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Tin Reconnaissance of the Kanuti and Hodzana Rivers Uplands, Central Alaska

By James C. Barker and Jeffrey Y. Foley

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
Donald Paul Hodel, Secretary

BUREAU OF MINES
Robert C. Horton, Director

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment 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 has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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PREFACE

This is one of a series of Bureau of Mines reports that present the findings of reconnaissance-type mineral assessments of certain lands in Alaska. These reports include data developed by both industry and government studies.

Assessing an area for its potential for buried mineral deposits is a difficult task because no two deposits are identical. Moreover, judgments prior to drilling, the ultimate test, frequently vary among evaluators and continue to change as a result of more detailed studies.

Included in these reports are estimates of the relative favorability for discovering mineral deposits similar to those mined elsewhere. Favorability is estimated by evaluation of outcrops, and analyses of data, including mineralogy, geochemistry, and evaluation of rock-forming processes that have taken place. Related prospects and the environment in which they occur are subjectively compared to mineral deposits and environments in well-known mining districts. Recognition of a characteristic environment allows not only the delineation of a trend but also a rough estimate of the favorability of conditions in the trend for the formation of minable concentrations of mineral materials.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	mi^2	square mile
ft^2	square foot	mm	millimeter
ft^3	cubic foot	pct	percent
g	gram	ppm	part per million
in	inch	yd^3	cubic yard
lb	pound	yr	year
lb/yd^3	pound per cubic yard	wt pct	weight percent

TIN RECONNAISSANCE OF THE KANUTI AND HODZANA RIVERS UPLANDS, CENTRAL ALASKA

By James C. Barker[1] and Jeffrey Y. Foley[2]

ABSTRACT

The Bureau of Mines evaluated the tin development potential of the uplands between the Kanuti and Hodzana Rivers from 1978 through 1980. Chemical and petrologic data indicate that local granitic intrusions are generally similar to "tin granites" that contain tin deposits elsewhere.

The tin mineral cassiterite (SnO_2) was identified in chlorite-rich greisen from the Sithylemenkat pluton. Greisen zones are located near the intersections of high-angle, linear structural features, and samples contain up to 0.23 pct Sn. One bedrock exposure of greisen is 10 to 15 ft wide.

Although some lode mineralization is present, the deeply eroded nature of the region suggests larger tin-bearing cupolas may have existed prior to erosion. Extensive stream gravel deposits have not been affected by glaciation, and potential exists for placer tin deposits. Especially favorable is a large semiclosed basin drained by the Kanuti Kilolitna River. Heavy mineral concentrates collected from surface alluvium in the Kanuti Kilolitna River valley contained up to 51.2 pct Sn (0.02 to 0.4 lb/yd^3 Sn), up to 5 pct W, up to 0.4 pct Cb(Nb), and up to 0.1 pct Ta. The concentration of heavy minerals is expected to increase with depth. Detailed mapping and extensive surface and subsurface sampling will be needed to quantify the mineral development potential of the lode and placer tin deposits in the uplands.

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INTRODUCTION

The Bureau of Mines investigated tin and associated metals in the Kanuti and Hodzana Rivers uplands as part of a program to assess the mineral development potential of critical and strategic minerals in Alaska. (The area studied is shown in figure 1.) The initial investigations were authorized and partially funded by the Bureau of Land Management (BLM) to improve the mineral data base needed to develop management plans for the Trans-Alaska pipeline corridor and adjacent lands. Because the United States relies on imports of tin, and because tin is essential to industry, tin is of critical and strategic importance.

Alaska has produced tin in the past and currently produces small amounts from placer deposits. Geochemical tin anomalies in the Kanuti and Hodzana Rivers uplands were originally reported by the Alaska Department of Natural Resources (*10*)[3] and were later reported by the U.S. Geological Survey (USGS) (*17*) and the Bureau of Mines (*2*). Sources of the tin anomalies were not located during these studies, and further investigations were recommended. (More details of these and other previous studies are included in the "Previous Work" section.)

The investigation reported here was initiated in 1978 and included a literature search followed by geologic mapping and sampling of surface exposures of both lode and placer tin occurrences. Field mapping was done during the field seasons of 1978 and 1979. Samples were collected for petrographic study and to determine chemical compositions of associated granitic plutons. Owing to logistical and personnel constraints, the investigation was largely limited to the Sithylemenkat pluton area. Because no drilling or subsurface sampling was done, the data presented in this report are not sufficient to completely assess the mineral development potential of the area.

ACKNOWLEDGMENTS

The Bureau of Land Management funded the early phases of this investigation. The U.S. Department of Energy, through the Bendix Field Engineering Corp., Grand Junction, CO, and the Los Alamos (NM) Scientific Laboratory, provided neutron activation, fluorometric, emission spectrographic, and X-ray fluorescence analyses of rock samples collected by the Bureau of Mines. Staff geochemists K. Stablien and W. Averett of Bendix supervised the analytical procedures on behalf of the Bureau of Mines. K. Clautice, geologist, formerly with the Bureau of Mines, Fairbanks, AK, conducted field studies in 1978. M. McDermott, geologist, also formerly with the Bureau in Fairbanks, directed the 1979 field work.

STUDY AREA

LAND STATUS AND OWNERSHIP

This report concerns lands in and adjacent to the 12- to 24-mile-wide Trans-Alaska Pipeline corridor that parallels the Dalton Highway (fig. 1). The corridor is presently under Federal management according to Public Land Order 5150, but is being considered for transfer to State ownership. Lands east of the corridor are designated as part of the Yukon Flats National Wildlife Refuge. The northern portion of the Kanuti and Hodzana River uplands west of the corridor is part of the Kanuti National Wildlife Refuge. To the south, the refuge is partially overlapped by unresolved Alaska Native selections. The land ownership pattern of the study area is likely to change in the near future as Native and State land claim entitlements are adjudicated.

LOCATION AND ACCESS

The uplands between the Kanuti River and the Hodzana River drainage systems are 100 to 140 miles northwest of Fairbanks. Except where accessible from the Dalton Highway (fig. 1), the area is best reached by helicopter or float plane.

PHYSIOGRAPHY AND CLIMATE

The uplands between the Hodzana and Kanuti Rivers are maturely eroded and are characterized by extensive alluvial gravel deposits in broad, terraced valleys with meandering streams that drain rounded hills. Outcrops are scarce. A generally treeless mat of vegetation covers all but the steepest terrain. The region is reported by Pewe (*20*) to be underlain by discontinuous permafrost. Alluvial deposits at these latitudes, however, are commonly frozen to depths of 100 to 400 ft.

There is no evidence that glaciation has significantly affected the uplands area or has been a factor in the formation and preservation of placer deposits. Pleistocene ice advances described by Hamilton (*9*) may have approached from the northwest, but the extent of glaciers or ice sheets is uncertain. They are not believed to have extended southeast of Sithylemenkat Lake. Some cirque and valley glaciation occurred in the Ray Mountains to the south of the study area, but studies by Yeend (*24*) indicate that the glaciers did not extend beyond the foothills.

Climate in the study area is arctic continental. The effective season for geologioc investigations extends from mid-May through late September.

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

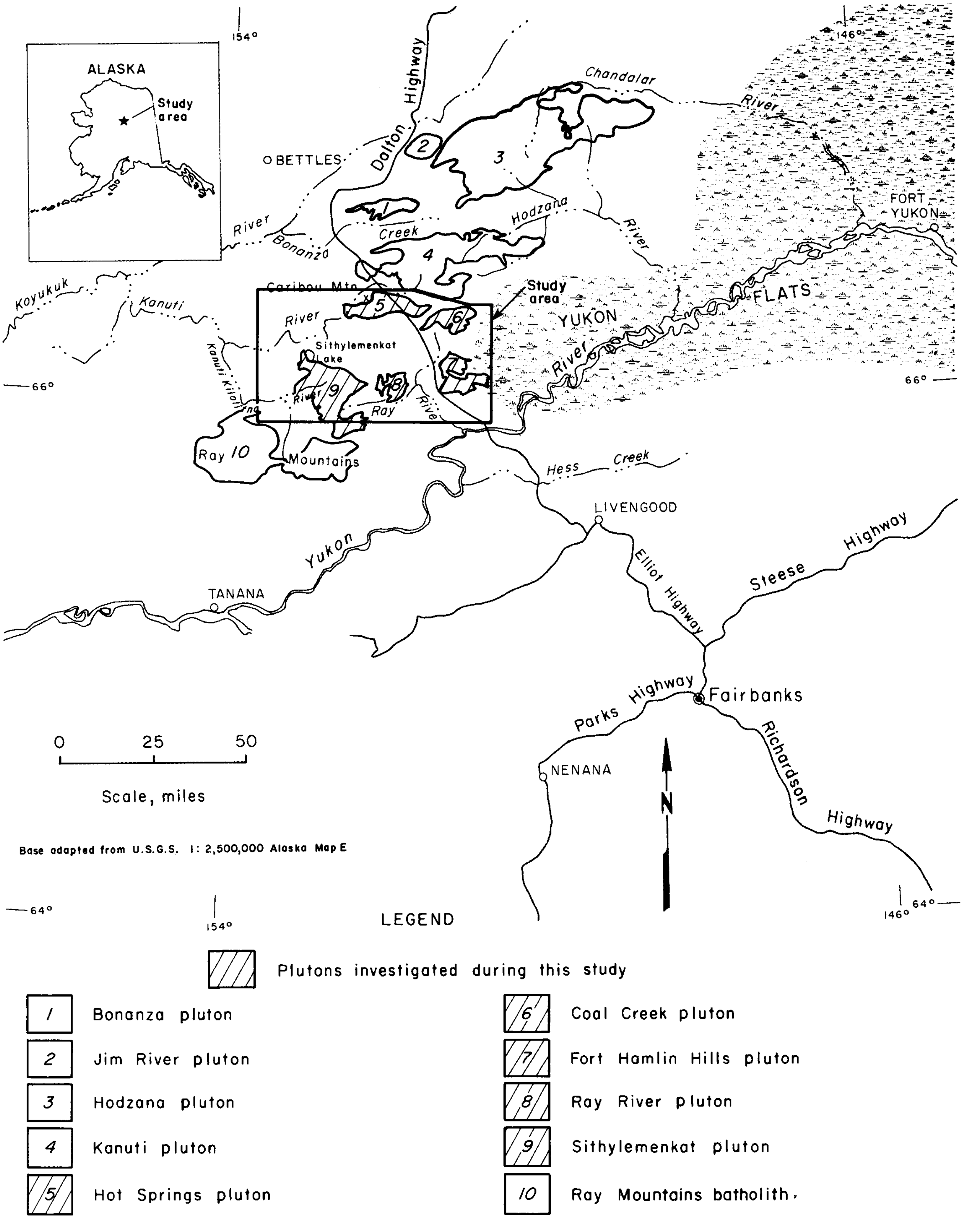


FIGURE 1.—Location of study area and granitic plutons in central Alaska.

PREVIOUS WORK

In 1963, a Bureau of Mines field crew observed an occurrence of topaz, lithium, and radioactive yttrofluorite a short distance south of the study area. These minerals are frequently associated with lode tin deposits. The first known mention of tin in the area was in an Alaska Department of Natural Resources report published in 1969, in which Hereid (*10*) reported that 10 granite samples from the Sithylemenkat pluton contained a mean of 32 ppm Sn, which is several times the normal trace-element background of tin in granitic rocks. In a 1970 USGS report, Patton and Miller (*17*) reported anomalous tin values in stream sediment (up to 300 ppm Sn) and in two geochemical rock samples (20 and 70 ppm Sn) from the Sithylemenkat pluton area; they recommended further investigation for lode and placer tin deposits. In 1973, the USGS released reconnaissance-scale (1:250,000) geologic maps and results of geochemical sampling in the Bettles and Southern Wiseman Quadrangles by Patton and Miller (*18-19*). Also in 1973, the USGS published the results of an aeromagnetic survey of the eastern Bettles Quadrangle (*23*). In 1978 and 1979, the Bureau collected 514 heavy-mineral panned concentrates (*2*) and found anomalous tin values in and southwest of the Sithylemenkat pluton area, near the westernmost part of the Hot Springs pluton, and northwest of the Fort Hamlin Hills pluton.

GENERAL GEOLOGY

The Kanuti and Hodzana Rivers uplands are underlain by crystalline rocks, including pelitic schists, quartzites, and phyllites of probable Paleozoic age (*18*). These rocks are intruded by five principal composite plutons: the Sithylemenkat, Ray River, Fort Hamlin Hills, Coal Creek, and Hot Springs plutons. All are composed primarily of biotite granite and biotite quartz monzonite, with minor quartz diorite and rhyolite porphyry.

A Cretaceous age is indicated for the plutons on the basis of available potassium-argon age determinations. Biotite from the Kanuti pluton immediately north of the study area (fig. 1) has been dated at 90.6 ± 6 million yr (*6*). Biotite from the Hodzana pluton, located approximately 30 miles north of the study area, has been dated at 101 ± 5 million yr (*5*). An age of 106 ± 3 million yr has been determined for biotite from the Sithylemenkat pluton (*18*). Radiometric ages are not available for the younger rhyolite porphyry that locally intrudes the granitic plutons.

PLACER INVESTIGATIONS

SAMPLING METHODS

Alluvial samples were shoveled from stream bars and cutbanks; cutbanks were preferentially sampled whenever possible. After they were measured and screened, the samples were sluiced with a regulated water flow and further reduced by panning. To compensate for the natural swell of loose, excavated material, the measured sample volumes were multipled by 0.80.

Extensive tundra cover, flood-washed coarse sand, and a lack of cutbank gravel exposures are characteristic of the study area. In some places, the only gravel exposures were under standing or flowing water. Consequently, some of the samples were collected with a floating gasoline-powered suction dredge with a 5-in-diam intake. This sampling method was chosen because the equipment is portable and is capable of processing a large volume of gravel from below the water. Dredge sample volumes were estimated by measuring the resultant cone-shaped excavation. Suction dredge recovery efficiency can only be qualitatively assessed; an unknown amount of concentrate probably was lost owing to the turbulent flow of unsized material over the sluice. Where this method was used, the tin recovery results are considered to be conservative.

The heavy-mineral samples were further prepared for analyses by heavy liquid and magnetic separation. Bromoform (2.85 specific gravity) was used to float the light-mineral fractions. The heavy fraction was then separated into magnetic and nonmagnetic fractions. Both the magnetic and nonmagnetic fractions were weighed, and the nonmagnetic fractions were analyzed for tin, tantalum, columbium (also called niobium), cerium, thorium, and tungsten by energy-dispersive X-ray fluorescence spectrometry.

SITHYLEMENKAT PLUTON AREA

The initial reconnaissances by the Bureau in 1978 and 1979 (*2*) indicated that the tin minerals are concentrated in alluvial gravels in the upper forks of the Kanuti Kiloitna River. Subsequent work has shown that placer samples (figs. 2-4) taken near the surface contain up to 0.4 lb/yd^3 Sn and lesser amounts of tantalum, columbium, tungsten, and rare-earth elements (tables 1 and 2).

Based on the sampling results, the grade of placer gravels is expected to increase with depth. A higher grade at depth is indicated at sample location 5 (samples 5a-5b), where gravel from 0- to 2-ft depth contained 0.025 lb/yd^3 Sn, whereas gravel from 2- to 3-ft depth contained 0.076 lb/yd^3 Sn. A similar relationship was observed at sample location 2. (See samples 2a-2b in table 1.)

The heavy-mineral content of surface samples varied markedly among closely spaced samples. Differences appeared to be related to the degree of washing during periodic floods. Generally, samples collected from compacted silt and clay-bound gravel in cutbanks and stream beds contained more tin. Gravel bars composed of fine, very loose, flood-deposited gravel with little silt and clay binder typically contained less heavy-mineral material. For example, at sample location 16, loose gravel on the right limit of the stream contained only 0.006 lb/yd^3 Sn, whereas silty gravel from the opposite cutbank contained 0.101 lb/yd^3 Sn. A sample of the intervening stream bed with more silt and clay contained 0.201 lb/yd^3 Sn.

