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Tin Occurrences Near Rocky Mountain (Lime Peak), East-Central Alaska

By J. Dean Warner, D. C. Dahlin, and L. L. Brown

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°C	degree Celsius
cm	centimeter
cm^3	cubic centimeter
ft	foot
ft^2	square foot
ft^3	cubic foot
g	gram
gal	gallon
in	inch
lb	pound
lb/st	pound per short ton
lb/yd^3	pound per cubic yard
mg	milligram
mg/pan	milligram per pan
mi^2	square mile
MMlb	million pounds
MMst	million short tons
m.y.	million years
mm	millimeter
μm	micrometer
pct	percent
ppm	part per million
wt pct	weight percent
yd^3	cubic yard

TIN OCCURRENCES NEAR ROCKY MOUNTAIN (LIME PEAK), EAST-CENTRAL ALASKA

By J. Dean Warner,[1] D. C. Dahlin,[2] and L. L. Brown[3]

ABSTRACT

In 1984 and 1985, as part of its critical and strategic minerals studies, the Bureau of Mines investigated lode and placer tin occurrences near Rocky Mountain (Lime Peak), in east-central Alaska. The lode occurrences consist of mineralogically complex, generally fault-controlled veins, and contain an average of approximately 0.05 pct Sn, as cassiterite. Beneficiation testing of two bulk samples of the vein material produced concentrates containing 65 and 59 pct of the total tin values at grades of 0.35 and 13.9 pct, respectively. Although as much as 30 million short tons (MMst) of mineralized rock containing up to 20 MMlb Sn may be present, the grade of these occurrences is too low to be considered economic at this time.

Trace amounts of cassiterite were also identified in surface samples of glacial outwash gravels collected along North Fork Preacher Creek, which partially drains the area of tin lode deposits near Lime Peak. Low tin grades in the samples do not account for the former erosion of a large volume of lode tin mineralization from near Lime Peak; higher tin grades may be present in gravels closer to bedrock.

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INTRODUCTION

The Bureau of Mines has intermittently investigated lode occurrences of tin and other metals in the Lime Peak (Rocky Mountain[4]) area since 1977. These investigations have been conducted as part of the Bureau's Alaskan critical and strategic minerals study, the goal of which is to identify reserves or resources of certain critical and strategic minerals that could be developed in times of prolonged national shortage. The investigations have also been partially motivated by the Federal Bureau of Land Management's need for mineral data in the Steese and White Mountains National Conservation and Recreation areas.

Results of Bureau reconnaissance investigations in the Lime Peak area prior to 1984 are presented in Bureau of Mines Open File Report 31-85 (*1*).[5] That report identifies an area of tin lode mineralization on the southeastern flank of the Lime Peak summit warranting further study and recommends that North Fork Preacher Creek be investigated for placer tin.

This report presents results of detailed investigations of the lode and placer tin occurrences identified in reference 1. Numerous occurrences of sub-ore-grade lode tin mineralization as well as low-grade concentrations of placer tin were located. Although the lode occurrences contain relatively large tonnages of resources, the tin grades are too low to be considered economic at this time.

ACKNOWLEDGMENTS

This report has benefited from geologic and geochemical data donated to the Bureau by Mapco Minerals. Florence Weber, geologist, U.S. Geological Survey, assisted field investigations in 1977 and 1985 and provided the interpretation of glacial geology present in this report. David Menzie, geologist, U.S. Geological Survey, provided logistical assistance to a portion of the fieldwork in 1984.

LOCATION AND LAND STATUS

Lime Peak is located in the Circle (C-6) quadrangle, Alaska, approximately 58 miles northeast of Fairbanks, in the White Mountains (fig. 1). The study area straddles the boundary between the White Mountains National Recreation Area to the west and the Steese National Conservation Area to the east. Both areas are administered by the Federal Bureau of Land Management, as authorized in 1980 by the Alaska National Interest Lands Conservation Act (Public Law 96-487), and are currently (1987) closed to mineral entry.

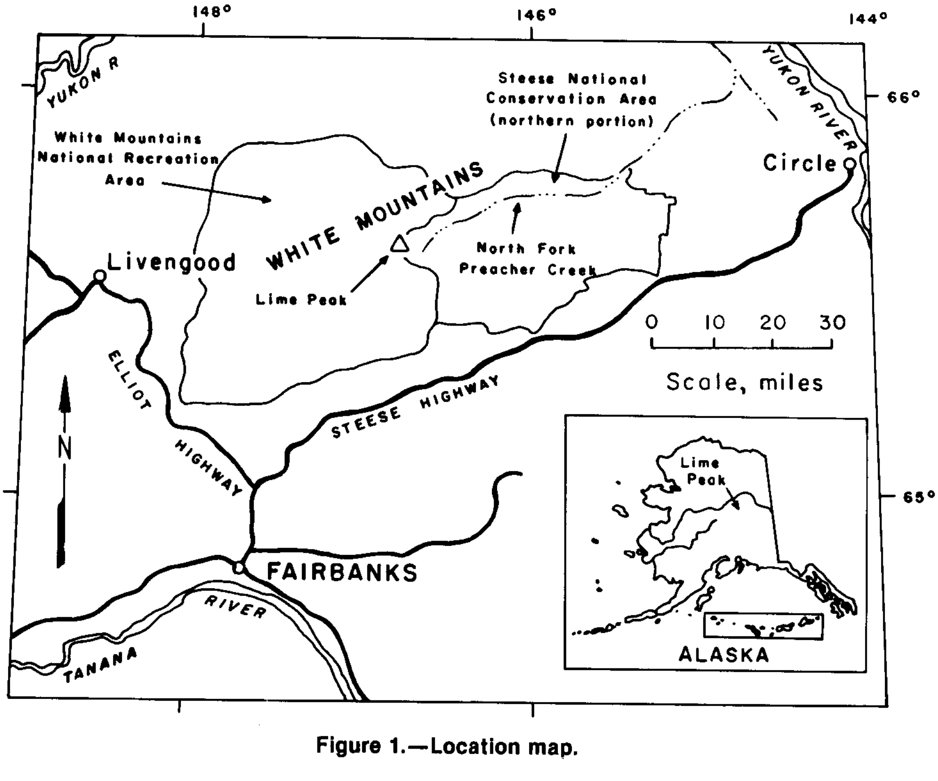

Figure 1.—Location map.

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[4] Although Rocky Mountain is the newly assigned name, the name Lime Peak is retained in this report because it is more widely known.

[5] Italic numbers in parentheses refer to items in the list of references preceding the appendixes at the end of this report.

PHYSIOGRAPHY

The White Mountains comprise the northwestern portion of the Yukon-Tanana physiographic division (*2*). Over much of its area, this province is characterized by a deeply eroded terrain of moderate relief with tundra- or mixed spruce- and birch-covered, gently rounded slopes and relatively flat ridgelines. Near Lime Peak, however, and elsewhere in areas with elevations above approximately 2,500 ft, steep rubble-covered unvegetated hillsides are characteristic. In areas of higher elevation that are underlain by granitic rocks, rock spires (tors) are common. Most of the Yukon-Tanana region has escaped the effects of continental glaciation; however, broad U-shaped valleys in many of the more elevated areas of the White Mountains attest to former valley glaciation.

PREVIOUS WORK

Intrusive rock was initially mapped in the Lime Peak area by Prindle (*3*), in 1913. Most recently, in 1983, the area was geologically mapped by Foster (*4*). In 1981, Wilson obtained a potassium-argon age of 56.7 ± 0.95 m.y. on biotite from the Lime Peak pluton (*5*).

The Lime Peak pluton was first publicly recognized as tin bearing by Barker, in 1978, who found anomalously high concentrations of tin, columbium, lead, tungsten, zinc, uranium, and yttrium in heavy mineral concentrates panned from streams draining the pluton (*6*). Subsequent investigations summarized by Burton in 1984, identified two major geochemically anomalous drainage areas near the Lime Peak pluton and numerous occurrences of tin-bearing veins (*1*). Burton recommended a more detailed investigation of mineralized zones in the Lime Peak summit area and potential placer tin occurrences in the North Fork Preacher Creek area. In 1983, Menzie identified the Lime Peak area as permissive to the occurrence of tin deposits (*7*).

Several mineral exploration companies have investigated the Lime Peak area for deposits of tin, uranium, tungsten, and other metals. Most notably, following an airborne radiometric survey in 1978, Mapco Minerals Co. located a large claim block just south of the Lime Peak summit. Mapco drilled one shallow diamond drill hole, but apparently did not encounter significant mineralization.

REGIONAL GEOLOGY

The Lime Peak pluton is one of five early Tertiary- and/or Late Cretaceous-age plutons exposed in the White Mountains (*4*). The composition of these intrusions is similar to that of known tin-bearing intrusions elsewhere in the world; tin mineralization similar to that associated with the Lime Peak pluton has been identified in one other pluton in the White Mountain area. The intrusions are composite biotite granites; however, minor to major amounts of muscovite, hornblende, and tourmaline are locally present and rock compositions include quartz monzonite (*1, 4, 8*).

These plutons intrude a diverse assemblage of variably metamorphosed and deformed upper Precambrian- to middle Paleozoic-age sedimentary and mafic volcanic rocks that have been partially imbricated along northeast-trending thrust faults (fig. 2). Northwest of Lime Peak, the rocks consist of sequences of early Paleozoic shales and cherts and middle Paleozoic mafic volcanic and clastic and calcareous sedimentary rocks that comprise the Livengood, White Mountains, and Kandik River tectonostratigraphic terranes of Churkin (*9*). Southeast of Lime Peak, on the other hand, the rocks consists of variably metamorphosed lower Paleozoic-age quartzites and shales and comprise the Beaver and Yukon Crystalline terranes. The boundary between the latter two terranes has been variably interpreted as gradational or thrust faulted (*10*).

LODE INVESTIGATIONS

In 1984, an 8-mi^2 area located near the southeastern flank of the Lime Peak summit, and outlined on figure 2, was mapped and sampled in detail (figs. 3-4). The area contains numerous occurrences on tin lode mineralization and is centered around an east-flowing stream that forks near its headwaters. This stream and its forks are referred to as Bedrock Creek and the east fork and west fork of Bedrock Creek, respectively, in this report (fig. 5).

GEOLOGY OF THE LIME PEAK PLUTON

Because intrusions associated with tin mineralization worldwide are known to display specific geologic attributes (for instance, see Taylor (*11*) or Hudson (*12*)), considerable effort was made to document the geology of the Lime Peak pluton. The following paragraphs briefly summarize the results of geologic mapping near Lime Peak (fig. 3); more detailed descriptions of the pluton and its various phases are presented in appendix A. In general, the geology of the Lime Peak pluton is comparable to that of many tin-mineralized plutons worldwide.

The Lime Peak pluton is a composite intrusion that outcrops over approzimately 30 mi^2 and is elongate to the northeast, parallel to the regional structural grain (fig. 2). The intrusion is exposed over 2,500 vertical ft with abundant rubble above 3,500-ft elevation and exhibits a sharp and steeply southeast-dipping and northeast-trending contact with metasedimentary rocks to the southeast (*1*). The lack of roof pendants or other country rock xenoliths, the relatively coarse-grained nature of most of the intrusive rocks, and the steep intrusive rock-country rock contacts

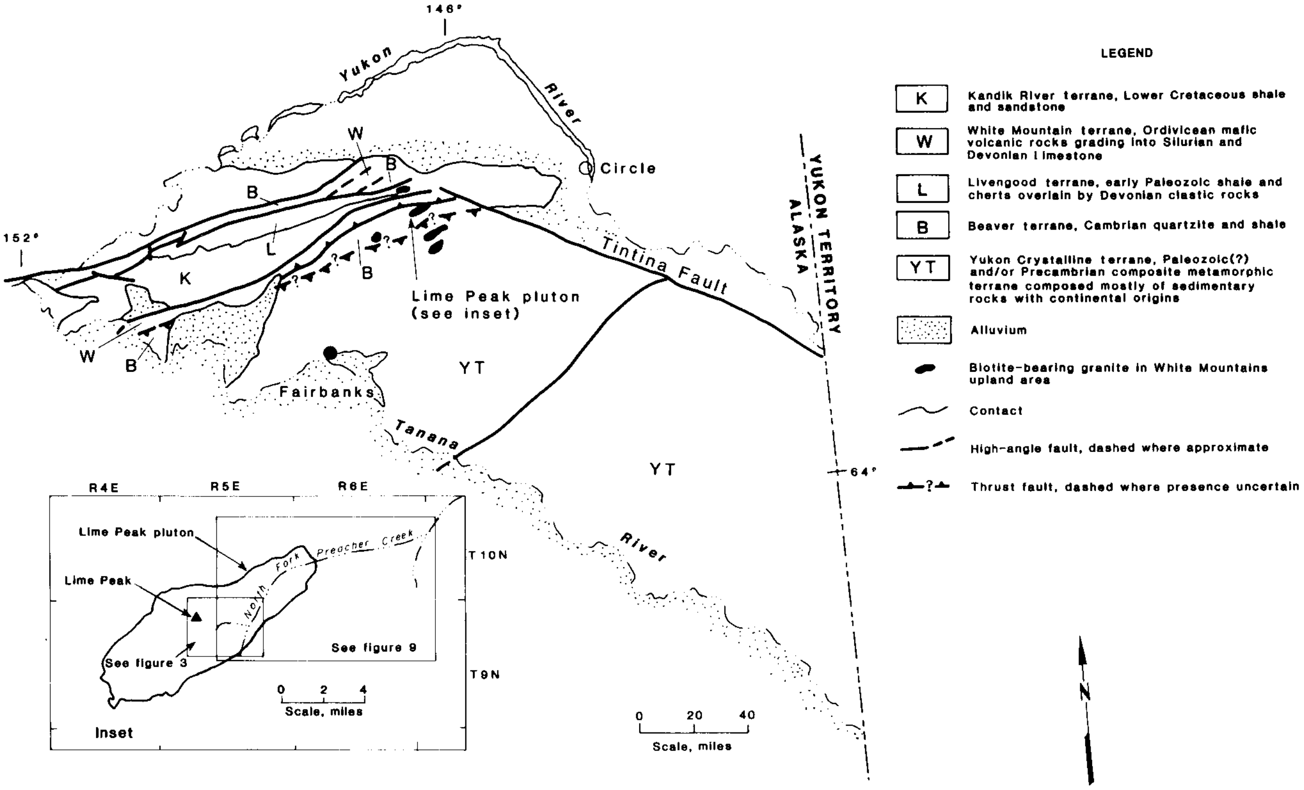


Figure 2.—Tectonostratigraphic map of the Yukon-Tanana physiographic province with inset map showing the Lime Peak pluton and the North Fork of Preacher Creek.

suggest the Lime Peak pluton is a deeply eroded mesozonal pluton.

Two major intrusive phases were mapped in outcrop and rubble in the study area (fig. 3). These two phases, coarse-grained granite (Tgc) and finer granied porphyritic granite (Tgp), form most of the Lime Peak composite pluton. Several rhyolite, andesite, and lamprophyre dikes, however, were also mapped near Lime Peak (figs. 3-4).

The contact relationship and relative ages of the coarse-grained and porphyritic granties are uncertain because of the extensive rubble cover. Where approximately located in the field, however, the contact between the two rock types appears to be relatively sharp, with rubble of one type grading into that of the other over a distrance of a few tens of feet. Although no crosscutting relationships were observed, the more lithophile-element-enriched nature of the porphyritic granite (see appendix A) suggests that it is the younger phase.

Numerous faults cut the Lime Peak pluton. Where exposed, the faults invariably trend northwest and are steeply dipping; however, a few outcrops of shallowly dipping faults were also observed. The most laterally extensive fault parallels Bedrock Creek, extending 9,000 ft west-northwest from at least the southeastern intrusive contact. Slickensided rubble on strike near sample site 55 (fig. 3) suggests this fault may extend to the northern flank of the Lime Peak summit and beyond.

