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GEOLOGICAL SURVEY CIRCULAR 597

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Distribution of Beryllium Tin, and Tungsten in the Lake George area, Colorado

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DISTRIBUTION OF BERYLLIUM, TIN, AND TUNGSTEN IN THE LAKE GEORGE AREA, COLORADO

By C. C. HAWLEY and W. R. GRIFFITTS

Abstract

Complex ore deposits are spatially associated with granitic bodies of Precambrian age in the Lake George area, Colorado. They include greisens that contain high concentrations of beryllium and subordinate amounts of tin, tungsten, and other metals associated with the Redskin Granite. Scheelite deposits in calc-silicate rocks and greisen deposits near Tappan Mountain that contain tin and tungsten minerals are associated with the Silver Plume(?) Granite.

Samples of stream sediments and soils locally show anomalous concentrations of beryllium, tin, copper, lead, and molybdenum. Some of the areas of anomalous concentrations correlate with known deposits; others do not, and this fact suggests that further prospecting is warranted.

INTRODUCTION

The Lake George area and adjacent Tarryall Springs area, near Lake George in south-central Colorado (fig. 1), are characterized by many small deposits of beryllium, tungsten, and fluorite. One of these deposits, that of the Boomer mine, has been a major domestic source of beryllium; others have produced small amounts of beryllium, tungsten, fluorite, and base and precious metals. Previous reports have described the beryllium deposits (Sharp and Hawley, 1960; Hawley, Sharp, and Griffitts, 1960; Hawley, 1963, 1968) and the scheelite-bearing deposits (Tweto, 1960).

This report describes geochemical anomalies of beryllium, tin, and tungsten found in stream sediments, soils, and bedrock and emphasizes the spatial association of ore deposits with plutons of the Silver Plume(?) Granite and the Redskin Granite.

OUTLINE OF MINING HISTORY

Deposits containing gold or silver were found in the Lake George area as early as 1890 and include many of the deposits now known to contain beryllium, tungsten, or tin. Although some precious metals were produced before 1900, the area was largely dormant until World War I, when some deposits such as the Redskin, Boomer, and Apex were reexamined for molybdenum. In 1943, scheelite ores were discovered (Tweto, 1960); small-scale mining and prospecting for scheelite continued for a few years and were succeeded by reexamination of some prospects for uranium. In 1955, beryllium ores were recognized in the Boomer mine, and the first important production began. The interest caused by the Boomer discovery led to discoveries of beryllium-tungsten ores in the Mary Lee area and beryllium ores in the China Wall cupola, recognition of cassiterite in at least three places, and discovery of bertrandite at the Redskin molybdenum prospect. The Boomer mine operated almost continuously from 1955 until July 1965 and produced an estimated 3,000 tons of beryllium ore, including 678 tons which averaged 8.77 percent BeO (Hawley, 1968). Other deposits, including the Mary Lee, Redskin, and those of the China Wall area, have produced a few tons of beryllium ore.

The late date of recognition of some of the complex ores of the district is significant and suggests that future prospecting and exploration may result in the discovery of other minable deposits.

GEOLOGIC SETTING

The Lake George area and adjacent region is underlain mainly by metamorphic and igneous rocks of Precambrian age (fig. 1). The metamorphic and older igneous rocks form a

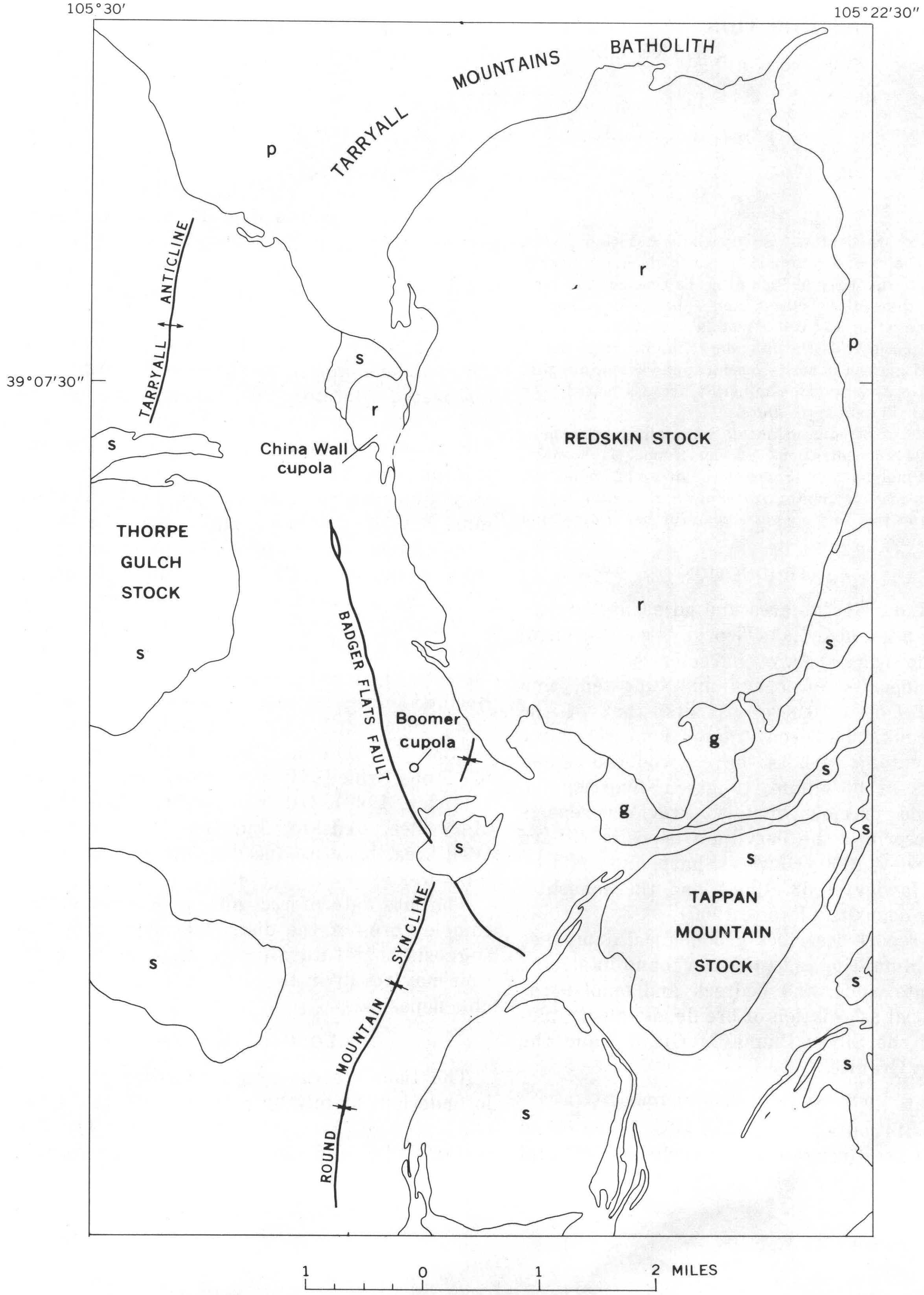


FIGURE 1.—Generalized geologic map of the Lake George beryllium area and adjacent region, with index map.

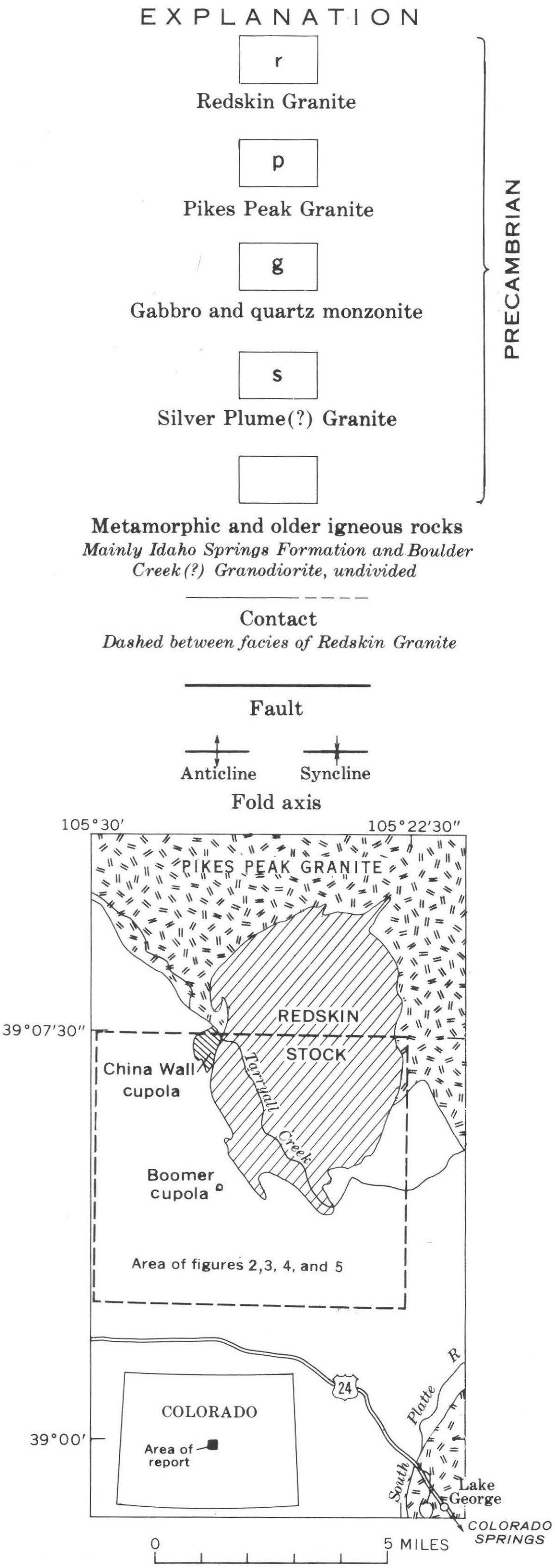


FIGURE 1.—Continued.

