppm Sn.

Mineralogical characterization by reflected-light microscopy determined that the sulfide mineralization is predominantly pyrite, with smaller amounts of sphalerite and galena. Inclusions of galena occur within the pyrite and sphalerite, indicating initial deposition of pyrite and galena, then later replacement of much of the galena by sphalerite

(fig. 4). Minor inclusions of chalcopyrite also occur within the sphalerite. Tin minerals were not detected by optical methods.

Examination by scanning electron microscopy and EDX microanalysis was also conducted. Emphasis was placed on characterizing the occurrence of Sn within the samples. It was determined that the Sn occurs as cassiterite (SnO_2) within the quartz-mica matrix and within pyrite or sphalerite (fig. 5). Grain size typically ranges from 2 to 10 μm , with the cassiterite occurring as both subhedral crystals within the sulfide grains or as anhedral, irregularly shaped grains within the matrix.



Figure 4.—SEM backscatter electron photomicrograph of multiphase grain with pyrite (gray), galena (white), and sphalerite (light gray) (X 500).

CORE SAMPLES



Figure 5.—Backscatter electron image (A) and element X-ray maps for Fe (B) and Sn (C) showing cassiterite inclusions in pyrite (X 500).

Two of the mineralized zones intercepted by drill hole DDH-SC1 (location shown in figures 2 and 3) were sampled and studied in this investigation. Zone 2, the 192- to 265-ft interval, was reported to contain 2.5 pct Zn, 1.2 pct Pb, 0.025 pct Sn, and 0.33 tr oz/st Ag. Samples of the core were selected for characterization, with the remainder of the core comprising a 13-kg sample used for concentration tests. Similarly, zone 3, the 308- to 392-ft interval, was sampled for characterization. This zone was reported to contain 2.5 pct Zn, 0.5 pct Pb, 0.127 pct Sn, and 0.30 tr oz/st Ag. After sampling for petrographic examination, a 12-kg sample from the remainder of the interval was used for concentration tests.

Zone 2 is a series of interlayered chert and quartz-mica schist horizons. Some of the intervals exhibit a porphyroclastic texture. Large porphyroclasts of quartz, contained within a quartz-mica matrix, are characteristic of these intervals. The porphyroclastic texture coincides with high grades of mineralization, suggesting that migrating mineral-rich fluids may have favored the path of these coarse-grained layers.

Three samples from zone 2 were chosen for specific characterization by reflected-light microscopy. Each sample exhibits the characteristic texture described above. From the 206-ft interval, sample PS 4 contains sulfides disseminated throughout a matrix of massive quartz. The predominant sulfide is pyrite, with minor sphalerite and rare galena. Textures reflect the same genetic relationships exhibited in the channel samples. Sample PS 5, from the 241-ft interval, contains massive sulfide mineralization enclosing large clasts of quartz. Massive intergrowths of pyrite and sphalerite predominate. The third sample from zone 2, PS 6, from the 245-ft interval, displays the same disseminated sulfide mineralization described for PS 4. A quartz-mica matrix encloses large quartz grains, with the sulfides occurring around the immediate perimeter of the quartz grains, within the matrix (fig. 6). The entire zone exhibits textures and mineralogy similar to that of the channel samples but with higher grades of sulfide mineralization.

Along with the higher grade of Pb (1.18 pct), the chemical analyses of the zone 2 interval (composite sample BS 4) reported the highest concentration of Ag, at 0.4 tr oz/st. The Ag grade paralleled the Pb grade in all five of the large (BS) samples. This fact, coupled with the failure to locate any Ag minerals with reflected-light or EDX microanalysis, led to speculation that the Ag present in the Sheep Creek mineralization is in solid solution with galena as argentiferous galena. Chemical analyses from

the head samples and the concentration products indicate an intimate association of the Pb and Ag and again suggest the presence of argentiferous galena.