LODE (GREISEN) OCCURRENCES

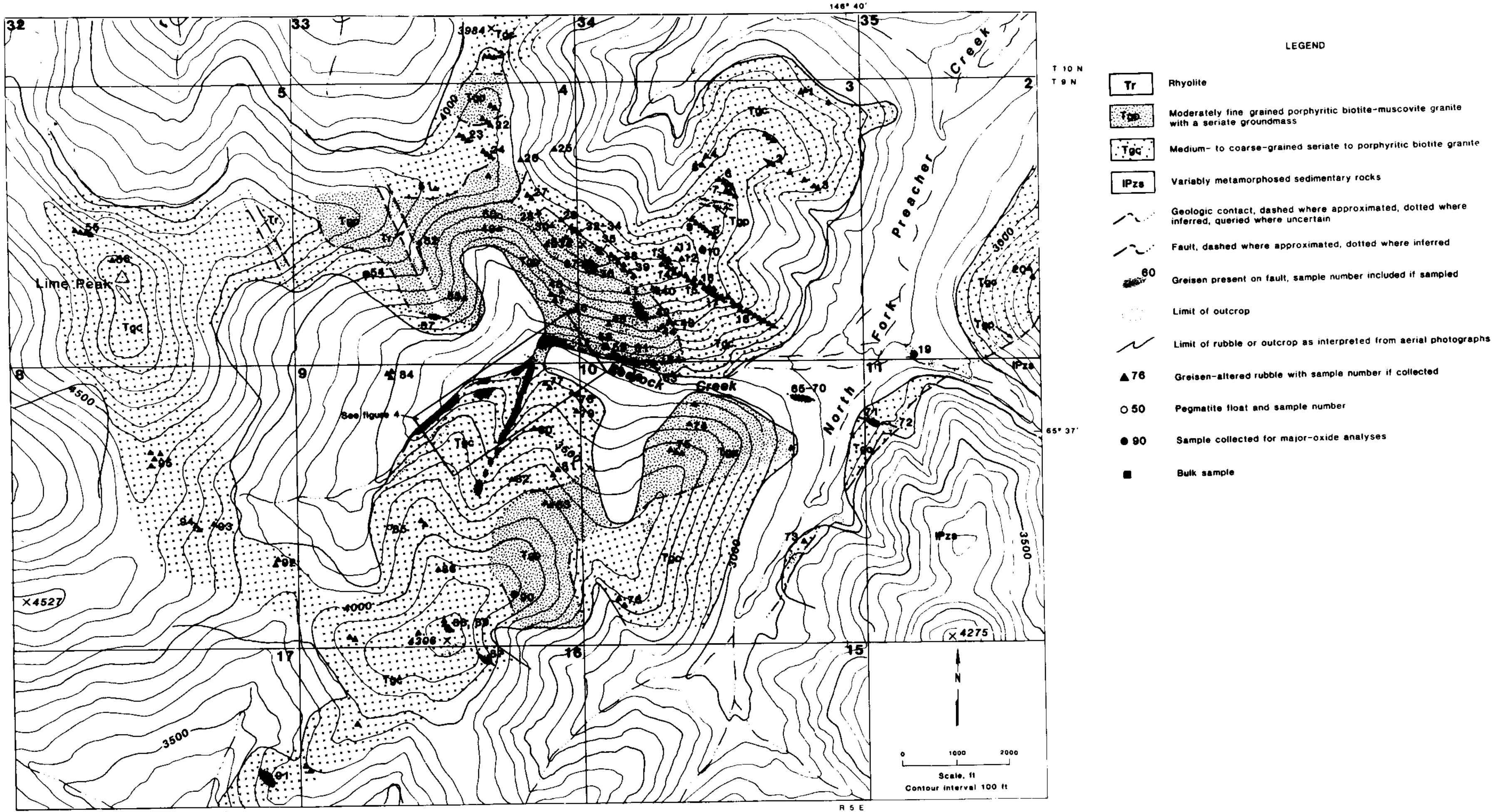
Greisen is a term referring to a hydrothermally altered, generally granitic rock composed mostly of variable amounts of quartz, mica, chlorite, topaz, fluorite, or tourmaline, as well as other alteration minerals, and the ore minerals cassiterite, scheelite, wolframite, molybdenite, and bismuth (*11, 13*).

Near Lime Peak, greisen is abundant in rubble and locally present in outcrop (figs. 3-4). The greisen generally comprises from less than an inch to several-foot-wide veinlike altered zones and faults that trend northwest or west-northwest. The lack of outcrops makes determination of mineralized widths difficult; however, the size of rubble boulders, together with the width of the few occurrences that could be channel sampled, suggests the veins are mineralized over an average width of 2.0 ft.

In outcrop, these veins are rarely traceable for more than a few tens of feet. Discontinuously exposed greisen and linear accumulations of greisen rubble, however, suggest that some greisen veins may extend for several thousand feet along strike and comprise several closely spaced occurrences over widths of up to 100 ft (fig. 3).

To the unaided eye, the greisen appears to consist of mostly manganese- and iron-stained quartz- and chlorite-altered granite with disseminated fluorite and pyrite and local crosscutting veinlets containing various mixtures of quartz, topaz, fluorite, tourmaline, pyrite, and chalcopyrite. Microscopically, however, the greisen is seen to consist of more complex alteration and mineralization assemblages. A paragenetic diagram listing the identified minerals and summarizing their crosscutting relationships is given in figure 6 and a detailed description of the greisen is given in appendix B.

In general, two alteration-mineralization assemblages are represented. Tin mineralization generally is restricted to the younger (stage 2) assemblage. Tungsten mineralization, on the other hand, is generally associated with the older (stage 1) assemblage. Cassiterite was observed by



Base adapted from U.S.G.S. 1:63,360 scale Circle (C-6) quadrangle

Figure 3.—Geologic and sample location map of Lime Peak area.

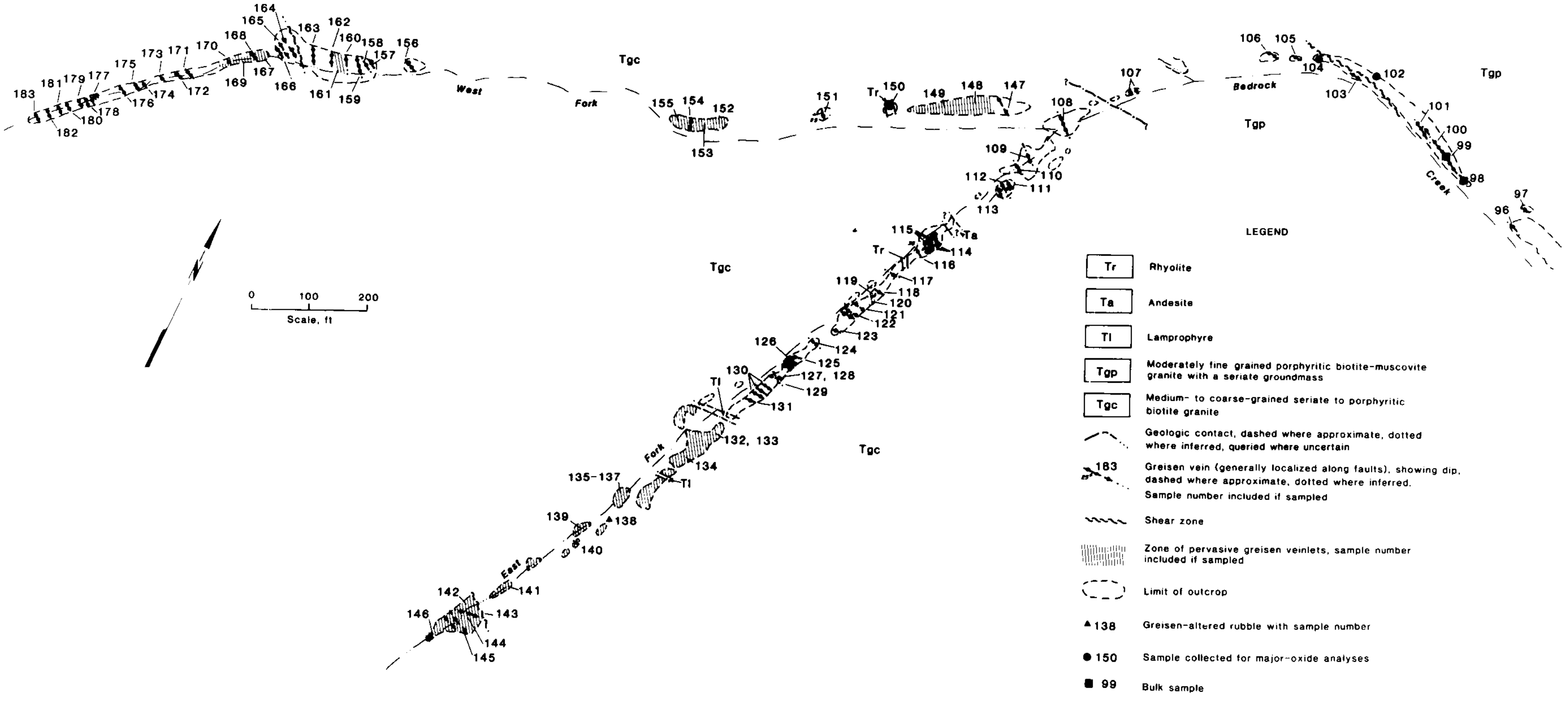


Figure 4.—Geologic and sample location map of Bedrock Creek area.

Figure 5.—View looking southeast showing main branch and east and west forks of Bedrock Creek.

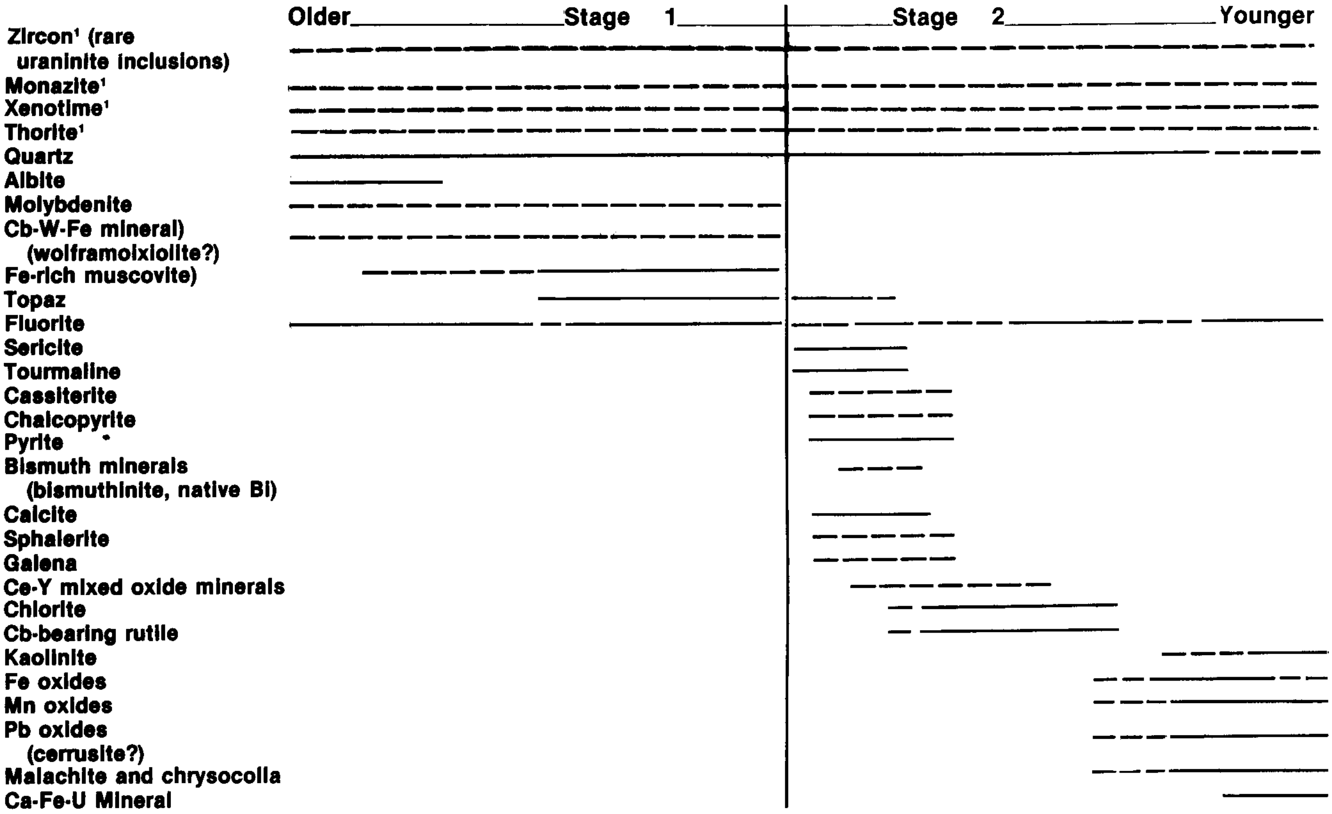
scanning electron microscope (SEM) in sample 98, where it occurred as a few scattered grains ranging from 10 to 100 µm in size (fig. 7). Despite a careful search, no other tin-bearing minerals were identified in this or other samples of greisen.

GEOCHEMICAL SAMPLING AND ANALYSES

One hundred seventy samples of mineralized rock were collected for geochemical analyses from the Lime Peak area during this investigation. Many of these are grab samples of rubble that consist of random chips collected within a few feet of the sample station. Some grab samples, however, were collected over larger, measured areas or along measured lengths in order to better evaluate the average grade of the mineralized rock in that area. Outcrops were sampled either by channeling a uniform volume of rock over a measured width or by collecting random or continuous chips from the portion of outcrop of interest.

Samples were crushed, split, and pulverized by a commercial laboratory. Subsequently, most were analyzed by the Bureau of Mines Reno (NV) Research Center for tin, tantalum, and columbium by X-ray fluorescence (XRF), for tungsten by colorimetry, for thorium by radiometric techniques, for uranium by fluorimetric techniques, and for gold and silver by fire assay-inductively coupled plasma techniques. Each sample was also analyzed for a suite of 40 elements by emission spectrometry. Splits of samples containing less than 50 ppm Sn were also analyzed by atomic absorption. Sample locations are shown on figures 3 and 4, and results of trace element analyses are given in appendix C.

Samples of greisen collected in the Lime Peak area contain up to 7,100 ppm Sn as well as locally anomalously high concentrations of arsenic, beryllium, boron, columbium, copper, gold, iron, lead, lithium, manganese, silver, strontium, tungsten, uranium, and zinc (table C-1 and C-2). Most samples with tin concentrations greater than 600 ppm were collected either from the northwest-trending ridge north of Bedrock Creek or from isolated occurrences of greisenized faults exposed in the Bedrock Creek area (figs. 3-4). Many of



[1] These minerals are common inclusions in chlorite and iron-rich muscovite, but likely represent residual minerals that originated as inclusions in biotite.

Figure 6.—Paragenesis of alteration and mineralization at Lime Peak. Vertical line represents time at which faulting was initiated. Solid line represents ubiquitous minerals; broken line represents occasional or inferred presence.

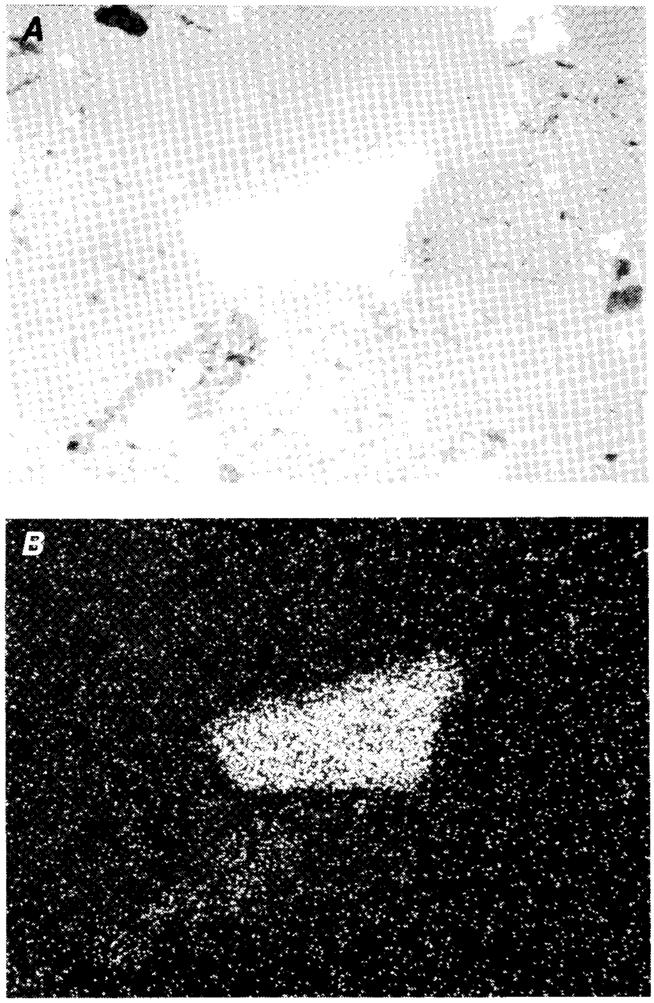


Figure 7.—SEM micrograph (*A*) and tin X-ray element map (*B*) showing cassiterite (white) in a chlorite (gray) matrix.

the samples in the ridge area also contain elevated concentrations of arsenic, copper, lead, silver, or zinc; however, there is no apparent correlation between concentrations of tin and other metals.