strongly deformed metamorphic complex which includes biotite gneiss and schist of the Idaho Springs Formation and amphibolite. Also present are orthogneisses, emplaced about 1.7 billion years ago (Hutchinson and Hedge, 1967) and tentatively correlated with the Boulder Creek Granodiorite of the Front Range. These rocks were intruded about 1.45 billion years ago by the Silver Plume and correlative granites and subsequently by the Pikes Peak and Redskin Granites slightly more than 1.0 billion years ago (Hawley and others, 1966).

The Silver Plume(?) Granite of the area is a fine- to medium-grained tan to light-gray biotite-muscovite quartz monzonite which forms crudely oval stocks. The older gneissic rocks adjacent to the Silver Plume(?) bodies are strongly deformed and are invaded by conformable tongues of the granite (fig. 1). Pegmatitic phases of the granite are common, and tactitelike calc-silicate rocks form inclusions in the granite or are adjacent to it. Two facies of the granite occur in the area and were mapped separately in the Tappan Mountain area (fig. 7). One is a fine-grained gneissic abundantly pegmatitic biotite-muscovite granite, the other, an almost massive medium-grained granite containing tabular potassium feldspar crystals.

The Redskin Granite, the youngest Precambrian rock of the area, formed in the igneous episode dominated by the Pikes Peak Granite. The Redskin forms the sharply discordant Redskin stock, the Boomer cupola, and small bodies not shown on the generalized map (fig. 1). It is a pink fine- to medium-grained nearly massive biotite or biotite-muscovite granite whose texture ranges from equigranular through seriate porphyritic to aplitic. The Redskin Granite and, to some extent, the nearby Pikes Peak Granite are enriched in trace elements and can be termed "tin-granites" (Hawley and others, 1966, p. C144). The beryllium deposits of the area, except for a few small pegmatite deposits, are associated with the Redskin Granite.

ORE DEPOSITS

Beryllium-bearing greisens associated with the Redskin Granite are the most important exploited deposits in the area. These deposits occur in veins, pipes, and complex bodies concentrated especially near the Boomer cupola but also near the Redskin mine, the Mary Lee mine, and east of the village of Tarryall. In the Redskin stock, greisens with low but anomalous amounts of beryllium are concentrated opposite the mouth of Redskin Gulch and approximately 1 mile southeast of Redskin Gulch.

Besides the beryllium-bearing minerals, which include beryl, bertrandite, and rare euclase (Sharp, 1961), the deposits contain trace to locally abundant amounts of argentiferous galena, sphalerite, chalcopyrite, arsenopyrite, molybdenite, wolframite, and cassiterite. Pitchblende is present in small amounts in at least two deposits. The greisen walls of the deposits consist mainly of quartz, muscovite, and topaz in widely ranging proportions. Where greisen has developed in granitic or pegmatitic rocks older than the Redskin or Pikes Peak Granites, it is bordered by a conspicuous hematitic halo.

The ore deposits contain a typical trace-element suite for greisen-type deposits. In addition to the metals listed in table 1, the ore deposits generally contain anomalous amounts of niobium, lithium, and rubidium and locally detectable amounts of bismuth and germanium. Greisen associated with the beryllium deposits

TABLE 1.—*Main ore metals in mineral deposits of the Lake George and Tarryall Springs areas*

[Analysts: J. C. Hamilton, R. G. Havens, and P. R. Barnett. Analyses, unless noted, are semiquantitative spectrographic and reported in parts per million and in series 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5 . . . or by the following symbols: N, not detected; L, detected but below limit of determination; >, greater than; <, less than]

Lab No.	Field No.	Ag	Be[1]	Cu	Mo	Pb	Sn	W	Zn	Description
Greisen: Boomer mine										
H–3610	IV–10a–g	N	10	15	N	200	100	N	N	Quartz-muscovite greisen.
H–3611	IV–10a–y	1.5	50,000	10	N	100	30	N	N	Quartz-bertrandite-muscovite greisen.
293626	C2–d	150	21,000	300	50	>100,000	50	N	3,000	Galena-bearing greisen.
289731	B0–1	15	22	150	N	3,000	300	>100,000	300	Topaz-quartz-wolframite greisen.
289733	B1–13	30	20,000	700	70	30,000	70	N	3,000	Beryl-quartz-muscovite greisen, footwall of sample B1–14.
289734	B1–14	3	31,000	700	N	700	70	300	300	Beryl vein.
281311	B1–19	N	44,300	70	N	70	15	N	N	Do.
281314	B1–22	N	70	30	N	150	70	N	150	Quartz-muscovite greisen, footwall of sample B1–19.
278782	B2–4	150	1,500	15,000	150	30,000	70	L	7,000	Sparse sulfides, Boomer vein.
H–3243	B2–7–2	.7	15	300	30	1,500	150	N	1,500	Muscovite-fluorite zone, Boomer vein.
Greisen: J+S (1), Blue Jay (2), Redskin (3–7), Minerva J (8), Black Prince (9), unnamed locality (10) *Numbers in parentheses refer to localities in figure 2*										
(1) 289719	J+S–1–1	N	17,000	30	N	1,500	150	N	700	Beryllium-bearing greisen.
(2) 288326	559–BJ–2	L	30	300	30	150	15	150	N	Vein material.
(3) 288294	560–RS–A	1.5	7,000	15	N	150	70	N	70	Greisen, lower pipe.
(4) 288295	560–RS–B	7	15,000	150	1,500	300	300	N	70	Greisen, main pipe.
(5) 288301	RS–M3	150	700	700	7	70,000	70	N	150	Do.
(6) 288307	RS–M912	150	15	700	70	3,000	150	150	70	Do.
(7) 288309	RS–M916	7	70,000	150	15,000	300	150	N	70	Bertrandite-molybdenite greisen.
(8) 288315	S60–J–M3	L	300	15	30	70	70	N	70	Greisen.
(9) 288323	S59–BPr–143b	150	30	15,000	N	15,000	150	1,500	300	Chalcopyrite-bearing greisen.
(10) 304816	BA–1006	N	15	N	5	100	1,000	N	300	Greisenized granite.
Calc-silicate deposits and fluorite veins										
278778	TR–53	N	70	7	30	30	15	3,000	N	
D116498	T3–SJ	N	10	1	10	N	N	N	N	Diopside-rich gneiss.
D128286	T2–17	N	1.5	50	N	N	30	[2]<5	N	Garnet-epidote-vesuvianite rock.
D128287	T4–220	N	3	7	7	10	15	[2] 45	700	Garnet-calcite rocks.
2888275	S60–27	L	150	7	N	70	700	L	150	Calc-silicate rock.
Tweto (1960, table 3, analysis 3)		1	20	500	30	20	20	<100	<200	Composite sample, calc-silicate rock.
Tweto (1960, table 3, analysis 4)		<1	50	10	200	10	<10	<100	<200	Do.
293635	BA–583	3	3	20	N	N	150	N	N	Fluorite vein.
288269	S60–35	3	1.5	700	N	N	30	N	L	Fluorite vein, Jacob Kolle vein.
288268	S60–17	1.5	1.5	150	1,500	30,000	N	N	L	Fluorite vein, Silver Dollar vein.
Limits of determination		.5	1	5	5–10	10	10	100	200	

[1] Semiquantitative spectrographic or morin-fluorescent.
[2] Dithiol spectrophotometric method by J. A. Thomas and J. E. Troxel.

generally contains from about 30 to 300 parts per million (ppm) tin, or about two to 20 times more than the Redskin Granite, which itself contains about five times as much tin as most granite (Hawley and others, 1966, p. C145). The tin content of the greisen is rarely as much as 1,000 ppm.

Greisen of a slightly different type occurs at the northeast end of the Tappan Mountain stock of Silver Plume(?) Granite. The greisen is a quartz-muscovite variety, has less beryllium but possibly more tin and tungsten than greisen of the Redskin type, and does not have associated hematitic alteration. Cassiterite, wolframite, scheelite, pyrite, and copper-bearing sulfides are present locally. Analyses of representative greisens associated with Silver Plume(?) Granite are given in the discussion of the Tappan Mountain area (table 3).