The principal tin-bearing drainage in the Sithylemenkat pluton area (fig. 2) is the east fork of the Kanuti Kilolitna River. This 10-mile-long tributary drains approximately one-third of the known areal extent of the Sithylemenkat pluton. Extensive alluvial deposits have accumulated along

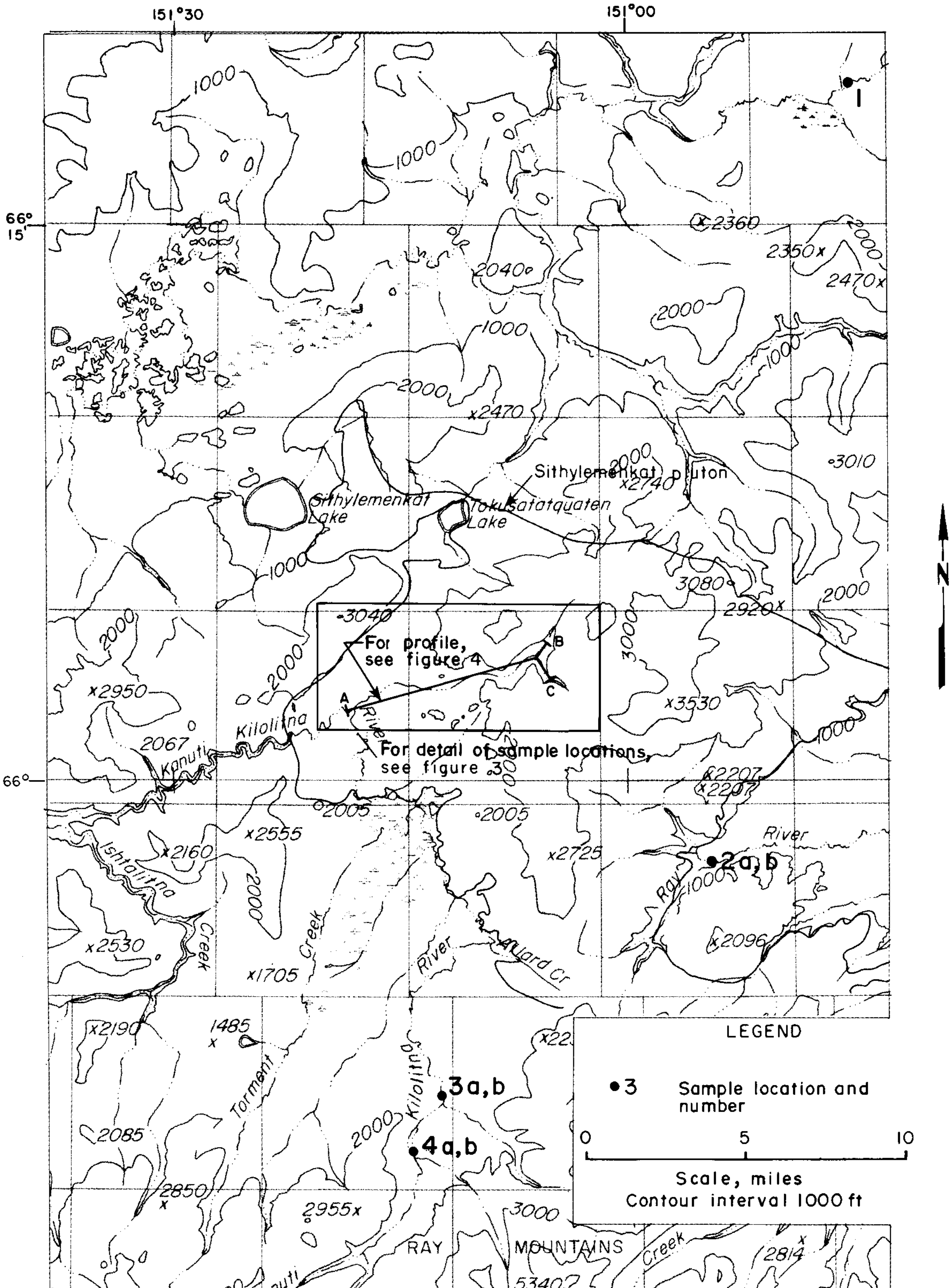


FIGURE 2.—Location of concentrated placer samples.

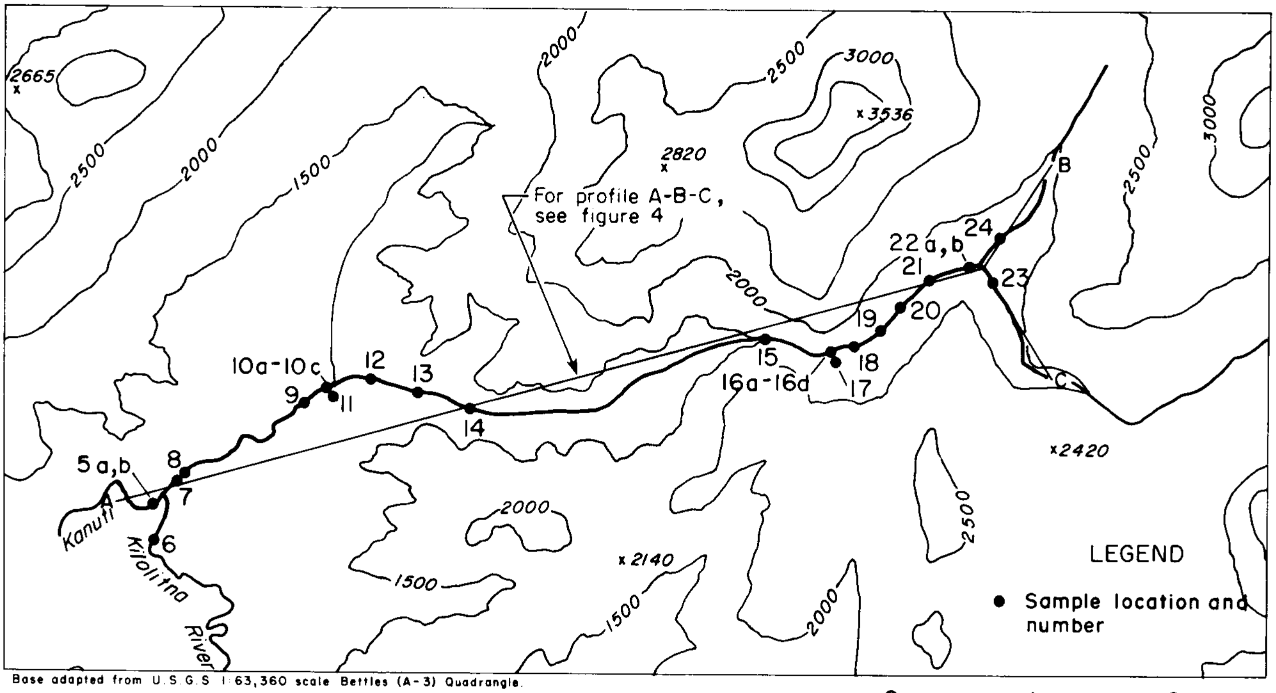


FIGURE 3.—Detail of sample locations on east fork of Kanuti Kilolitna River.

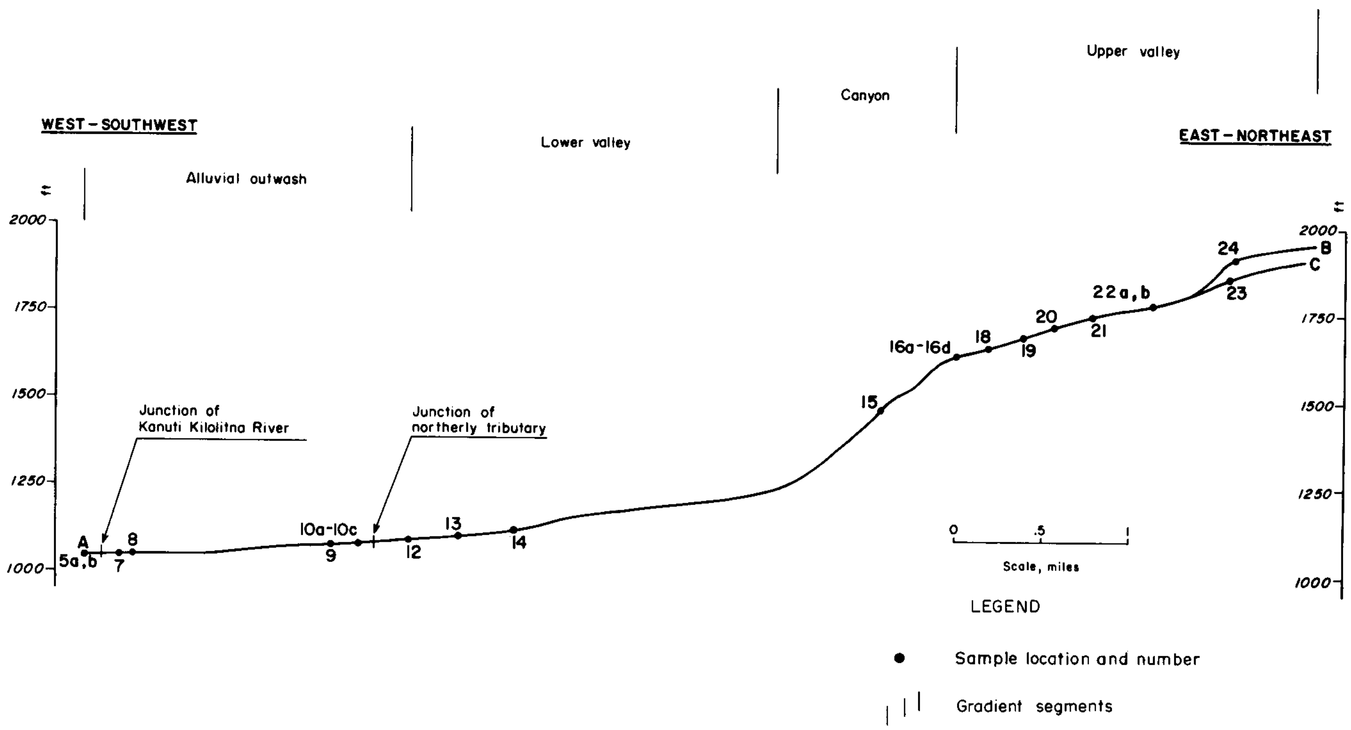


FIGURE 4.—Steam profile of east fork of Kanuti Kilolitna River.

Table 1.—Tin analyses, weights, and volumes of placer concentrate samples

(Samples are located by number in figures 2-4.)

Sample	Volume, ft³			Concentrate, g		Sn, pct	Sn in original vol, lb/yd³	Sampling method and remarks
	Original	Minus 5 in	Minus 0.25 in	Nonmagnetic	Magnetic			
1	NA	5.1	NA	63.36	3.78	0.7	[1]0.005	Shoveled from active channel, concentrated in 8- by 30-in portable sluicebox.
2a	[2]49.0	NA	NA	134.03	15.84	5.1	.008	Suction dredge sample from active channel; from caisson between 0- to 5-ft depth in gravel.
2b	[2]9.5	NA	NA	45.93	4.21	5.4	.015	Suction dredge sample from caisson between 5- to 7-ft depth in gravel at same location as 2a.
3a	[2]9.0	NA	NA	26.67	3.80	13.9	0.25	Suction dredge sample from active channel along river.
3b	[2]18.0	13.40	3.48	67.31	8.96	9.2	0.20	Suction dredge sample on active gravel bar with many medium-size boulders.
4a	[2]19.6	NA	NA	79.49	16.46	10.6	.026	Suction dredge sample from gravel bar along Kanuti Kilolitna River; cobbly gravel with boulders to 12-in diam; contains well-sorted gravel-silt fraction; cassiterite nuggets noted.
4b	7.22	NA	2.41	45.16	5.20	4.3	.016	Shoveled from opposite side of gravel bar where 4a collected; screened and processed through 12- by 36-in sluicebox.
4c	[2]1.5	NA	1.34	21.60	.60	8.2	.081	Shoveled from 5-ft-deep pit in dry stream channel about 250 ft west of river bank, gravel uncompacted and appeared deposited by river flooding. Sample processed in 12- by 36-in sluicebox.
5a	[2]28.0	NA	NA	93.50	.28	12.8	.025	Suction dredge sample from depth of 0 to 2 ft in active channel of Kanuti Kilolitna River.
5b	[2]5.0	NA	NA	84.71	.36	8.2	.076	Suction dredge sample from depth of 2 to 3 ft in hole excavated for 5a.
6	NA	5.06	NA	38.35	.27	4.5	[1].018	Shoveled from active channel and concentrated in 8- by 30-in portable sluicebox.
7	NA	6.75	NA	89.63	.38	51.2	[1].404	Do.
8	[2]15.0	NA	NA	197.79	.33	37.7	.29	Suction dredge sample from edge of active channel; mostly sand and cobbles; a few boulders.
9	NA	.93	.46	5.01	.04	26.2	[1].084	Shoveled from channel center; concentrated by hand panning.
10a	[2]7.24	NA	NA	199.93	0.52	22.5	0.369	Suction dredge sample from main channel; cobbles in creek to 14-in diam; most coarse material 2- to 3-in diam; fines are decomposed granite sand.
10b	7.70	NA	4.06	128.13	.43	13.2	.131	Shoveled from creek bank, approximately 4 ft below tundra level; processed in 12- by 36-in sluicebox.
10c	2.14	NA	1.04	102.38	.09	7.6	.216	Located on left limit stream bank; sample shoveled from gravels immediately under 3 ft of muck and tundra; processed in 12- by 36-in sluicebox.
11	.80	NA	.47	18.56	.02	2.54	.035	Shoveled from edge of left limit alluvial bench, 500 ft from present main channel; concentrated in 12- by 36-in sluicebox.
12	NA	1.08	46	6.70	.01	11.2	[1].041	Shoveled from channel center; concentrated by hand panning.
13	NA	.93	.46	26.90	.04	23.3	[1].041	Do.
14	NA	.93	.46	33.24	.07	11.5	[1].244	Do.
15	NA	.93	.46	5.28	.03	12.5	[1].042	Do.
16a	5.56	NA	1.92	5.28	.03	10.6	.006	Shoveled from active flood-washed gravel bar near right limit bedrock bank; concentrated in 12- by 36-in sluicebox.
16b	4.28	NA	1.92	13.56	.06	15.7	.030	Shoveled from active gravel bar in main channel; concentrated in 12- by 36-in sluicebox.
16c	[2]24.20	NA	NA	222.62	.44	36.8	.201	Suction dredge sample from streambed of the active channel.
16d	7.27	NA	3.85	73.11	.90	16.8	.101	Shoveled from base of left limit cutbank, approximately 7 ft below tundra level; concentrated in 12- by 36-in sluicebox; gravel contains higher silt fraction than observed elsewhere.
17	1.4	NA	NA	12.34	.01	0.3	.002	Shoveled from upper alluvial bench approximately 150 ft from stream; sample was dry, friable, and composed mostly of silt and some gravel.

See explanatory notes at end of table.

Table 1.—Tin analyses, weights, and volumes of placer concentrate samples—Continued

Sample	Volume, ft³ Original	Minus 5 in	Minus 0.25 in	Concentrate, g Nonmagnetic	Magnetic	Sn, pct	Sn in original vol, lb/yd³	Sampling method and remarks
18	NA	0.77	0.46	1.56	0.01	8.5	[1].010	Shoveled from channel center; concentrated by hand panning.
19	NA	.93	.46	7.17	.01	22.3	[1].102	Do.
20	NA	.62	.46	9.33	.07	39.4	[1].353	Do.
21	NA	.93	.46	17.13	.81	33.7	[1].369	Do.
22a	[2]5.0	3.64	1.40	47.60	.06	24.5	.139	Located on right limit of stream; sample shoveled and sluiced from bank approximately 4 ft below tundra level; gravel somewhat iron stained.
22b	[2]59.5	NA	NA	478.80	10.40	39.9	.191	Suction dredge sample from midchannel at 22a.
22c	[2]7.0	4.71	1.40	69.57	.10	(3)	(3)	Located on left limit, occasional boulders up to 4-ft diam; samples shoveled and sluiced from bank approximately 6 ft below tundra level.
23	NA	5.5	NA	102.31	.29	36.1	[1].399	Shoveled from active channel; concentrated in 8- by 30- in sluicebox.
24	NA	3.04	NA	9.41	.04	41.9	[1].077	Do.
(4)	NA	5.5	NA	58.51	7.48	.1	[1].001	Sample shoveled from granitic terrane as a check on regional background Sn concentrations; sluiced in 8- by 30-in sluicebox.

NA Not available, owing to method of sample recovery used.
[1]Calculated on the basis of the minus 5-in volume, because sampling recovery method did not permit accurate measurement of in-place volume.
[2]Estimated.
[3]Data lost owing to computer failure.
[4]Not shown on accompanying maps; sample from approximately 4.7 miles east of Dalton Highway in T 19 N, R 14 W, section 13.

NOTE.—Analyses by semiquantitative X-ray fluorescence spectrometry by the Bureau's Juneau (AK) laboratory.

Table 2.—Semiquantitative X-ray fluorescence spectrometry analyses of trace elements in nonmagnetic fraction of placer concentrates,[1] percent

(Samples are located by number in figures 2-4.)