In contrast, elevated concentrations of beryllium, columbium, gold, and tungsten are generally confined to greisen sampled in the upper forks of Bedrock Creek. Most of the higher concentrations of beryllium and tungsten were found in samples containing the paragenetically older (stage 1) mineral assemblages; higher concentrations of tin were found in samples containing the younger (stage 2) assemblages.

The average tin content of samples of stage 2 greisen is 475 ppm. The weighted average of all channel or continuous chip samples of stage 2 greisen is also 475 ppm Sn over an average width of approximately 2 ft. The average tin concentration of samples collected on the northwest-trending ridge north of Bedrock Creek is 735 ppm.

BULK SAMPLING AND ANALYSES

Four bulk samples of greisen, each weighing 100 to 200 lb, were collected at Lime Peak for mineralogical and metallurgical characterization. Sample locations are shown on figures 3 and 4 and head analyses are summarized in table 1. Sample 32 is from a 4.5-ft-long channel across two stage 2 greisen veins, 1.7 and 0.7 ft wide. These two veins are part of an up to 100-ft-wide zone of greisen veins that can be traced for 6,000 ft along strike. Sample 89 is a grab sample from a 12- to 15-ft-wide rubble train of massive stage 2 greisen that can be traced for 100 ft and inferred for 1,000 ft along the strike. Sample 98 is from a 3-ft-wide channel across a stage 2 greisen vein that consists of quartz-chlorite and massive chlorite greisen with traces of pyrite and fluorite. Sample 99 is from a channel across a 1.0-ft-wide stage 2 greisen vein consisting of a 0.6-ft-wide core of limonite- and manganese-stained dense, black massive chlorite, a 0.1-ft-wide hanging wall of massive pyrite altered to clay, and a 0.5-ft-wide footwall of progressively less chlorite-altered granite. This greisen vein pinches and swells over at least a 300-ft strike length. Its maximum width of 5.0 ft is at sample site 98.

Table 1.—Head analyses of bulk samples of greisen collected at Lime Peak, percent

Sample	Cu	F	Fe	Pb	S	Sn	W	Zn
32	0.02	0.42	19.2	0.13	0.02	0.04	<0.01	0.21
89	.04	.59	6.9	.06	.02	<.02	<.01	.07
98	.01	.27	16.7	.04	.57	.03	<.01	.10
99	.07	.63	20.9	.38	3.95	.18	<.01	.26

BENEFICIATION

Beneficiation tests were conducted on four bulk samples at the Bureau's Albany (OR) Research Center. In the first test, a composite sample with a calculated head analysis of 0.06 pct Sn was prepared from equal weights of the four samples. The composite was stage ground in rod mills to pass 100 mesh, but elaborate steps were not taken to prevent overgrinding. The sample was then tabled on a slime deck of a wet shaking table to produce a concentrate, coarse table tailings (those that settled and banded on the table), and fine table tailings (those that washed off the table without settling). A distinct band of sulfides with minor cassiterite formed in the heavy concentrate fraction. The metallurgical balance for this test is shown in table 2. The concentrate contained 65 pct of the tin at a grade of 0.35 pct Sn.

Although recovery of concentrate was emphasized over grade, nearly 35 pct of the tin was lost to the tailings. Microscopic examination of the coarse tailings showed that most of the cassiterite was liberated and, based on chemical analyses, the tin content of the two tailings products was low (0.02 pct Sn). However, the tailings represent 90 pct of the low-grade sample weight and, thus, tin losses in those fractions are relatively high. Recovery may be improved by more precise control of the grinding to prevent excessive fines and/or by regrinding the coarse tailings and retreating them with the rougher fine tailings on equipment more suitable to fine-particle treatment than shaking tables.

In the second test, a split of sample 99, which had a head analysis of 0.18 pct Sn (table 1), was stage ground to minus 100 mesh and tabled, as described previously, to produce a rougher concentrate, coarse tailings, and fine tailings. As in the first test, good recovery of the heavy, sulfide-rich fraction was emphasized. The rougher table concentrate was then treated in a bulk flotation step to produce a sulfide concentrate float product and a nonfloat tin concentrate. A rougher flotation step was done with 0.1 lb/st potassium amyl xanthate as the collector at natural pH of 5.1. The froth was very heavily laden with sulfide minerals. A

Table 2.—Metallurgical balance for tabling composite bulk sample[1]

Minus 100-mesh product	wt pct	Analyses, pct		Distribution, pct	
		Sn	S	Sn	S
Concrete[2]	9.8	0.35	8.68	65.4	69.9
Coarse tailings	45.9	.02	.31	17.3	11.6
Fine tailings	44.3	.02	.51	17.3	18.5
Composite or total	100.0	.05	1.22	100.0	100.0

[1] Calculated composite head analysis, percent: 0.04 Cu, 0.48 F, 0.15 Pb 1.14 S, 0.06 Sn, 0.16 Zn.

[2] Additional analyses, percent: 0.07 Cu, 1.56 F, 0.46 Pb, 0.40 Zn.

Table 3.—Metallurgical balance for tabling and flotation of sample 99

Minus 100-mesh product	wt pct	Analyses, pct		Distribution, pct	
		Sn	S	Sn	S
Rougher table concentrate	12.6	1.05	21.3	93.7	70.5
Sulfide flotation concentrate[1]	6.5	.25	40.3	11.3	68.7
Nonfloat tin concentrate[2]	6.1	1.91	1.10	82.4	1.8
Cleaner table concentrate[3]	.6	13.9	NA	58.8	NAp
Cleaner table tailings[4]	5.5	.60	NA	23.6	NAp
Rougher table coarse tailings	39.4	.01	.71	2.8	7.3
Rougher table fine tailings	48.0	.01	1.76	3.5	22.2
Composite or total	100.0	.14	3.81	100.0	100.0

NA Not analyzed. NAp Not applicable.

Additional analyses, percent:

[1] 0.15 Cu, 42.9 Fe, 0.67 Pb, 0.85 Zn.

[2] 2.91 F.

[3] 1.10 F.

[4] 4.93 F.

scavenger flotation step with 0.01 lb/st collector produced a very small amount of additional float material that was combined with the rougher float product for analysis. The nonfloat tin concentrate was then retabled in a cleaner step to further concentrate the tin. The metallurgical balance for the test is shown in table 3. The cleaner table concentrate contained 59 pct of the tin at a grade of 13.9 pct Sn.

As in the first test, tin recovery was relatively low in the concentrate, but for different reasons. The cleaner table tailings contained an additional 24 pct of the tin at a grade of 0.60 pct Sn, and it could be recycled to improve recovery. The sulfide flotation concentrate contained 11 pct of the tin, some of which conceivably could be cleaned from the sulfide concentrate and recovered in the cleaner table operation. More elaborate flowsheets and optimum conditions were not investigated.

LODE TIN RESOURCES

Although the Lime Peak area apparently contains tin-mineralized greisen occurrences that are distributed over an area in excess of 8 mi^2, the grade of these occurrences is too low and irregular to allow for adequate definition of in-place tin resources. An estimate of total contained metal, however, may be made by summing all of the mapped lengths and inferred extensions of greisen occurrences, and by assuming they continue for one-half their length at depth and are mineralized over an average width of 2 ft. At an average grade of approximately 0.05 pct Sn and an estimated tonnage factor of 11, this calculation suggests that approximately 5 MMst of rock containing 5 MMlb Sn is present. A slightly higher estimate of 6 to 7 MMlb Sn may be made by assuming the greisen occurrences located on the ridge north of Bedrock Creek have a slightly higher average grade of approximately 0.07 pct Sn.

This calculation assumes greisen occurrences are confined to a single 2-ft-wide vein. Clearly, as mentioned previously, this is not always the case. For example, the northwest-trending greisen zone in the southern portion of section 3, north of Bedrock Creek and including sample sites 13 through 18, appears to be partially mineralized over a width of 50 ft along its 3,000-ft strike length. Assuming this zone continues for 1,500 ft at depth and is mineralized over 40 pct of its width for an average grade of 0.03 pct Sn (approximately equal to 0.4 × 0.07 pct Sn), this zone may contain approximately 20 MMst of rock containing 12 MMlb Sn. Similarly, if the greisen zone extending northwest from section 3 to section 4, located along the same ridge and extending between sample sites 27 and 40, is assumed to be mineralized over 40 pct of its 20-ft width and is 3,000 ft long and extends to a depth of 1,500 ft, approximately 8 MMst of rock containing 5 MMlb Sn may be present.

Therefore, the resources for the area mapped may be on the order of 30 MMst of rock containing 20 MMlb Sn. Beneficiation testing suggests that approximately 60 pct, or 12 MMlb, of this tin could be readily concentrated. It cannot be overemphasized, however, that this resource is too low grade to be considered economic at the present time.

PLACER INVESTIGATIONS

In 1985, gravels located along the upper portions of North Fork Preacher Creek were investigated for tin-bearing placer deposits. The headwaters of the North Fork partially drain the tin greisen occurrences located near Lime Peak that were discussed in previous sections of this report. Numerous large samples of surface gravels were collected and gravel types were mapped. Because samples were collected from surface exposures, the grade of tin in deeper gravels cannot be directly assessed but comparison with placer tin deposits elsewhere in Alaska suggests grade will increase.

SURFICIAL GEOLOGY OF NORTH FORK PREACHER CREEK

From headwaters located 2 miles southeast of Lime Peak, North Fork Preacher Creek flows northeast toward the lowlands of the Yukon Flats (fig. 2). In its lower course, beyond approximately 5 miles from the headwaters, the creek is mature with a gradient of 1 vertical ft for every 130 to >600 horizontal ft. In this area, the creek consists of a shallow meandering stream surrounded by a broad alluvial plain containing abundant oxbow lakes. For much of its lower course, the creek also occupies a generally asymmetric (to either the northwest or southeast) valley with relatively steep slopes and a flat trough.

Within 5 miles of its headquarters, the North Fork is a juvenile stream with a gradient of 1 vertical ft for every 100 to <50 horizontal ft. In this area, it has stretches of broad braided stream interspersed with short lengths of poorly developed meandering stream. In its upper course the creek also occupies and has partially incised the trough of a broad, generally U-shaped valley (fig. 8).

The upper reaches of North Fork Preacher Creek show evidence of having been affected by at least two periods of

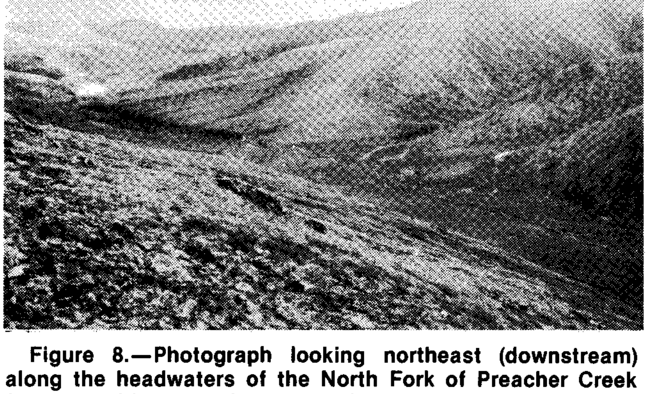


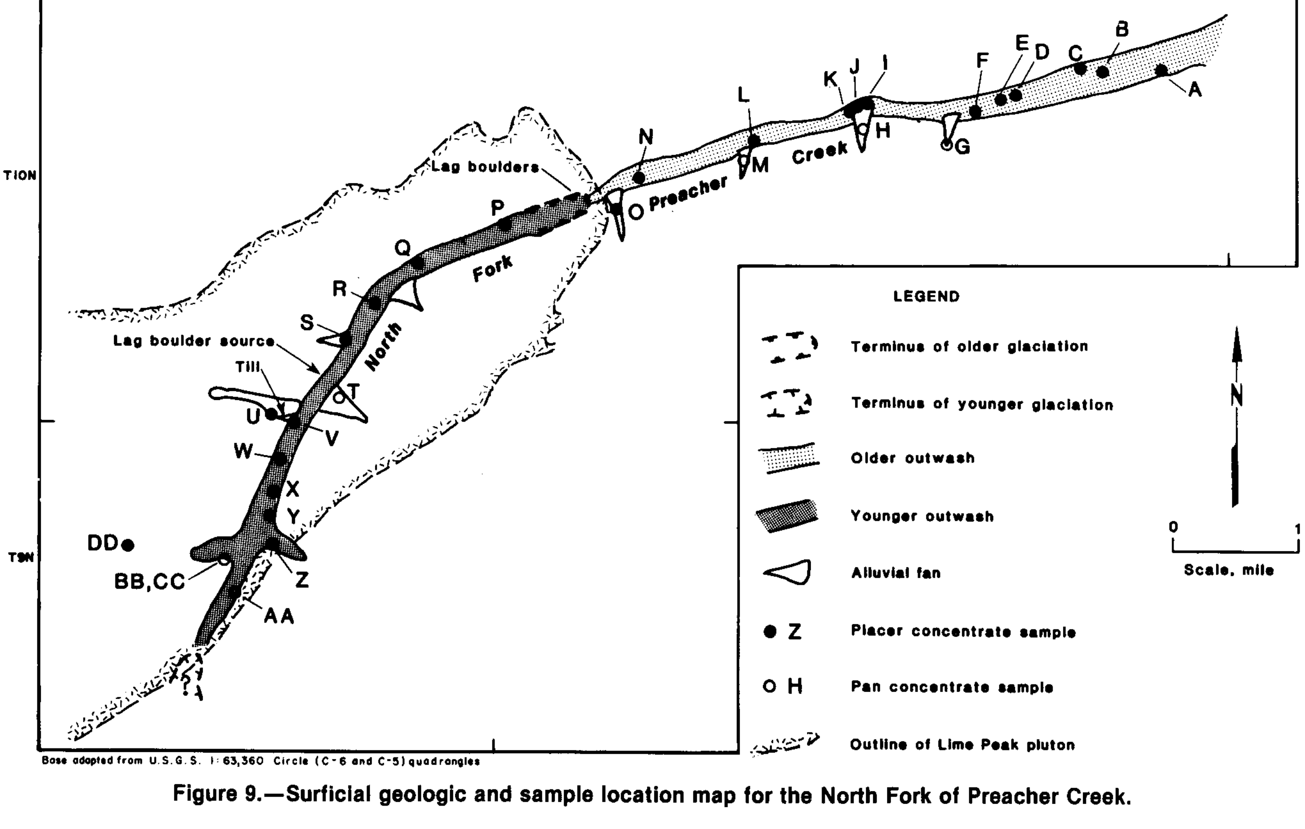
Figure 8.—Photograph looking northeast (downstream) along the headwaters of the North Fork of Preacher Creek from a position near the center of section 10.

valley glaciation (fig. 9). The older glacier extended at least 5 miles northeastward along the North Fork to a down-valley limit approximately coincident to the northeastern contact between the Lime Peak pluton and neighboring metasedimentary rocks. The position of the terminal moraine of this glacier is indicated by the last of a train of large subangular granite lag boulders that were plucked from an outcrop approximately 3 miles farther up the valley in the central portion of section 35 (fig. 9). A possible remnant of lateral moraine from the older glaciation is located near the lag boulder source at the left limit of the creek in the south-central portion of section 35 (fig. 9).