The scheelite deposits are in calcium-rich metamorphic rocks, mainly in the southern and southwestern part of the area (fig. 1). With a few exceptions, the deposits are in discontinuous belts (Tweto, 1960, p. 1413) near or in roof pendants of metamorphic rocks in the Silver Plume(?) Granite. Individual deposits are lenses or pods, generally in clusters. The deposits are complex mineralogically, but most contain diopside, garnet, clinozoisite, vesuvianite, epidote, quartz, and calcite. Besides scheelite, the principal metal-bearing minerals are bornite, chalcopyrite, molybdenite, manganiferous silicates, and sphalerite. The trace-element suite in the scheelite deposits is somewhat similar to that of the greisen deposits, but concentrations of tungsten and molybdenum generally exceed those of beryllium and tin; bismuth (not shown in table 1) is generally present.

Vein deposits of fluorite, barite, and precious and base metals also occur in the area. The fluorite deposits are small but are fairly numerous in the Redskin Granite in a northwestward-trending belt passing through Redskin Gulch. They locally contain galena and copper minerals but generally have only very minute contents of beryllium (table 1). The vein deposits are younger than the beryllium-bearing greisens but probably formed during the same period of magmatic activity. They are spatially associated with the Redskin-Pikes Peak igneous series. Furthermore, the abundance of fluorite in both the granitic host and the veins and the similar rare earth contents (not given in table 1) of the fluorite ores and certain facies of the granite suggest a genetic relation between them.

GEOCHEMICAL SAMPLING AND ANALYSES

Stream-sediment samples, some soil samples, and abundant rock materials were collected by the authors and by W. N. Sharp. The stream-sediment samples consisted of sand, silt, and clay-sized materials, most of them collected from the courses of intermittent streams. Soil samples, collected on traverses at 50-foot intervals across or near the Badger Flats fault zone, were predominantly of silt-sized material with intermixed residual rock fragments. They were collected at an average depth of about 6 inches. The rock materials were as fresh as it was possible to obtain and came from outcrops, mine workings, and mine or prospect dumps.

Beryllium determinations were made by the morin-fluorescence method or by spectrograph. Comparisons made between the two methods on samples of granite used for background determination (Hawley and others, 1966, table 5) show very close agreement; comparisons made on sieved stream-sediment samples suggest an average positive bias towards the spectrographic method, although in most cases the morin-fluorescence analysis is within one subgroup of the spectrographic determination, that is, within one numerical value in the series 1, 1.5, 2, 3, 5, 7. The disagreement does not affect the values enough to discredit any anomalous area, especially since most anomalies are also defined by copper, lead, or tin.

Most of the stream-sediment and soil samples were sieved to –100 mesh or –200 mesh and the fine portions analyzed. Comparisons were made between analyses of unscreened pulverized samples and the sieved splits. Except for beryllium in samples from just below the Boomer mine, discussed later, the finer portions contain greater amounts of metals, as shown by data on 20 samples from the Redskin Gulch area:

Element	Content, in parts per million	
	Sieved split	Pulverized sample
Be	16	11
Cu	11	6
Nb	66	39
Pb	44	33
Sn	27	16

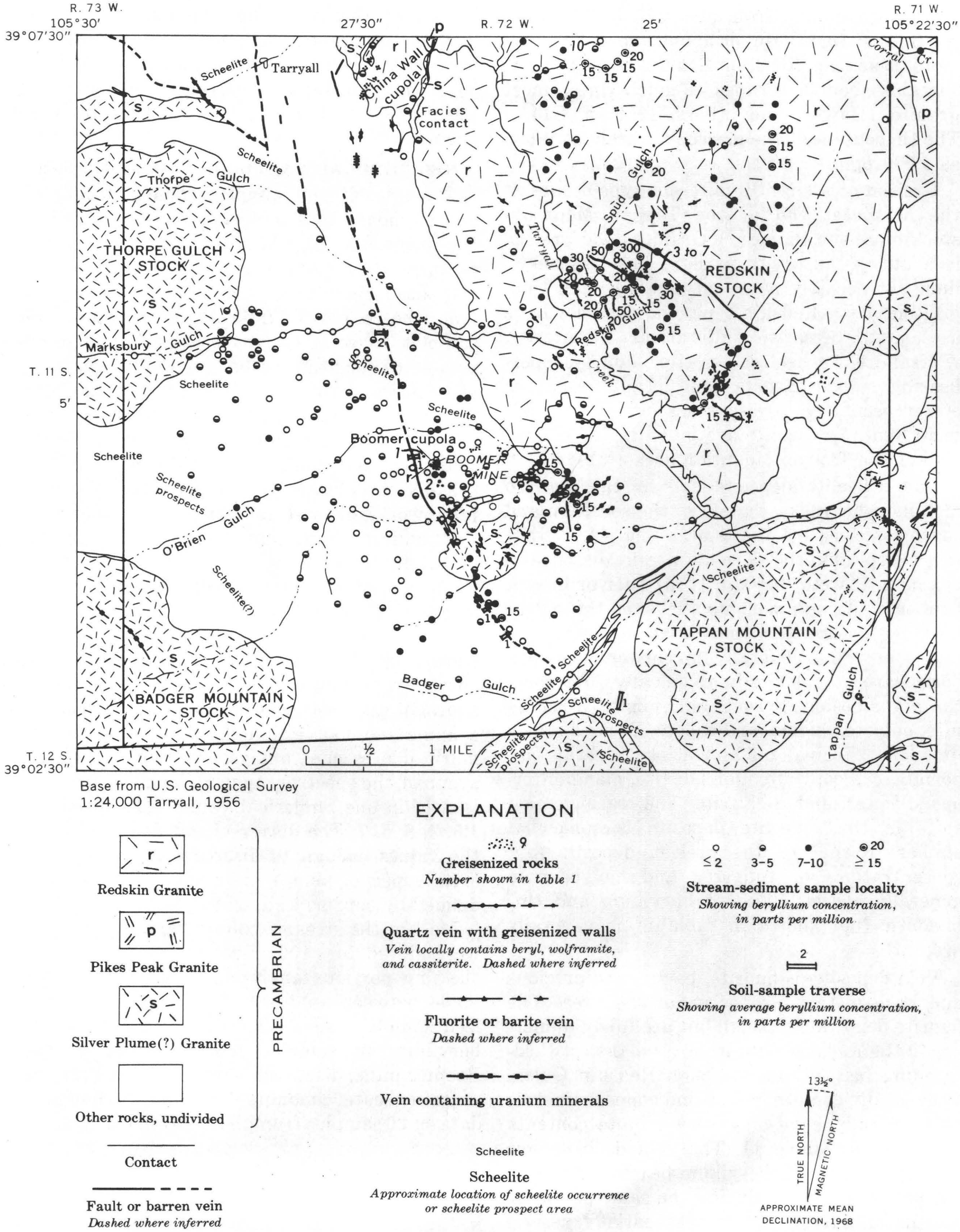


FIGURE 2.—Geochemical map showing distribution of beryllium in stream sediments and soils.