The mineralogy described for zone 2 is essentially continued in zone 3. The entire core is a sequence of inter-layered tuffaceous cherts and quartz-mica schists. Material in zones 2 and 3 are distinguished by their anomalous concentrations of sulfide mineralization. Sample PS 7 (fig. 3), from the 326-ft interval, contains massive intergrowths of pyrite and sphalerite within a quartz-mica matrix, nearly identical to PS 5 from zone 2 (fig. 7). PS 8, from the 350-ft interval, exhibits bands or stringers of sulfides transecting a silicate matrix, which in turn enclose extremely large grains (1 to 2 cm diameter) of

quartz. These sulfide bands appear to parallel the schistosity of the overall rock sample.

CONCENTRATION PRODUCTS

Polished mounts of the gravity concentration products were prepared for microscopic examination. Overall mineralogy of the gravity concentrate includes cassiterite, minor sulfides locked with silicate gangue, and several iron oxides. Most abundant of the iron oxides is ilmenite, followed by hematite and minor magnetite.

Polished mounts were also prepared from the bulk sulfide flotation products. The sulfides pyrite, sphalerite, and galena are the most abundant phases present, as expected.



Figure 6.—Photomicrograph with pyrite (white) and sphalerite (light gray) present along edge of large quartz grain (dark gray).

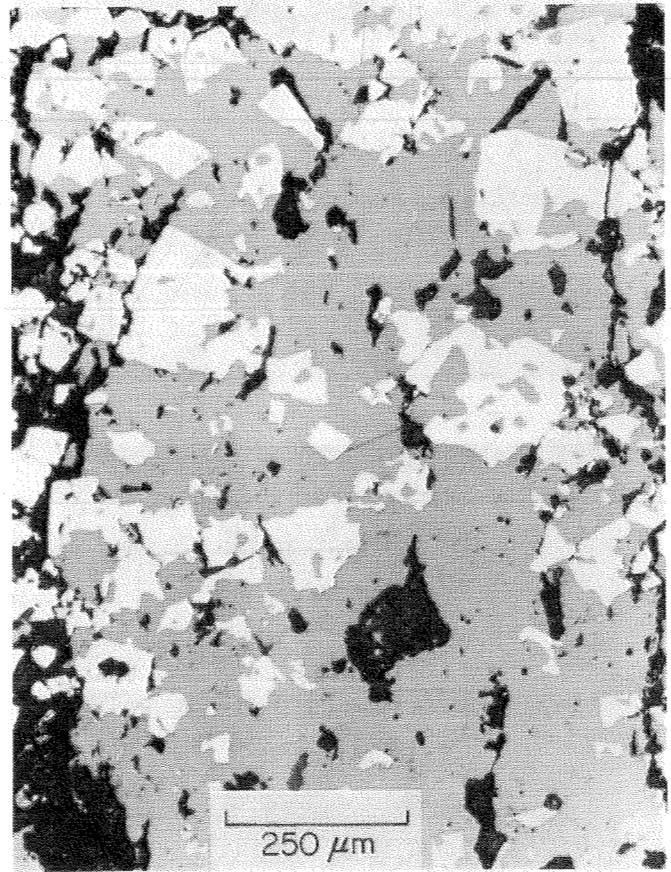


Figure 7.—Photomicrograph of massive pyrite (white) and sphalerite (gray).

Quartz and minor silicate gangue are present predominantly as locked particles with the sulfides, but a few free gangue particles are also present.

Because of the fine grain size (2 to 10 μm) of cassiterite in the channel samples and the failure to locate any cassiterite grains in the head samples, the core was concentrated to produce products for detailed Sn characterization. Scanning electron microscopy was successful in locating liberated grains of cassiterite in the concentrates. Grain size is consistent with the results determined from the channel samples, generally less than 10 μm .

Locating the source of the Ag proved to be difficult for all the samples. The authors suggest, based on analyses of the head and concentration products, that the Ag is present as argentiferous galena. The Ag values increase or decrease with corresponding Pb values. To verify this, a sample from the fraction with the highest Pb grade (scavenger flotation concentrate from sample BS 3) was selected for detailed scanning electron microscope (SEM) examination. Element maps for Pb and Ag were compiled for several galena grains within the sample. X-ray maps for Pb, Fe, and Ag from one of these grains are shown in figure 8. Silver content was too low (generally less than 1 pct) for any Ag minerals, such as argentite, freibergite, or native Ag. However, the presence of Ag in solid solution with the galena was verified. The Ag values reported in the bulk chemical analyses can therefore be explained, at least in part, by the presence of argentiferous galena in the samples.