An outwash plain extends from the terminus of the older glacier at least another 5 miles farther down the creek (fig. 9). These outwash gravels are locally overlain by 10 to 15 ft of organic material that has crept off the valley's frozen southern slope. Elsewhere along the southern slope, the outwash gravels are also overlain by alluvial fan gravels. Outwash terraces located 3 to 5 ft above the present creek level are common along this stretch of North Fork Preacher Creek, especially where recent stream erosion during flooding has removed overlying organic material. The outwash gravels are moderately well sorted and locally crudely stratified with rounded clasts that are generally less than 0.5 ft in diameter within a clayey matrix containing only minor amounts of grus. These gravels may contain more abundant fine intrusive phase and tourmaline-bearing cobbles than other gravels of the area.

The retreat of the older and the possible advance of a younger glacier caused the development of a relatively younger outwash plain in the headquarter portion of North Fork Preacher Creek. This plain extends from near the headwaters of North Fork Preacher Creek to the southern terminus of the older glacier (fig. 9). In places along its left limit, the plain truncates alluvial fan and till gravels but elsewhere, on its right limit, it is overlain by alluvial fan gravels. This suggests that the valley is presently cutting to the northwest.

The outwash is somewhat variable, ranging from loosely packed and poorly sorted grus-rich, to dense, well-sorted clay-rich gravels. Cobbles tend to be subangular to subrounded and moderately coarse, averaging about 0.4 ft in diameter, and are dominantly of intrusive origin. Incipient podzolic soil development on these gravels is marked



Base adopted from U.S.G.S. 1:63,360 Circle (C-6 and C-5) quadrangles

Figure 9.—Surficial geologic and sample location map for the North Fork of Preacher Creek.

in places by a loose and weathered grus-rich horizon that overlies a thin clay layer, which, in turn, overlies manganese- and iron-stained gravel. The outwash plain gravels grade into unstratified, coarse, grus-rich colluvium along both slopes.

SAMPLING AND ANALYSES

Twenty-three gravel samples were collected on or near North Fork Preacher Creek (fig. 9). Samples were mostly collected from gravel exposures in cutbanks, a few, however, were also collected from gravel bars. Samples were excavated by hand and loose volumes were measured in 5-gal buckets. Where possible, in-place volumes were also measured. Most samples were subsequently screened to minus 3/8 in and panned to a rough concentrate. A few larger samples were also concentrated with a Keene model HMJ-1 hydromatic jig,[6] and two samples were concentrated with a 4-ft-long backpack-style sluice box. In all cases, the rough concentrate was further panned in the field to an approximately pint-size volume.

Figure 10 is a flow diagram illustrating how the samples were reduced in the laboratory. Concentrates were screened to minus 16 mesh, further pan concentrated to a standardized volume, examined for mineralogy, and weighed. The samples were then analyzed for tin, columbium, tantalum, yttrium, and cerium by x-ray fluorescence (XRF) and for tungsten using a colorimetric technique. Splits of samples with tin concentrations greater than 2 pct were subsequently assayed for tin.

Descriptions, loose volumes, concentrate weights, analytical results, and calculated tin grades of placer samples collected along North Fork Preacher Creek are tabulated in appendix D. Sample volumes range from less than 0.1 to 1.0 yd^3 and average approximately 0.2 yd^3. The two larger 1-yd^3 samples were concentrated with the hydromatic jig. Measured in-place volumes of four samples ranged between 2 and 35 pct smaller than the loose volumes (table 4).

Smaller pan concentrate samples were collected from drainages feeding North Fork Preacher Creek in order to help pinpoint potential sources of the placer minerals (fig. 9). Samples were shoveled from gravels located either at the center of the active channel on smaller creeks or from the leading edge of gravel bars on larger streams. Samples were concentrated with a 14-in diameter pan that was heap filled. Concentrates were further reduced, inspected, and

Table 4.—Swell factors[1] calculated from gravel samples

Sample	Gravel type	Volume, ft^3 Loose	Volume, ft^3 In-place	Swell factor, pct
F	Older outwash	10.4	9.4	10
R	Recent outwash	5.5	5.4	2
S	Alluvial fan	6.24	5.4	15
V	Glacial till	5.46	4.0	35

[1] Determined by dividing loose volume by in-place volume and subtracting 1.

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[6] Reference to specific products does not imply endorsement by the Bureau of Mines.

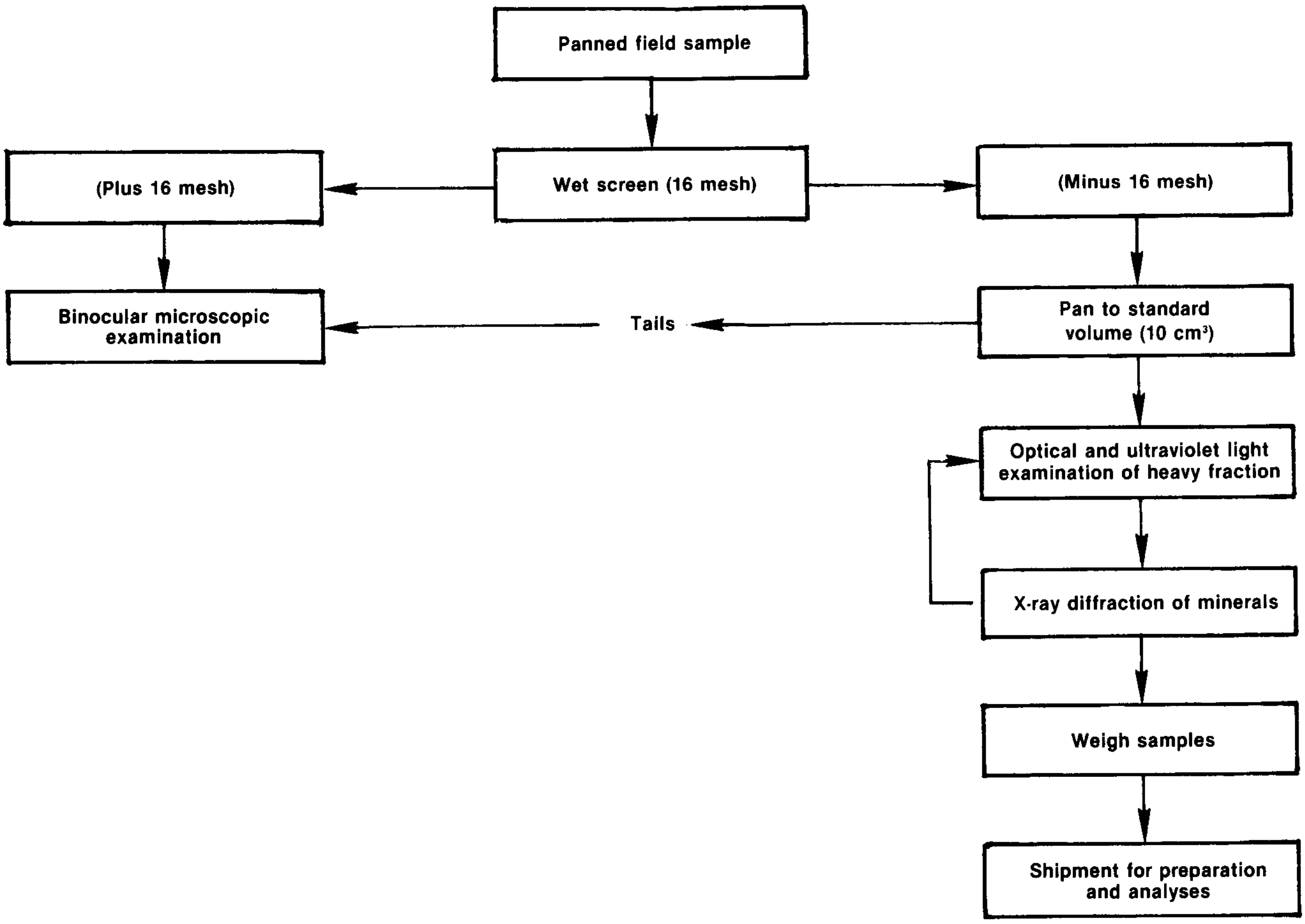

Figure 10.—Flow diagram depicting laboratory sample reduction and examination method.

weighed in the laboratory and subsequently analyzed by the same method used on the larger placer samples.

The heaviest fraction[7] of the placer concentrate samples are composed of variable amounts of cassiterite, magnetite, zircon, monazite, xenotime, topaz, tourmaline (schorl), scheelite, garnet, pyrite (or limonite), columbium-bearing rutile, and chalcopyrite (table 5). Except for magnetite, all of the minerals occur in grains smaller than 1 mm in diameter; magnetite occurs in up to 0.5-cm-wide rounded pebbles. Cassiterite generally occurs as subrounded to subangular, light to dark brown anhedral crystals. However, in sample W, some of the cassiterite occurs as subhedral to euhedral crystals with minor amounts of attached greisen.

Placer concentrate samples collected along North Fork Preacher Creek contain between 2,100 ppm and 7.25 pct Sn, with grades ranging from 0.002 to 0.04 lb/yd^3 Sn (appendix D). Tin grades of outwash gravel samples systematically decrease downstream as an inverse function of the square of the distance from maximums located both in the Bedrock Creek area and near where North Fork Preacher Creek crosses the northeastern intrusive contact (fig. 11). Concentrations of tungsten, columbium, tantalum, cerium, and yttrium also decrease downstream of the intrusive contact.

Table 6 shows the results of analyses of panned concentrate samples collected from North Fork Preacher Creek and from streams draining into it. Samples collected by Burton (*1*) also are included. Relative tin concentrations of the samples have been converted to weight per pan volume calculations, as described by Barker (*14*), in order to facilitate comparing the results. Only one of the samples (BB) contained significantly greater than 10 mg/pan Sn, which is the threshold value for anomalous tin concentrations determined by Burton (*1*) for this area. Sample BB was collected from residual material overlying greisen adjacent to Bedrock Creek (fig. 9).

Table 5.—Placer sample concentrate mineralogy[1] and relative amounts of minerals

Sample[2]	W	Q	P	O	N	L	K	I	E
Beryl	NO	NO	R?	NO	NO	NO	NO	NO	NO
Cassiterite	A	C	A	M?	C	A	C	C	A
Chalcopyrite	NO	NO	R	NO	NO	R	NO	NO	NO
Garnet	T?	M	NO	NO	NO	NO	NO	NO	NO
Magnetite	M	A	C	NO	C	C	A	C	A
Monazite	A	A	A	M	A	C	C	C	C
Pyrite or limonite	NO	NO	R	NO	NO	R	T	T	NO
Topaz	M	M	M	T	M	T?	NO	M	NO
Tourmaline	M	M	C	NO	M	T	NO	T?	NO
Scheelite	M	M	R	T	M	T	NO	T	T
Wolframite	T?	NO	NO	NO	NO	NO	NO	NO	NO
Xenotime	M	C	M	NO	M	M	NO	M	M
Zircon	C	A	C	M	A	A	M	C	A

A Abundant. C Common. M Minor. T Trace.
R Rare. NO None observed. ? Identification uncertain.

[1] Determined by optical and X-ray diffraction methods.

[2] Samples listed according to location on North Fork Preacher Creek, starting near the headwaters.

PLACER TIN RESOURCES

The distribution of placer sample tin grades along North Fork Preacher Creek (see figure 11) clearly indicates that most of the tin in North Fork Preacher Creek is derived from two sources. One of these sources is located near the northeastern intrusive contact where it is crossed by North

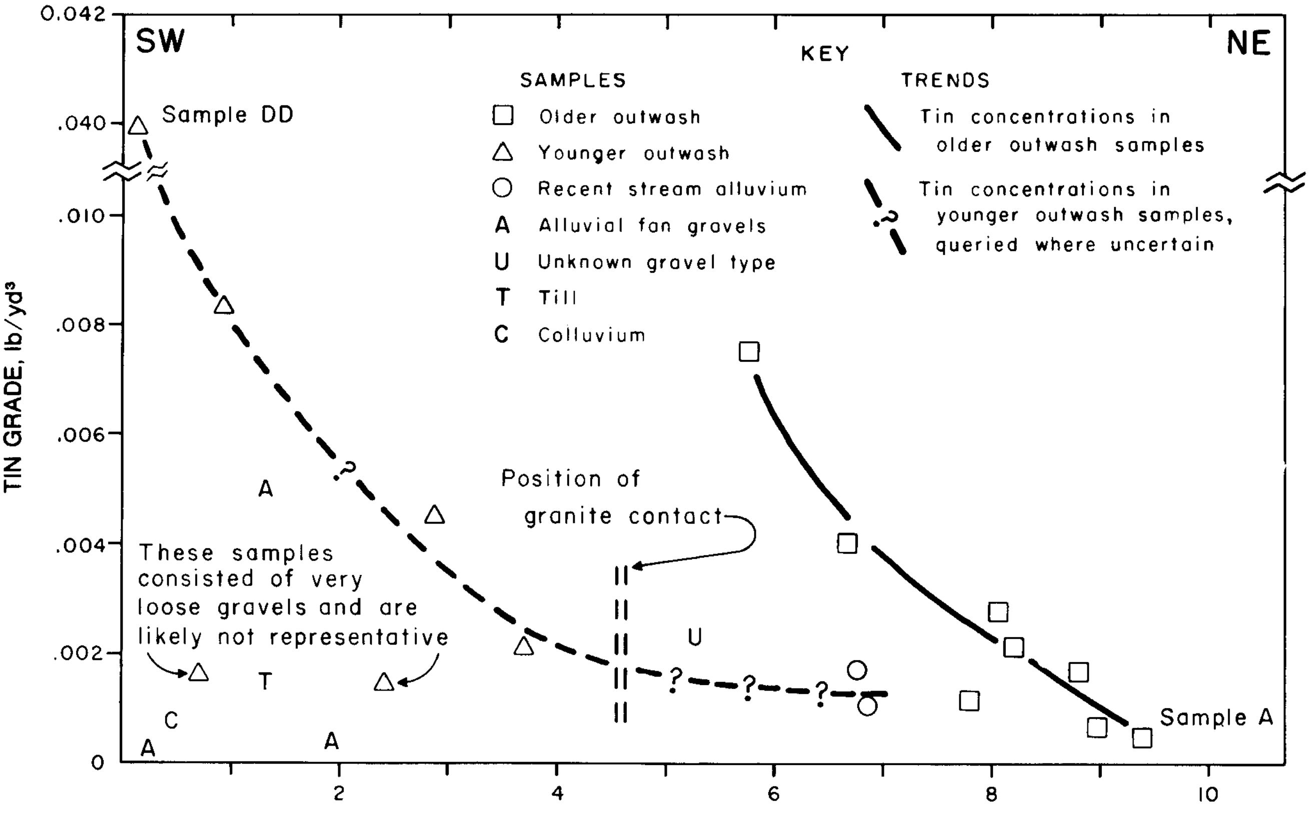

Figure 11.—Variation of tin grade along the North Fork of Preacher Creek.

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[7] Approximately greater than a specific gravity of 3.5.

Table 6.—Analysis and relative tin concentrations of panned concentrate samples

Sample	Analysis, ppm						Sn conc	
	Cb	Ce	Sn	Ta	W	Y	Weight, g	mg/pan[1]
G	16	66	9	<3	9	9	15.7	0.14
H	16	315	110	3	10	28	19.24	2.11
M	17	320	340	3	20	36	20.07	6.82
T[2]	500	NA	5,000	NA	5,000	NA	2.17	10.85
AA[2]	<70	NA	<100	NA	<200	NA	6.40	<.64
BB[3]	94	4,600	8,700	16	855	250	17.37	16.0
CC[4]	I	3,400	2,000	36	58	400	19.24	2.5

I Interference because of Zr. NA Not analyzed.

[1] Calculated as decribed by Barker (*14*) using the formula:

$$\text{mg/pan} = \frac{\text{(ppm value) [1,000 (weight in grams)]}}{1 \times 10^6}$$

[2] From Burton (*1*).

[3] Represents concentrate from approximately 9 gal of residual material lying directly on bedrock. Milligram-per-pan value adjusted accordingly.

[4] Represents concentrate from approximately 15 gal of colluvium near bedrock. Milligram-per-pan value adjusted accordingly.

Fork Preacher Creek and is coincident to a hypothesized glacial terminal moraine (compare figures 9 and 11). The second source of tin lies near the headquarters of North Fork Preacher Creek in the Bedrock Creek area. Analytical results, however, show low metal grades that do not indicate a significant placer tin resource under present economic conditions.