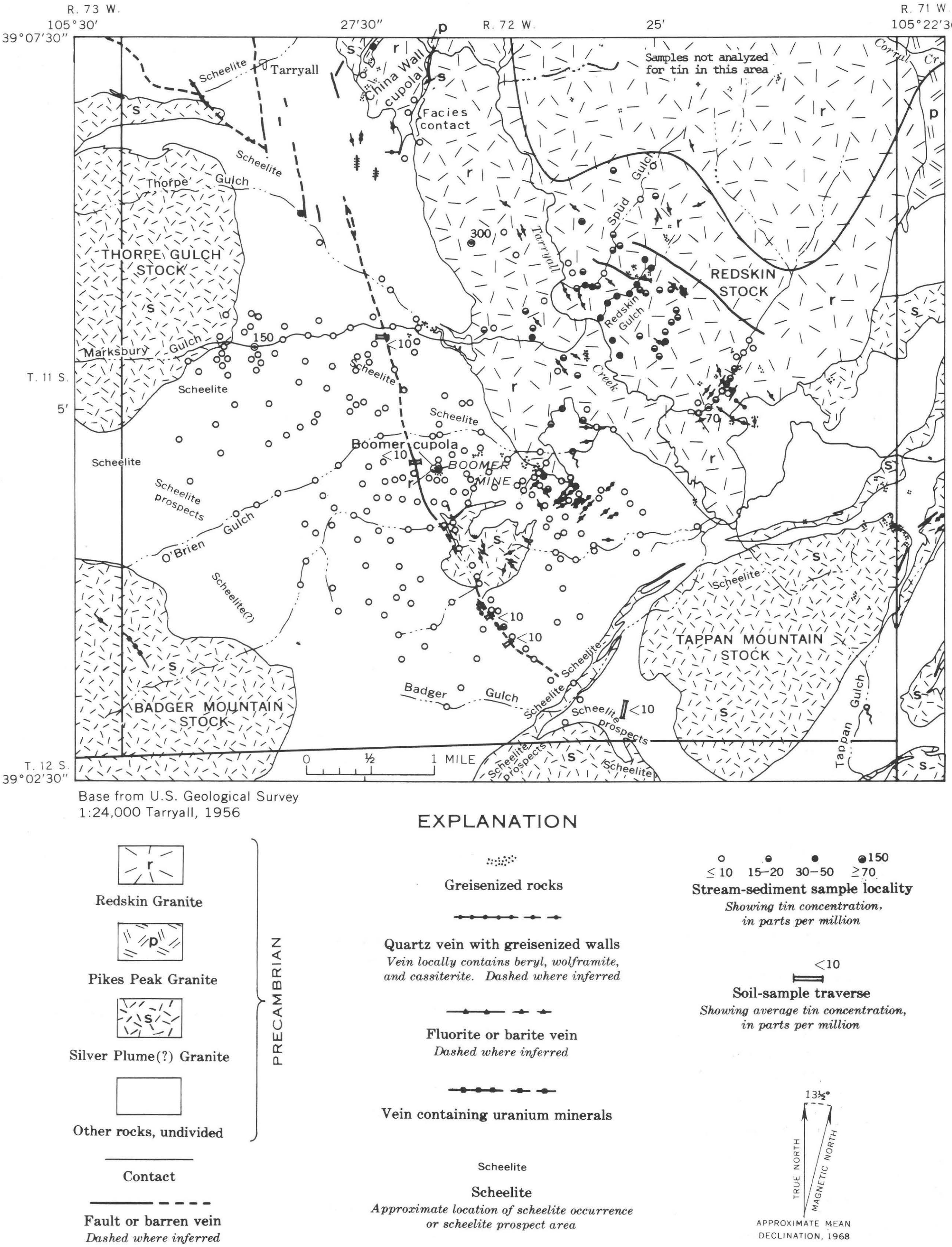


FIGURE 3.—Geochemical map showing distribution of tin in stream sediments and soils.

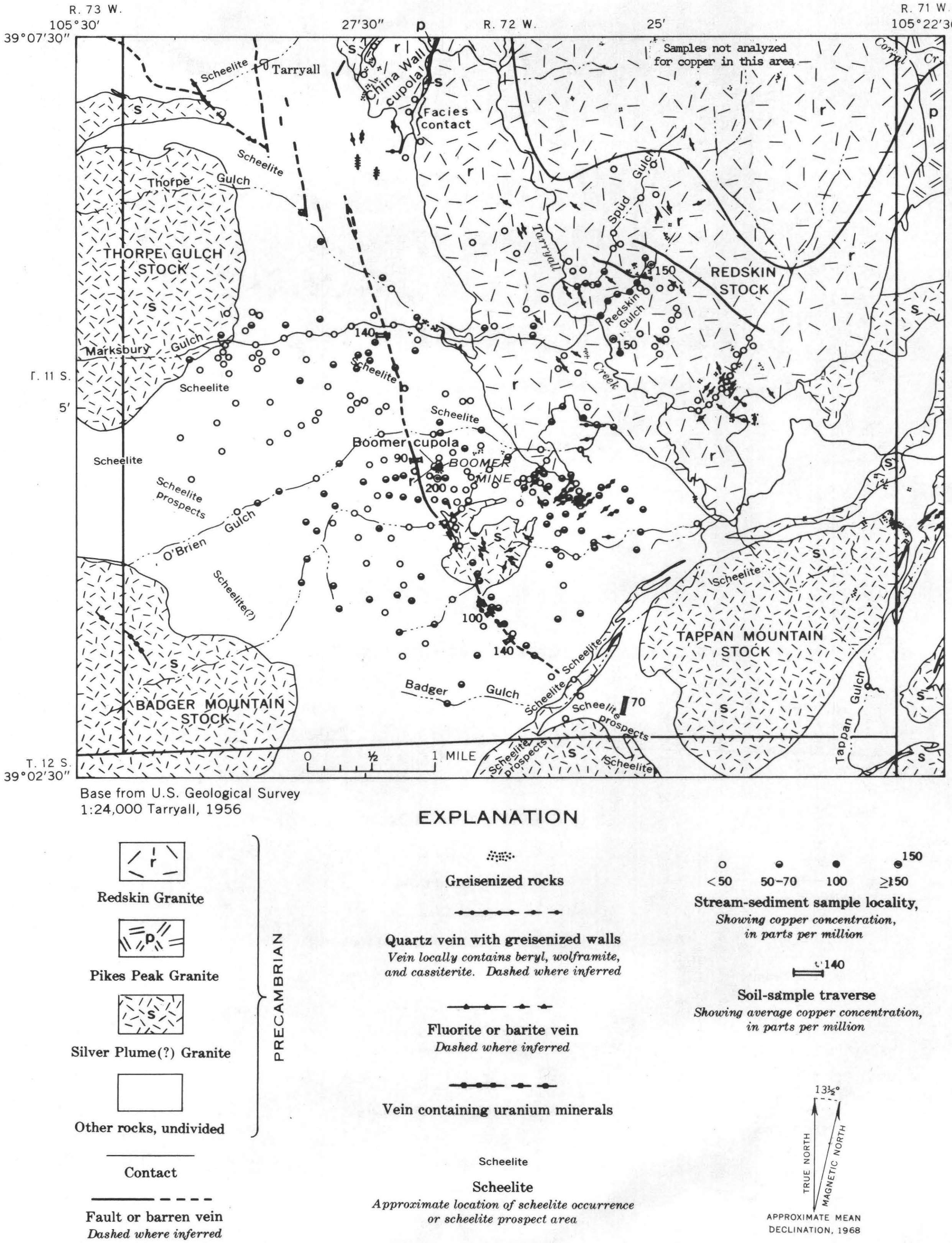


FIGURE 4.—Geochemical map showing distribution of copper in stream sediments and soils.