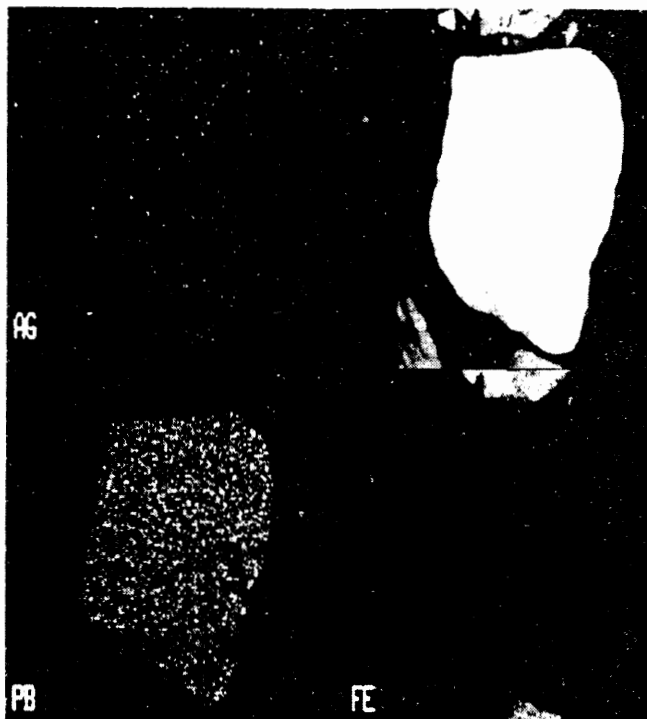


Figure 8.—Backscatter electron image of galena grain, with X-ray element maps for Pb, Fe, and Ag (X 250).

CONCENTRATION TESTS

The primary purpose of the mineral separation tests was to produce concentrates of the cassiterite and sulfide minerals for mineralogical studies. However, the results also give preliminary estimates of the potential grade and recoveries of the valuable minerals of the deposit. The BS sample series (appendix) was used in this portion of the investigation.

SAMPLE PREPARATION

After hand specimens were selected (from the BS sample series) for petrographic studies, the remainder of each sample was crushed and sized to minus 1/4 in. A

representative head sample was split for analysis, and the remainder was used for the concentration tests. Head analyses of the five samples are shown in table 2. Tin grades ranged from less than 0.04 to 0.24 pct, Zn grades ranged from 0.07 to 2.96 pct, Pb grades ranged from less than 0.01 to 1.18 pct, and Ag grades ranged from 0.03 to 0.4 tr oz/st. Sample BS 5 contained the best grades of Sn (0.24 pct) and Zn (2.96 pct), and sample BS 4 contained the highest grades of Pb (1.18 pct) and Ag (0.4 tr oz/st).

As a means of liberating the minerals, samples of minus 1/4-in material were ground in a rod mill to minus 150 μm . The size distribution of the table feed for each sample is shown in table 3.

Table 2.—Head analyses of Sheep Creek bulk and composite samples

Analysis	BS 1	BS 2	BS 3	BS 4 ¹	BS 5 ¹
Al ₂ O ₃ pct ..	0.62	3.36	1.02	1.18	1.82
Cu pct ..	0.12	0.02	0.02	0.03	0.03
Fe pct ..	5.12	6.05	5.34	7.63	14.1
MgO pct ..	0.25	0.76	0.40	0.23	0.70
S pct ..	4.01	2.08	2.85	9.33	15.6
SiO ₂ pct ..	86.4	81.9	84.3	73.7	56.1
Sn pct ..	0.07	0.22	² <0.04	0.06	0.24
Zn pct ..	0.22	0.07	0.33	2.02	2.96
Pb pct ..	0.03	<0.01	0.34	1.18	0.70
Ag tr oz/st ..	0.14	0.03	0.17	0.4	0.2
Au tr oz/st ..	² <0.0002	² <0.0002	² <0.0002	0.001	² <0.0002
Pd tr oz/st ..	² <0.0003	² <0.0003	² <0.0003	0.003	² <0.0003
Pt tr oz/st ..	² <0.0002	² <0.0003	² <0.0003	0.004	² <0.0003