Probable large volumes of former low-grade lode tin mineralization, eroded from sources near Bedrock Creek, are not accounted for by the low placer tin grades found during this investigation. Cassiterite identified in both placer and greisen samples, however, is very fine grained and may be dispersed over a very large area. Additionally, much of the fine cassiterite within the gravels likely has been concentrated at or near bedrock, so the low grades reported from surface gravel samples do not conclusively indicate a low potential for placer tin deposits.

SUMMARY AND CONCLUSIONS

The intrusion at Lime Peak is one of several plutons that underlie the White Mountains highland area north of Fairbanks, AK. These plutons generally intrude a sequence of clastic and carbonate metasedimentary rocks. The geology of the Lime Peak pluton is comparable to that of many tin-mineralized plutons worldwide.

Numerous occurrences of tin-mineralized greisen are associated with the Lime Peak pluton in the Bedrock Creek area southeast of the Lime Peak summit. The greisen is composed of complex mineralization-alteration assemblages that can be roughly subdivided into two stages based on their paragenetic relationship to faulting. Cassiterite mineralization is related to the younger of the two assemblages, whereas tungsten is associated with the older event.

The average tin grade of 170 samples of greisen from the Lime Peak study area is approximately 0.05 pct; 30 samples from the ridge north of Bedrock Creek define a smaller area, with an average tin grade of approximately 0.07 pct. Beneficiation testing of two bulk greisen samples produced concentrates containing 65 and 59 pct of the total tin values at grades of 0.35 and 13.9 pct, respectively.

The lack of outcrops makes determination of mineralized widths difficult; however, the size of rubble boulders, together with the width of occurrences that could be channel sampled, suggests that greisen veins are mineralized over an average width of approximately 2.0 ft. Individual occurrences can rarely be continuously traced for more than a few tens of feet; however, discontinous exposures and rubble distribution suggest several greisen veins may comprise zones up to 100 ft wide that can be traced for up to several thousand feet along strike.

The grade of the greisen occurrences is too low and variable to allow adequate definition of tin resources. An estimate of total contained metal, however, suggests the area has a resource potential of 20 MMlb Sn. Beneficiation testing suggests that approximately 60 pct, or 12 MMlb, of the tin could be readily concentrated. This, however, is contained in rock that is too low grade to be considered economic at the present time.

Outwash gravels along North Fork Preacher Creek contain a diverse suite of fine-grained heavy minerals, including cassiterite; however, analytical results of surface samples show very low metal concentrations that do not indicate a significant resource. Two sources of cassiterite are defined by the distribution of tin grades in gravels. One source is greisen mineralization in the Bedrock Creek area, the other is located on North Fork Preacher Creek where it crosses the northeastern intrusive contact. Low tin grade in surface gravel samples do not account for the former erosion of a large volume of tin-mineralized material from the Bedrock Creek area and suggest that higher grades may be present in gravels closer to bedrock.

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APPENDIX A.—DESCRIPTION OF IGNEOUS ROCKS MAPPED NEAR LIME PEAK

Two major plutonic phases and numerous dikes of various compositions were mapped near Lime Peak (figure 3, main text). Descriptions of each rock type follow.

A coarse-grained intrusive phase (Tgc) underlies most of the higher elevations of the Lime Peak area and forms tors along ridges. This unit comprises medium- to coarse-grained seriate to porphyritic biotite granite and contains modal compositions between 30 and 38 pct quartz, 40 and 45 pct orthoclase, 14 and 20 pct plagioclase, and 3 and 7 pct biotite. Trace to minor amounts of fluorite and black tourmaline fill miarolitic cavities in this rock, and zircon and other high-refractive index minerals are common inclusions in biotite. Plagioclase, quartz, and biotite typically form a granular groundmass within which are larger anhedral twinned orthoclase crystals.

Major-oxide analyses of four samples of the coarse-grained granite indicate subaluminous[1] (*15*)[2] to metaluminous[3] (*15*) and subalkaline (*16*) compositions that are generally comparable to that of average biotite alkali granite reported by Nockolds (*17*) (table A-1). All four analyzed samples of this phase have differentiation indexes[4] of 92, indicating a high degree of fractionation, and two of the samples contain minor amounts of normative corundum. Trace element analyses indicate this phase is relatively enriched in boron, beryllium, fluorine, lithium, tin, uranium, and thorium compared to the average granite as compiled by Rose (*19*) (table A-1).

The second most abundant lithology, a relatively finer grained, porphyritic granite (Tgp), underlies much of Bedrock Creek and the surrounding hillsides. This unit is characterized by a variable texture, but is most commonly porphyritic with a hypidiomorphic seriate groundmass and phenocrysts of anhedral orthoclase and quartz. Fine-grained to moderately coarse grained equigranular varieties of this unit are also locally present.

Samples of this rock contain modal compositions between 40 and 50 pct quartz, 29 and 34 pct orthoclase, 10 and 20 pct plagioclase, 3 to 7 pct biotite, and 1 to 3 pct muscovite, as well as trace to minor amounts of tourmaline, fluorite, topaz, zircon, monazite, and xenotime. Quartz typically shows undulose to polycrystalline extinction and orthoclase commonly has micrographic intergrowths of plagioclase as well as local, especially near phenocryst margins, micrographic intergrowths with quartz. Muscovite ex-

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[1] Molecular porportion of Al_2O_3 is approximately equal to that of the sum of Na_2O and K_2O, but is less than the sum of CaO, Na_2O, and K_2O.

[2] Italic numbers in parentheses refer to items in the list of references preceeding this appendix.

[3] Molecular proportion of Al_2O_3 exceeds that of the sum of Na_2O and K_2O, but is less than the sum of CaO, Na_2O, and K_2O.

[4] Sum of normative quartz, orthoclase, and albite (*18*).

Table A-1—Composition of Lime Peak pluton samples

Rock type	Tgc				Tgp					Tgm	Tr	Av BAG (*17*)	Av granite (*19*)
Sample[1]	10	19	54	21218	58	63	89	102	104	20730	50		
					MAJOR OXIDE ANALYSES,[2] wt pct								
SiO_2	74.00	74.50	75.50	75.00	75.70	77.30	77.00	77.40	76.50	74.00	71.50	75.01	NAp
Al_2O_3	12.70	12.30	12.30	12.30	12.40	12.10	12.30	12.40	12.20	13.60	14.80	13.16	NAp
Fe_2O_3	2.50	2.20	.26	2.15	.18	.27	.43	.12	.22	1.20	.90	.94	NAp
FeO	NA	NA	1.94	NA	1.52	1.83	1.37	1.68	1.58	NA	NA	.88	NAp
MgO	.15	.10	.19	.05	.04	.09	.05	.03	.03	ND	ND	.24	NAp
CaO	.85	.80	.76	.85	.67	.86	.45	.68	.80	.50	.70	.56	NAp
Na_2O	2.70	2.70	1.90	3.00	2.10	2.10	2.00	2.20	2.10	4.40	5.80	3.48	NAp
K_2O	5.70	5.80	4.60	5.50	4.50	4.60	4.90	4.20	4.40	4.80	4.40	5.01	NAp
TiO_2	.15	.10	.18	.05	.05	.05	.09	.03	.04	ND	ND	.11	NAp
P_2O_5	.04	.03	.08	.03	.08	.08	.06	.07	.06	.04	.02	.07	NAp
LOI	.75	.76	NA	.51	NA	NA	NA	NA	NA	.58	.54	.54	NAp
Total	99.54	99.29	97.71	99.44	97.24	99.35	98.65	98.81	97.93	99.12	98.66	99.90	NAp
					NORMATIVE MINERAL COMPOSITION,[2] wt pct								
Albite	23.16	23.20	16.45	25.67	18.27	17.89	17.15	18.84	18.14	37.78	50.02	29.48	NAp
Anorthite	4.00	3.83	3.32	3.89	2.88	3.77	1.87	2.95	3.65	2.25	1.38	2.06	NAp
Apatite	.09	.07	.19	.07	.19	.19	.14	.16	.14	.08	.05	.26	NAp
Corundum	.65	.20	3.08	ND	3.13	2.31	3.70	3.20	2.73	.36	ND	1.16	NAp
Diopside	ND	ND	ND	.13	ND	ND	ND	ND	ND	ND	ND	ND	NAp
Enstatite	.38	.25	3.61	.06	2.74	3.18	2.17	3.05	2.77	1.22	ND	.60	NAp
Hematite	ND	.61	ND	.46	ND	ND	ND	ND	ND	1.22	.92	ND	NAp
Ilmenite	.29	.19	.35	.10	.10	.23	.17	.06	.08	ND	ND	.32	NAp
Magnetite	2.06	1.47	.39	1.60	.27	.39	.63	.18	.33	ND	ND	1.36	NAp
Orthoclase	34.12	34.81	27.82	32.87	27.35	27.36	29.35	25.12	26.55	28.78	26.50	29.64	NAp
Quartz	35.00	35.36	44.80	35.13	45.08	44.68	45.46	46.44	45.59	29.51	20.30	34.07	NAp
Wollastanite	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	.85	ND	NAp
					CONCENTRATION,[3] ppm								
B	100	100	100	200	100	200	100	100	100	200	100	NAp	10
Ba	200	<200	600	70	90	200	100	200	20	<20	<200	NAp	840
Be	10	7	40	30	70	30	30	10	20	20	40	NAp	3
Cb	<50	<50	<50	<50	<50	51	<50	57	<50	<50	80	NAp	20
F	980	1,500	1,800	570	3,900	2,900	1,200	5,700	4,800	930	1700	NAp	810
Li	50	44	37	100	61	27.5	64	97	53	NA	25	NAp	40
Rb	210	270	390	240	480	420	370	590	510	NA	330	NAp	276
Sn	7	7	<5	<5	<5	<5	<5	<5	7	NA	48	Nap	3.0
Sr	3	3	46	<10	<10	20.8	<10	<10	<10	<10	<10	Nap	100
Ta	<100	<100	<100	<100	<100	100	<100	<100	<100	<100	<100	NAp	3.5
Th	70	60	75	60	70	85	55	75	75	40	35	NAp	20
U	5.3	7.8	4.3	7.8	11	8.5	6.6	14	14	4.8	12.0	NAp	3.9
W	<5	<5	<5	<5	8	6	<5	6	<5	NA	<5	NAp	1.5
Zr	<30	30	200	<30	550	210	170	92	120	<30	<30	NAp	175

Rock types: Tgc Coarse-grained granite. Tgp Porphyritic granite. Tgm Muscovite granite. Tr Rhyolite.
BAG Biotite alkali granite. NA Not analyzed. ND Not detected. NAp Not applicable.

[1] Sequentially numbered generally from northeast to southwest on figure 3 of main text. Samples with 5-digit numbers were collected from outside the area shown in figure 3. Sample 21218 is from near the pluton's southern contact in the southeast quarter of T 9 N, R 4 E; sample 20730 is from a small tongue of granite that extends south from the pluton in the south-central portion of T 9 N, R 4 E (see Burton (*1*) for location).

[2] Normalized to 100 pct.

[3] Ba, Cb, and Ta determined by XRF; B by emission spectrography; W, U, and F by specific chemical methods; Th by radiometric techniques; Zr and Be by ICP methods; and Rd, Sr, Li, and Sn by AA.

hibits anomalously high mid-third-order birefringence colors and clear to pale-green pleochroism indicative of a high-iron composition (*20*), and occurs both in patches associated with biotite and disseminated in the matrix. Topaz occurs as subhedral to anhedral crystals within the groundmass and is interpreted as primary.

Major-oxide compositions of five samples of the porphyritic granite (Tgp) indicate subalkalic and markedly peraluminous compositions with relatively lower total-alkali, Al_2O_3, TiO_2, and MgO concentrations than those of the coarse-grained granite (Tgc). Differentiation indexes of samples of the porphyritic granite, ranging between 89 and 91, are also somewhat less than those of the coarse-grained granite. In contrast, however, the porphyritic granite is relatively enriched in SiO_2 and P_2O_5 and has greater than 2 pct normative corundum. The porphyritic granite is also enriched in uranium, thorium, rubidium, fluorine, and possibly columbium, beryllium, zirconium, and tungsten, and contains higher uranium-to-thorium and rubidium-to-strontium ratios relative to samples of the coarse-grained granite and to an average granite composition.

Dikes of porphyritic rhyolite, andesite, and lamprophyre are also common in the Bedrock Creek area. These dikes range from a few feet to several tens of feet wide, and typically trend northwest, cutting the two more abundant intrusive phases. The rhyolite is composed of subequal amounts of subhedral to euhedral quartz, orthoclase, and albitic plagioclase and minor irregularly shaped biotite phenocrysts in a fine matrix of quartz, orthoclase, and muscovite (*1*). Phenocrysts make up 60 pct of this rock, and fluorite occurs rarely in miarolitic cavities. Major oxide analyses of one sample (50) of the rhyolite indicate a peraluminous and alkalic composition with a differentiation index of 96 (table A-1). One andesite dike was mapped in the east fork of Bedrock Creek, and andesite rubble is common on the south flank of the Lime Peak summit. The andesite is dark green to gray and commonly contains phenocrysts of plagioclase feldspar. Two lamprophyre dikes were also mapped in the east fork of Bedrock Creek; this rock is dark green to black and contains no obvious phenocrysts. Neither the andesite nor lamprophyre were examined optically or analyzed for major oxide composition.

The major oxide composition of a sample (20730) of medium-grained equigranular muscovite granite (Tgm) from the southern portion of the Lime Peak pluton is included in table A-1. Although this rock is not present in the area of detailed mapping, its analysis is included for comparative purposes. Analysis indicates a metaluminous and sodium-enriched subalkalic composition with a differentiation index of 96. This rock appears to be the most evolved plutonic phase of the Lime Peak pluton. Where observed in one thin section, the muscovite granite was composed of approximately 40 pct quartz, 30 pct plagioclase, 25 pct orthoclase, 4 pct muscovite, and variable but generally minor amounts of fluorite, topaz, and blue tourmaline. Tourmaline and fluorite fill miarolitic cavities, and plagioclase occurs as euhedral laths surrounded by anhedral quartz, orthoclase, and topaz, and subhedral muscovite crystals. The muscovite is similar to muscovite in samples of the porphyritic granite.

APPENDIX B.—DESCRIPTION OF GREISEN OCCURRENCES SAMPLED NEAR LIME PEAK

Approximately 30 different minerals have been identified in greisen samples collected near Lime Peak. These minerals and their paragenetic relationships are listed in figure 6 of the main text. Based on their paragenetic relationship to faulting, two alternation-mineralization stages appear to be represented. Each of these stages is discussed in the following.

The paragenetically older (stage 1) mineral assemblage is best exposed, and is largely confined to the East Fork of Bedrock Creek area (fig. 4). Samples containing similar alteration minerals, however, have also been found on the hillside north of Bedrock Creek. This greisen assemblage is relatively barren of tin. Stage 1 may actually represent several separate or paragenetically overlapping mineral suites; however, all of the vein sets are cut by faults or fractures associated with later stage 2 alteration.

Most characteristically, stage 1 veins sets trend west-northwest and comprise 3- to >25-ft-wide zones containing three to six thin veins per foot (fig. 4). Locally, however, veins may obtain thickness of up to 0.5 ft or may crisscross in a stockwork fashion (sample 47). The veins may also be very irregular and poddy (sample 119).

Stage 1 veins are typically composed of relatively coarse grained muscovite, quartz, and topaz with lesser purple fluorite, molybdenite, and a columbium-tungsten-iron mineral, tentatively identified as wolframoixiolite (fig. 6). The muscovite is quite distinctive and contains anomalously high third-order birefringence colors, and clear to pale green pleochroism similar to that found in the porphyritic and muscovite granites, and similarly indicates a high-iron content[1] (*20*).[2] In places along Bedrock Creek, especially near sample site 126, the muscovite-rich veins parallel up to 1-in-wide veins of quartz, albite, green fluorite, and green muscovite. The two vein sets may be contemporaneous; however, in a thin section of sample 126, the quartz-albite vein was observed to be cut by a more typical stage 1 veinlet of quartz and topaz.

Analysis of fluid inclusions[3] in quartz and topaz of the stage 1 vein set indicates a wide range of homogenization and decrepitation temperatures, with homogenization to either a liquid or a vapor (fig. B-1). These results suggest the fluid was boiling at the time that these minerals were precipitated. Corresponding last melting temperature measurements cluster near −25° C, but range as high as −6° C, indicating a range of salinities between 10 and 43 equivalent wt pct NaCl.