Sample	Cb	Ce	La	Ta	Th	W	Sample	Cb	Ce	La	Ta	Th	W
1	ND	0.44	0.24	0.02	0.11	ND	12	0.30	3.30	1.70	0.07	1.10	1.20
2a	ND	1.58	.86	.04	.51	0.48	13	.30	3.50	1.90	.10	1.20	3.40
2b	ND	1.10	.56	.03	.48	.33	14	.30	3.60	1.90	.06	1.20	2.30
3a	0.13	2.70	1.44	.004	.10	.15	15	.30	4.10	2.30	.06	1.50	2.30
3b	.27	2.35	1.09	.07	.96	1.86	16a	ND	3.72	1.95	.08	1.36	2.08
4a	ND	2.03	1.10	.04	.58	.78	16b	.27	3.30	1.80	.06	.10	2.31
4b	.13	2.18	1.17	.01	.07	.52	16c	ND	1.81	.92	.08	.56	3.55
4c	ND	2.90	1.58	.04	1.22	1.39	16d	.21	2.93	1.68	ND	.09	2.72
5a	.33	2.92	1.41	.07	.79	1.43	17	ND	4.75	2.73	.01	1.28	.23
5b	.20	2.10	1.10	.08	.70	.20	18	.30	2.20	1.20	.05	.90	1.80
6	.11	.39	.21	.04	.08	.05	19	.40	2.90	1.50	.10	1.00	3.30
7	.23	.90	.46	.11	.02	.58	20	.30	1.50	.80	.10	.60	4.40
8	ND	.79	.39	.08	.31	.96	21	.30	2.20	1.10	.10	.70	4.80
9	.30	2.30	1.20	.08	.80	1.90	22a	ND	2.60	1.30	.08	.80	2.56
10a	ND	1.08	.56	.04	ND	.77	22b	ND	1.50	.78	.11	.53	4.30
10b	ND	2.59	1.37	.07	.77	1.08	23	.34	2.22	1.05	.08	.64	4.03
10c	ND	3.90	2.10	.05	1.25	.93	24	.24	1.00	.47	.10	.40	2.71
11	ND	.61	.31	.04	.11	ND	(2)	.12	.31	.16	.03	.12	ND

ND Not detected; actual value below detection limit.
[1]Analyses were performed on the minus 14-mesh nonmagnetic concentrate by the Bureau's Juneau (AK) laboratory.
[2]Not shown on accompanying maps; sample from approximately 4.7 miles east of Dalton Highway in T 19 N, R 14 W, section 13.

its lower course. Cassiterite, the only tin mineral identified in the area, is a major component in heavy-mineral fractions from the Kanuti Kilolitna River (based on identification by x-ray diffraction and petrographic methods, using a random suite of samples–samples 1, 6, 7, and 23-24, as listed in table 1). Cassiterite was found as nuggets ranging in size up to 0.75 in across and varying in color from mostly black to, less commonly, gray and brown. Larger nuggets that may have been present would have been lost during screening or sluicing of the sampled material. However, the cassiterite grains generally did not exceed the size of course sand. Nugget loss, if it occurred at all, probably was not significant.

The concentrated heavy-mineral samples also commonly contained fragments of greisen with finely disseminated sulfide minerals and cassiterite. Although some pieces of greisen contained minor magnetite, the greisen fragments were found in the nonmagnetic fraction. Because of its lower specific gravity, most greisen material generally was not recovered in the heavy-mineral concentrates. Placer concentrates examined petrographically and by X-ray diffraction (samples 1, 6-7, and 23-24) also contained variable amounts of wolframite, pyrite, ilmenite, hematite, garnet, monazite(?), and lesser unidentified heavy minerals. The wolframite mineral in sample 23 was identified as ferberite, and traces of scheelite were observed by ultraviolet fluorescence in samples 7, 23, and 24. Generally, magnetite grains are sparse in the Sithylemenkat area (table 1) and comprise less than 0.5 wt pct of most concentrates. All of the concentrates in table 1 were visually examined; no gold and only trace amounts of scheelite were observed.

Four gradient segments of the east fork of the Kanuti Kilolitna River were sampled. (See profile A-B-C in figure 4.) The first segment, shown in figure 5, is the lower end of a broad alluvial outwash deposit. The outwash deposit is ap-

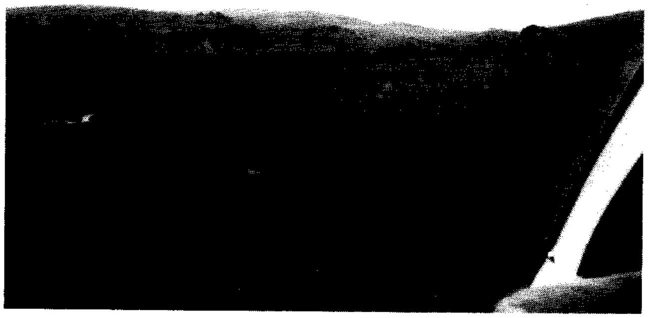


FIGURE 5.—Broad, alluvial outwash valley of east fork of Kanuti Kilolitna River.

proximately 0.25 mile wide and is bordered by terraced alluvial deposits. This lower segment contains the largest alluvial gravel deposits within the east fork valley and yielded some of the higher tin values (up to 0.404 lb/yd^3 Sn, from sample 7). The second gradient segment is a generally well-rounded valley with local bedrock constrictions in the lower portion and gravel terraces along the midsection to upper section. Samples from the lower portion (of the second segment) also contained significant tin values (samples 13-14). The third segment is a more steeply inclined canyon with numerous boulders and little sediment accumulation. Although tin was found in samples (samples 15 and 16a-16d), the lack of alluvial gravel deposits precludes potential for placer reserves. Lastly, the fourth, upper-valley segment is well-rounded and terraced, but is considerably narrower than the lower valley. Samples collected in this segment generally contained 0.1 to 0.4 lb/yd^3 Sn. The difference in tin content between the two upper forks (0.077 lb/yd^3 Sn in sample 24 and 0.399 lb/yd^3 Sn in sample 23) is coincident with the occurrence of greisen veins within the area drained by the southern fork (sample 23).

Two placer samples, 2a and 2b (fig. 2), were collected from a single location on the upper Ray River immediately downstream from the southeasterly margin of the Sithylemenkat pluton. Only minor concentrations of tin (0.008 to 0.015 lb/yd^3 Sn) were found; however, the only gravels available for sampling were well sorted and lacked a fine sediment fraction. Consequently, the relatively low tin values may or may not indicate a lack of significant placer tin at depth in the alluvium.

NORTHERN RAY MOUNTAINS AREA

The Ray Mountains, another possible source of tin located south of the study area, are underlain by a deeply eroded granitic batholith of the same name (figure 1, location 10). North-flowing streams, such as the south fork of the Kanuti Kilolitna River, have reworked and deposited alluvial and glaciofluvial granitic sediments beyond the foothills of the Ray Mountains and within the study area (fig. 1). Sample sites 3 and 4 (fig. 2) were selected because they are areas of slightly reduced stream gradient with a corresponding widening alluvial plain. To the south, the river is swift and turbulent and generally occupies a single channel, but braided sections occur locally where the gradient abruptly decreases. Beyond the foothills (north of sample location 3 in figure 2), the gradient decreases, and the river becomes a meandering stream.

Although the tin content in the gravels of the south fork of the Kanuti Kilolitna River was lower (not exceeding 0.08 lb/yd^3 Sn) than that encountered on the river's east fork, the south fork gravels appeared to be considerably deeper and occupied a much wider river plain (varying from 0.25 to 1 mile in width). Consequently, surface gravels are subject to reworking by migrating channels, and dilution occurs from other gravel sources. The heavy-mineral fraction would be expected to be more highly concentrated at some depth below the active streambed, and surface samples would only contain relatively low tin concentrations. For this reason, drilling or trenching is needed to further locate and assess cassiterite concentrations in the northern Ray Mountains area.

INVESTIGATION OF GRANITIC PLUTONS

SAMPLING METHODS

Granitic plutons within the study area (fig. 1) were investigated as potential hosts for tin deposits. Cassiterite-bearing float was found in the Sithylemenkat pluton area, and subsequent investigations identified several rubble exposures of tin greisen. The chemistry of the other plutons was compared with the chemistry of the Sithylemenkat pluton and well-known Australian tin granites to determine if the studied plutons are favorable for tin deposits.

Rock samples were collected for petrographic examination and major-oxide and trace-element analyses (Appendix A). Major-oxide samples were chipped from relatively unweathered, frost-riven boulders over areas of at least 1,000 ft^2. Samples collected for trace-element analyses consisted of random chips collected within a few feet of the sample station (unless otherwise noted in Appendix A). The descriptions of the samples listed in Appendix A were taken from field notes that were supplemented in some cases by thin-section examination.

Sample analyses were provided by the U.S. Department of Energy (DOE) under an agreement with the Bureau of Mines. Analyses for beryllium and lithium were performed by emission spectrography. X-ray fluorescence was used for arsenic, silver, bismuth, cadmium, copper, columbium, nickel, lead, tin, tungsten, and zirconium analyses. Neutron activation with a short time delay before analysis was used for barium, chlorine, manganese, strontium, titanium, and vandadium analyses; neutron activation with a long time delay before analysis was used in analyses for gold, cerium, cobalt, rubidium, antimony, tantalum, thorium, and zinc. The procedures used and complete analytical results are presented in open file reports by DOE (*1, 21*). In these DOE reports, samples are identified by their field numbers; however, in this report, a simplified numbering system is used to identify the same samples. For this reason, a sample identification key (appendix B) is included to show the correspondence of the sample numbers used here with those used in the DOE reports (the field numbers).

SITHYLEMENKAT PLUTON

Geology

The Sithylemenkat pluton is a 200-mi^2 composite batholith located west of the Dalton Highway (figs. 1 and 6). Geologic mapping confined to the northern half of the pluton identified four texturally different granite phases (fig. 6): porphyritic granite, granite porphyry, coarse-grained granite, and graphic granite. Age relations between the four phases are unclear because of a lack of outcrop.

Mineralization

Tin-bearing rocks were found in two areas in the Sithylemenkat pluton (MZ on figure 6), and mineralized float commonly occurs in the upper tributaries of the east fork of the Kanuti Kilolitna River. Chlorite-bearing and locally magnetite-bearing greisen are intermixed with aplite, frost-riven graphic granite (gg), and coarse-grained granite (cg) rubble. The north end of the western MZ area overlies an intersection of linear structural features (fig. 7) where the extent of greisen and otherwise altered rock could not be determined due to a lack of bedrock exposure. A north-trending greisen zone was traced for 1,200 ft along the southern end of the area. At one bedrock exposure, the zone was between 10 and 15 ft wide.

Mineralized rock samples show variable effects of greisenization, with tourmaline and magnetite sometimes present. Fine-grained sericite- and quartz-rich veins and altered dikes contain abundant secondary chlorite, and locally contain up to several percent sulfide minerals, including pyrite, arsenopyrite, galena, and molybdenite. Greisen ruble is recognized in the field by its dark green to reddish-brown color, well-rounded weathered surface, and high specific gravity.

In thin section, the greisen showed a relict porphyritic texture in which feldspar phenocrysts were replaced by a felty intergrowth of very fine-grained quartz and sericite. This material was further replaced by a felty aggregate of chlorite and clay minerals in more pervasively altered specimens. Anhedral bladed cassiterite grains, less than 1 mm long and intimately intergrown with a felty aggregate of fine-grained chlorite, quartz, and white mica, were identified petrographically in creek float of chloritic greisen collected downstream from sample location 71 (fig. 8).

Greisen samples from the areas labeled MZ in figure 6 contained from 25 to 2,300 ppm Sn (table A-1). Greisen samples from these areas also contained, up to in parts per million, 5,126 As, 326 Bi, 253 Cs, 1,808 Cu, 15,340 Mn, 34,027 Pb, 1,156 Rb, 135 W, and 4,044 Zn (table A-1). Greisen from these areas ranges from light-colored to dark green. The highest tin concentrations were detected in the dark green chloritic greisen (sample 71d, figure 8 and table A-1).

The extent of the tin-rich greisen at sample location 71 was not determined, but it appeared to be concentrated in a 300-ft-long, 100-ft-wide area along the east side of the south-striking ridge shown in figures 6 through 8.

RAY RIVER PLUTON

Geology

The Ray River pluton is a poorly exposed intrusive body that occupies a 35-mi^2 area west of the Dalton Highway (fig. 1). It is composed mainly of fine- to medium-grained equigranular granite and quartz monzonite, with subordinate amounts of nonequigranular to porphyritic granite. These rocks are composed of 30 to 50 pct orthoclase, 20 to 40 pct oligoclase, 20 to 25 pct quartz, and less than 5 pct biotite. Muscovite and tourmaline were also observed in rocks from the center of the area, and feldspar is commonly altered to sericite and clay minerals. Aeromagnetic data (*23*) indicate that the Sithylemenkat and Ray River plutons may be connected at shallow depths.

Mineralization

No tin mineralization was observed in the Ray River pluton, and geochemical rock samples were not anomalous. Rock sample locations are shown in figure 8, and sample analyses and descriptions are presented in table A-1.

HOT SPRINGS PLUTON

Geology

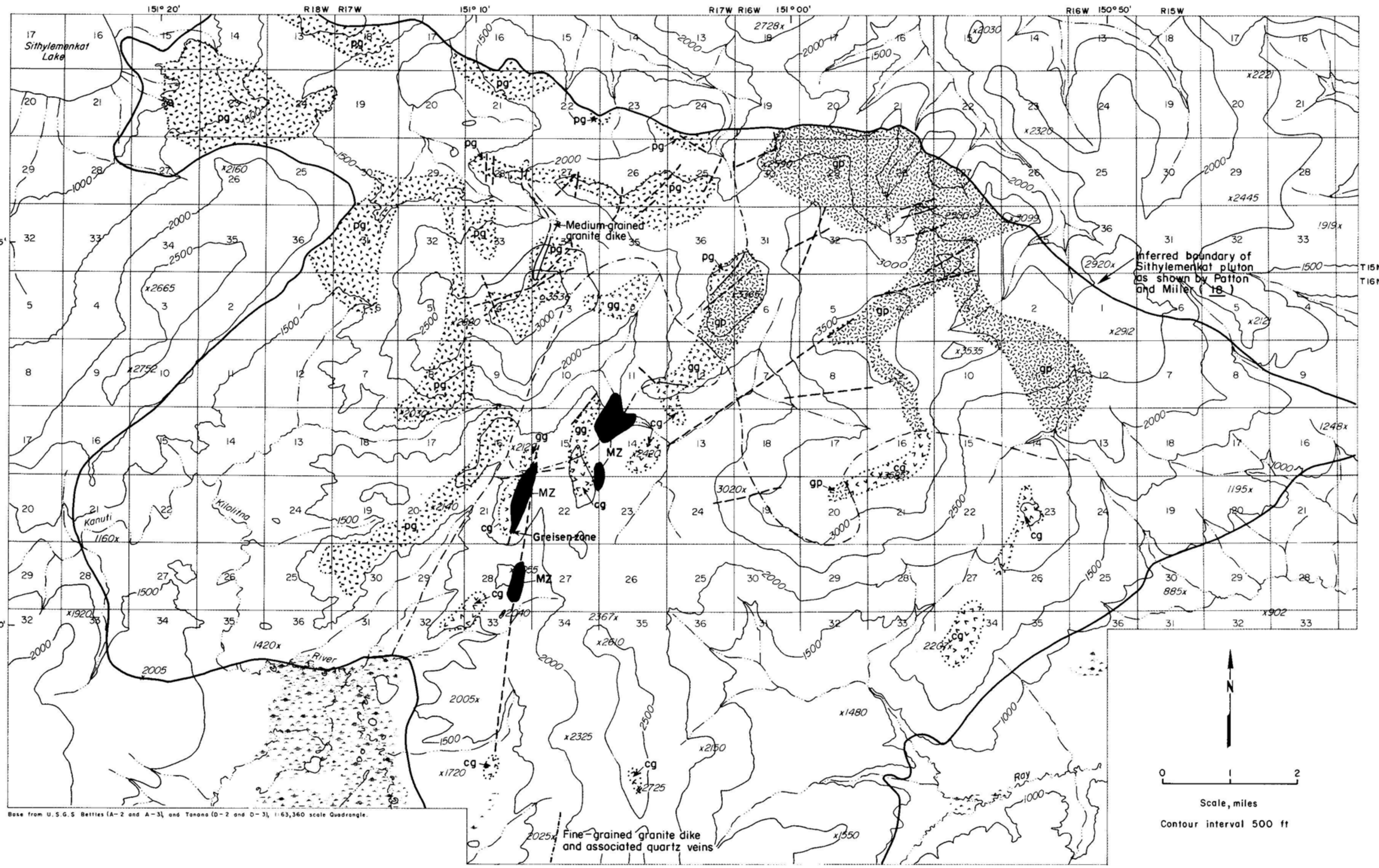
The Hot Springs pluton (fig. 1) is a 100-mi^2 east-trending granitic complex composed mostly of coarse-grained porphyritic and seriate biotite granite and biotite quartz monzonite with minor hornblende. The pluton is locally intruded by younger dikes and stocks of rhyolite porphyry.