¹DDH-SC1 drill-core materials.²Lower detection level.Table 3.—Size distribution of minus 150- μ m feed to rougher shaking table

Size, μ m	BS 1		BS 2		BS 3		BS 4		BS 5	
	wt pct	pct ¹ retained	wt pct	pct ¹ retained	wt pct	pct ¹ retained	wt pct	pct ¹ retained	wt pct	pct ¹ retained
Plus 106	24.0	24.0	18.9	18.9	23.3	23.3	13.7	13.7	16.6	16.6
106 by 75	16.0	40.0	14.8	33.7	15.5	38.8	12.6	26.3	15.3	31.9
75 by 53	13.5	53.5	15.8	49.5	12.5	51.3	15.0	41.3	20.1	52.0
53 by 38	14.6	68.1	17.2	66.7	15.1	66.4	37.5	78.8	28.6	80.6
38 by 25	11.0	79.1	12.0	78.7	10.7	77.1	8.5	87.3	6.3	86.9
Minus 25	20.9	100.0	21.3	100.0	22.9	100.0	12.7	100.0	13.1	100.0

¹Cumulative.

CONCENTRATION PROCEDURE

The concentration procedure was essentially the same for each sample and is illustrated in figure 9. Gravity concentration, using a wet shaking table equipped with a slime deck, produced a rougher concentrate, coarse tailings (those that settled and banded on the table), and slime tailings (those that washed off the table without settling). In the rougher tabling, recovery of mineral values, which included both cassiterite and sulfides, in the concentrate was emphasized over concentrate grade.

The rougher table concentrate was further treated by rougher and scavenger bulk sulfide flotation. In the rougher step, potassium amyl xanthate was added as the collector at a dosage that ranged from 0.05 to 0.11 lb/st. Flotation was done at natural pH, which ranged from 4.6 to 5.6. For scavenger flotation, collector reagent addition was equivalent to half the amount used in the rougher step. Because the two drill-core samples contained substantially more Zn and Pb than the three surface samples, copper sulfate (CuSO₄) was added to the pulp as an activator (0.23 to 0.37 lb/st) prior to the scavenger step for those two samples to promote flotability of the more difficultly floated sulfides.

The flotation tailings were treated in a cleaner table step to produce the final Sn concentrate. Concentrate grade was emphasized over recovery in the cleaner step.

CONCENTRATION RESULTS

The results of the concentration procedure are shown in the metallurgical balances in tables 4 through 8. Tin concentrates ranged in grade from 0.75 to 30.4 pct Sn with recoveries up to 52 pct. The best result came from sample BS 2, in which 52 pct of the Sn was recovered at a grade of 22.1 pct Sn. The Sn concentrate from sample BS 5 had a grade of 30.4 pct Sn, but the recovery was only 16 pct; 71 pct of the Sn was lost to the rougher table slime tailings and the cleaner table tailings.

The best values are comparable to those obtained in commercial operations on lode deposits. Although placer Sn concentrates may be nearly pure cassiterite (70 to 75 pct Sn), concentrates from lode deposits are substantially lower in grade and may contain only 15 to 20 pct Sn. Recoveries range from 50 to 65 pct because slime losses are a major problem (7).

The rougher and scavenger bulk flotation concentrates from all five bulk samples contained primarily pyrite with some sphalerite and galena. Zinc and lead grades ranged from less than 1 to over 6 pct, with recoveries of 44 to 59 pct and 21 to 49 pct, respectively. Silver is associated with the Pb (tables 7 and 8). Selective flotation techniques were not investigated, but the Zn, Pb, and Ag grades would be expected to be improved substantially by such treatment.