The paragenetically younger (stage 2) alteration-mineralization assemblage at Lime Peak consists dominantly of quartz, chlorite, and sericite, with locally abundant topaz, fluorite, tourmaline, and pyrite. The pyrite locally contains inclusions of bismuth minerals, (bismuthinite and native bismuth). In addition, sphalerite, galena, chalcopyrite, cassiterite (see figure 7), columbium-bearing rutile (fig. B-2), and other fine-grained accessory minerals are sometimes present. Most of these minerals occur as random clots, small veins, and scattered grains, usually within the chlorite matrix. Late-stage alteration minerals include iron, manganese, and lead oxide minerals, kaolinite, an unidentified calcium-iron-uranium mineral, and malachite and chrysocolla (fig. 6). Sericite in the stage 2 assemblage is distinguished from muscovite of the stage 1 assemblage by its fine-grained nature, lack of pleochroism, and relatively lower birefringence colors, and is probably of the low-iron variety (*20*). Tourmaline exhibits anomalous purple to blue pleochroism. Chlorite has a light green to yellow pleochroism and exhibits high first-order birefrigence colors indicative of a high-iron, low-silica composition (*16*).[4]

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[1] Microprobe analysis indicates the green muscovite has a general composition of $K[(Fe)_2Al]lAl_{3.3}O_{10}(OH)_2$.

[2] Italic numbers in parentheses refer to items in the list of references preceding appendix A.

[3] Analyses by S. Masterman, graduate student, University of Alaska.

[4] Microprobe analyses indicate a composition of approximately $(Fe_{0.87}Al_{0.13})_4(Al_{0.42}Si_{0.56})_4O_{10}(OH)_3$.

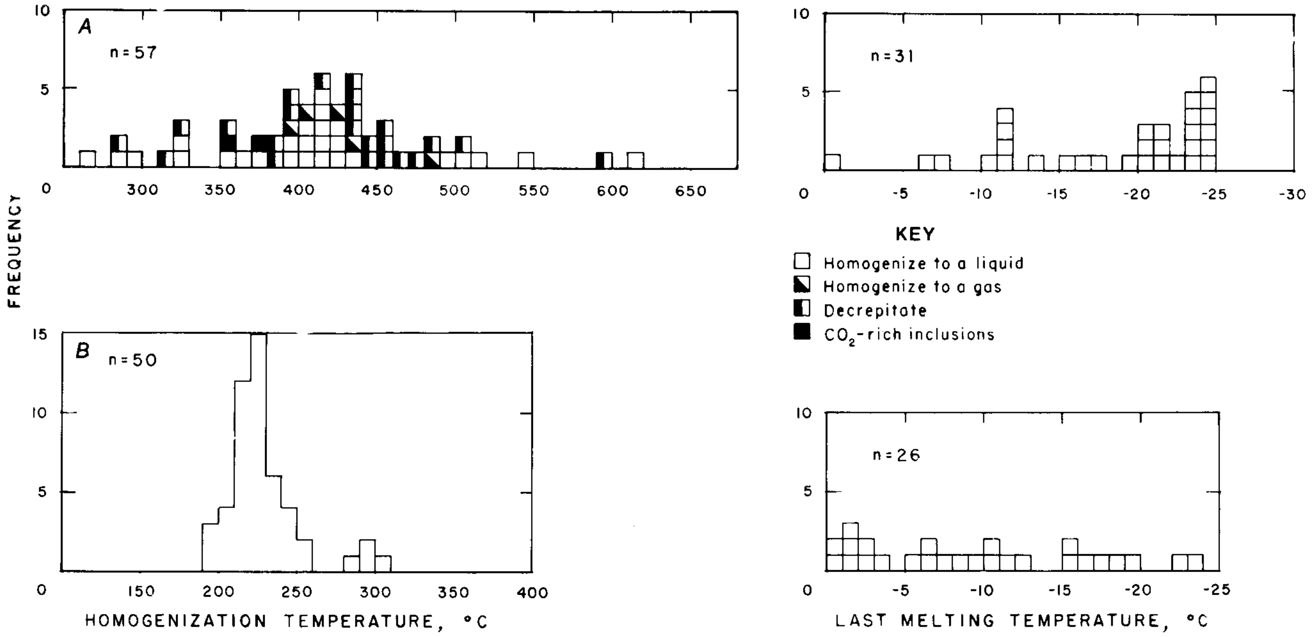

Figure B-1.—Results of fluid inclusion analyses; (*A*) stage 1 vein and (*B*) stage 2 vein.

Figure B-2.—SEM micrograph of crystals of columbium-bearing rutile (white) in a chlorite (gray) and quartz (black) matrix.

Where most pervasively developed, the younger (stage 2) greisen assemblage consists of a mass of chlorite and quartz intergrown with, and partially replacing, sericite, topaz, fluorite, and tourmaline. These minerals may be developed around a central open-space-filling veinlet of similar composition. Locally, for example at sample site 89, the wallrock is so thoroughly recrystallized that vugs lined with quartz, chlorite, and fluorite are present. Pervasive greisen alteration is progressively developed from a less altered, porphyritic-appearing rock containing partially replaced relict anhedral quartz grains in a matrix-of fine-grained quartz, chlorite, sericite, fluorite, and tourmaline. Chlorite and sericite replace biotite and feldspars; chlorite replaces sericite as the alteration progresses.

In many altered specimens or outcrops, the alteration zoning is asymmetric. Where the zoning is asymmetric, the most pervasively altered rock, which comprises massive, penetratively deformed chlorite and angular quartz fragments, is truncated by a planar slickensided surface and undoubtedly represents gouge adjacent to a fault. The abundance of greisen-altered float with slickensided surfaces indicates that much of the paragenetically younger (stage 2) greisen is localized along faults.

Analysis of fluid inclusions in quartz from a vein within the quartz-chlorite greisen indicates a relatively narrow range of homogenization temperatures, with an average value of 220° C (fig. B-1). In contrast, corresponding last melting temperature measurements exhibit a wide range of values from 0° to $-24°$ C. The range in last melting temperatures suggests that this greisen assemblage was deposited under a wide range of salinities corresponding to 0 to 40 equivalent wt pct NaCl.

APPENDIX C.—RESULTS OF ANALYSES OF ROCK SAMPLES COLLECTED FROM THE LIME PEAK AREA

Table C-1.—Results of quantitative geochemical analyses[1] of rock samples

Sample[2]	Type	Length[3] or area	Analyses, ppm						Field description[4]
			Ag	Au	Sn	U	W	Cb_2O_5	
1	G	NAp	LD	LD	310	28	6	LD	Mn-stained coarse granite.
2	Ch	2 ft	[5]0.3	LD	300	5.9	LD	LD	Chlorite greisen.
3	G	150 ft^2	[5].8	LD	1,010	8.5	8	100	Chlorite-quartz greisen.
4	G	NAp	2.9	LD	280	12	16	66	Quartz-chlorite-sericite-fluorite greisen.
5	C	3 ft	1.0	LD	380	14	36	LD	Chlorite-quartz limonitic greisen boulder.
6	G	>0.5 ft	15.0	LD	1,100	8.8	12	LD	Chlorite-quartz-muscovite-fluorite-tourmaline-chalco-pyrite greisen.
7	G	125 ft^2	1.5	LD	730	18	6	LD	Chlorite greisen.
8	G	300 ft^2	4.1	LD	200	12	LD	LD	Do.
9	G	300 ft^2	2.8	LD	220	9.4	LD	LD	Do.
11	G	300 ft^2	2.0	LD	950	25	LD	LD	Chlorite-sericite-quartz-fluorite-topaz-pyrite-chalcopyrite greisen.
12	C	NAp	1.1	LD	300	7.6	6	LD	Greisen boulder with open-space-filling quartz-muscovite-fluorite-topaz vein. Open spaces are filled with chlorite.
13	C	5 ft	1.6	LD	120	10	LD	LD	Chlorite-altered coarse granite.
14	G	60 ft^2	4.1	LD	340	19	LD	LD	Chlorite-altered granite and quartz veins.
15	C	4 ft	1.6	LD	310	11	LD	LD	Massive chlorite greisen.
16	G	NAp	[5].8	LD	1,200	14	LD	LD	Massive limonitic chlorite greisen.
17	C	60 ft	[5].4	LD	430	19	LD	LD	Massive chlorite and chlorite-altered granite.
18	G	100 ft	1.0	LD	860	16	6	LD	Limonitic quartz-chlorite greisen.
20	G	NAp	LD	LD	130	8.5	LD	LD	Chlorite-altered granite.
21	G	<0.8 ft	[5]0.6	[5]0.007	370	17	LD	LD	Sericite-quartz-chlorite-pyrite-fluorite-greisen.
22	G	200 ft	1.7	LD	230	30	10	LD	Chlorite-quartz greisen.
23	G	30 ft^2	2.4	LD	210	33	12	69	Quartz-chlorite Mn-stained greisen.
24	G	60 ft^2	[5].4	LD	480	37	10	LD.	Do.
25[6]	G	NAp	36.4	ND	99	NA	16	LD	Chalcopyrite-pyrite-arsenopyrite-bearing limonitic greisen.
26	G	1 ft	NA	NA	170	NA	6	LD	Fluorite-bearing greisen.
27	G	NAp	1.9	.025	850	22	14	LD	Mn-stained quartz-chlorite greisen.
28	C	20 ft	1.4	LD	730	17	LD	LD	Chlorite-quartz-sericite greisen zone.
29	G	20 ft	[5].8	.024	670	15	8	LD	Quartz-chlorite greisen.
30	G	60 ft^2	1.5	[5].007	940	27	8	LD	Quartz-chlorite and massive chlorite greisen.
31	G	30 ft^2	3.10	LD	1,000	31	6	LD	Chlorite-quartz greisen.
33	C	NAp	10.8	LD	200	42	200	LD	Quartz-chlorite-sericite-fluorite greisen.
34	C	NAp	17.5	.016	35	<.5	20	LD	Quartz-chlorite-fluorite greisen.
35	G	NAp	17.8	LD	800	18	60	LD	Do.
36	C	NAp	LD	.019	600	14	12	LD	Chlorite-sericite-quartz greisen.
37	C	NAp	LD	LD	530	20	20	LD	Chlorite-sericite-quartz altered granite.
38	G	30 ft	2.1	LD	100	9.8	32	LD	Chlorite greisen.
39	G	50 ft	5.1	LD	400	8.7	6	LD	Chlorite-sericite-altered granite and massive chlorite greisen.
40	C	5 ft	20.6	LD	3,800	36	LD	LD	Do.
41	C	0.4 ft	1.4	LD	120	8.5	10	LD	Chlorite-sericite altered granite.
42	C	NAp	LD	LD	300	NA	LD	68	Muscovite-sericite-topaz greisen.
43	C	3 ft	LD	[5].007	1,030	9.4	12	LD	Massive chlorite greisen.
44	G	NAp	2	LD	620	15	6	LD	Chlorite greisen.
46	G	NAp	2.1	[5].009	54	13	LD	79	Quartz-green fluorite pegmatite.
47	G	NAp	1.3	LD	10.4	15	160	LD	Stockwork quartz-muscovite-topaz-fluorite veins with trace molybdenite.
48	G	NAp	LD	.038	6	11	14	LD	Stockwork quartz-fluorite-chlorite-veins.
49[6]	G	NAp	6.3	LD	660	22	16	LD	Limonitic pyrite-chalcopyrite-bearing chlorite greisen.
50	G	NAp	NA	NA	120	30	6	LD	Biotite-tourmaline pegmatite.
51	G	20 ft^2	2	LD	220	6.9	8	LD	Chlorite-sericite-quartz greisen.
52	G	25 ft^2	LD	LD	280	15	6	LD	Sericite-chlorite-quartz greisen.
53	G	NAp	1.5	[5].007	220	15	12	LD	Mn-stained quartz-chlorite greisen.
55	G	900 ft^2	LD	.045	200	19	LD	LD	Chlorite greisen.
56	G	60 ft^2	8.5	LD	150	51	LD	LD	Do.
57	C	NAp	LD	LD	2,700	14	10	LD	Chlorite-quartz greisen.
59	C	4 ft	LD	LD	490	16	10	LD	Quartz-chlorite greisen.
60	C	10 ft	.5	LD	210	17	8	LD	Quartz-chlorite altered zone along fault.
61	G	NAp	1.6	LD	180		6	LD	Pervasively chlorite-altered granite.
62	C	1 ft	LD	LD	210	13	32	LD	Quartz-chlorite altered granite adjacent to fault.
64	C	NAp	3.5	LD	240	19	900	56 10 19 20	Quartz-sericite-pyrite-tourmaline-altered granite cut by quartz-tourmaline-sericite veins.
65	G	NAp	NA	NA	120	NA	30	15	Dense chlorite greisen.

See explanatory notes at end of table.

Table C-1.—Results of quantitative geochemical analyses[1] of rock samples—Continued

Sample[2]	Type	Length[3] or area	Analyses, ppm						Field description[4]
			Ag	Au	Sn	U	W	Cb_2O_5	
66	C	5 ft	NA	NA	79	NA	80	22	Dense chlorite greisen.
67	C	5 ft	NA	NA	220	NA	8	17	Do.
68	C	7 ft	NA	NA	210	NA	8	LD	Do.
69	C	7 ft	NA	NA	62	NA	4	LD	Do.
70	C	2.5 ft	NA	NA	595	NA	5	LD	Do.
71	C	4 ft	[5]0.5	LD	15.1	7.5	LD	LD	Mn-stained, chlorite-altered granite.
72	G	NAp	LD	LD	120	1.7	LD	LD	Chlorite-pyroxene skarn.
73	G	NAp	6.6	LD	300	8.3	LD	LD	Chlorite-altered granite.
74	G	NAp	LD	[5]0.009	510	12	10	LD	Quartz-chlorite greisen.
75	G	NAp	[5].4	LD	750	7.3	12	LD	Do.
76	G	NAp	2.9	[5].012	100	11	LD	LD	Mn-stained chlorite greisen.
77	G	1,000 ft	9.2	[5].008	210	33	10	<50	Quartz-chlorite greisen.
78	G	30 ft²	3.8	.011	1,050	17	6	52	Quartz-chlorite-fluorite greisen.
79	G	30 ft²	[5].7	LD	170	13	6	LD	Do.
80	G	NAp	[5].9	[5].007	12.6	13	6	62	Quartz-chlorite greisen.
81	G	NAp	1.1	LD	580	27	24	LD	Do.
82	G	NAp	[5].8	.125	5	85	LD	LD	Do.
83	G	100 ft²	1.1	LD	190	13	8	LD	Do.
84	G	150 ft²	LD	.021	100	28	LD	77	Do.
85	G	NAp	LD	LD	LD	8.1	LD	LD	Incipiently chlorite-altered granite.
86	G	NAp	LD	LD	7.9	[5].8	LD	LD	Do.
87	C	NAp	[5].3	.007	3,400	60	6	LD	Massive chlorite greisen.
88	G	NAp	LD	[5].010	250	11	6	52	Vuggy quartz-chlorite greisen with open space filled with fluorite.
91	G	5,000 ft²	LD	LD	270	17	LD	LD	Quartz-chlorite greisen.
92	G	NAp	LD	LD	24.9	9.3	LD	LD	Do.
93	G	800 ft²	LD	[5].007	530	20	LD	LD	Do.
94	G	1,000 ft²	LD	LD	230	60	LD	62	Quartz-chlorite fluorite greisen.
			LD						
95	C	6 ft	LD	[5].009	36	5.7	6	LD	Mn-stained, chlorite-altered granite.
96	Ch	2 ft	1.2	[5].008	810	32	6	LD	Quartz-chlorite greisen.
97	Ch	0.5 ft	[5].3	LD	250	7.8	LD	LD	Moderately developed chlorite greisen.
100	Ch	0.8	5.4	LD	1,090	17	LD	LD	Quartz-chlorite-green fluorite greisen.
101	Ch	2.5	[5].7	LD	380	20	LD	LD	Quartz-chlorite greisen.
103	Ch	1 ft	5.4	.092	520	24	6	58	Do.
105	Ch	3 ft	1.2	.219	460	35	LD	54	Do.
106	Ch	2 ft	5.2	.284	330	26	LD	52	Do.
107	G	[8]0.4 ft	[5].8	.080	1,110	28	LD	LD	Do.
108	Ch	6 ft	1.2	LD	350	30	LD	60	Do.
109	Ch	2 ft	2.8	[5].008	500	23	LD	LD	Do.
110	Ch.	2.5 ft	1.6	[5].011	380	41	6	72	Do.
111	Ch.	0.7 ft	4.1	[5].010	68	26	6	LD	Do.
112	Ch	3 ft	9.1	LD	270	19	LD	78	Do.
113	C	NAp	16.6	[5].013	200	93	LD	LD	Topaz-muscovite greisen.
114	C	[9]0.4 ft	1.8	[5].007	58	22	14	63	Quartz-chlorite greisen.
115	C	[10]12 ft	1.7	LD	210	20	LD	110	Do.
116	C	10 ft.	6.8	[5].007	280	25	LD	93	Do.
117	Ch	0.3 ft	LD	LD	39	22	LD	LD	Do.
118	Ch	0.5 ft	[5].3	.032	120	17	1,000	100	Quartz-topaz vein with topaz-muscovite-fluorite-altered selvage.
119	G	NAp	LD	.067	11.7	22	3,200	80	Topaz-muscovite-fluorite greisen.
120	Ch	3 ft	LD	[5].008	53	12	20	140	Zone of thin muscovite-topaz(?) quartz veins.
121	Ch	0.8 ft	[5]0.6	[5].007	150	22	24	200	Topaz-muscovite-fluorite greisen.
122	G	NAp	8.6	LD	870	19	LD	70	Muscovite-rich greisen adjacent to fault.
123	Ch	0.5 ft	6.6	[5].008	210	30	LD	160	Minor quartz-chlorite-greisen zone.
124	Ch	3 ft	1.8	[5].007	340	12	20	110	Quartz-chlorite greisen cut by thin muscovite-quartz veins.
125	Ch	1 ft	4.6	LD	1,060	17	10	140	Chlorite greisen with chlorite alteration selvage.
126	C	0.4 ft	LD	[5].008	87	12	6	LD	Quartz-albite-fluorite vein with selvage of muscovite-topaz-altered feldspar.
127	H	1 ft	205.8	.100	1,050	8.9	ND	LD	Quartz-chalcopyrite-chlorite vein.
128	H	1 ft	NA	NA	590	NA	LD	LD	Do.
129	Ch	4 ft	23.4	LD	660	16	LD	LD	Quartz-chlorite-chalcopyrite greisen zone.
130	C	[11]25 ft	9.4	[5].010	670	18	6	LD	Quartz-chlorite greisen.
131	Ch	0.7 ft	91.1	LD	3,700	44	14	LD	Chlorite greisen with pyritic center of vein.
132	Ch	2 ft	LD	LD	17	8.3	6	LD	Zone of 12 chlorite veinlets and 1.2-ft-wide quartz-albite-chlorite-biotite vein.
133	Ch	0.2 ft	LD	LD	7.6	6.7	6	LD	Quartz-albite-chlorite-biotite vein from sample 132.
134	Ch	3.5 ft	LD	LD	11.4	16	60	LD	Quartz-chlorite-biotite(?) veinlet zone.
135	C	16 ft	LD	LD	67	11	28	LD	Zone of 50 quartz-chlorite-biotite(?) veinlets and 1.3-ft-wide quartz-chlorite greisen vein.
136	C	0.3 ft	LD	LD	270	14	LD	LD	Quartz-chlorite greisen vein from sample 135.
137	C	0.3 ft	LD	LD	300	11	280	LD	Do.