In thin section, textures in the granitic rocks of the Hot Springs pluton vary from hypidomorphic to granular. Graphic and micrographic intergrowths among quartz and feldspar grains are common in the groundmass of these granites. Perthitic orthoclase, albite-twinned plagioclase, and biotite phenocrysts are set in a groundmass of anhedral quartz and two feldspars, with interstitial and euhedral biotite. Biotite phenocrysts sometimes contain metamict zircon inclusions. Accessory minerals include tourmaline, zircon, apatitie, magnetite, and pyrite.

Dikes and stocks in the Hot Springs pluton area are composed of porphyritic rhyolite and granular, leucocratic granite. These rocks are variably altered and range in color from bleached white to iron-stained red.

Mineralization

Above-average concentrations of lithium, copper, arsenic, tin, antimony, lead, and uranium were detected in samples of altered rhyolite porphyry, biotite granite, and leucocratic granite that occur as rubble on a narrow, steep-sided ridge in the Hot Springs pluton. Metazeunerite [$Cu(UO_2)2(AsO_4)_2 \cdot 8H_2O$] was identified by X-ray diffraction of sample 149, a gray-green-weathering, altered rhyolite porphyry that contained over 1,000 ppm U, 341 ppm Cu, 2,616 ppm Pb, and 218 ppm Sn. Similar pieces of mineralized float were sparsely distributed along the ridge. The extent of the mineralization is masked by soil and talus, but may account for tin anomalies in panned concentrates of alluvial gravel found nearby (*2*). Figures 9 and 10 show the sample locations and geology along the ridge and the locations of other samples from the Hot Springs pluton. Results of the geochemical analyses are listed in table A-2.



LEGEND

pg — Porphyritic granite:
Granite and quartz monzonite with large (up to 2.5 in) creamy white perthitic K-feldspar phenocrysts (orthoclase) in a coarse-grained groundmass of orthoclase, euhedral oligoclase, anhedral and crushed smoky quartz grains, and biotite. A typical modal composition, in percent, is orthoclase, 45; oligoclase, 25; quartz, 25; and biotite, up to 5. The orthoclase-oligoclase ratio varies widely, from 5:1 to 2:1. Accessory minerals include zircon, apatite, allanite, rutile, monazite, tourmaline, and opaques. This lithology is locally cut by a biotite-deficient, medium-grained, granular phase.

gp — Granite porphyry:
Granite and quartz monzonite with large (up to 2.5 in) creamy white perthitic K-feldspar phenocrysts (orthoclase) in a fine- to medium-grained groundmass of orthoclase, euhedral oligoclase, anhedral and crushed smoky quartz grains, and biotite. A typical modal composition, in percent, is orthoclase, 40; oligoclase, 20; quartz, 30 to 35; and biotite, up to 5. Accessory minerals include apatite, zircon, sphene, and opaques.

cg — Coarse-grained granite:
Granite with minor quartz monzonite; coarse-grained hypidiomorphic granular texture with subhedral to euhedral perthitic orthoclase, euhedral zoned oligoclase, dark smoky crushed granular quartz, and euhedral biotite. A typical modal composition, in percent, is orthoclase, 45; oligoclase, 20; quartz, 30; and biotite, 5. accessory minerals include apatite, zircon, and opaques.

gg — Graphic granite:
Texturally, a highly variable unit forming the core of the pluton. Textures may vary from fine to coarse-grained, equigranular to inequigranular, with graphic intergrowths of orthoclase and quartz (occasionally oligoclase and quartz) common throughout. A texture approaching miarolitic is commonly found within this unit. Compositionally, this unit, least variable of the four mappable units, is a granite with a typical modal composition, in percent, of orthoclase, 45; oligoclase, 15; quartz, 40; and biotite, 5. Accessory minerals include apatite and, locally, abundant tourmaline.

MZ — Altered zones:
Altered rock shows a wide range of alteration varying form sericitized and silicified, quartz-feldspar porphyry (greisen) to extensively chloritized greisen. The latter is sometimes strongly magnetic and contains abundant opaques including magnetite, pyrite, galena, molybdenite, and cassiterite. Includes dark green, heavy rock intermixed with granite and quartz monzonite rubble.

Limit of known geology

Contact

Inferred contact

Inferred fault or joint interpreted from linear features on aerial photography

FIGURE 6.—Geologic map of Sithylemenkat pluton.

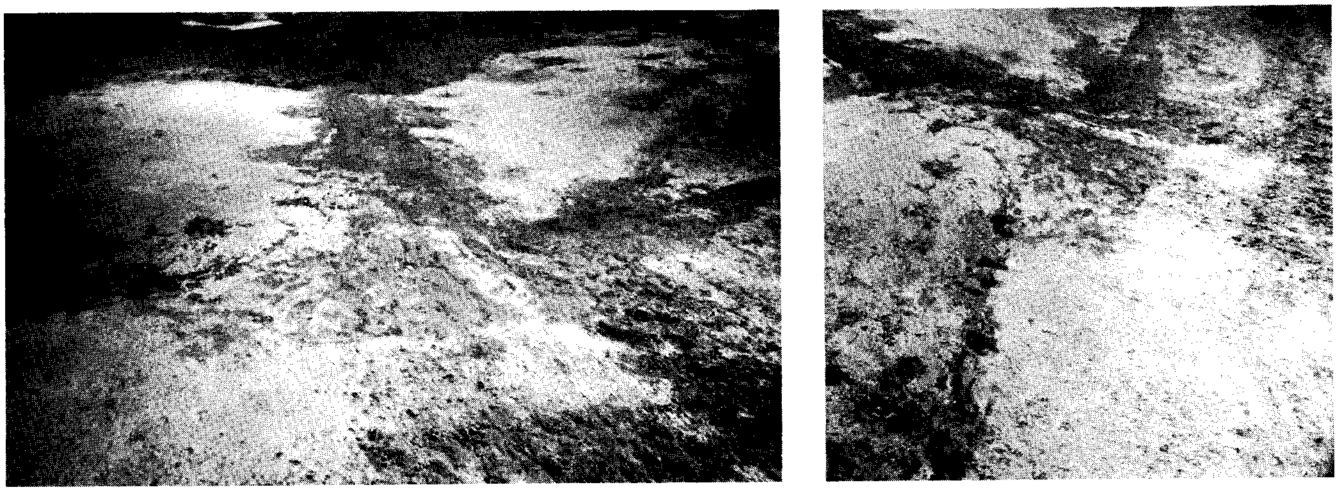


FIGURE 7.—Aerial views of structural intersection where a chlorite-rich tin-bearing greisen occurs (sample locations 72 and 73, as shown in figure 8), looking to the west (left) and north (right).

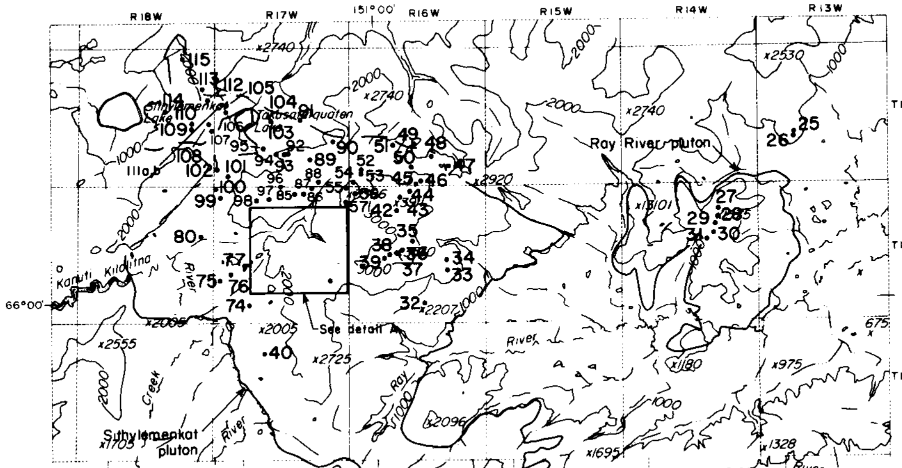


FIGURE 8.—Rock sample location map for Sithylemenkat and Ray River plutons.

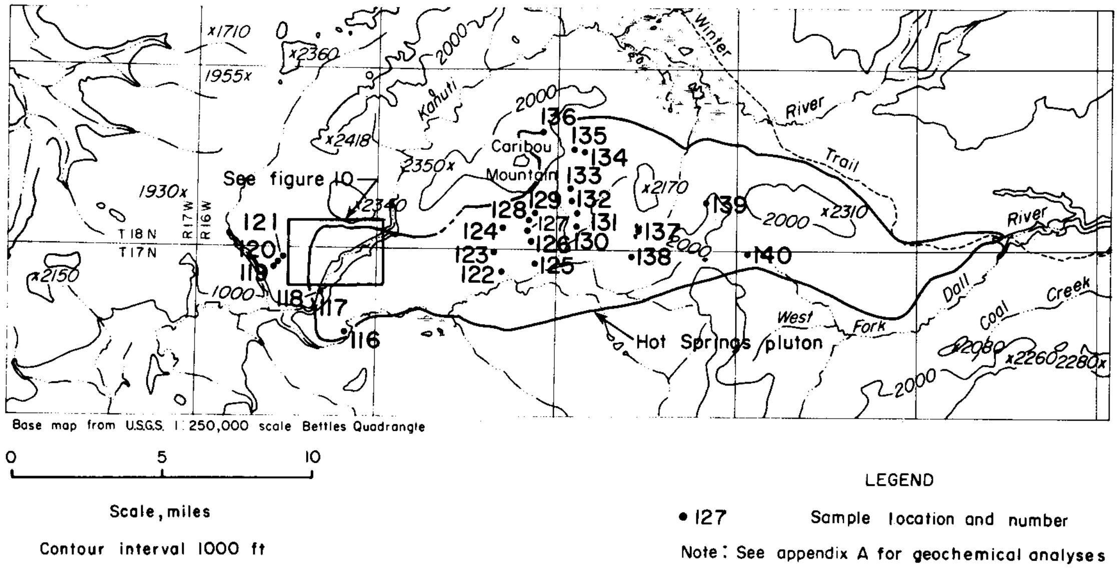


FIGURE 9.—Sample location map for Hot Springs pluton.

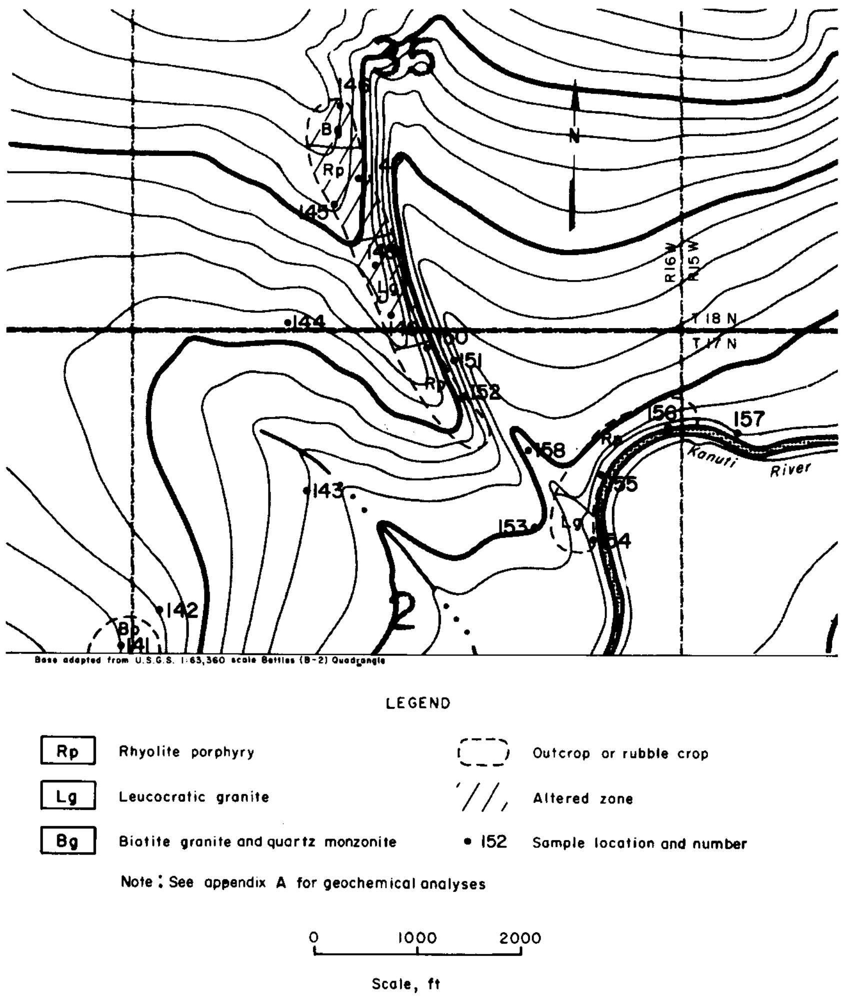


FIGURE 10.—Sample location and geologic map of metazeunerite occurrence in Hot Springs pluton.

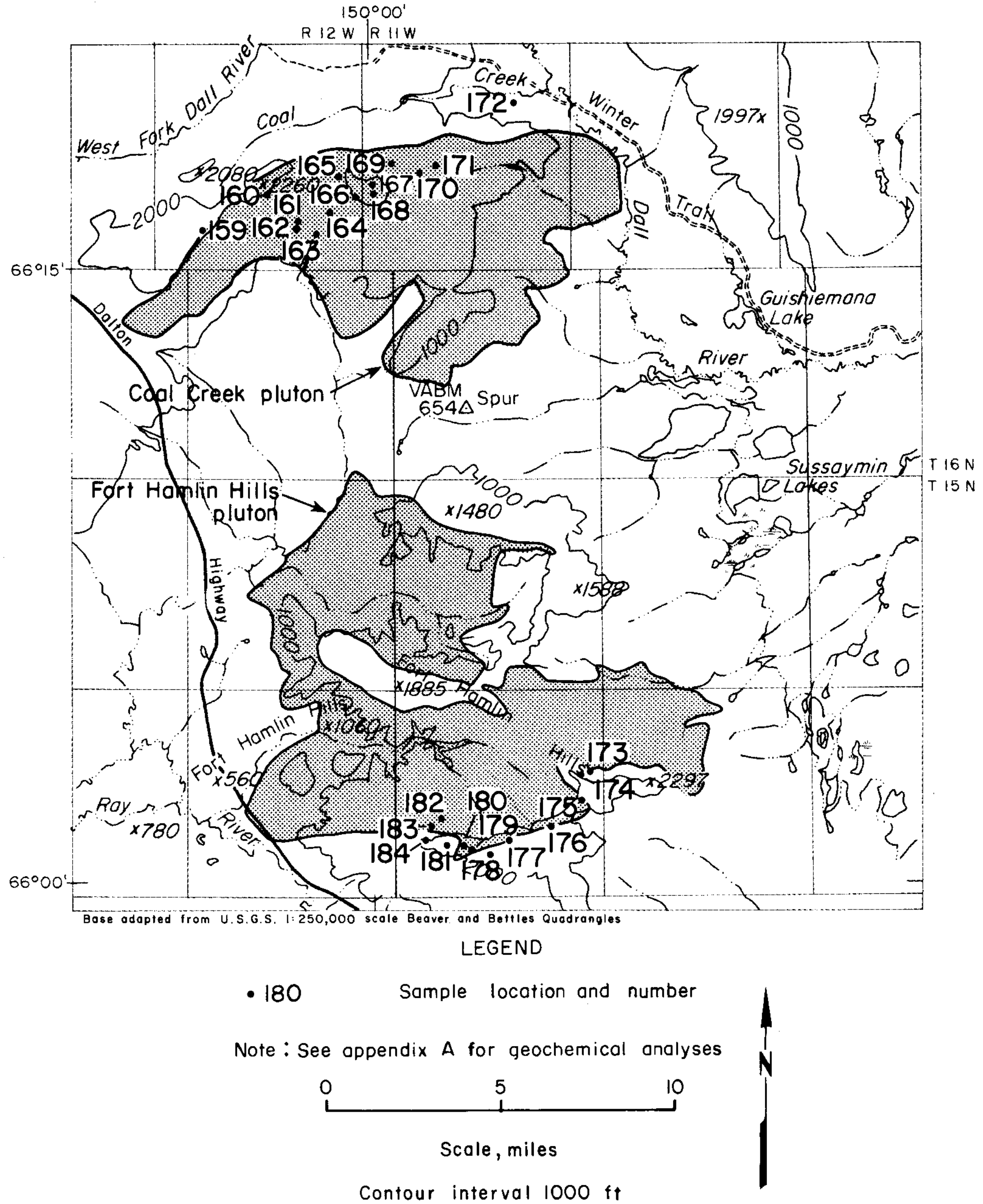


FIGURE 11.—Rock sample location map for Coal Creek and Fort Hamlin Hills plutons.