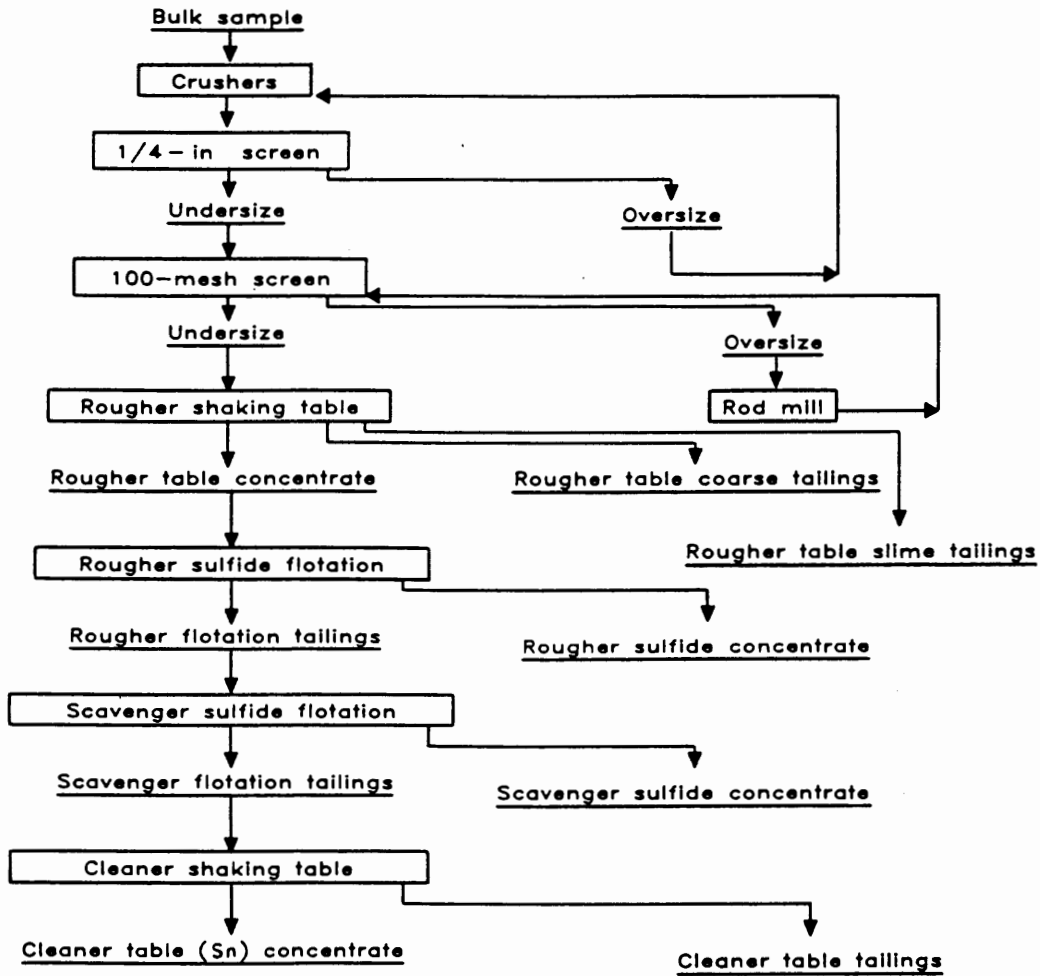


Figure 9.—Concentration flowsheet for the three surface bulk samples and two drill-core samples.

The loss of sulfides to the rougher table slime tailings was obvious during the concentration tests, and recovery of some of those sulfides is possible by flotation. A sample of the rougher table slime tailings from sample BS 5 was treated by rougher and scavenger bulk sulfide flotation with potassium amyl xanthate as the collector at natural pH. The rougher flotation concentrate contained 67 pct of the Zn, 48 pct of the Pb, and 57 pct of the Ag in the slime fraction, at a grade of 15.6 pct Zn, 3.44 pct Pb, and 1.20 tr oz/st Ag. Results are shown in table 9.

Overall recoveries of Zn, Pb, and Ag for the sample would be 89, 73, and 75 pct, respectively, by combining results from tables 8 and 9.