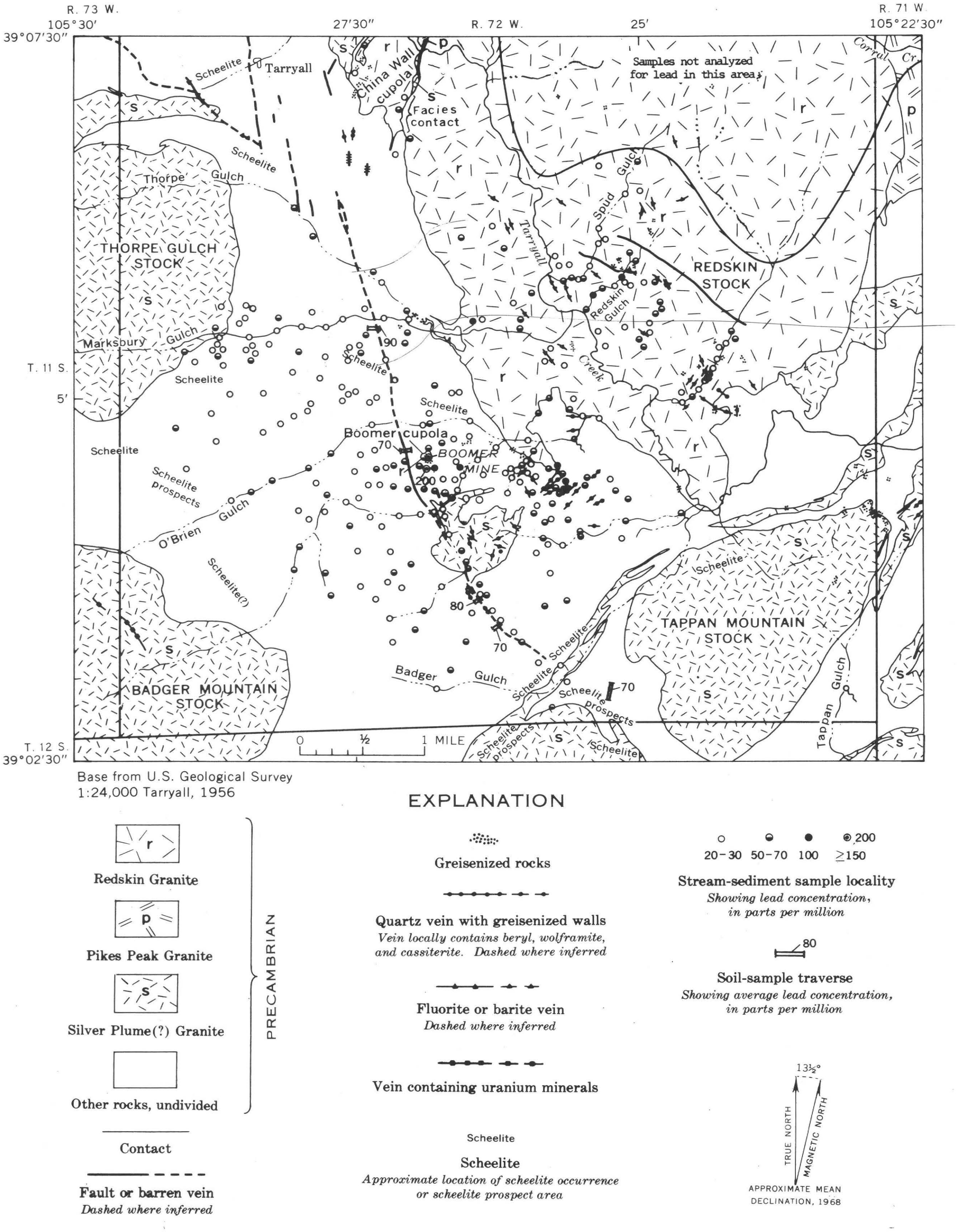
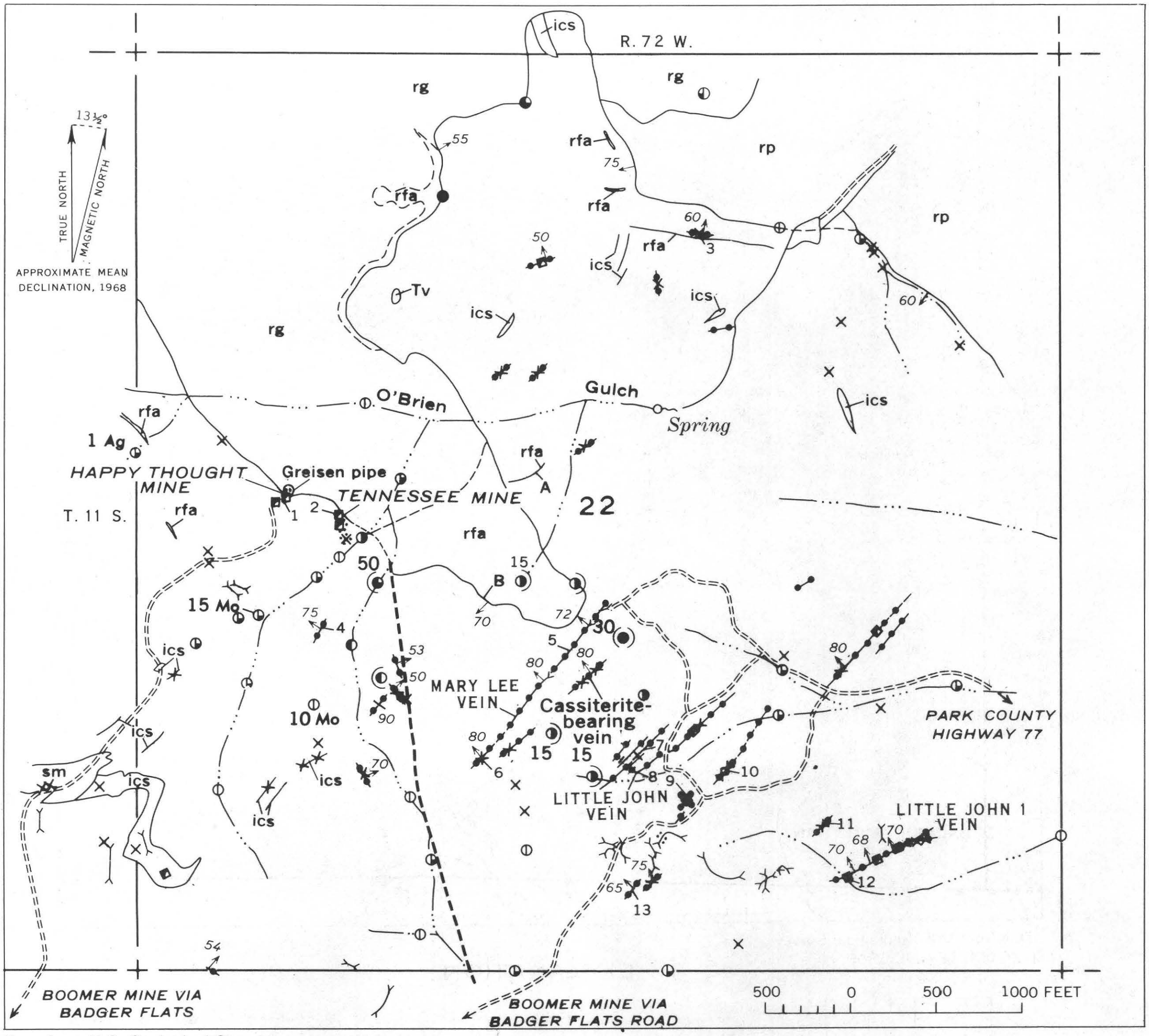


FIGURE 5.—Geochemical map showing distribution of lead in stream sediments and soils.



Base from U.S. Geological Survey
1:24,000 Tarryall, 1956

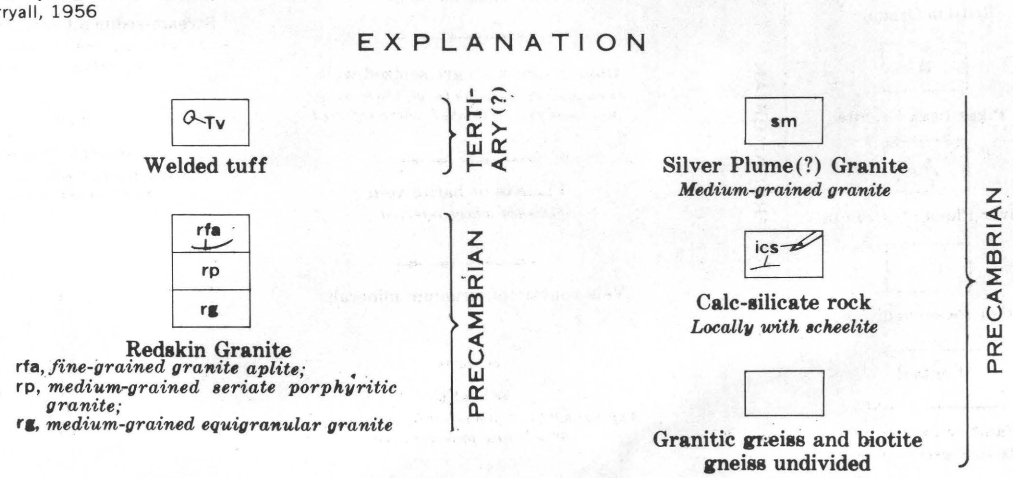


FIGURE 6.—Geologic and geochemical map of the Mary Lee mine area.

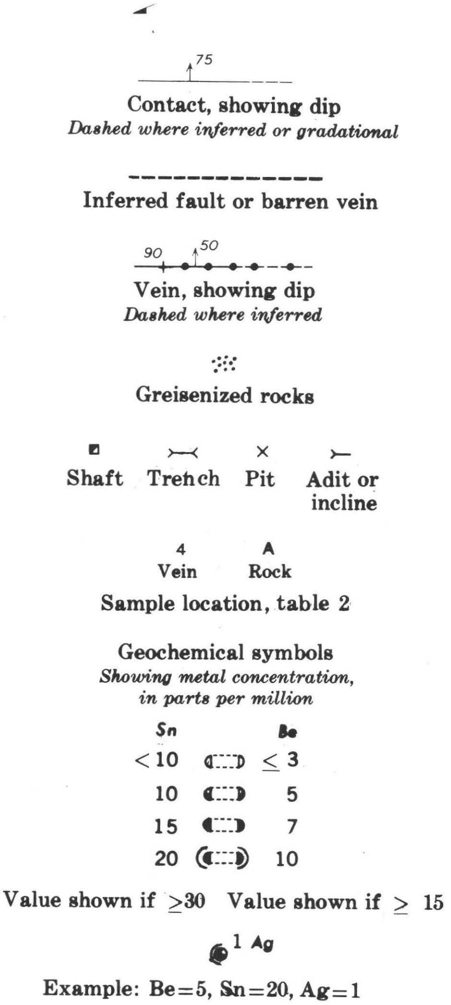


FIGURE 6.—Continued.

Geochemical data for stream and soil samples for beryllium, tin, copper, and lead are summarized on four maps (figs. 2–5). Additional data on some areas are given on more detailed geologic maps (figs. 6–8). These four elements are enriched in the greisen deposits and to some extent in the calc-silicate deposits. Beryllium, copper, and lead were detected in most samples; their lower limits of determination were respectively, 1, 5, and 10 ppm. Tin was not detected in most samples from streams draining the terrane of older rocks but was generally detected in streams draining the Redskin stock; the lower limit of detection was 10 ppm. Tungsten was not detected in any sample of stream sediment, probably because the lower limit of detection was high (100 ppm). Molybdenum was detected in only a few samples which are cited at appropriate places in the text or on detailed maps.