FORT HAMLIN HILLS PLUTON

Geology

The Fort Hamlin Hills pluton (fig. 1) underlies an 80-mi^2 area between the Dalton Highway and the Yukon Flats. Most of the pluton is covered by unconsolidated surficial deposits. The Bureau's investigation was confined to the southern portion of the pluton, where the contact with hornfelsed Paleozoic schists and quartzites is exposed. The examined area is composed mostly of medium- to coarse-grained, locally porphyritic biotite granite and quartz monzonite that are locally intruded by hydrothermally altered leucocratic, felsic dikes that contain accessory pyrite and tourmaline.

Mineralization

Sample 181 was collected from a tourmaline- and pyrite-bearing altered 5- to 8-ft-wide felsic dike that cuts the biotite granite. The dike was variably stained brick-red and green, and exposed for 50 ft along a north-trending strike. An altered zone extends into the granite for at least several feet. Secondary minerals in the dike and the biotite granite host rock include minor chlorite, sericite, tourmaline, hematite, and pyrite. Sample 181 contained 308 ppm Sn and 1,102 ppm Rb, with traces of tantalum (29 ppm) and tungsten (16 ppm). The sample locations are shown in figure 11, and the analytical results are listed in table A-3.

Table 3.—Major-oxide analyses and normative mineralogy of samples from plutons in Kanuti and Hodzana River uplands,[1] weight percent

(Samples are located by number in figures 8-11.)

Sample[2]	46	60	110	161b	170c	166	137a	150	129	184b
					MAJOR-OXIDE ANALYSES					
SiO_2	75.80	76.20	75.40	77.60	75.10	71.90	70.60	78.00	75.10	74.80
TiO_2	.16	.20	.26	.12	.14	.38	.45	.11	.35	.15
Al_2O_3	13.40	12.40	13.10	12.60	12.90	14.20	14.00	12.30	12.80	13.00
Fe_2O_3	.65	.86	.26	.24	.33	.73	1.40	.40	1.10	.78
FeO	.83	1.10	1.40	.35	.57	1.80	1.70	.13	1.20	1.00
MnO	.03	.04	.04	.02	.02	.05	.05	0	.04	.02
MgO	.15	.22	.31	.04	.09	.56	.81	.07	.37	15
CaO	.59	.70	.89	.53	.69	1.70	1.60	.04	.89	.63
Na_2O	3.20	2.90	2.80	3.70	3.40	3.40	3.20	.38	3.10	3.00
K_2O	5.00	5.30	5.20	3.90	5.10	5.20	5.10	4.90	5.00	5.30
P_2O_5	.02	.02	.02	.02	.02	.10	.09	.02	.08	.02
Total	99.83	99.97	98.68	99.12	98.36	100.02	99.00	96.35	100.03	98.85
					NORMATIVE MINERALOGY					
Quartz	34.45	35.25	34.50	37.82	32.58	27.04	26.78	56.96	35.34	33.83
Orthoclase	30.13	32.09	31.35	23.55	31.03	30.73	31.12	31.31	29.55	32.34
Albite	29.31	26.29	25.66	33.96	31.44	28.77	29.67	3.69	26.23	27.82
Anorthite	2.99	3.43	4.93	2.69	3.53	7.78	7.59	.21	3.89	3.23
Corundum	1.84	.75	1.22	1.48	.68	.13	.59	7.44	.86	1.33
Hypersthene	.61	.88	1.18	.13	.33	3.56	2.49	.21	1.71	.68
Magnetite	.45	.59	.75	.19	.30	1.06	.92	.00	1.59	.54
Ilmenite	.23	.29	.37	.17	.20	.72	.65	.10	.66	.22
Apatite	0	.04	.04	0	0	.23	.19	0	.19	0

[1]Rapid rock technique by Skyline Laboratories, Wheatridge, CO.
[2]Sample description:
46 Porphyritic biotite granite with fine-grained groundmass from Sithylemenkat pluton.
60 Coarse-grained porphyritic biotite granite with micrographic texture from Sithylemenkat pluton.
110 Coarse-grained porphyritic biotite granite from Sithylemenkat pluton.
161b Coarse-grained biotite granite from Coal Creek pluton.
170 Medium-grained biotite granite from Coal Creek pluton.
166 Coarse-grained biotite granite from Coal Creek pluton.
137a Porphyritic biotite granite with medium- to coarse-grained groundmass from Hot Springs pluton.
150 Rhyolite porphyry from Hot Springs pluton.
129 Seriate to porphyritic biotite granite from Hot Springs pluton.
184b Coarse-grained biotite granite from Fort Hamlin Hills pluton.

COAL CREEK PLUTON

Geology

The 75-mi² Coal Creek pluton crops out east of the Dalton Highway and north of the Yukon Flats (fig. 11). This body is very similar in composition to the Sithylemenkat pluton. Porphyritic and seriate biotite granite and quartz monzonite are the most common rock types. Granular textures are observed more rarely. Locally, veins and radial aggregates of tourmaline were observed. Siliceous fine-grained felsic rocks with tourmaline crystals up to 4 in long were commonly seen in float at the northeastern margin of the pluton. In thin section, the porphyritic rocks show micrographic and cataclastic textures.

Mineralization

No mineralization was observed during the Bureau's investigation of the Coal Creek pluton. However, a previously reported stream-sediment sample collected from a gulch containing abundant vein quartz on the easternmost extent of the pluton contained 185 ppm U (*1*). Sample locations for the Coal Creek pluton are shown in figure 11, and the analytical results are listed in table A-3.

MAJOR-OXIDE ANALYSES

Major-oxide analyses on 10 chip samples (listed in table 3 and located in figures 8-9 and 11) indicate that plutons in the Kanuti and Hodzana Rivers uplands are similar in composition to tin granites found in New South Wales, Australia. Juniper and Kleeman concluded that "tin-mineralizing granites" can be characterized on the basis of their aluminum, calcium, iron, magnesium, potassium, silica, and sodium contents (*14*). For comparison, fields for tin-mineralizing granites in New South Wales, as determined by Juniper and Kleeman (*14*), are shown in ternary diagrams in figure 12. The ternary diagrams are based on normalized compositions in the following systems:

$$CaO + MgO + FeO : SiO_2 : Na_2O + K_2O + Al_2O_3 \quad \text{(fig. 12}A\text{)}$$

$$Na + K : Fe : Mg \quad \text{(fig. 12}B\text{)}$$

$$K : NA : Ca \quad \text{(fig. 12}C\text{)}$$

Plots of samples from the Sithylemenkat, Coal Creek, Hot Springs, and Fort Hamlin plutons generally fell within the fields for tin-mineralizing granites. No samples were collected from the Ray River pluton for major-oxide analyses. A sample of rhyolite porphyry intrudes the plots near the tin-mineralizing fields in figures 12*A* and 12*B*, but is well outside the tin-mineralizing field in figure 12*C*. Samples from the Sithylemenkat, Coal Creek, and Fort Hamlin Hills plutons consistently plotted within, or very near, the fields for tin-mineralizing granites.

TRACE-ELEMENT ANALYSES

Trace-element analyses on 146 rock samples from plutons in the Kanuti and Hodzana Rivers uplands (appendix A) indicate that the plutons are chemically similar to tin granites elsewhere in the world. All are enriched in lithium, copper, zinc, arsenic, rubidium, tin, cesium, lead, tungsten, bismuth, and thorium. Locally elevated levels of columbium and tantalum were also detected. Only the Ray River pluton samples were enriched in beryllium, but all were depleted in barium. All but the Coal Creek pluton samples were depleted in manganese, and all but the Fort Hamlin Hills samples were depleted in zirconium. These enrichment-depletion findings, as compared to average granites, are common among tin granites described by various authors (*3-4, 7-8, 11-13, 16, 22*).

Analyses of unaltered, nonmineralized samples from the plutons are summarized and compared to those of average granites in table 4. Mineralized or altered samples (which are not included in table 4). are noted in appendix A (footnote 2 in each of the appendix tables). In table 4, the elements are presented in order of increasing atomic number, and the number of analyses (n) for each element varies due to matrix interferences during analysis.

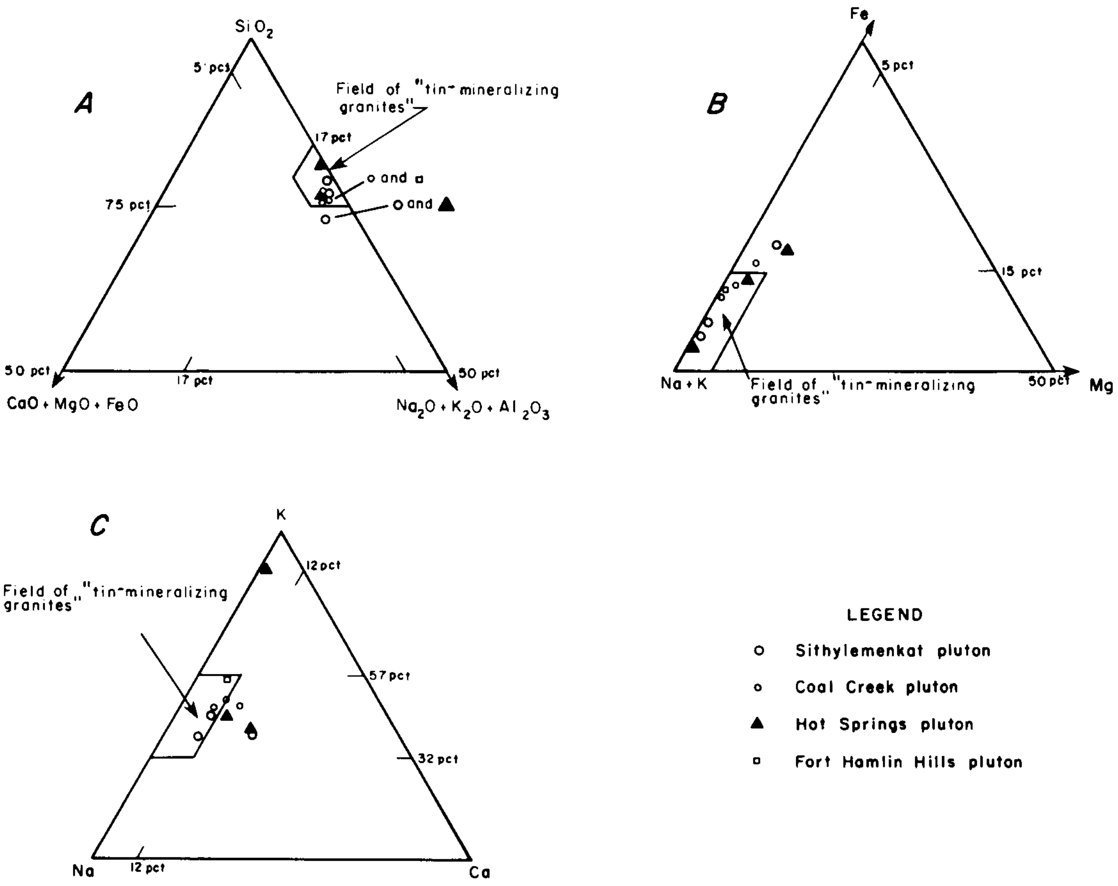


FIGURE 12.—Comparison of Kanuti and Hodzana Rivers uplands plutons with Australian "tin-mineralizing granites."

Table 4.—Average concentration of trace elements in unmineralized rock samples from plutons in Kanuti and Hodzana Rivers uplands,[1] parts per million

Element[2]	Av granite[3]	Sithylemenkat		Ray River		Fort Hamlin Hills		Coal Creek		Hot Springs		Cumulative	
		Av	n	Av	n	Av	n	Av	n	Av	n	Av	n
Li	30	97.83	64	79.67	6	92.4	10	80.33	18	92.53	47	88.5	145
Be	5	8.95	64	24.0	6	5.5	10	6.72	18	4.85	47	9.8	145
Mn	500	330.21	67	283	7	262.2	10	497.8	18	218.72	47	318.39	149
Cu	10	18.05	64	27.7	7	20.6	10	26.33	18	20.11	47	22.58	146
Zn	40	52.08	65	73.0	7	70.2	10	82.33	18	66.36	47	68.8	147
As	1.5	20.49	61	9.7	7	19.2	10	18.27	18	24.75	44	18.5	140
Rb	150	389.95	64	349.	7	480.4	10	292.25	16	271.34	44	356.6	141
Zr	180	124.84	62	74	7	215.4	10	118.22	18	143.77	44	135.2	141
Sn	3	11.33	64	14.2	7	10.	10	11.56	18	10.04	47	11.4	146
Cs	5	17.43	64	18.8	7	9.74	10	25.76	16	14.09	44	17.2	141
Ba	600	237.88	65	101.3	7	390.9	10	295.82	17	261.48	45	257.5	144
Ta	3.5	2.90	63	3.3	7	1.56	9	1.62	16	1.29	44	2.1	139
W	2	17.05	61	15.1	7	19.67	9	20.82	17	15.68	44	17.7	138
Pb	20	49.59	64	27.4	7	29.9	10	58.16	18	58.57	47	44.7	146
Bi	0.1	9.81	64	8.6	7	9.2	10	9.16	18	7.26	46	8.8	145
Th	17	44.27	67	26.5	7	34.38	10	31.9	18	40.31	47	35.5	149

n Number of analyses.
[1]Analyses by Los Alamos (NM) Scientific Laboratories.
[2]In ascending order according to atomic number.
[3]Adapted from Levinson (*15*).

DISCUSSION AND RECOMMENDATIONS

TIN PLACER DEVELOPMENT POTENTIAL

The data in tables 1 and 2 indicate that placer tin, tungsten, tantalum, and columbium minerals occur in deposits of unknown grade at several localities in the Kanuti Kilolitna River drainage. Sampling was limited to shallow pits. No samples were taken from near bedrock; therefore, the grade and extent of the underlying gravels could not be assessed. However, it is likely that the amount of concentrate present per cubic yard of gravel increases with depth, particularly in the coarse granitic sands and gravels.

Further work should include sampling of the subsurface gravels by backhoe trenching supplemented by drilling where necessary. It is suggested that the areas denoted on figure 13 (by the numbers 1 through 6) and listed below be sampled for placer concentrations of cassiterite and associated economic minerals.

1. The westerly flowing streams, both north and south of the Kanuti Kilotina east fork valley, may contain relatively small but possibly high-grade stream placers. These streams drain areas where tin occurrences were found.
2. The semiclosed basin drained by the south fork of the Kanuti Kilolitna contains complex alluvial and glaciofluvial deposits derived from the Ray Mountains batholith further to the south. The tin content of five placer samples downstream from Kilo Hot Springs (samples locations 3-4, figure 2) and heavy-mineral panned concentrates (*2*) from other tributaries suggest that cassiterite concentrations are present. The placer samples collected from flood-plain gravels contained 0.02 to 0.08 lb/yd^4 Sn. Exploration should assess the extensive active and ancient alluvial channels leading into and within the basin. Placer tin deposits, if present, may be large, but are likely of lower grade than the smaller stream placers.
3. Placer deposits may be present in the active alluvium and alluvial terraces of the main valley of the Kanuti Kilolitna River for 3 to 4 miles downstream of the basin mentioned above. Two placer samples collected from flood-plain gravels contained 0.03 to 0.08 lb/yd^3 Sn (sample locations 5a-5b, figure 3). A sample from further upstream (location 6, figure 3) contained approximately 0.02 lb/yd^3 Sn.
4. Residual or eluvial placer deposits may occur in the immediate area of lode mineralization south of hill 3536 (fig. 36). This area maybe more extensive than shown in figure 13.
5. Channel deposits in glaciofluvial outwash along the upper south fork of the Kanuti Kilolitna, which are derived from the Ray Mountains, may contain significant placer tin deposits. The Ray Mountains batholith, south of the study area, is a deeply eroded granitic body; and although no lode tin mineralization is known, tin was previously found in panned concentrate samples of alluvium derived from the batholith (*2*).
6. West- and north-flowing streams, particularly the Ray River, which drains the Sithylemenkat pluton to the east, should be further evaluated for placer tin deposits, despite the relatively low values found in placer samples at location 2 (fig. 2). Panned concentrates from the upper Ray River contained anomalous tin (*2*).
7. Areas of anomalous alluvial tin (*2*) in the northwestern vicinity of the Fort Hamlin Hills and western Hot Springs plutons (not shown in figure 13 – see fgure 1) should be further evaluated for tin mineralization. Logistic constraints prevented sampling in these areas during this investigation.