See explanatory notes at end of table.

Table C-1.—Results of quantitative geochemical analyses[1] of rock samples—Continued

Sample[2]	Type	Length[3] or area	Analyses, ppm Ag	Au	Sn	U	W	Cb_2O_5	Field description[4]
138	G	NAp	1.5	LD	920	66	80	LD	Muscovite-chlorite-fluorite-altered granite. 1 grain calcite observed.
139	C	21 ft	LD	LD	LD	15	20	56	Zone of >75 quartz-chlorite veins and veinlets.
140	Ch	0.9 ft	LD	0.164	LD	20	400	LD	Quartz-chlorite greisen with 2 quartz veinlets.
141	Ch	4 ft	LD	LD	75	15	60	LD	Zone of approximately 25 quartz-chlorite veins and veinlets.
142	C	5 ft	LD	LD	7.6	15	14	LD	Zone of quartz-chlorite-veinlets.
143	Ch	3 ft	LD	LD	140	22	8	LD	Quartz-chlorite greisen fault zone.
144	Ch	2 ft	LD	.017	230	16	280	LD	Quartz-chlorite-tourmaline-pyrite greisein vein.
145	G	NAp	1.6	LD	110	16	200	LD	Composite of several diffuse quartz-chlorite greisen zones in area.
146	Ch	0.5 ft	LD	LD	77	17	32	LD	Quartz-chlorite greisen with central quartz vein.
147	Ch	0.3 ft	1.2	.007	100	22	LD	LD	Quartz-chlorite greisen.
148	H	NAp	1.1	LD	10.7	18	LD	LD	Quartz-chlorite veinlets.
149	H	NAp	1	.064	8.9	14	LD	LD	Do.
151	Ch	0.5 ft	2.6	LD	91	24	LD	78	Quartz-chlorite greisen.
152	Ch	0.3 ft	0.8	LD	340	22	12	LD	Quartz-chlorite veinlet zone.
153	G	NAp	LD	0.015	260	15	8	LD	Quartz-chlorite veinlets.
154	Ch	0.3 ft	[5].6	LD	1,150	23	6	LD	Quartz-chlorite greisen fault zone.
155	C	15 ft	LD	LD	96	19	LD	LD	Quartz-chlorite veinlet zone.
156	C	0.2 ft	1.6	LD	9.9	37	LD	LD	Quartz-chlorite greisen fault zone.
157	G	NAp	1.2	LD	17.5	22	10	LD	Do.
158	G	NAp	3.9	[5].007	35	22	50	LD	Do.
159	Ch	1 ft	8.0	LD	70	34	LD	200	Do.
160	Ch	0.1 ft	6.9	LD	25	28	LD	LD	Do.
161	Ch	0.4 ft	10.4	[5].008	67	23	LD	LD	Do.
162	Ch	0.1 ft	19.2	.009	7,100	24	240	110	Quartz-chlorite veinlets.
163	Ch	1.8 ft	22.5	LD	230	41	ND	LD	Green fluorite vein with quartz-chlorite greisen selvages.
164	Ch	0.2 ft	2.5	.033	2,600	22	12	95	Quartz-chlorite greisen fault zone.
165	Ch	7 ft	4.5	LD	46	33	LD	77	Quartz-chlorite greisen vein zone.
166	C	0.2 ft	4.6	LD	14.2	24	LD	LD	Quartz-chlorite greisenized fault zone.
167	Ch	25 ft	LD	LD	15.1	24	200	87	Quartz-chlorite veinlet zone.
168	C	0.3 ft	3.1	LD	LD	22	6	LD	Iron- and manganese-stained greisen vein.
169	G	NAp		LD	56	19	80	78	Quartz-chlorite veinlets with minor molybdenite.
170	C	0.3 ft	[5].3	LD	49	21	160	LD	Quartz-chlorite greisenized fault zone.
171	C	0.1 ft		LD	21.7	19	200	LD	Do.
172	G	NAp	2.0	LD	49	16	160	73	Do.
173	C	0.9 ft	[5].6	LD	22.7	19	16	LD	Coarse chlorite(?) greisen.
174	C	0.9 ft	7.3	LD	940	37	LD	53	Quartz-chlorite greisenized fault.
175	C	0.2 ft	1.6	LD	33	27	LD	53	Do.
176	C	0.6 ft	3.2	LD	460	22	LD	100	Do.
177	G	NAp	1.4	LD	22.7	22	60	LD	Composite of quartz-chlorite greisen material from 25 ft of exposures along creek.
178	Ch	1 ft	7.9	[5]0.007	140	33	LD	LD	Quartz-chlorite greisen.
179	C	0.1 ft	9.5	[5].009	500	50	ND	LD	Do.
180	C	0.1 ft		LD	77	20	LD		Do.
181	C	0.2 ft	3.5	LD	250	25	LD	LD	Do.
182	C	0.2 ft	5.2	LD	200	39	6	LD	Do.
183	C	0.3 ft	21.2	LD	720	50	10	LD	Do.

Sample types:		LD	Less than detection limit.
C	Chip	NA	Not analyzed.
Ch	Channel	NAp	Not applicable.
G	Grab	ND	Not determined because of interference
H	High grade		

[1] Sn, Ta, and Cb (Cb_2O_5) determined by XRF (Ta not detected); splits of samples with 50 ppm analyzed by AA; W by colorimetry; Th and U by radiometric techniques, and Ag and Au by fire assay-ICP.

[2] Gaps in sample numbers correspond to samples listed in table 1 of main text or table A-1 of Appendix A.

[3] True thickness.

[4] Supplemented with thin section observations.

[5] Analysis is near detection limit and must be interpreted accordingly.

[6] Also contains 28 ppm Mo, 3,900 ppm Cu, 1,700 ppm Pb, and 520 ppm Zn.

[7] Also contains 1,500 ppm Cu, 230 ppm Pb, and 340 ppm Zn, but <2 ppm Mo.

[8] Grab sample of material from several 0.4-ft-wide veins over 20-ft-wide interval.

[9] Composite of 3 0.4-ft-wide veins over 10-ft-wide interval.

[10] Composite of 3 veins separated by 4 ft.

[11] 3 zones, 0.4, 0.7-, and 3.0-ft-wide, sampled over 25.0-ft interval.

Table C-2.—Results of semiquantitative emission spectrographic analyses[1] of rock samples

Sample	ppm[2]											pct				
	As	B	Ba	Be	Cr	Cu	Ni	Pb	Sb	Zn	Zr	Fe	Li	Mg	Mn	Ti
1	>200	100	200	20	70	40	<4	2,000	<700	1,000	<30	5	0.07	0.05	>4	<0.04
2	<100	100	200	20	40	<6	<3	100	<900	400	60	8	.06	.2	>1	.1
3	90	2,000	40	10	10	<6	<10	<60	<1,000	700	<30	8	.06	.1	>2	<.04
4	<200	200	50	200	30	400	<9	800	<1,000	600	<30	7	.1	.03	>3	.05
5	<300	200	60	30	20	<6	<6	300	<1,000	600	<30	7	.1	.1	>2	.03
6	<600	100	70	10	30	800	<20	400	<800	800	30	9	.05	.1	>2	<.05
7	<500	<60	<20	10	<8	10	<20	200	<1,000	1,000	70	10	.06	.03	>4	<.03
8	<90	100	30	20	10	10	<20	200	<1,000	700	<30	8	.08	.1	>2	<.04
9	<400	<100	<20	10	<3	200	<40	200	<1,000	2,000	<30	10	.03	.09	>5	<.3
11	<500	90	<20	10	20	<6	<2	<30	<800	400	<30	7	.1	.08	.6	<.03
12	<700	200	30	10	<5	90	<50	500	<1,000	800	40	10	.06	.08	>4	.05
13	<700	<70	30	10	20	20	<2	500	<800	600	80	8	.04	.07	>2	<.08
14	<90	100	100	10	<6	90	<60	60	<1,000	500	100	10	.07	.04	>7	.1
15	<90	<40	50	10	10	90	<30	100	<900	400	90	10	.04	.04	>2	.05
16	<90	100	60	70	<5	20	<40	300	<2,000	1,000	<30	9	.09	.1	>3	.07
17	<70	100	50	20	20	10	<30	300	<1,000	800	<30	9	.09	.1	>4	<.07
18	<200	100	<20	20	<8	300	<10	90	<2,000	500	40	9	.06	.07	<2	<.03
20	<90	<60	300	10	40	<6	<30	600	<900	1,000	<30	7	.03	.1	>4	<.06
21	<90	90	50	20	20	100	<6	2,000	<800	800	30	5	.02	.2	>2	<.03
22	<90	<40	<20	20	<5	<6	<3	<70	<2,000	900	300	8	.04	.2	>4	<.03
23	<100	100	<20	30	20	6	<8	100	<1,000	600	<30	7	.03	.1	>2	<.03
24	<200	100	40	40	20	30	<5	500	<1,000	900	<30	7	.04	.2	>3	<.04
25	20,000	<60	<20	20	30	2,000	9	3,000	<600	700	<30	5	.02	.2	.8	<.03
26	<90	<80	40	10	20	<6	8	20	<600	400	<30	5	.01	.3	.3	<.03
27	<300	500	90	30	30	200	20	200	<600	700	<30	7	.07	.1	.7	<.06
28	<100	90	70	400	10	<6	<7	80	<2,000	700	<30	7	.09	.03	>3	<.03
29	<200	100	40	50	20	30	<10	300	<1,000	700	<30	7	.09	.2	>2	<.05
30	<200	100	70	50	20	300	<10	800	<1,000	900	<30	7	.1	.2	>3	.07
31	<90	<30	80	10	<6	200	<6	400	<1,000	800	40	8	.06	.07	>5	<.07
33	<90	90	<20	20	10	300	<5	3,000	<1,000	1,000	<30	6	.08	.1	>4	<.03
34	<300	<60	<20	20	30	2,000	<8	4,000	<2,000	1,000	<30	10	>.08	.2	>3	<.03
35	<400	<50	<20	20	<7	40	<7	700	<2,000	1,000	<30	7	>.09	.1	>4	<.03
36	<600	600	<20	30	10	<6	<30	<30	<2,000	1,000	<30	10	>.04	.07	>4	<.03
37	<200	100	30	20	10	<6	<10	100	<1,000	600	<30	8	>.1	.1	>2	<.05
38	<90	200	100	30	30	10	<40	500	<1,000	600	<30	8	>.2	.2	>4	<.09
39	<90	<80	60	20	20	9	<2	200	<900	1,000	<30	10	>.09	.2	>2	<.06
40	<400	<80	<20	20	<7	<6	<10	<40	<1,000	600	<30	7	>.04	.004	>2	<.03
41	<90	100	70	20	20	800	<2	400	<1,000	1,000	<30	8	>.06	.1	>2	<.03
43	<300	<100	<20	40	<3	<6	<90	<20	<2,000	700	<30	10	>.06	.08	>6	<.03
44	<100	<80	<20	20	30	<6	<10	<30	<1,000	400	<30	7	>.08	.02	>3	<.03
45	<90	80	40	10	10	10	<30	200	<1,000	700	70	9	>.08	.03	>4	<.03
46	<500	<30	200	6	30	10	<6	2,000	<600	2,000	<30	2	.002	ND	>7	<.03
47	<90	100	50	4	50	<6	10	<70	<600	40	<30	3	>.2	.005	.1	<.03
48	<200	100	<20	8	30	<6	<7	<40	<600	30	<30	3	>.2	.008	.1	<.03
49	<90	<80	<20	700	<3	10	<4	<50	<1,000	2,000	<30	10	>.3	.2	>4	<.03
50	<90	<30	20	300	<3	20	<30	<60	<1,000	2,000	<30	9	>.06	.2	>2	<.03
51	<100	100	60	20	<6	<6	<10	300	<2,000	900	<30	8	>.04	.2	3	<.04
52	<200	200	<20	20	30	10	10	<30	<2,000	1,000	<30	5	>.09	.003	4	<.03
53	<500	<40	30	8	20	80	<5	200	<600	200	100	7	>.04	.06	>3	<.05
55	<100	<40	<20	10	20	<6	<7	<70	<1,000	2,000	<30	10	>.04	.03	.8	<.03
56	400	<50	90	10	30	700	<20	<40	<2,000	400	<30	10	.03	.03	>2	<.03
57	<200	400	200	80	40	30	<9	400	<600	700	<30	6	>.06	.1	6	<.04
59	<90	90	50	20	20	30	<8	400	1,000	700	<30	7	>.05	.02	>3	<.03
60	<200	200	40	90	70	<6	10	<60	<600	400	<30	7	>.2	.08	.8	<.03
61	<400	<60	100	40	20	800	<6	<60	<600	700	<30	5	>.09	.05	7	<.03
62	<90	100	<20	20	20	20	<7	<20	<1,000	500	<30	6	>.1	.05	7	<.03
64	<200	800	60	100	70	<6	9	<40	<600	200	<30	6	>.3	.05	4	<.03
71	<90	<70	300	20	30	10	<30	1,000	<1,000	700	<30	7	7.05	0.09	>5	<0.05
72	<500	<40	2,000	6	20	<6	<40	<30	<1,000	300	<30	9	<0.003	.9	>5	.3
73	<700	90	100	40	20	<6	<30	100	<1,000	800	50	9	.03	.1	>3	<.06
74	<100	600	90	30	70	100	<6	<60	<1,000	200	<30	7	>.2	.06	.6	<.04
75	<400	<80	<20	60	10	<6	<3	<40	<8,000	700	<30	6	.03	.06	>2	<.03
76	<300	<30	70	30	30	8	<4	300	<2,000	3,000	<30	9	.02	.1	>4	<.03
77	<200	<40	<20	20	<8	400	<6	200	<2,000	2,000	<30	7	>.09	.2	>2	<.03
78	<500	<70	<20	20	20	20	<3	<70	<600	200	<30	7	>.08	.02	>2	<.04
79	<200	100	90	20	70	80	<9	200	<800	200	60	7	.02	.04	>2	<.04
80	<200	<60	60	20	30	<6	<6	<30	<1,000	2,000	<30	7	>.04	.1	>2	<.03
81	<300	900	20	10	10	80	<2	100	<600	800	<30	6	>.04	.1	.7	<.03
82	400	90	200	100	30	10	10	500	<800	1,000	<30	6	.006	.08	>2	<.03
83	<90	100	80	10	40	50	<2	200	<1,000	500	<30	10	.03	.1	>3	.09
84	400	90	100	60	40	<6	<10	<20	<900	1,000	<30	8	.09	.01	3	<.03
85	300	<70	90	7	60	<6	<6	<20	<600	100	<30	2	<.005	.08	.09	<.03
86	400	80	20	30	70	<6	10	<20	<600	50	<30	4	>.06	.08	.08	<.03
87	<600	<100	20	20	<7	<7	<100	5,000	<2,000	2,000	<30	10	.02	.2	>8	<.03
88	<90	<90	50	40	<4	8	<90	1,000	<1,000	4,000	<30	10	.008	.4	>8	<.05
91	<200	<30	200	20	<3	<6	40	<20	<1,000	800	<30	10	>.05	.1	.7	<.03
92	300	<70	<20	20	20	40	<20	<20	<600	1,000	<30	8	.02	.1	6	<.03
93	<200	<30	40	10	30	40	<8	<20	<1,000	3,000	<30	10	.03	.2	>2	<.03
94	500	100	400	50	80	<6	20	90	<80	700	<30	7	>.07	.7	.4	<.03
95	400	<80	700	60	90	<6	<7	<60	<600	300	<30	4	<.002	.3	.7	<.05
96	<90	90	90	20	20	40	<5	300	<2,000	600	60	9	>.09	.03	>3	<.03
97	<90	90	50	100	20	<6	<2	<80	<900	900	<30	7	>.04	.05	>2	<.03