On the geochemical maps the analyses are grouped in four ranges:

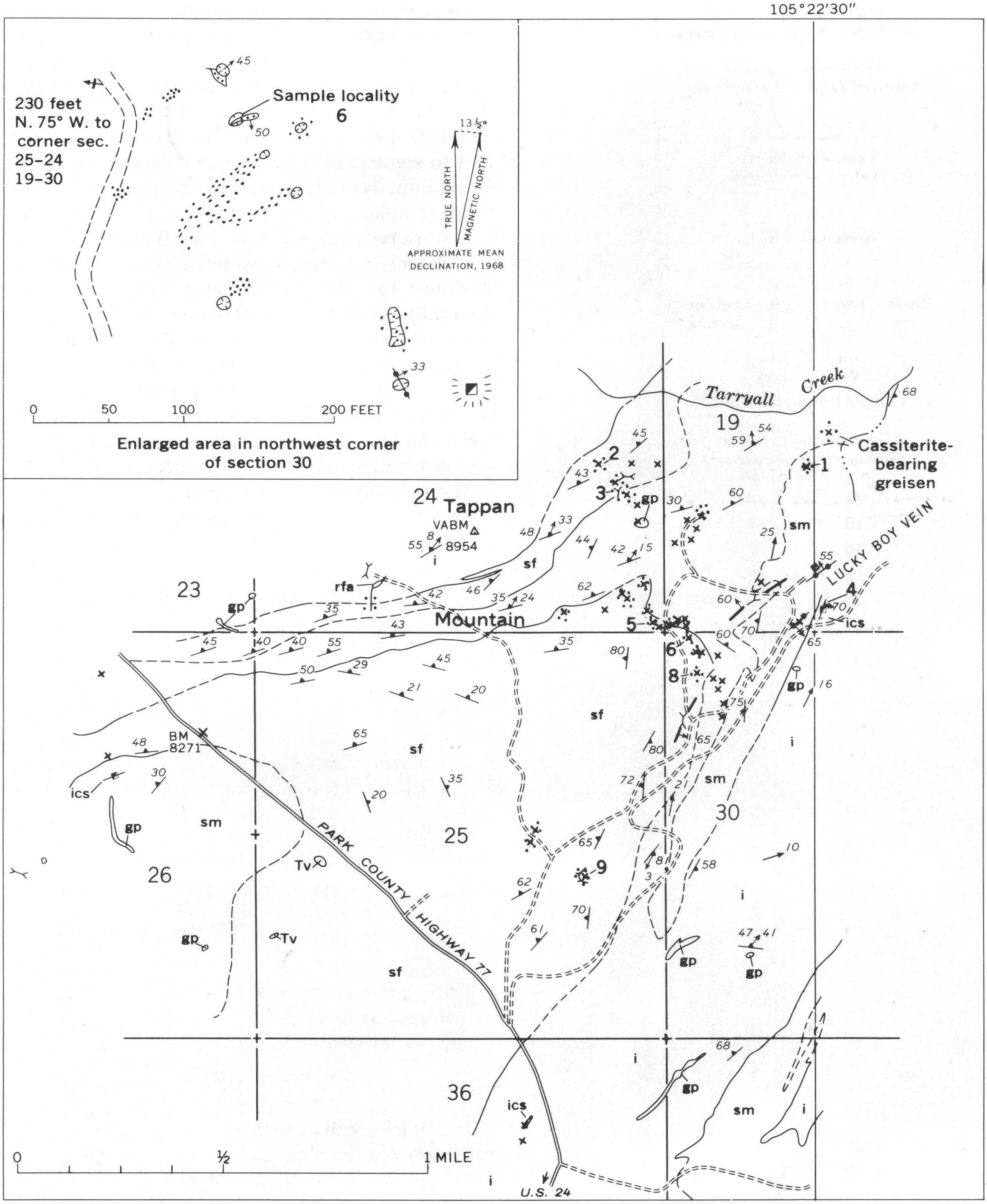
Element	Values, in parts per million, for indicated ranges			
	1	2	3	4
Be	≦ 2	3–5	7–10	(≧ 15, value shown)
Sn	≦10	15–20	30–50	(≧ 70, value shown)
Cu	<50	50–70	100	(≧150, value shown)
Pb	20–30	50–70	100	(≧150, value shown)

These ranges reflect approximate frequency distribution of the analyses but also, to some extent, the analytical method or reporting interval and variations in regional background. For example, the Redskin stock contains an average of about 6 ppm beryllium and 15 ppm tin, the schist and older granitic terrane probably about 3 ppm or less beryllium and less than 3 ppm tin. Hence a geochemical map based on the schist background would suggest that all samples from the Redskin Granite terrane are quite noticeably anomalous.

ANOMALOUS AREAS

Boomer Mine Area

Anomalous values of copper, lead, and beryllium occur in a small area near the Boomer mine, the main beryllium deposit of the area. Replicate analyses of stream-sediment samples near the mine show beryllium concentrations of as much as 20 ppm in crushed samples compared with the maximum of 10 ppm in sieved



Base from U.S. Geological Survey 1:24,000
Tarryall, 1956, and Hackett Mountain, 1956

FIGURE 7.—Geologic map of the Tappan Mountain area.

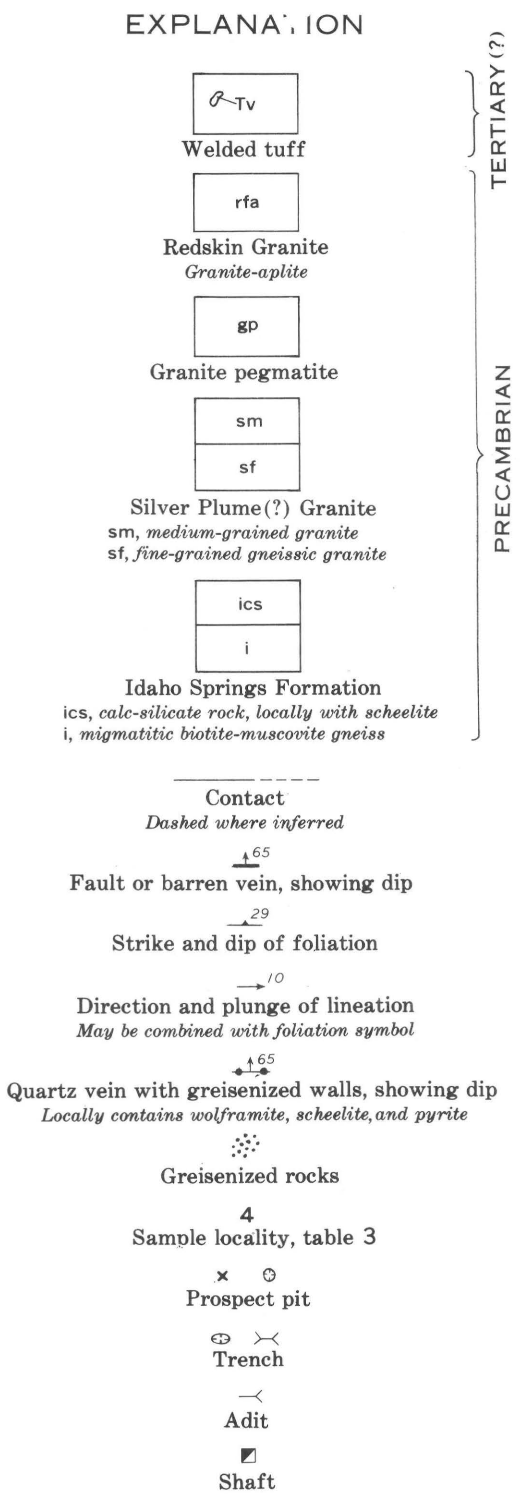


FIGURE 7.—Continued.

samples. The values of lead and copper are as high as 200 ppm in the sieved portion but are only 30–50 ppm in crushed material. Additional data on the mine, including some suggestions for prospecting, are included in other reports on the beryllium deposits of the area (Hawley, 1963, 1968).

Redskin Area

The area drained by Redskin Gulch and lower Spud Gulch is strongly anomalous in beryllium, lead, copper, and tin. Anomalous metal concentrations are to be expected because the berylliferous Redskin and Minerva greisen pipes are in the area. The highest concentration (300 ppm), however, was in a sample collected topographically above these pipes, which suggests that an undiscovered deposit may occur nearby. The rather high concentrations of metals in Redskin Gulch and Spud Gulch are very striking when compared to the low concentration of beryllium below the Boomer deposit; hence, it is possible that larger or richer deposits than those discovered thus far could exist in the Redskin Gulch area. Undiscovered beryllium deposits almost certainly are in the adjacent Spud Gulch drainage, as indicated by beryllium values of as much as 50 ppm in stream-sediment samples.

Samples taken from two intermittent streams southeast of the mouth of Redskin Gulch show copper concentrations similar to those in Redskin Gulch (fig. 4); therefore, the drainage areas of these streams may also be favorable for prospecting.

MARY LEE MINE AREA

Geology

The Mary Lee mine area (fig. 6), about 1 mile east of the Boomer mine, is underlain partly by Redskin Granite and partly by older igneous and metamorphic rocks. Local layers and lenses of calc-silicate gneiss are distinguished on the map because they have been prospected for scheelite.