Further field mapping and sampling is required to determine the significance of the tin anomalies in the western Hot Springs and Fort Hamlin Hills plutons. The northern poorly exposed portion of the Fort Hamlin Hills pluton is particularly recommended for further examination due to the presence of tin in panned concentrates.

LODE TIN DEVELOPMENT POTENTIAL

Major-oxide and trace-element analyses and tin occurrences indicate that the plutons of the investigated area are chemically similar to other granitic intrusions that have given rise to tin mineralization. Tin mineralization in granites typified by their similar chemistries results from post magmatic processes involving the development of an alkali-rich volatile phase during crystallization (*16*). Tin greisen deposits are typically found in the upper, volatile-rich portions and cupolas of plutons. It is possible that such upper intrusive levels and associated tin deposits have been mostly or completely removed during subsequent erosion of the exposed plutons in the study area. The Sithylemenkat pluton, however, hosts several mineralized zones near the head of the east fork to the Kanuti Kilolitna River. This is evidence that at least some remaining deposits have escaped erosion.

Trenching and further sampling near the mineralized zones in the Sithylemenkat pluton are needed to determine the nature and extent of mineralization. Additional detailed mapping is also needed to delineate the host phase of the tin occurrences. The distribution of placer tin indicates that the mineralized zones are, or were, more widespread than those found. Initially, magnetometer surveys may serve to better define the zones.

CONCLUSIONS

The east fork of the Kanuti Kilolitna River contains cassiterite with lesser amounts of tungsten, columbium, tantalum, and rare-earth minerals in near-surface alluvial and bench gravels. These minerals were also found in the gravels of the south fork of the Kanuti Kilolitna near the foothills of the Ray Mountains. Placer samples collected from surface exposures commonly contained 0.02 to 0.14 lb/yd^3 Sn. It is likely that the concentration of heavy minerals increases with depth. The sample results suggest that tin and associated elements may occur as placer deposits in these and other streams draining the granitic plutons in the Kanuti and Hodzana Rivers uplands. A large semibasinal area in the Kanuti Kilolitna drainage that contains ancient and present alluvial channels appears to be particularly favorable for large placer tin deposits.

Analyses of rock samples showed that the granitic

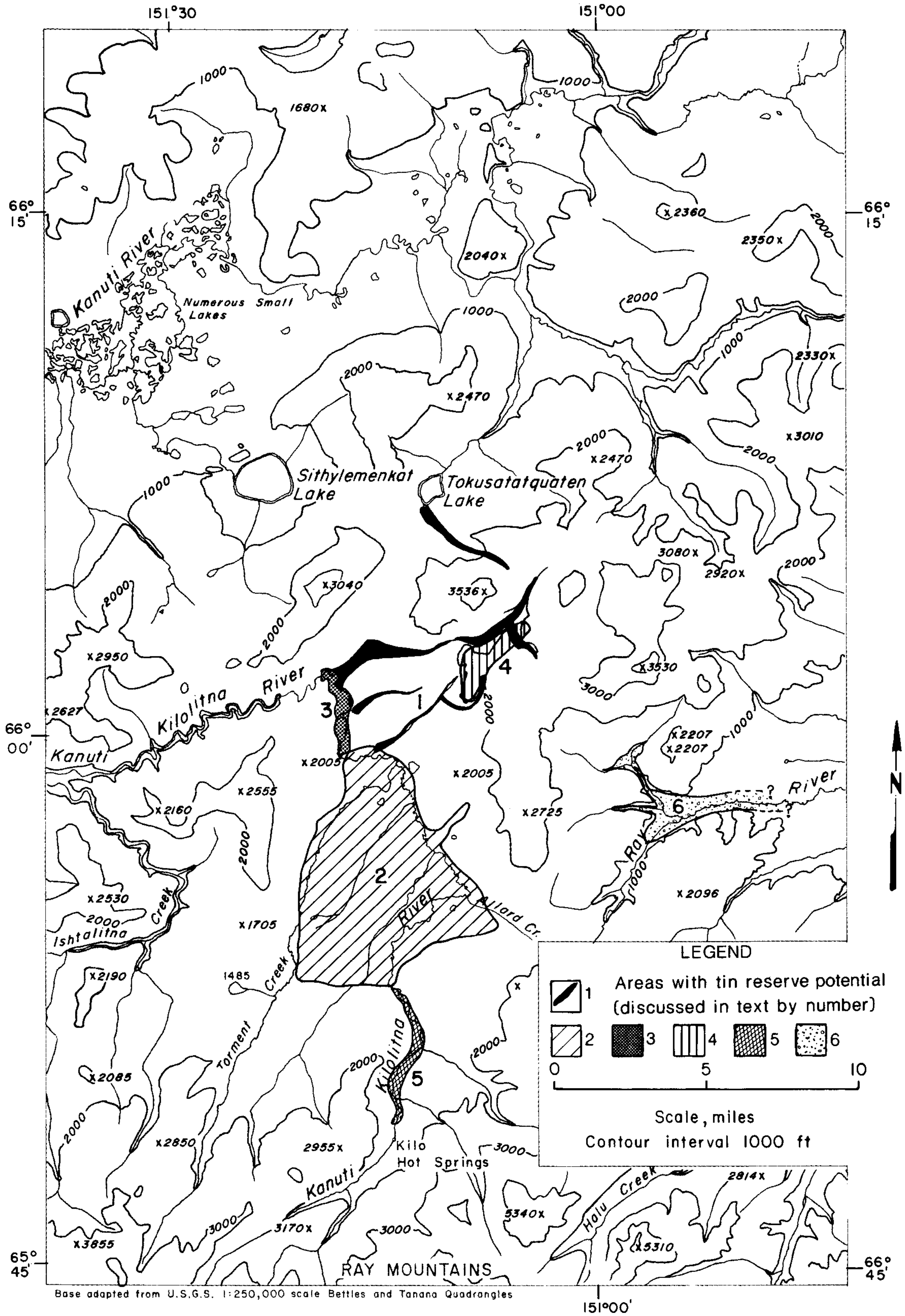


FIGURE 13.—Areas of tin reserve potential suggested for further placer investigations.

plutons studied resemble granitic bodies elsewhere in the world that are known to contain valuable deposits of tin and associated metals. Mineralized zones in the Sithylemenkat pluton were identified in rubble and indicate that at least some lode tin deposits exist. However, the deeply eroded nature of the region suggests that larger tin-bearing cupola zones, if originally present, may now be eroded away.

Estimating the potential value of lode and placer tin deposits in the uplands between the Kanuti and Hodzana Rivers and adjacent areas will require extensive surface and subsurface exploration.

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APPENDIX A.—GEOCHEMICAL ANALYSES OF ROCK SAMPLES

Table A-1.—Geochemical analyses[1] of rock samples collected in Ray River and Sithylemenkat pluton areas, parts per million

(Samples are located by number in figure 8.)

Sample	Li	Be	Cl	Mn	Cu	Zn	As	Rb	Sr	Zr	Cb	Sn	Sb	Cs	Ba	Ta	W	Pb	Bi	Th	U	Description
25	26	<1	<37	441	38	211	27	<35	<183	111	<20	<10	<2	<1.7	<97	<1	<15	9	<5	4.2	2.13	Foliated biotite granite with limonite cavities.
26	NAn	NAn	<23	228	70	41	6	<18	<113	28	<20	<10	<1	<.8	<61	<1	<15	<5	5	1.2	1.00	Medium-grained foliated granite (orthogneiss) with limonite in vugs.
27	81	7	171	227	19	<25	12	396	<169	109	<20	<10	<1	14.6	<102	<1	<15	25	16	63.9	6.04	Medium-grained biotite granite with abundant K-feldspar phenocrysts.
28	80	104	<100	313	20	86	6	537	<222	71	<20	24	NAn	32.7	<113	4	<15	31	<5	35.4	9.20	Medium-grained granular biotite granite with occasional K-feldspar phenocrysts.
29	78	17	<113	220	14	54	<5	482	<196	69	<20	25	<1	25.9	<102	5	<15	35	7	27.0	6.46	Medium-grained biotite granite with smoky quartz.
30	81	9	<102	316	19	61	<5	484	<227	79	<20	<10	NAn	33.4	<121	3	16	47	15	38.0	6.60	Medium-grained granular biotite granite.
31	132	6	<127	236	14	<33	7	491	<217	51	<20	11	<1	22.8	<113	8	<15	40	7	15.9	17.92	Medium-grained foliated granite with biotite and tourmaline.
32	179	6	117	248	<10	<58	5	381	<211	131	<20	<10	<2	12.9	235	<1	<15	46	11	57.2	5.59	Coarse-grained biotite granite.
33	78	11	<93	306	12	49	10	473	<214	141	<20	14	<1	24.9	<109	3	<15	48	14	66.2	10.35	Coarse-grained biotite granite with smoky quartz.
34	80	5	<103	321	18	102	10	487	<232	131	<20	13	<1	22.1	<128	<1	21	44	12	63.3	11.49	Do.
35	81	5	183	415	20	<81	<5	338	<216	116	<20	<10	NAn	15.5	349	<1	17	56	11	42.7	4.74	Coarse-grained hypidiomorphic biotite granite.
36	81	10	165	392	13	<50	31	367	<215	139	<20	<10	NAn	18.8	328	3	15	49	10	36.9	4.15	Do.
37	81	10	137	315	11	<41	31	495	<184	113	<20	<10	NAn	29.6	<94	4	<15	46	11	55.8	14.35	Do.
38	140	6	292	154	22	<58	5	385	<146	124	<20	<10	NAn	13.5	<88	2	<15	39	8	65.0	7.85	Do.
39[2]	196	7	139	141	38	<18	29	639	<148	106	<20	46	<1	15.0	<88	5	19	57	12	56.0	9.72	Porphyritic biotite granite with fine- to medium-grained groundmass.
40	45	10	<110	158	24	<17	10	496	<184	132	<20	11	NAn	15.5	<111	6	16	95	17	33.9	32.65	Fine-grained pink biotite granite dike.
42	80	10	134	292	10	<40	NAn	539	<211	115	<20	<10	NAn	29.5	<114	5	19	68	16	66.0	11.19	Fine- to medium-grained, biotite granite.
43	74	7	<98	339	10	<16	7	449	<227	129	<20	<10	NAn	28.7	185	5	<15	44	6	57.2	8.19	Porphyritic granite with fine-grained groundmass.
44	140	5	170	210	10	39	<5	418	<200	87	<20	<10	<1	18.0	<127	<1	<15	43	6	43.9	6.74	Do.
45	178	9	<100	363	<10	34	NAn	257	<295	NAn	<20	<10	NAn	15.9	<135	3	15	44	<5	45.9	9.84	Coarse-grained biotite quartz monzonite with pink K-feldspar phenocrysts.
46	71	11	NAn	190	46	26	50	NAn	61	98	17	<5	90	NAn	10	NAn	NAn	14	10	47.0	NAn	Granite porphyry with fine-grained groundmass.
47	35	8	<96	172	<10	29	<5	385	<163	97	<20	<10	<1	32.1	<102	4	<15	68	<5	44.5	5.79	Medium-grained pink granite dike in schist.
48[2]	82	3	137	971	62	145	72	182	<237	254	<20	<10	<3	15.1	407	<1	22	22	5	13.0	4.65	Quartz-mica schist.
49[2]	85	2	227	1,511	27	184	106	103	<280	208	<20	<10	6	14.6	<156	<2	20	7	5	10.4	2.35	Quartz-biotite schist.
50	42	6	<121	552	23	31	NAn	72	<354	NAn	21	10	<3	7.3	<154	2	<15	13	<5	39.1	5.53	Red-stained granite with altered feldspar.
51	NAn	NAn	<99	170	NAn	53	NAn	433	<177	NAn	NAn	NAn	53	24.3	<94	3	NAn	NAn	NAn	65.9	15.71	Fine- to medium-grained biotite granite.
52	187	6	174	394	18	<64	<5	466	<210	125	<20	<10	<2	17.0	397	<1	16	56	9	55.0	4.82	Coarse-grained biotite granite.
53	177	8	<85	130	21	33	50	527	<147	75	<20	<10	<1	14.9	<89	4	<15	72	12	41.2	10.56	Medium-grained granular biotite granite.
54	166	6	142	339	<10	68	<5	386	<193	143	<20	<10	<1	19.4	225	3	<15	41	8	62.3	7.20	Coarse-grained biotite granite.
55	81	9	<92	285	21	<14	<5	679	<203	86	<20	<10	NAn	42.2	<107	6	18	71	12	53.0	16.12	Medium-grained biotite granite.
56	94	8	<81	206	21	117	15	443	<148	135	<20	<10	NAn	16.1	<88	4	19	44	12	52.9	10.30	Do.
57	127	69	<96	136	19	36	<5	643	<192	100	<20	19	NAn	27.9	<100	9	17	49	13	42.4	14.06	Do.
58[2]	57	5	<542	15,340	<10	1,231	259	<66	NAn	179	87	599	<3	7.2	<1,255	<2	135	<5	<5	69.6	26.17	Fine-grained magnetic aggregate of chlorite, magnetite,and quartz.
59a	80	7	<112	150	13	<50	<5	500	<232	44	<20	<10	<1	13.3	123	3	<15	64	<5	30.9	5.92	Fine-grained tourmaline-bearing biotite granite.
59b	193	6	<115	193	<10	<40	5	396	<212	104	<20	<10	<2	17.0	<126	<1	20	40	<5	44.7	7.11	Coarse-grained tourmaline-bearing biotite granite.
60	84	8	NAn	310	59	25	50	NAn	61	64	17	<5	185	NAn	NAn	NAn	NAn	12	7	47.0	Nan	Coarse-grained porphyritic biotite granite with micrographic texture.
61	184	6	<112	341	22	<19	5	415	<219	144	<20	12	<2	13.9	<130	NAn	32	16	15	53.6	10.19	Coarse-grained porphyritic biotite granite.
62[2]	69	8	<54	276	130	<151	5,126	561	<174	127	<20	1,149	<4	28.0	137	2	30	21	<5	48.8	11.85	Greisen float.
63[2]	NAn	NAn	NAn	NAn	84	470	NAn	NAn	NAn	NAn	NAn	250	NAn	NAn	NAn	NAn	<5	800	NAn	NAn	NAn	Dense, magnetic, chloritic greisen.
64	65	5	<106	758	53	141	33	162	<229	303	<20	<10	<2	24.7	176	3	<15	21	13	50.2	13.02	Weathered granite from stream cutbank.

See explanatory notes at end of table.