See explanatory notes at end of table.

Table C-2.—Results of semiquantitative emission spectrographic analyses[1] of rock samples—Continued

Sample	ppm[2]										pct				
	As	B	Ba	Be	Cr	Cu	Ni	Pb	Sb	Zn	Zr	Fe	Li	Mg	Mn	Ti
100	<400	<60	50	10	<6	<6	<2	300	<1,000	500	<30	7	>.06	.05	>4	<.03
101	<200	200	80	30	60	9	<10	100	<900	200	<30	7	.03	.02	>2	<.03
103	<200	100	70	30	20	<6	<3	2,000	<700	900	<30	6	.02	.02	>3	<.03
105	<90	<80	40	100	10	<6	<7	<60	<600	800	<30	5	>.04	.01	.9	<.03
106	<90	90	30	30	30	30	<6	200	<1,000	500	<30	7	.02	.01	>2	<.03
107	<90	90	<20	10	30	<6	10	<70	<600	800	<30	6	>.07	.01	>2	<.03
108	<90	<80	30	30	30	<6	<7	100	<1,000	700	<30	6	.03	.009	>2	<.03
109	400	100	100	60	70	<6	<10	200	<1,000	500	<30	6	>.1	.03	>2	<.03
110	<100	90	100	200	30	<6	<6	100	<1,000	800	<30	7	>.1	.05	>3	<.03
111	400	<80	30	30	6	<6	<9	200	<1,000	2,000	<30	8	>.05	.02	>2	<.03
112	<100	<80	40	30	50	<6	<2	1,000	<900	2,000	<30	5	.02	.03	>3	<.03
113	400	<30	200	>1,000	30	70	<30	5,000	<900	3,000	<30	7	.02	.03	>4	<.03
114	300	<70	60	70	20	<6	<4	400	<900	2,000	<30	8	>.2	.03	>3	<.03
115	<200	100	100	50	40	<6	<3	500	<900	800	<30	7	>.1	.01	>3	<.03
116	<200	<30	100	20	<7	40	<20	2,000	<1,000	2,000	<30	7	.02	.02	>5	<.03
117	200	<50	30	10	20	<6	<5	<20	<600	600	<30	6	>.05	.02	.5	<.03
118	<100	90	40	8	80	<6	<8	<40	<800	200	40	7	>.3	.01	.4	<.03
119	300	<50	<20	<2,000	30	<6	<8	<20	1,000	400	<30	8	>.5	.03	.4	<.03
120	<200	100	50	10	60	40	9	60	<600	60	<30	4	>.2	.02	.2	<.03
121	<200	<200	30	>3,000	<3	200	<80	2,000	<2,000	5,000	<30	10	>.09	<.005	>10	<.03
122	<200	100	100	30	50	200	<9	300	<1,000	700	<30	7	>.1	.1	>2	<.03
123	<90	1,000	20	30	60	200	<7	<40	<600	300	<30	3	.01	.04	2	<.03
124	600	100	100	20	50	<6	30	<50	800	200	<30	5	>.09	.03	.3	<.03
125	400	<80	200	10	50	40	40	1,000	1,000	1,000	<30	6	.04	.04	7	<.03
126	<90	<80	30	10	20	<6	<3	<80	<600	700	<30	4	.04	02	.8	<.03
127	<90	<30	<20	<1	<3	70,000	50	6,000	<600	3,000	<30	8	<.002	.007	>2	<.03
128	<200	<30	50	5	30	80,000	<8	9,000	<1,000	2,000	<30	9	.01	.04	>3	>.04
129	<90	<60	20	20	10	2,000	<20	4,000	<3,000	1,000	<30	8	>.08	.05	>6	<.03
130	<200	100	50	20	50	70	<20	500	<600	700	<30	6	>.1	.05	>3	<.03
131	<90	<30	40	5	10	200	<20	3,000	<1,000	400	<30	9	>.05	.2	>5	<.03
132	<200	200	50	30	40	10	10	<40	<600	80	<30	3	>.2	.07	.1	<.03
133	400	200	60	200	90	40	20	100	<600	40	<30	4	>.3	.05	.1	<.03
134	400	200	80	100	60	40	10	<80	<600	20	<30	4	>.1	.05	.1	<.04
135	300	200	60	70	50	<6	10	<50	<600	70	<30	3	>.1	.05	.1	<.03
136	300	200	50	50	60	60	20	100	<600	300	<30	6	>.3	.06	.9	<.03
137	<90	200	<20	6	40	20	10	<20	<600	100	<30	5	>0.4	0.05	0.6	<0.03
138	6,000	<100	40	40	20	70	20	100	<600	1,000	<30	6	>.3	.03	.6	<.03
139	300	400	50	20	90	<6	9	<50	<600	90	<30	3	>.1	.02	.1	<.03
140	<100	500	<20	10	90	<6	10	<20	<600	70	<30	5	>.2	,02	.2	<.03
141	<90	100	<20	20	30	<6	8	<20	<600	70	<30	4	>.3	.007	.2	<.03
142	<200	100	<20	20	40	<6	7	<20	<600	20	<30	3	>.09	.004	.08	<.03
143	<200	300	<20	100	50	30	20	<60	<600	200	<30	6	>.1	.03	.7	<.03
144	<200	2,000	<20	30	20	<6	9	<20	<600	100	<30	4	>.2	.002	.2	<.03
145	<90	500	<20	400	60	40	40	<50	<1,000	200	<30	6	>.1	.04	.9	<.03
146	<100	100	100	50	50	<6	10	<30	<600	100	<30	5	>.3	.1	.5	<.05
147	400	<70	40	100	20	<6	<4	<60	<900	9,000	<30	8	>.06	.04	>2	<.03
148	500	100	40	70	60	<6	10	80	<600	300	<30	4	>.03	.02	2	<.03
149	600	100	80	20	20	<6	40	<70	2,000	40	<30	3	.02	.01	.2	<.03
151	4,000	9,000	50	>3,000	<3	30	<2	<20	<600	<1	<30	.002	<.002	.002	ND	<.03
152	700	100	60	30	30	40	20	300	3,000	200	<30	4	>.5	.02	.4	<.03
153	500	100	20	20	50	10	20	<40	1,000	50	<30	3	>.5	.01	.2	<.03
154	<200	100	<20	20	10	20	50	200	7,000	700	<30	5	>.03	.02	<2	<.03
155	400	100	70	20	20	<6	20	<30	3,000	200	<30	4	>.3	.03	.5	<.03
156	300	90	100	30	<5	7	70	90	6,000	500	<30	5	>.09	.04	>2	<.03
157	300	<80	<20	9	20	<6	30	<20	3,000	500	<30	4	.008	.007	.3	<.03
158	300	100	<20	20	10	<6	40	200	5,000	400	<30	5	>.08	.007	.6	<.03
159	400	100	100	600	20	30	60	800	7,000	900	<30	3	>.94	.02	>2	<.03
160	300	100	30	20	30	40	40	2,000	3,000	2,000	<30	5	.03	.03	>3	<.03
161	300	100	<20	200	20	100	70	1,000	7,000	3,000	<30	6	>.06	>.03	>2	<.03
162	300	90	<20	20	20	<6	40	100	5,000	400	<30	5	>.2	.01	.5	<.03
163	<90	<100	20	100	<8	100	30	6,000	5,000	4,000	<30	6	>.05	.02	>7	<.03
164	300	90	30	50	20	<6	30	90	2,000	300	<30	5	>.2	.009	.6	<.03
165	300	100	20	30	20	20	20	60	3,000	800	<30	4	.01	.02	.4	<.03
166	300	<70	80	10	20	50	20	1,000	1,000	400	<30	4	.006	.009	.9	<.03
167	400	90	50	10	30	<6	20	<20	1,000	70	<30	3	>.1	.003	.08	<.03
168	300	<80	<20	8	20	10	20	1,000	300	300	<30	3	<.002	.002	.3	<.03
169	400	100	<20	40	50	<6	20	<20	<600	20	<30	4	>.2	.003	.09	<.03
170	300	<80	<20	10	20	<6	20	<20	<1,000	100	<30	4	>.3	.005	.1	<.03
171	400	90	60	8	50	<6	20	<20	1,000	200	<30	4	>.2	.02	.1	<.03
172	400	80	60	90	30	<6	50	<50	2,000	200	<30	5	>.1	.05	.2	<.03
173	400	<60	60	<3	60	<6	40	300	<700	500	<30	4	>.1	.03	.6	<.03
174	<100	<30	80	10	<3	200	100	300	<3,000	1,000	<30	10	>.3	.1	>7	<.03
175	400	<70	40	9	40	<6	60	<40	2,000	500	<30	6	>.08	.05	.5	<.03
176	300	<70	50	10	40	<6	20	<20	900	200	<30	4	>.2	.02	.1	<.03
177	400	<50	200	200	20	<6	20	1,000	<600	1,000	<30	3	<.004	.02	.5	<.03
178	400	<80	200	10	50	40	40	1,000	1,000	1,000	<30	6	>.04	.04	.7	<.03
179	<100	100	30	10	40	30	20	200	<600	800	<30	5	>.09	.02	>2	<.03
180	<200	90	40	100	50	90	20	200	<600	600	<30	6	>.2	.06	>3	<.03
181	<200	100	<20	20	30	100	10	<60	<600	100	<30	4	>.2	.07	.2	<.03
182	<90	<70	<20	10	10	10	<2	500	<700	1,000	<30	5	>.04	.02	>2	<.03
183	90	<60	100	8	10	70	<20	900	<800	800	<30	8	>.09	.07	>3	<.04

ND Not detected.

[1] Au, Cd, Co, Ga, Mo, P, Pd, Pt, Sc, Ta, V, and Y sought but not detected.

[2] Originally reported in percent

NOTE.—No data available for samples 65 through 70, other gaps in sample numbers correspond to samples listed in table 1 of the main text or table A-1 of appendix A.

APPENDIX D.—RESULTS OF ANALYSES AND CALCULATED TIN GRADES OF PLACER SAMPLES COLLECTED ALONG NORTH FORK PREACHER CREEK

Sample	Analysis, ppm						Weight, g	Volume, yd^{3}	Sn grade, lb/yd^{3}	Remarks
	Cb	Ce	Sn	Ta	W	Y				
A	69	3,500	5,400	7	340	310	20.24	0.375	0.0006	10-ft-high cutbank in older outwash.
B	68	3,100	5,100	8	430	300	18.63	.247	.0008	Possibly slumped, older outwash.
C	76	3,900	6,700	LD	520	355	20.45	.175	.0017	5-ft-high cutbank, older outwash(?), or possibly recent stream channel.
D	110	6,200	14,000	12	945	530	16.25	.225	.0022	5 ft of gravels beneath approx. 15 ft of muck, older outwash.
E	150	9,700	16,000	14	1,395	^{1}750	17.81	.225	.0028	3 ft of gravels beneath approx. 15 ft of muck, older outwash.
F	110	7,000	11,600	23	900	625	19.81	.384	.0013	3-ft-high cutbank in older outwash.
I	150	>10,000	^{2}2.67	37	1,350	^{1}1,000	19.39	1.00	.0011	3-ft-high cutbank in recent gravels. Concentrated with jig.
J	120	6,200	20,000	33	1,125	510	18.99	^{2}.50	.0017	3-ft-cutbank in recent stream gravel bar. Concentrated with jig.
K	150	>10,000	^{2}7.25	50	>2,000	885	19.39	1.00	.0031	3-ft-high cutbank in older(?) outwash. Sampling of tailings indicate this sample probably only represents 62 pct recovery. Concentrated with jig.
L	I	>10,000	^{2}6.54	42	>2,000	1,135	20.49	.388	.0076	12-ft-high exposure of gravels, probably remnant of older outwash.
N	I	>10,000	9,800	24	>1,170	1,265	16.97	.150	.0024	Either older outwash or recent stream gravels.
O	16	445	750	LD	25	67	19.03	.150	.0002	Gravel bar in recent active stream gravels.
P	I	>10,000	10,000	26	>2,000	1,150	18.68	.188	.0022	3-ft-high cutbank in more recent outwash.
Q	120	8,700	14,000	11	1,550	^{1}750	18.65	.125	.0046	Do.
R	I	9,800	6,300	11	1,530	1,270	12.24	.175	.0014	Do.
S	I	>10,000	2,900	34	540	3,055	25.8	.200	.0004	Cutbank in fan gravels.
U	180	NA	^{2}1.75	LD	1,470	NA	16.39	.180	.0050	Recent gravels concentrated with 5-ft long sluice box.
V	I	>10,000	7,800	20	1,395	2,310	18.62	.175	.0016	Lateral moraine(?), 10-ft-high-cutbank (older than recent outwash).
W	135	9,600	^{2}4.87	23	>2,000	600	20.59	.213	.0094	5-ft-high cutbank in more recent outwash. Probably a poor sample.
X	67	3,300	8,300	9	1,800	225	19.63	.200	.0019	2-ft-high cutbank in more recent outwash. Probably a poor sample.
Y	I	8,100	2,100	10	1,125	1,320	18.27	.150	.0006	Base of 15-ft-high cutbank in recent outwash gravels(?). Probably large dilution from colluvium.
Z	I	915	400	9	50	^{1}200	29.7	.050	.0003	2-ft cutbank in alluvial fan(?) gravel.
DD	NAp	NAp	^{2}4.80	NAp	NAp	NAp	29.70	.080	.0400	Small alluvial (outwash?) gravel bench. Sample concentrated with 5-ft-long sluice box.

I Not detected because of interference with Zr. LD Less than detection limit. NA Not analyzed. NAp Not applicable.

[1] Interference noted because of Zr.

[2] Percent.

[3] Approximate only.

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