The results indicate the potential for recovery of Sn, Zn, Pb, and Ag. Optimum conditions and processes were not investigated, but control of grinding to prevent excessive fines, selective flotation of Pb and Zn concentrates, and treatment of fines on gravity or other equipment suitable for fine-particle treatment could conceivably improve both grade and recovery of the valuable minerals.

Table 4.-Concentration results on sample BS 1

Product	wt pct	Analysis, pct				Distribution, pct	
		Sn	Zn	Pb	Ag ¹	Sn	Zn
Rougher table concentrate:							
Flotation concentrate:							
Rougher ²	6.3	0.08	1.38	0.04	0.2	8.8	42.7
Scavenger ³ .....	.4	.45	3.45	.22	<.1	3.1	6.8
Flotation tailings:							
Cleaner table:							
Sn concentrate ⁴ .....	.4	5.38	.08	NA	<.1	37.7	.2
Tailings	5.9	.05	.01	NA	<.2	5.1	.3
Rougher table:							
Coarse tailings	65.4	.01	.03	NA	<.1	11.4	9.6
Slime tailings	21.6	.09	.38	NA	.2	33.9	40.4
Composite or total	100.0	.06	.20	NC	NC	100.0	100.0

NA Not analyzed.

NC Not calculated.

¹Troy ounce per short ton.²Additional analyses, percent: 0.21 As, 38.9 Fe, 47.5 S; troy ounce per short ton: 0.001 Au, <0.0003 Pd, <0.0003 Pt.³Additional analyses, percent: 0.21 As, 19.0 Fe, 20.7 S; troy ounce per short ton: <0.002 Au, <0.003 Pd, <0.003 Pt.⁴Additional analyses, percent: 12.6 Fe, 0.57 S, 62.5 SiO₂; troy ounce per short ton: 0.015 Au, 0.003 Pd, 0.004 Pt.

Table 5.-Concentration results on sample BS 2

Product	wt pct	Analysis, pct				Distribution, pct: Sn
		Sn	Zn	Pb	Ag ¹	
Rougher table concentrate:						
Flotation concentrate:						
Rougher and scavenger ²	3.4	0.18	0.90	0.05	0.5	2.4
Flotation tailings:						
Cleaner table:						
Sn concentrate ³ .....	.6	22.1	NA	NA	.3	51.3
Tailings	6.0	.42	NA	NA	ND	9.7
Rougher table:						
Coarse tailings	62.4	.05	NA	NA	ND	12.1
Slime tailings	27.6	.23	NA	NA	.2	24.5
Composite or total	100.0	.26	NC	NC	NC	100.0

NA Not analyzed.

NC Not calculated.

ND Not detected.

¹Troy ounce per short ton.²Additional analyses, percent: 0.25 As, 40.0 Fe, 57.9 S; troy ounce per short ton: <0.0002 Au, <0.0003 Pd, <0.0003 Pt.³Additional analyses, percent: 10.8 Fe, 0.50 S, 33.5 SiO₂; troy ounce per short ton: 0.0008 Au, <0.001 Pd, <0.001 Pt.

Table 6.-Concentration results on sample BS 3

Product	wt pct	Analysis, pct				Distribution, pct		
		Sn	Zn	Pb	Ag ¹	Sn	Zn	Pb
Rougher table concentrate:								
Flotation concentrate:								
Rougher ²	4.5	³ <0.04	3.66	1.31	0.1	2.4	55.8	18.1
Scavenger ⁴ .....	.2	.48	.85	6.58	NA	2.5	.6	4.0
Flotation tailings:								
Cleaner table:								
Sn concentrate ⁵ .....	.4	1.52	.20	4.49	.5	16.1	.3	5.5
Tailings	3.8	.04	.03	.21	<.1	4.0	.4	2.4
Rougher table:								
Coarse tailings	66.0	³ <.04	.04	.11	<.1	35.0	8.9	22.3
Slime tailings	25.1	.06	.40	.62	.3	40.0	34.0	47.7
Composite or total	100.0	.04	.30	.33	NC	100.0	100.0	100.0

NA Not analyzed.

NC Not calculated.