Table A-1.—Geochemical analyses[1] of rock samples collected in Ray River and Sithylemenkat pluton area, parts per million—Continued

Sample	Li	Be	Cl	Mn	Cu	Zn	As	Rb	Sr	Zr	Cb	Sn	Sb	Cs	Ba	Ta	W	Pb	Bi	Th	U	Description
65	147	11	<103	269	34	85	11	403	<231	120	<20	18	<2	13.2	<118	2	<15	44	14	49.1	8.67	Coarse-grained biotite granite monzonite.
66	103	5	<115	262	11	<13	7	378	<255	103	<20	<10	<2	11.1	<139	<1	15	38	7	50.5	8.26	Do.
67	171	7	<111	224	13	<53	11	375	<201	103	<20	<10	<1	11.8	219	<1	<15	38	8	44.4	7.42	Medium-grained biotite granite.
68	187	7	<108	289	<10	<35	7	355	<240	94	<20	<10	2	14.1	<134	3	<15	48	6	43.8	7.78	Coarse-grained porphyritic biotite granite.
69	153	6	<136	246	<15	93	5	382	<224	95	<20	12	<2	13.7	<119	<1	<15	53	6	37.6	7.21	Tourmaline-bearing, coarse-grained, porphyritic biotite granite.
70a	47	5	<95	96	20	<17	10	327	<188	37	<20	14	<1	7.7	<105	2	<15	54	<5	15.1	6.25	Coarse-grained graphic granite.
70b[2]	NAn	NAn	NAn	NAn	185	480	NAn	NAn	NAn	NAn	NAn	220	NAn	NAn	NAn	NAn	22	580	NAn	NAn	NAn	Chloritic greisen.
70c	88	5	<94	318	17	69	5	301	<217	161	<20	15	<1	10.5	292	<1	23	44	<5	56.2	5.55	Coarse-grained graphic granite.
70d[2]	NAn	NAn	NAn	NAn	85	70	NAn	NAn	NAn	NAn	NAn	25	NAn	NAn	NAn	NAn	16	35	NAn	NAn	NAn	Chloritic greisen.
70e[2]	NAn	NAn	NAn	NAn	95	490	NAn	NAn	NAn	NAn	NAn	135	NAn	NAn	NAn	NAn	20	300	NAn	NAn	NAn	Do.
71a	46	9	<105	133	28	44	54	395	<176	148	<20	16	<2	9.0	<105	5	<15	85	13	34.5	11.62	Coarse-grained porphyritic biotite granite.
71b[2]	NAn	NAn	NAn	NAn	160	1,250	NAn	NAn	NAn	NAn	NAn	190	NAn	NAn	NAn	NAn	35	1,960	NAn	NAn	NAn	Magnetic, chloritic greisen.
71c[2,3]	NAn	NAn	NAn	NAn	74	71	NAn	NAn	NAn	NAn	NAn	5	NAn	NAn	NAn	NAn	3	40	NAn	NAn	NAn	Chloritic quartz-rich rock with leached vugs.
71d[2]	NAn	NAn	NAn	NAn	34	450	NAn	NAn	NAn	NAn	NAn	2,300	NAn	NAn	NAn	NAn	23	155	NAn	NAn	NAn	Dense, dark, magnetic greisen with abundant chlorite.
71e[2]	NAn	NAn	NAn	NAn	90	100	NAn	NAn	NAn	NAn	NAn	190	NAn	NAn	NAn	NAn	48	740	NAn	NAn	NAn	Chlorite greisen.
71f[2]	44	9	<132	540	232	480	<5	389	<254	115	<20	28	<1	14.3	<131	7	<15	166	<5	33.5	8.66	Fine-grained quartz and feldspar in chlorite, sericite, and quartz groundmass.
72[2]	NAn	NAn	NAn	NAn	110	155	NAn	NAn	NAn	NAn	NAn	20	NAn	NAn	NAn	NAn	<5	440	NAn	NAn	NAn	Friable, dense, chloritic greisen.
73a[2]	NAn	NAn	NAn	NAn	75	45	NAn	NAn	NAn	NAn	NAn	6	NAn	NAn	NAn	NAn	2	20	NAn	NAn	NAn	Chloritic greisen with boxworks.
73b[2]	69	5	<297	8,314	1,808	4,044	<5	<57	NAn	289	<20	405	6	4.0	<657	3	27	34,027	326	90.3	66.84	Dark green, magnetic, chloritic greisen with quartz, hematite, and relict feldspar euhedra.
74	90	5	145	379	11	72	<5	217	<228	221	<20	<10	<2	8.1	563	<1	20	30	14	43.9	4.94	Coarse-grained biotite granite.
75	81	4	<81	364	11	<28	<5	277	<190	193	<20	<10	<1	5.2	1,164	<1	<15	31	<5	30.2	3.70	Coarse-grained porphyritic biotite granite.
76	41	9	<94	54	12	38	6	299	<180	37	<20	<10	<1	8.6	<101	7	<15	62	<5	9.2	2.43	Fine-grained leucocratic dike cutting coarse-grained porphyritic granite.
77	80	5	300	480	24	138	8	454	<216	593	<20	<10	<2	18.3	424	2	<15	64	11	58.4	26.17	Medium-grained granite segregation in coarse porphyritic granite.
78	81	5	<82	198	15	<24	5	305	<175	155	<20	<10	NAn	12.7	311	<1	<15	49	8	39.6	5.61	Coarse-grained biotite granite.
79	113	5	98	273	21	<46	14	332	<201	139	<20	<10	<2	11.6	333	3	21	48	13	56.7	6.84	Do.
80a	30	9	479	614	67	258	248	494	<320	876	68	11	11	22.8	<173	6	33	73	33	224.8	50.90	Chloritic greisen.
80b	26	2	<38	911	18	195	24	80	<246	85	<20	21	9	8.1	<126	<1	16	48	11	32.3	36.32	Vuggy, leached, iron-stained rock with abundant quartz euhedra.
81a[2]	NAn	NAn	130	NAn	NAn	230	<100	NAn	NAn	NAn	NAn	400	<200	NAn	NAn	<300	32	110	NAn	NAn	NAn	Dark green, fine-grained, sugary aggregate of quartz, chlorite, hematite, feldspar, and magnetite.
81b[2]	NAn	NAn	88	NAn	NAn	890	<100	NAn	NAn	NAn	NAn	400	<200	NAn	NAn	<300	16	580	NAn	NAn	NAn	Nonmagnetic, chloritic greisen.
82	63	4	<41	323	29	<26	147	503	<160	133	<20	49	2	23.9	168	<1	35	<5	108	46.9	8.46	Greisen float.
83[2]	59	4	508	6,567	82	272	149	1,156	NAn	118	48	193	<2	253.3	<536	4	<15	<5	<5	40.1	11.39	Magnetite and pyrite in chloritic greisen.
84	151	6	<103	260	21	<27	<5	358	<188	127	<20	<10	<1	12.7	<111	2	<15	44	6	53.6	10.02	Coarse-grained porphyritic biotite granite.
85	77	15	<125	244	10	<32	26	363	<224	87	<20	12	<2	16.1	397	3	<15	60	<5	29.5	18.03	Chloritized pyroxene and hornblende in medium-grained monzonite.
86	87	8	<107	162	14	<21	<5	372	<185	93	<20	10	<1	11.2	<132	3	<15	50	<5	35.9	11.49	Medium-grained, biotite granite with hematite and tourmaline.
87	90	7	<106	171	15	<67	11	523	523	101	<20	16	<2	17.3	118	3	22	60	7	39.9	10.69	Fine-grained, biotite granite.
88	138	12	<106	168	23	<22	114	631	631	99	<20	24	<1	24.7	<175	5	59	53	28	41.6	11.66	Hematite-bearing fine-grained biotite granite.
89	107	8	<84	226	17	54	14	454	<184	105	<20	17	<1	17.5	98	4	<15	50	15	58.8	7.60	Coarse-grained, biotite granite with tourmaline.
90	65	3	<90	258	<10	35	5	248	<165	163	<20	<10	<1	8.1	685	<1	<15	40	5	34.2	3.97	Porphyritic biotite granite.
91[2]	24	10	<108	33	27	NAn	26	341	<170	131	<20	<10	<1	10.6	<91	4	<15	103	11	27.2	21.27	Aplite dike in quartz-mica schist near margin of pluton.
92[2]	50	2	<47	65	20	<13	<5	109	<90	32	<20	<10	<1	3.4	<50	<1	<15	22	8	14.1	2.46	Vein quartz with chlorite and hematite.

See explanatory notes at end of table.

Table A-1.—Geochemical analyses[1] of rock samples collected in Ray River and Sithylemenkat pluton areas, parts per million—Continued

Sample	Li	Be	Cl	Mn	Cu	Zn	As	Rb	Sr	Zr	Cb	Sn	Sb	Cs	Ba	Ta	W	Pb	Bi	Th	U	Description
93	138	6	163	257	11	20	6	417	<149	114	<20	<10	<1	14.1	<88	4	<15	55	21	54.6	9.02	Coarse-grained, biotite granite.
94	162	6	<85	147	11	31	<5	390	<177	81	<20	11	NAn	21.4	<93	2	15	91	11	31.1	5.69	Medium-grained, granular biotite granite.
95	97	8	<88	118	14	34	6	464	<177	76	<20	<10	NAn	13.9	<98	5	<15	73	9	28.9	12.67	Coarse-grained, biotite granite with minor tourmaline.
96	143	7	<92	235	17	65	<5	471	<198	86	<20	14	NAn	23.7	211	5	<15	72	8	34.9	6.79	Medium-grained, granular biotite granite.
97	159	6	151	285	12	55	11	442	<193	127	<20	<10	<1	23.0	<99	3	<15	49	12	60.6	8.33	Coarse-grained, biotite granite.
98	81	6	<98	263	10	<34	280	386	<218	98	<20	<10	<1	25.7	859	<1	<15	67	<5	32.6	7.41	Medium-grained, biotite granite.
99	NAn	NAn	<120	133	NAn	<28	NAn	521	<198	NAn	NAn	NAn	<3	18.4	<104	10	NAn	NAn	NAn	15.7	6.61	Fine-grained, granular biotite granite.
100	80	16	188	1,512	21	<80	11	<63	<401	52	<20	<10	<4	<3.4	<202	<2	<15	49	<5	<2.0	1.88	Dark green amphibolite float from streambed.
101	NAn	NAn	175	261	NAn	<22	NAn	385	<158	NAn	NAn	NAn	1	14.1	<95	3	NAn	NAn	NAn	63.1	6.39	Medium to coarse-grained granite porphyry with biotite included in feldspar phenocrysts.
102[2]	26	<1	<106	1,577	164	<57	35	<51	<351	67	31	<10	23	14.3	<171	<2	<15	6	<5	<1.6	0.35	Quartz-biotite-chlorite schist.
103	104	5	<97	368	14	89	9	304	<181	208	<20	15	NAn	12.2	586	2	<15	42	10	49.2	4.56	Porphyritic biotite granite.
104	175	4	<93	381	<10	<83	5	380	<218	254	<20	<10	<2	9.0	722	<1	<15	44	11	59.2	4.48	Fine-grained, biotite granite clot near margin of pluton.
105a	76	6	<118	303	14	94	39	388	<217	136	<20	<10	<3	23.2	489	2	23	60	12	52.1	7.60	Porphyritic biotite granite with coarse-grained groundmass.
105b	35	5	<20	18	24	40	46	131	<71	63	<20	<10	3	10.6	198	2	15	20	6	17.2	6.70	Abundant hematite in alaskite.
106	81	7	<88	312	18	<45	6	345	<166	95	20	<10	<3	24.0	306	2	17	54	16	43.4	5.77	Porphyritic biotite granite with coarse-grained groundmass.
107	74	8	<99	279	10	75	8	502	<214	100	<20	<10	<2	19.5	<117	4	<15	58	13	44.6	13.09	Medium-grained, biotite granite with tourmaline veinlets.
108	78	5	<90	301	<10	<21	<5	405	<201	114	<20	12	NAn	24.7	471	2	<15	68	9	52.9	6.09	Porphyritic biotite granite with smoky quartz.
109	97	8	<96	145	<10	<20	5	358	<165	75	<20	10	NAn	22.6	<99	4	<15	78	8	25.2	9.60	Medium-grained granite dike with tourmaline.
110	110	9	NAn	300	54	61	25	NAn	61	64	32	<5	800	NAn	NAn	NAn	NAn	15	5	21.0	NAn	Coarse-grained, porphyritic biotite granite.
111a	<1	<1	<126	326	26	37	39	574	<228	110	<20	26	<3	52.4	<117	6	<15	104	12	32.8	13.50	Fine to medium-grained, biotite granite.
111b	136	8	<33	240	28	120	119	438	<139	54	<32	30	7	29.3	<74	5	<15	85	16	23.7	15.30	Abundant hematite in alaskite.
112[2]	75	5	<99	257	12	<63	246	390	<180	102	<20	87	16	31.8	664	2	<15	252	10	23.7	6.13	Hematite in porphyritic biotite granite with fine- to medium-grained groundmass.
113	168	5	<98	202	16	<65	53	375	<171	110	30	10	8	29.6	575	<1	<15	62	13	45.2	12.50	Porphyritic biotite granite with fine- to medium-grained groundmass.
114	77	6	<98	396	12	91	<5	361	<230	140	<20	25	NAn	27.9	217	2	<15	51	11	66.3	7.13	Porphyritic biotite granite with smoky quartz.
115	109	<1	<99	1,144	33	<57	81	<44	<298	57	35	<10	108	19.3	366	<2	<15	6	<5	<1.5	0.52	Diabase float.

NAn Not analyzed.
[1]Analyses performed by Los Alamos (NM) Scientific Laboratories.
[2]Mineralized or altered samples, and samples not part of the plutonic complexes; not included in calculation of statistics presented in table 4.
[3]Analyses by Technical Services Laboratories (TSL), Spokane, WA, using atomic-absorption methods.

NOTE.—Elements are listed in ascending order according to atomic number.

Table A-2.—Geochemical analyses[1] of rock samples collected in Hot Spring pluton area, parts per million

(Samples are located by number in figures 9 and 10.)

Sample	Li	Be	Cl	Mn	Cu	Zn	As	Rb	Sr	Zr	Cb	Sn	Sb	Cs	Ba	Ta	W	Pb	Bi	Th	U	Description
116a	43	3	<60	118	23	<41	100	228	<170	233	28	<10	<2	10.8	300	<1	<15	54	<5	46.8	10.77	Medium-grained, equigranular, leucocratic granite.
116b	99	7	<109	95	16	55	<5	286	<183	199	<20	<10	<2	10.1	<109	<1	21	75	<5	27.7	7.32	Rhyolite porphyry with smoky quartz and sanidine phenocrysts.
117	119	7	<118	121	23	85	<5	284	<201	142	<20	<10	<4	25.6	<109	<1	<15	58	<5	44.4	10.63	Rhyolite porphyry.
118	<1	<1	<116	146	28	180	15	388	<239	112	<20	11	<4	21.6	<132	2	<15	105	<5	46.2	6.97	Medium-grained biotite granite dike cutting metagabbro.
119	24	5	<124	56	18	107	10	249	<242	370	<20	<10	<2	8.3	<129	<1	15	32	15	47.1	7.66	Buff-colored, orange-weathering rhyolite porphyry cut by quartz veinlets.
120	60	7	<102	25	24	<11	17	<31	<198	72	<20	<10	158	16.6	166	<2	15	18	7	25.2	5.73	Buff-colored, orange-weathering rhyolite.
121	61	5	<116	240	31	91	5	200	<216	219	<20	<10	26	11.7	246	<1	22	157	9	29.7	6.31	Buff-colored rhyolite with beta-quartz pseudomorphs.
122	94	4	<108	310	12	120	7	254	<135	135	<20	<10	<2	10.7	262	<1	<15	41	9	42.1	7.37	Coarse-grained biotite granite with miarolitic texture.
123	183	4	<111	282	12	69	<5	352	<120	120	<20	<10	<1	22.2	<142	<1	<15	42	6	53.8	12.42	Coarse-grained sub-equigranular biotite granite and dark quartz grains.
124	116	6	<126	210	<10	40	7	336	<70	70	<20	<10	<1	16.4	<115	<1	<15	53	13	38.6	9.82	Coarse-grained biotite quartz monzonite with miarolitic cavities and tourmaline.
125	100	4	<96	215	<10	40	7	264	<211	136	<20	<10	<1	7.9	532	<1	<15	39	7	45.0	5.93	Coarse-grained biotite granite.
126	93	6	<111	169	<10	<24	6	363	<189	108	<20	12	<1	20.3	<101	3	16	48	8	68.7	8.66	Fine-grained biotite granite.
127	102	4	<97	217	10	28	7	286	<172	110	<20	<10	<1	14.3	<102	<1	<15	43	9	77.1	8.60	Tourmaline in fine-grained miarolitic biotite granite.
128	81	6	<124	372	<10	230	8	329	<235	155	<20	<10	2	18.1	409	<1	<15	43	<5	59.1	7.42	Seriate to porphyritic biotite granite.
129	69	9	NAn	300	55	60	25	NAn	61	92	35	<5	230	NAn	NAn	NAn	NAn	8	6	47.0	NAn	Seriate to porphyritic biotite granite with smoky quartz.
130	49	9	<104	178	14	<15	<5	499	<175	57	<20	13	<2	34.7	<103	4	<15	101	<5	24.2	19.13	Fine-grained leucocratic granite with minor tourmaline.
131	131	6	<106	447	13	62	<5	287	<249	145	<20	<10	<1	12.9	541	<1	<15	69	<5	45.4	6.78	Coarse-grained biotite granite.
132	100	5	<113	412	<10	56	<5	270	<260	192	<20	<10	<1	12.1	740	<1	<15	52	<5	47.0	8.50	Do.
133	107	3	<115	231	<10	<48	<5	260	<204	105	<20	<10	<1	12.8	242	<1	<15	61	<5	45.2	6.92	Porphyritic biotite granite with medium-grained groundmass.
134	39	4	<109	347	40	<107	34	120	<245	147	<20	<10	<3	11.9	787	<2	16	54	17	46.4	33.65	Decomposed granite from red-stained area.
135	108	6	<100	161	12	57	11	374	<172	119	<20	<10	NAn	15.2	<104	<1	<15	60	<5	53.0	13.58	Medium-grained biotite granite.
136a	62	5	<100	102	18	<51	<5	353	<162	125	<20	<10	<1	13.7	<87	<1	<15	98	<5	42.7	8.94	Coarse-grained biotite granite.
136b	155	5	<91	148	11	<33	<5	344	<190	95	<20	<10	NAn	15.6	275	<1	<15	54	9	40.0	3.84	Do.
137a	31	8	NAn	350	47	51	100	NAn	61	42	38	<10	200	NAn	10	NAn	NAn	13	10	23.0	NAn	Porphyritic biotite granite with medium- to coarse-grained groundmass.
137b	70	4	<103	372	13	<49	<5	194	<228	194	<20	<10	<2	8.7	901	<1	<15	49	12	44.0	5.99	Porphyritic biotite granite with coarse-grained groundmass.
138	162	6	<113	638	26	<34	<5	306	<275	275	<20	<10	<3	18.7	544	<1	<15	79	11	47.8	6.81	Medium-grained segregation in porphyritic biotite granite.
139	100	3	<110	401	29	<30	<5	193	<247	150	<20	<10	<2	9.2	1,008	<1	<15	28	9	25.6	7.58	Coarse-grained biotite granite.
140	178	5	<143	410	13	<82	<5	196	<264	159	<20	<10	<2	11.2	729	2	<15	27	<5	30.3	12.10	Do.
141	115	3	<46	40	25	40	18	229	<111	92	<20	<10	NAn	11.0	<102	<1	<15	78	5	24.4	4.79	Rhyolite porphyry.
142	149	8	<128	210	10	55	5	412	<225	90	<20	<10	<3	28.0	<119	2	<15	42	<5	22.2	10.09	Medium-grained biotite granite.
143	74	5	<4	47	14	67	12	275	<107	107	<20	<10	8	8.9	<73	<1	<15	47	9	32.6	8.34	Rhyolite float.
144	154	4	<49	23	20	102	7	264	<116	123	<20	10	4	8.4	<73	<1	22	89	5	22.4	6.59	Rhyolite porphyry float.
145[2]	147	4	<38	84	40	291	831	198	<130	111	<20	14	372	29.6	<76	<2	22	42	17	85.4	116.30	Altered and silicified granite with hematite and limonite.
146a	43	7	<100	63	17	<43	13	290	<163	115	<20	<10	<2	14.1	<88	2	<15	55	<5	38.0	6.38	Porphyritic biotite granite with fine-grained groundmass.
146b	70	5	<100	33	12	51	94	332	<147	112	<20	<10	5	13.5	<85	<1	<15	87	<5	37.4	11.04	Silicified equivalent of sample 146a.
146c	57	3	304	835	28	117	<5	229	<261	462	<20	<10	<2	14.3	977	<2	20	53	5	31.2	7.23	Porphyritic biotite granite.
147[2]	<1	1	<108	42	23	109	10	248	<179	145	26	<10	<4	16.1	<99	<1	<15	58	<5	37.9	8.27	Altered rhyolite with metazeunerite(?).
148[2]	104	4	<26	133	62	212	2,181	145	159	98	<20	46	127	33.5	225	<2	39	336	73	86.4	80.24	Altered and silicified rhyolite porphyry with hematite.
149a[2]	112	5	<48	375	341	87	NAn	124	<322	NAn	<20	218	35	12.9	898	<2	<15	2,616	<5	37.0	1,000.0	Gray-green, silicified rhyolite porphyry with metazeunerite.
149b	111	4	<39	536	<10	54	NAn	183	<256	NAn	<20	<10	18	12.4	<112	1	<15	45	<5	54.7	17.08	Fine-grained aplite cutting rhyolite porphyry.