Three facies were distinguished in the Redskin Granite: a medium-grained equigranular facies, which is predominant; granite-aplite, which forms a lobate cap on the granular rocks near the center of the section; and a seriate porphyritic granite, which forms a local border zone in the northeast part. Exposures in the

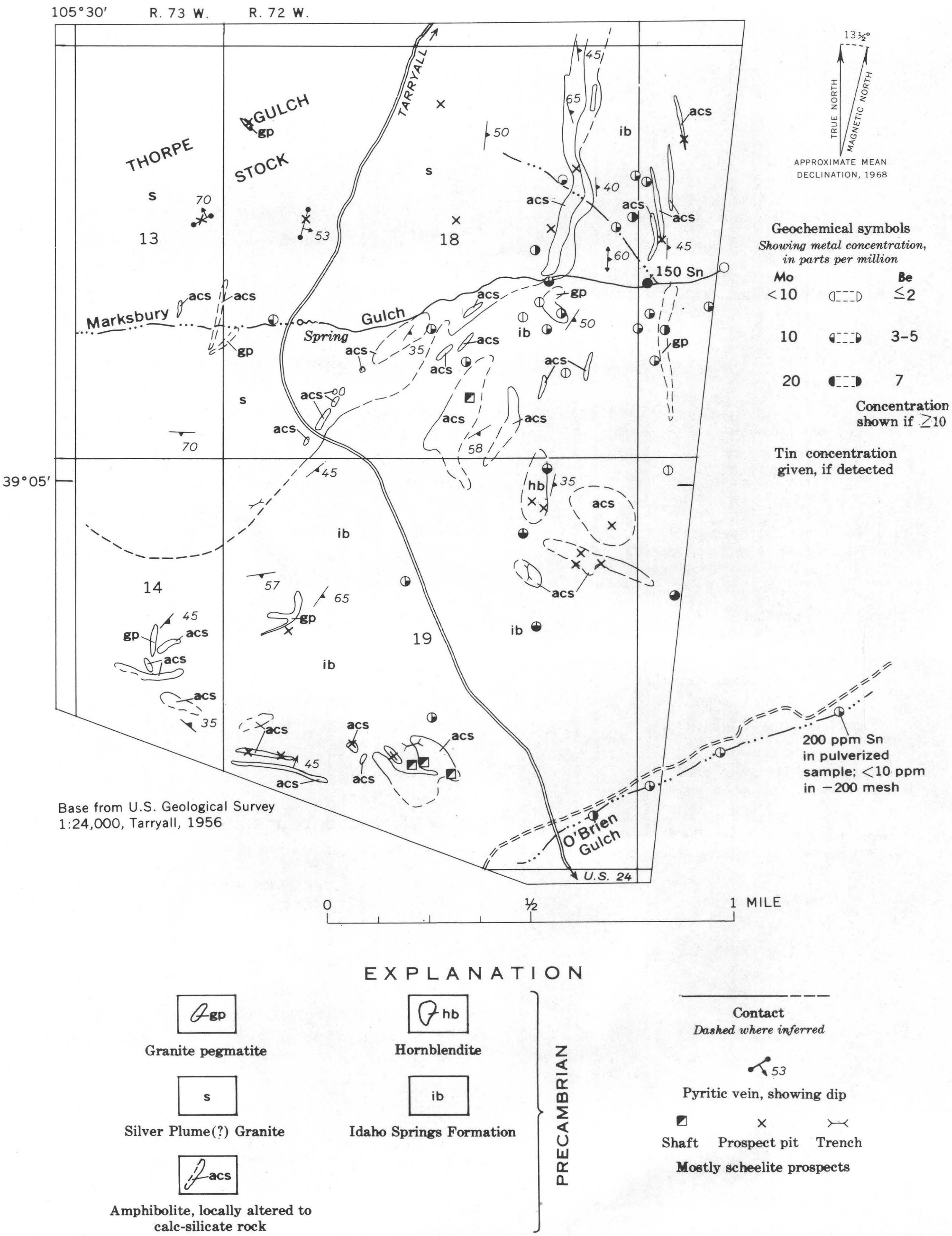


FIGURE 8.—Geologic and geochemical map of the Marksbury Gulch area.

Mary Lee mine show that the granite-aplite lobe continues to the southeast for at least a short distance in the subsurface and that the lobe is inferred to extend outward even farther, possibly below the zone of veins which are oriented at about right angles to the trend of the lobe.

Greisen occurs in a pipe at the Happy Thought mine, in irregular masses and veins at the Tennessee mine, and along the walls of the steep northeast-striking Mary Lee and Little John veins and other shorter veins. Beryl, the main beryllium mineral of the area, is present locally at the Tennessee, Mary Lee, and Little John deposits, where it is associated with quartz, topaz, and wolframite. Cassiterite has been found in one vein (noted in fig. 6) and probably occurs at locality 4 (table 2). Galena and sphalerite occur at the Happy Thought deposit and probably in small amounts in most of the veins. Table 2 is a compilation of the available analyses of vein and bedrock samples of the area.

Geochemistry

Stream sediments from the Mary Lee area are locally anomalous in beryllium and tin, and some samples have detectable molybdenum. The high concentrations of beryllium (as much as 15 ppm) and tin (as much as 50 ppm) correlate fairly well with known veins or suspected faults such as the inferred north-northwest-trending fault west of the Mary Lee vein. Detectable molybdenum was found only near calc-silicate rocks.

TAPPAN MOUNTAIN AREA

Greisen bodies and veins containing discrete tin and tungsten minerals or noticeable amounts of these metals as detected by chemical analysis are concentrated in a small area east and southeast of the top of Tappan Mountain (fig. 7).

Geology

The Tappan Mountain area is underlain by the Silver Plume(?) Granite and by biotite gneiss of the Idaho Springs Formation which in turn contains widely scattered lenses of calc-

TABLE 2.—*Semiquantitative spectrographic analyses of veins, greisen, and granite, Mary Lee mine area*

[Analysts: U. Oda, E. F. Cooley, and J. C. Hamilton. Results reported in parts per million and in series 0.1, 0.15, 0.2, 0.3, 0.7, 1.0, 1.5 . . . or by the following symbols: N, not detected; L detected but below limit of determination; >, greater than]

Sample locality No.	Lab. No.	Field No.	Ag	Be	Cu	Mo	Pb	Sn	W	Zn	Description
1	289735	HT–1	N	70	150	75	300	150	N	700	Greisen.
	289736	HT–2	3	30	700	15	3,000	70	300	L	Greisen, topaz-bearing.
	289737	HT–3	3	15	300	15	700	150	N	700	Greisen.
	HT–1	HT–1	N	3	150	N	200	30	N	700	Do.
	HT–2	HT–2	N	7	300	10	500	50	N	500	Do.
	HT–3	HT–3	N	7	2,000	N	5,000	300	N	1,500	Do.
	HT–4	HT–4	N	15	2,000	N	5,000	N	N	2,000	Do.
	HT–5	HT–5	30	2	3,000	50	5,000	N	N	300	Do.
2	Tenn–1	Tenn–1	N	5,000	15	N	50	30	N	200	Quartz-beryl vein.
3	288013	BA–385B	N	15	300	N	700	150	N	N	Greisen.
4	288003	BA–190	N	3	150	N	N	1,500	N	N	Quartz vein, greisenized walls.
5	288153	ML–2	N	15	30	N	70	15	N	300	7.0-ft. chip, shear zone.
	288154	ML–3	N	3	15	N	70	30	N	300	Vein.
	H3238	ML–4–2	1	7	150	N	700	70	N	300	Greisen on wall of ML–4–3.
	H3239	ML–4–3	3	15	700	70	1,500	7	N	700	Quartz-topaz vein.
	H3240	ML–4–4	1.5	7	700	15	1,500	70	N	300	Greisen on wall of ML–4–3.
	ML–1	ML–1	10	10	150	150	>10,000	150	10,000	1,000	Quartz-wolframite vein.
	ML–2	ML–2	1	20	500	100	5,000	N	N	700	Greisen.
	ML–3	ML–3	30	70	10,000	100	>10,000	15	N	>10,000	Vein.
	ML–4	ML–4	N	5	30	N	50	N	150	N	Greisen.
6	287994	BA–62	7	3	150	N	1,500	30	N	300	Vein.
7	288015	BA–470A	N	150	150	7	1,500	70	N	N	Beryl-bearing veinlets.
	288016	BA–470B	3	7	300	30	3,000	70	N	L	1.0-ft. chip across zone of BA–470A.
8	288017	BA–473	N	7	30	N	15	70	N	N	Greisen.
9	288011	BA–351A	N	15	7	N	N	300	N	N	Do.
10	289726	BA–352	N	15,000	30	15	300	70	N	N	Quartz-beryl fluorite vein.
11	288014	BA–408	N	7	7	N	N	150	N	L	Greisen
12	288336	BA–399	7	7	150	15	700	150	1,500	N	Do.
13	288008	BA–336	N	15	15	N	15	300	N	N	Do.
A	278794	BA–11	N	7	15	7	70	N	N	N	Granite-aplite.
B	278793	BA–10	1.5	7	70	7	70	30	N	N	Do.
Limits of determination			1	1	5–10	10	10	10	100	200	

silicate rock. The main body of Silver Plume(?) Granite is the northeast part of the Tappan Mountain stock. The northwest flank of the stock dips northwest at about 20°–50°, or about parallel to the foliation of the adjacent biotite gneiss. The southeast flank of the stock is poorly exposed; it probably also dips northwest, but at a high angle. The northeast end of the stock is blunt and probably plunges to the northeast at a moderately high angle beneath the biotite gneiss country rock. Smaller, mainly concordant bodies of Silver Plume(?) occur on both the northwest and southeast flanks of the stock.