¹Troy ounce per short ton.²Additional analyses, percent: 0.11 As, 39.4 Fe, 52.1 S; troy ounce per short ton: <0.0002 Au, <0.0003 Pd, <0.0003 Pt.³Assumed 0.02 to calculate balance.⁴Additional analyses, percent: 0.13 As, 15.8 Fe, 14.2 S.⁵Additional analyses, percent: 16.7 Fe, 2.13 S, 40.5 SiO₂; troy ounce per short ton: 0.007 Au, <0.003 Pd, <0.003 Pt.

Table 7.—Concentration results on sample BS 4

Product	wt pct	Analysis, pct				Distribution, pct		
		Sn	Zn	Pb	Ag ¹	Sn	Zn	Pb
Rougher table concentrate:								
Flotation concentrate:								
Rougher ²	15.7	0.06	5.86	2.96	0.84	32.5	50.9	47.6
Scavenger ³ .....	.7	.11	1.36	6.43	1.70	2.6	.5	4.6
Flotation tailings:								
Cleaner table:								
Sn concentrate ⁴ .....	.2	.75	.26	2.85	NA	5.2	.0	.6
Tailings	6.9	.03	.09	.31	.07	7.1	.3	2.2
Rougher table:								
Coarse tailings	47.0	.02	.27	.25	.06	32.3	7.0	12.0
Slime tailings	29.5	.02	2.53	1.09	.25	20.3	41.3	33.0
Composite or total	100.0	.03	1.81	.98	⁵ .25	100.0	100.0	100.0

NA Not analyzed.

¹Troy ounce per short ton.²Additional analyses, percent: 0.12 As, 32.1 Fe, 39.6 S; troy ounce per short ton: <0.001 Au, <0.001 Pd, <0.001 Pt.³Additional analyses, percent: 0.04 As, 17.0 Fe, 20.6 S; troy ounce per short ton: <0.001 Au, <0.001 Pd, <0.001 Pt.⁴Additional analyses, percent: 30.7 Fe, 10.1 S, 20.4 SiO₂.⁵Approximate.

Table 8.—Concentration results on sample BS 5

Product	wt pct	Analysis, pct				Distribution, pct		
		Sn	Zn	Pb	Ag ¹	Sn	Zn	Pb
Rougher table concentrate:								
Flotation concentrate:								
Rougher ²	25.9	0.10	6.35	1.09	0.49	6.6	56.4	46.4
Scavenger ³	1.5	.55	6.31	3.95	1.72	2.1	3.2	9.7
Flotation tailings:								
Cleaner table:								
Sn concentrate ⁴ .....	.2	30.4	.17	3.25	NA	15.6	.0	1.1
Tailings	5.1	.79	.07	.27	.05	10.3	.1	2.3
Rougher table:								
Coarse tailings	37.4	.05	.35	.14	.07	4.8	4.5	8.6
Slime tailings	29.9	.79	3.50	.65	.33	60.6	35.8	31.9
Composite or total	100.0	.39	2.92	.61	⁵ .28	100.0	100.0	100.0

NA Not analyzed.

¹Troy ounce per short ton.²Additional analyses, percent: 0.11 As, 37.3 Fe, 40.5 S; troy ounce per short ton: <0.001 Au, <0.001 Pd, <0.001 Pt.³Additional analyses, percent: 0.07 As, 23.7 Fe, 29.9 S; troy ounce per short ton: <0.001 Au, <0.001 Pd, <0.001 Pt.⁴Additional analyses, percent: 21.7 Fe, 3.61 S, 8.41 SiO₂.⁵Approximate.

Table 9.—Sulfide flotation on rougher table slime tailings from sample BS 5

Product	wt pct	Analysis, pct					Distribution, pct				
		Zn	Fe	S	Pb	Ag ¹	Zn	Fe	S	Pb	Ag
Rougher concentrate	13.5	15.6	24.5	38.6	3.44	1.20	67.3	30.8	53.3	47.9	56.8
Scavenger concentrate	5.2	9.78	22.4	31.3	.97	² <.04	16.3	10.9	16.7	5.2	.4
Flotation tailings	81.3	.63	7.7	3.6	.56	.15	16.4	58.3	30.0	46.9	42.8
Composite or total	100.0	3.13	10.7	9.8	.97	.28	100.0	100.0	100.0	100.0	100.0

¹Troy ounce per short ton.²Assumed 0.02 to calculate balance.