See explanatory notes at end of table.

Table A-2.—Geochemical analyses[1] of rock samples collected in Hot Springs pluton area, parts per million—Continued

Sample	Li	Be	Cl	Mn	Cu	Zn	As	Rb	Sr	Zr	Cb	Sn	Sb	Cs	Ba	Ta	W	Pb	Bi	Th	U	Description
149c	154	4	<38	325	11	33	NAn	149	<206	NAn	<20	<10	6	11.1	97	1	<15	42	<5	37.1	10.92	Rhyolite with smoky quartz and iron-stained fractures.
149d	100	3	<55	61	42	105	20	298	<149	135	25	10	9	10.6	<93	<1	<15	99	<5	31.9	8.05	Rhyolite porphyry with beta-quartz pseudomorphs and sanidine phenocrysts.
149e[2]	67	3	<39	363	31	85	448	222	<224	90	<20	60	18	11.7	<115	<1	36	290	36	26.5	13.80	Altered rhyolite with tourmaline and hematite.
149f[2]	66	3	<48	269	218	80	2,336	290	<215	154	<20	207	40	18.6	358	<3	<15	533	<5	35.2	241.30	Altered rhyolite with metazeunerite(?).
150	71	4	NAn	61	55	35	15	NAn	40	69	7	<10	120	NAn	NAn	NAn	NAn	15	NAn	<20.0	NAn	Composite sample of fresh rhyolite porphyry.
151	118	3	<47	80	17	<37	47	263	<141	115	<20	<10	8	8.6	<86	<1	<15	48	<5	41.6	11.29	Rhyolite porphyry with smoky beta-quartz pseudomorphs.
152	110	4	184	100	36	<75	29	318	<189	111	35	12	5	11.6	<104	<1	<15	54	<5	34.4	11.01	Rhyolite porphyry chip sample.
153	92	3	<50	97	28	<95	145	228	<118	120	<20	<10	13	10.9	<78	<1	<15	83	<5	30.3	7.22	Rhyolite porphyry.
154	71	5	<101	110	17	96	35	244	<184	183	<20	<10	<4	17.0	256	<1	18	45	11	40.0	9.96	Medium-grained, equigranular biotite granite with limonite.
155	97	6	<86	58	15	79	49	331	<177	129	<20	<10	<1	11.6	<104	<1	<15	64	12	46.6	12.69	Seriate biotite granite.
156	47	2	125	67	11	56	44	248	<124	135	<20	<10	9	10.2	<74	<1	<15	65	9	44.0	13.78	Medium-grained, equigranular biotite granite.
157	77	4	<41	71	19	98	127	268	<100	150	<20	<10	19	15.2	182	<1	<15	88	11	40.8	11.41	Rhyolite porphyry with dark, smoky, beta-quartz pseudomorphs and clay after K-feldspar.
158	102	4	<43	390	<10	<25	NAn	132	<284	NAn	<20	<10	24	11.1	<139	2	<15	75	<5	52.1	14.99	Iron-stained, fine-grained rock with quartz veins.

NAn Not analyzed.
[1]Analyses performed by Los Alamos (NM) Scientific Laboratories.
[2]Mineralized or altered samples, and samples not part of the plutonic complexes; not included in calculation of statistics presented in table 4.

NOTE.—Elements are listed in ascending order according to atomic number.

Table A-3.—Geochemical analyses[1] of rock samples collected in Coal Creek and Fort Hamlin Hills pluton areas, parts per million

(Samples are located by number in figure 11.)

Sample	Li	Be	Cl	Mn	Cu	Zn	As	Rb	Sr	Zr	Cb	Sn	Sb	Cs	Ba	Ta	W	Pb	Bi	Th	U	Description
159	123	4	205	253	10	<17	<5	258	<194	126	<20	<10	<2	8.9	218	<1	<15	45	13	53.8	4.49	Coarse-grained biotite granite.
160	88	4	<87	230	<10	<46	8	238	<183	147	<20	<10	<1	7.8	316	<1	<15	34	12	45.0	3.93	Do.
161a	76	8	<93	139	13	34	10	412	<156	57	<20	10	<2	17.8	<93	4	<15	66	13	23.2	9.10	Graphic granite with tourmaline.
161b	54	9	NAn	95	46	25	25	NAn	61	60	5	<10	240	NAn	NAn	NAn	15	15	4	28.0	NAn	Coarse-grained biotite granite with tourmaline.
162	81	7	<38	388	17	64	5	306	<188	151	<20	12	<1	24.5	296	<1	<15	40	11	32.3	5.22	Do.
163	81	6	<113	403	30	392	18	291	<261	135	<20	<10	<3	16.2	362	2	<15	285	5	24.8	4.88	Porphyritic granite.
164a	81	11	<116	267	<10	79	7	393	<236	82	<20	25	<3	149.9	<121	<1	<15	56	6	35.7	6.26	Fine-grained miarolitic phase in porphyritic biotite granite.
164b	175	9	<108	227	16	<71	<5	280	<194	73	<20	<10	NAn	21.3	516	<1	<15	67	<5	10.9	3.34	Medium-grained granular biotite granite.
164c	64	6	<126	378	14	<30	<5	285	<234	151	<20	<10	<2	23.3	498	<1	<15	49	6	32.9	6.00	Coaraw-grained porphyritic biotite granite.
165	81	11	<110	18	35	<32	7	265	<205	109	<20	<10	<1	14.5	<109	3	<15	53	41	26.2	8.20	Fine-grained, micrographic, leucocratic granite dike.
166	71	9	NAn	330	84	80	25	NAn	85	28	42	<5	175	NAn	7	NAn	NAn	8	7	<20.0	NAn	Coarse-grained biotite granite.
167	37	5	<110	578	23	121	7	392	<223	205	<20	<10	NAn	28.3	510	<1	<15	56	8	35.3	5.04	Biotite-rich granular segregation in coarse-grained biotite granite.
168	30	7	<101	103	15	<11	57	357	<200	62	<20	<10	<1	10.7	<112	2	<15	58	9	33.4	10.75	Coarse-grained biotite granite with radial aggregates of tourmaline.
169	80	5	<108	236	20	<11	<5	265	<236	197	<20	<10	<2	15.6	629	<1	24	56	<5	34.5	10.76	Coarse-grained porphyritic biotite granite.
170a	91	3	<117	363	<10	<20	9	292	<224	42	<20	<10	3	8.9	<117	<1	<15	61	<5	17.6	7.29	Tourmaline and pyrite in fine-grained leucocratic dike.
170b	80	7	<99	366	21	<90	39	283	<222	153	<20	23	NAn	23.4	358	2	<15	43	<5	39.6	10.46	Coarse-grained porphyritic biotite granite.
171	80	6	<104	390	20	<71	<5	286	<194	183	<20	13	<1	21.4	416	2	<15	50	<5	38.6	5.35	Do.
172	73	4	<156	4,197	80	288	87	<73	<714	167	<20	<10	8	19.7	<351	<2	105	<5	<5	42.4	25.55	Medium-grained granular biotite granite.
173	55	5	229	93	17	180	22	141	<282	581	<20	<10	<1	12.0	589	3	<15	30	9	47.9	9.27	Coarse-grained porphyritic biotite granite.
174	153	5	242	393	<10	72	25	257	<181	254	<20	10	<2	11.9	559	1	22	21	9	40.0	3.89	Do.
175	93	4	228	343	12	55	9	264	<223	220	<20	<10	<2	10.7	625	<1	<15	22	6	24.2	5.21	Coarse-grained porphyritic biotite granite.
176	51	5	162	346	<10	<53	7	241	<230	208	<20	<10	<2	8.3	473	<1	<15	34	8	33.2	2.89	Coarse-grained biotite granite.
177	72	6	<112	207	10	<59	13	264	<199	193	<20	<10	<2	6.4	264	<1	<15	32	10	36.0	4.27	Medium-grained hypidiomorphic biotite granite.
178[2]	23	<1	391	1,384	205	189	64	<43	<285	99	<20	10	<2	3.6	<139	<1	<15	15	<5	6.2	1.92	Altered quartz-mica schist with pyrite.
179	111	6	200	121	13	72	<5	334	<200	74	<20	<10	<2	11.3	<113	3	25	48	<5	40.5	4.89	Medium-grained hypidiomorphic biotite granite.
180	85	6	222	224	17	<59	13	359	<209	146	<20	<10	<2	10.4	319	<1	<15	37	7	35.0	4.98	Coarse-grained porphyritic biotite granite.
181[2]	72	8	<109	658	15	87	5	1,102	<281	40	<20	308	<1	31.4	<146	29	16	<5	<5	11.0	9.08	Fine-grained leucocratic, felsic dike with pyrite, tourmaline, and hematite.
182	122	4	237	427	16	<56	64	290	<231	241	<20	<10	<2	9.8	456	<1	<15	29	10	33.3	2.91	Porphyritic biotite granite with medium-grained groundmass.
183	128	6	267	298	52	<46	19	272	<212	190	<20	<10	<2	11.6	502	2	40	30	19	32.7	3.79	Do.
184a[2]	88	4	<76	56	54	<35	90	189	<136	152	<20	<10	<2	11.4	1,255	2	18	20	<5	12.5	3.20	Fine-grained leucocratic, felsic dike in schist.
184b	54	8	1,300	170	49	50	15	2,400	61	46	18	<10	100	5.0	9	NAn	NAn	16	9	21.0	NAn	Coarse-grained biotite granite with minor tourmaline.

NAn Not analyzed.
[1]Analyses performed by Los Alamos (NM) Scientific Laboratories.
[2]Mineralized or altered samples, and samples not part of the plutonic complexes; not included in calculation of statistics presented in table 4.

NOTE.—Samples 159 through 172 are from the Coal Creek area; samples 173 through 184 are from the Fort Hamlin Hills area. Elements are listed in ascending order according to atomic number.

APPENDIX B.—SAMPLE IDENTIFICATION KEY

(Sample numbers used in this report related to field numbers used in DOE open file reports (*1, 21*))

Sample	Field number	Sample	Field number	Sample	Field number	Sample	Field number	Sample	Field number
1	KA10838	34	PB11127	71e	PB12356	111a	PB12994	149B	KA11263
2a	RM11014	35	PB10285	71f	PB16182	111b	PB12995	149c	KA11264
2b	RM11015	36	PB10286	72	PB12364	112	PB12996	149c	PB15690
3a	RM10073	37	PB10287	73a	PB12366	113	PB12997	149e	PB15691
3b	RM10074	38	PB10288	73b	PB16183	114	PB11147	149f	PB15693
4a	RM10066	39	PB10289	74	PB12623	115	PB12999	150	PB15633
4b	RM10067	40	PT11129	75	PB10292	116a	PB15771	151	PB15628
4c	RM10068	42	PB10284	76	PB10291	116b	PB15772	152	PB15689
5a	RM11013	43	PB11155	77	PB10290	117	PB15635	153	PB15678
5b	RM11012	44	PB11156	78	PB12659	118	PB15697	154	PB15773
6	KA10839	45	KA 9696	79	PB12658	119	PB12691	155	PB15774
7	KA10837	46	PB15878	80a	PB10420	120	PB12690	156	PB15775
8	RM11011	47	PB11157	80b	PB10422	121	PB12689	157	PB15776
9	PB15145	48	PB12657	81a	PB16041	122	PB12939	158	KA 9961
10a	PB10403	49	PB10192	81b	PB16042	123	PB12938	159	PB11131
10b	PB10405	50	KA 9698	82	PB10425	124	PB12937	160	PB11132
10c	PB10406	51	PB10243	83	PB10423	125	PB15861	161a	PB11133
11	PB10404	52	PB12645	84	PB10307	126	PB15860	161b	PB12925
12	PB16230	53	PB12646	85	PB10303	127	PB15859	162	PB11134
13	PB16228	54	PB12647	86	PB10304	128	PB15858	163	PB15799
14	PB16224	55	PB12648	87	PB15872	129	PB15857	164a	PB15584
15	PB16216	56	PB12654	88	PB15870	130	PB15856	164b	PB15585
16a	PB16214	57	PB12649	89	PB12643	131	PB15855	164c	PB15586
16b	PB16215	58b	PB15873	90	PB11154	132	PB15854	165	PB15588
16c	PB16221	59a	PB15874	91	PB11152	133	PB15853	166	PB15802
16d	PB16211	59b	PB15875	92	PB12633	134	PB16047	167	PB15589
17	PB16222	60	PB10311	93	PB12632	135	PB16046	168	PBv15587
18	PB16218	61	PB10310	94	PB12631	136a	PB16156	169	PBv15591
19	PB16219	62	PB10419	95	PB12630	136b	PB16157	170a	PBv15590
20	PB16220	63	PB12362	96	PB12635	137a	PB12934	170b	PBv15592
21	PB15146	64	PB15869	97	PB12636	137b	PB12935	171	PBv15593
22a	PB10411	65	PB15867	98	PB10188	138	PB12936	172	PBv15576
22b	PB10412	66	PB15868	99	PB10185	139	PB236	173	PBv15561
22c	PB10410	67	PB10299	100	PB10186	140	PB249	174	PBv15562
23	KA10840	68	PB10300	101	PB10183	141	PB12697	175	PBv15559
24	KA10841	69	PB10301	102	PB10187	142	PB12696	176	PBv15556
25	PB12617	70a	PB16179	103	PB12638	143	PB12693	177	PBv15563
26	PB12618	70b	PB12360	104	PB11150	144	PB12699	178	PBv15555
27	PB15551	70c	PB16180	105a	PB12969	145	PB15596	179	PBv15564
28	PB15550	70d	PB12357	105b	PB12970	146a	PB15594	180	PBv15565
29	PB11126	70e	PB12373	106	PB12968	146b	PB15595	181	PBv15568
30	PB15549	71a	PB16181	107	PB11141	146c	PB15632	182	PBv15521
31	PB15548	71b	PB12374	108	PB11142	147	PB15695	183	PBv15522
32	PB12620	71c	PB12352	109	PB11143	148	PB15631	184a	PBv15567
33	PB11128	71d	PB12355	110	PB15877	149a	KA 9946	184b	PBv15662