Faults, locally mineralized, strike northeast and dip steeply northwest or southeast.

Ore Deposits

The mineralized bodies of the area are veins and irregular greisen masses noticeably clustered at the blunt end of the Tappan Mountain stock. Mineralized rock is very abundant as is emphasized by a sketch map of part of the area. (See inset, fig. 7.) Greisen and probably related quartz masses and veins are also exposed in prospect pits or shallow mine workings to the northeast.

The deposits contain discrete concentrations of scheelite, wolframite, and pyrite (Lucky Boy mine), copper-stained pyrite (loc. 3), and cassiterite at the locality shown in the northeast corner of figure 5. Rocks in fault zones are also locally greisenized and contain fluorite. Tin, ranging in amounts from traces to as much as 700 ppm, and one high concentration of tungsten (1000 ppm) were found in random grab samples of greisenized materials (table 3).

Significance and Suggestions for Prospecting

The greisen at Tappan Mountain is spatially related to the Silver Plume(?) Granite rather than the Redskin Granite. The strong localization of the greisen at the nose of the stock and the northeasterly fracture pattern suggest that greisenization continues at depth along the plunge direction of the stock; the intensity of mineralization indicates that further exploration of the area is justified. Placer concentrations of wolframite or cassiterite can be inferred to be present in the drainages below the greisen occurrences.

MARKSBURY GULCH AREA

Geology

The Marksbury Gulch area, on the southeast flank of the Thorpe Gulch stock of Silver Plume(?) Granite (fig. 8), is underlain by the granite, by biotite gneisses of the Idaho Springs Formation, and by numerous bodies of amphibolitic rocks that have locally been converted to tungsten-bearing calc-silicate rocks. The amphibolitic rocks occur in lens-shaped masses in the biotite gneiss and in roof pendants engulfed in the granite.

Geochemical Anomaly

One sample of stream sediment in Marksbury Gulch contains 150 ppm tin and 20 ppm molybdenum. Molybdenum (10 ppm) was detected in several other samples from the area and probably is associated with mineralized calc-silicate bodies. The occurrence of tin-rich stream sediment near the contact of the granite body suggests that mineralized rock may occur near that contact. Tin (200 ppm) was also found in the pulverized split of a sample from O'Brien

TABLE 3.—*Semiquantitative spectrographic analyses of mineral deposits, Tappan Mountain area*

[Analysts: A. L. Sutton and J. C. Hamilton. Analyses reported in parts per million and in series 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5 . . . or by the following symbols: N, not detected; L, detected but below limit of determination]

Sample locality No.	Lab No.	Field No.	Ag	Be	Cu	Mo	Pb	Sn	W	Zn	Description
1	278768	TR-35	N	7	70	30	15	700	N	N	All samples except T1-235 are greisen.
2	D114212	T1-207	10	30	500	7	300	150	N	N	
3	D114211	T1-206	10	3	3,000	20	1,000	10	1,000	700	Copper-stained greisen.
4	D114214	T1-235	N	3	200	N	N	N	N	N	Calc-silicate rock.
5	D114209	T1-173	N	5	100	N	N	100	N	N	
6	D114226	T1-239	N	7	50	N	100	150	N	N	
8	288285	S60-62	N	7	100	N	L	300	N	N	
9	D114213	T1-230	N	2	100	N	15	300	N	N	
	---------	T1-202	N	10	3	N	N	100	N	N	
Limits of determination			0.5	1	5	5–10	10	100	200	--	

Gulch but was not detected in the sieved portion; it is thus suspected that at least one cassiterite grain was present in the original sample.

BADGER FLATS FAULT-ZONE ANOMALY

An anomalous area about 1¼ miles south-southeast of the Boomer mine is suggested by the presence of a maximum of 15 ppm beryllium and a copper concentration averaging 140 ppm in a series of soil samples, and of detectable tin in one sample. The area is alined along the Badger Flats fault, a pregreisen structure (Hawley, Sharp, and Griffitts, 1960) which strikes north-northwest and can be traced for more than 4 miles across the Badger Flats. About 1⅓ miles south-southeast of the Boomer mine, rocks in the fault zone exposed in a trench are greisenized and contain fluorite, pyrite, and as much as 300 ppm tin.

Significance

A possibility exists that the Boomer cupola of Redskin Granite was localized partly by preexisting fault structures related to the Badger Flats fault, which occurs about a quarter of a mile to the west. Granitic bodies similar to the Boomer cupola but not yet exposed by erosion may be present along this fault zone. If present, a clue to their location might be provided by the geochemical anomalies, which may have formed by leakage into the faults from concealed mineral deposits.

OTHER AREAS

Anomalous concentrations of metals were also found in some isolated samples or in small groups of samples. A stream-sediment sample containing the highest content of tin found in the area (300 ppm) came from a locality in the Redskin stock northwest of Redskin Gulch, far from known greisen deposits. This sample also showed a high concentration of niobium (300 ppm) and zirconium (700 ppm). Niobium is known to be an associate of tin. The high concentrations of tin, niobium, and zirconium were probably caused by placer concentration of the heavy minerals.

Anomalous contents of tin were also found locally in the Thorpe Gulch drainage and in the first main drainage southeast of Redskin Gulch. These values, plus the anomalous concentrations of tin in O'Brien Gulch, seem to suggest that tin (cassiterite), like gold, tends to occur in nuggets and that whether or not any split of a sample contains a particle will depend on the number and grain size of the particles. This in turn suggests that if a systematic survey for tin is carried out in the area, the heavy minerals should be concentrated prior to sample splitting.

Anomalous concentrations of tin and beryllium have also been found in reconnaissance of the adjacent McCurdy Mountain quadrangle north of the Lake George area. A stream-sediment sample from a tributary to Hay Creek at a point 5,850 feet N. 35° W. from South Tarryall Peak contained 20 ppm beryllium, 700 ppm lanthanum, 200 ppm tin, and 3,000 ppm zirconium in a −80 mesh split and 5 ppm beryllium, 200 ppm lanthanum, 30 ppm tin, and 200 ppm zirconium in a pulverized split. Greisen float was noted in two intermittent drainages at the north edge of the quadrangle. One stream is the southeastward-trending portion of Refrigerator Gulch; the second stream is 1,200 feet to the west, at the same approximate altitude. The occurrences in the McCurdy Mountain quadrangle are in terrain underlain by the Pikes Peak Granite.

SUMMARY AND CONCLUSIONS

Complex polymetallic deposits of greisen and contact-metasomatic type occur in the Lake George area and adjacent regions and are associated with the Redskin, Silver Plume(?) and perhaps Pikes Peak Granites.

Known beryllium-bearing deposits at the Boomer mine, in the Redskin Gulch area, and in the Mary Lee mine area are reflected in anomalous concentrations of one or more of the metals beryllium, lead, copper, and tin in stream-sediment samples. Especially in the Redskin Gulch area, anomalous metal concentrations in drainages above or away from known deposits suggest that other deposits exist. Anomalous concentrations of tin found west of the Mary Lee vein may be related to veins in or near an inferred northwestward-striking fault structure.

Anomalous concentrations of metals found in stream-sediment samples or bedrock samples from the Marksbury Gulch and Tappan

Mountain areas, respectively, are believed to be related to mineralization associated with the Silver Plume(?) Granite, and contacts of the granite in both areas are favorable for prospecting. Mineralization is strongly controlled by the lobate northeastern projection of the Tappan Mountain stock, and this area deserves more surface prospecting and possibly drilling.

The main economic deposit of the area, at the Boomer mine, is of the classic cupola type, occurring in the upper part of a small granite plug (Hawley, 1968). The plug is barely unroofed, and similar bodies could exist in the area; possibly such an area is about 1¼ miles south of the Boomer cupola, where anomalous concentrations of metals were noted in some stream sediments, soils, and fault-zone materials along the Badger Flats fault.

Finally, it should be pointed out that the recognition of ore association with the Silver Plume(?) Granite indicates that all three major Precambrian granite series of the Colorado Front Range—Boulder Creek at about 1.7 billion years, Silver Plume at about 1.45 billion years, and Pikes Peak-Redskin at slightly more than 1 billion years—are now known to have associated metallic mineralization; Antweiler (1966) has already reported isotopic evidence of mineralization at 1.7 and 1.0 billion years. This in turn suggests that the mineral potential of Precambrian rocks of Colorado and adjacent regions should be reevaluated.

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