CONCLUSIONS

The Bureau completed a preliminary characterization and evaluation of the Pb, Zn, Ag, and Sn resource mineralogy and recovery prospects at the Sheep Creek deposit in the north-central Alaska Range. Tin occurs as cassiterite in stratiform mineralization within a series of inter-layered tuffaceous cherts and schists. The Sheep Creek deposit is atypical of the other volcanogenic massive sulfides that occur in a 250-mile belt of Precambrian to Mississippian schists in the northern Alaska Range. The Sn mineralization is thought to make it a unique occurrence within this belt.

Combined gravity and sulfide flotation concentration tests on one of the channel samples recovered 52 pct of

the Sn at a grade of 22.1 pct Sn. These values compare favorably with results from commercial lode-mining operations. Bulk sulfide flotation tests recovered up to 89 pct of the Zn, 73 pct of the Pb, and 75 pct of the Ag, but grades were relatively low; selective flotation would significantly increase the grades. Although the concentration procedures were conducted primarily to prepare mineral concentrates for mineralogical studies, the results indicate the potential for recovery of Sn, Zn, Pb, and Ag at the Sheep Creek deposit.

REFERENCES

1. Warner, J. D. Critical and Strategic Minerals in Alaska. Tin, Tantalum, and Columbium. BuMines IC 9037, 1985, 19 pp.
2. Carlin, J. F., Jr. Tin. Ch. in BuMines Minerals Yearbook 1986, v. 1, pp. 931-943.
3. Wahrhaftig, C. Schists of the Central Alaska Range. U.S. Geol. Surv. Bull. 1254-E, 1968, 22 pp.
4. Hammit, J. W. (Bear Creek Mining Co.). Private communication, 1984; available upon request from W. K. O'Connor, BuMines, Albany, OR.
5. Wolfe, J. A., and C. Wahrhaftig. The Cantwell Formation of the Central Alaska Range. Sec. in Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1968. U.S. Geol. Surv. Bull. 1294-A, 1970, pp. A41-A46.
6. Wahrhaftig, C. Geologic Map of the Healy D-3 Quadrangle, Alaska. U.S. Geol. Surv. GQ-805, 1970.
7. Aplan, F. F. Tin. Sec. in SME Mineral Processing Handbook, ed. by N. L. Weiss. Soc. Min. Eng. AIME, 1985, pp. 27-10-27-14.

APPENDIX.-SAMPLE KEY

Sample	Field or laboratory No.	Description
Bulk:¹		
BS 1	AS 21647	Channel sample, footwall mineralization, 9.3-ft channel.
BS 2	AS 21648	Channel sample, hanging-wall mineralization, 10.3-ft channel; same location as BS 1.
BS 3	AS 21649	Channel sample, combined 7-ft-channel footwall and 8-ft-channel hanging-wall mineralization; 3,500 ft west of BS 1 and BS 2.
BS 4	None	Composited sample, Bear Creek Mining diamond drill hole DDH-SC1, zone 2, 192- to 265-ft interval.
BS 5	None	Composited sample, Bear Creek Mining diamond drill hole DDH-SC1, zone 3, 308- to 392-ft interval.
Petrographic:²		
PS 1	PS 1828	Specimen from BS 1.
PS 2	PS 1829	Specimen from BS 2.
PS 3	PS 1830	Specimen from BS 3.
PS 4	PS 2347	Drill core, zone 2, 206-ft interval.
PS 5	PS 2348 a,b	Drill core, zone 2, 241-ft interval.
PS 6	PS 2349	Drill core, zone 2, 245-ft interval.
PS 7	PS 2350	Drill core, zone 3, 326-ft interval.
PS 8	PS 2351	Drill core, zone 3, 350-ft interval.

¹Field.²Laboratory.

Mission: As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.