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

By C. C. Hawley and W. R. Griffitts

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CONTENTS

Abstract ........................................................................................................ 1
Introduction ................................................................................................. 1
Outline of mining history........................................................................... 1
Geologic setting ......................................................................................... 1
Ore deposits ............................................................................................. 3
Geochemical sampling and analyses ....................................................... 5
Anomalous areas ....................................................................................... 11
Boomer mine area .................................................................................... 11
Redskin area ............................................................................................ 13
Mary Lee mine area .................................................................................. 13
Geology .................................................................................................... 13
Geochemistry ............................................................................................ 15
Tappan Mountain area ............................................................................... 15
Geology .................................................................................................... 15
Ore deposits ............................................................................................. 16
Significance and suggestions for prospecting ......................................... 16
Marksbury Gulch area ............................................................................... 16
Geology .................................................................................................... 16
Geochemical anomaly ............................................................................. 16
Badger Flats fault-zone anomaly .............................................................. 17
Significance ............................................................................................... 17
Other areas ................................................................................................. 17
Summary and conclusions ...................................................................... 17
References ................................................................................................. 18

ILLUSTRATIONS

FIGURE 1. Index map and generalized geologic map of the Lake George area
and adjacent region .................................................................................. 2
2-5. Geochemical maps showing distribution of elements in stream sediments
and soils:
   2. Beryllium ............................................................................................ 6
   3. Tin ..................................................................................................... 7
   4. Copper .............................................................................................. 8
   5. Lead .................................................................................................. 9
   6. Geologic and geochemical map of the Mary Lee mine area ............. 10
   7. Geologic map of the Tappan Mountain area .................................... 12
   8. Geologic and geochemical map of the Marksbury Gulch area .......... 14

TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Main ore metals in mineral deposits of the Lake George and Tarryall Springs areas</td>
<td>4</td>
</tr>
<tr>
<td>2. Semiquantitative spectrographic analyses of veins, greisen, and granite, Mary Lee mine area</td>
<td>15</td>
</tr>
<tr>
<td>3. Semiquantitative spectrographic analyses of mineral deposits, Tappan Mountain area</td>
<td>16</td>
</tr>
</tbody>
</table>
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.
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 con-
centrated 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

<table>
<thead>
<tr>
<th>Lab No.</th>
<th>Field No.</th>
<th>Ag</th>
<th>Be</th>
<th>Cu</th>
<th>Mo</th>
<th>Pb</th>
<th>Sn</th>
<th>W</th>
<th>Zn</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-3611</td>
<td>IV-10a-g</td>
<td>N</td>
<td>10</td>
<td>15</td>
<td>N</td>
<td>200</td>
<td>100</td>
<td>N</td>
<td>N</td>
<td>Quartz-muscovite greisen.</td>
</tr>
<tr>
<td>H-3611</td>
<td>IV-10a-g</td>
<td>1.5</td>
<td>50,000</td>
<td>N</td>
<td>100</td>
<td>N</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>289626</td>
<td>28-2</td>
<td>150</td>
<td>21,000</td>
<td>300</td>
<td>50</td>
<td>&gt;100,000</td>
<td>50</td>
<td>N</td>
<td>5,000</td>
<td>Tops-bertrandite greisen.</td>
</tr>
<tr>
<td>289731</td>
<td>BO-1</td>
<td>15</td>
<td>22</td>
<td>150</td>
<td>N</td>
<td>3,000</td>
<td>300</td>
<td>&gt;100,000</td>
<td>300</td>
<td>Beryl-bertrandite greisen.</td>
</tr>
<tr>
<td>289733</td>
<td>B1-13</td>
<td>30</td>
<td>20,000</td>
<td>700</td>
<td>70</td>
<td>30,000</td>
<td>70</td>
<td>N</td>
<td>3,000</td>
<td>Beryl-bertrandite greisen.</td>
</tr>
<tr>
<td>289734</td>
<td>B1-14</td>
<td>3</td>
<td>31,000</td>
<td>700</td>
<td>N</td>
<td>700</td>
<td>70</td>
<td>N</td>
<td>300</td>
<td>Beryl vein.</td>
</tr>
<tr>
<td>281311</td>
<td>B1-19</td>
<td>N</td>
<td>44,300</td>
<td>70</td>
<td>N</td>
<td>70</td>
<td>15</td>
<td>N</td>
<td>N</td>
<td>Do.</td>
</tr>
<tr>
<td>281314</td>
<td>B1-22</td>
<td>N</td>
<td>70</td>
<td>N</td>
<td>30</td>
<td>N</td>
<td>150</td>
<td>N</td>
<td>N</td>
<td>Quartz-muscovite greisen.</td>
</tr>
<tr>
<td>278782</td>
<td>B2-4</td>
<td>150</td>
<td>1,500</td>
<td>15,000</td>
<td>150</td>
<td>30,000</td>
<td>70</td>
<td>L</td>
<td>7,000</td>
<td>Muscovite-fluorite zone.</td>
</tr>
<tr>
<td>H-3243</td>
<td>B2-7-2</td>
<td>.7</td>
<td>15</td>
<td>300</td>
<td>30</td>
<td>1,500</td>
<td>150</td>
<td>N</td>
<td>1,500</td>
<td>Muscovite-fluorite zone.</td>
</tr>
<tr>
<td>H-3243</td>
<td>B2-7-2</td>
<td>.7</td>
<td>15</td>
<td>300</td>
<td>30</td>
<td>1,500</td>
<td>150</td>
<td>N</td>
<td>1,500</td>
<td>Muscovite-fluorite zone.</td>
</tr>
</tbody>
</table>

**Greisen: J+S (1), Blue Jay (2), Redskin (3-7), Minerva J (8), Black Prince (9), unnamed locality (10)**

### Calc-silicate deposits and fluorite veins

| 289776  | TR-33 | N | 70 | 7 | 30 | 30 | 15 | 3,000| N | Diopsid-rich greisen. |
| 2898286 | T2-8J | N | 10 | 1 | 10 | N | N | N | N | Garnet-epidote-veunisaitan rock. |
| 2898286 | T2-17 | N | 1.5| 50 | N | N | N | 30 |< |< |< |
| 2898287 | T2-220 | N | 3 | 7 | 7 | 10 | 15 | 2 | 45 | Garnet-actinolite rocks. |
| 2898275 | S60-27 | L | 150| 7 | 7 | 70 | 70 | N | 150 | Calc-silicate rock. |
| 289363  | BA-583 | 3 | 3 | 20 | N | N | 150| N | N | Fluorite vein. |
| 289269  | S60-35 | 3 | 1.5| 700 | N | N | N | N | Fluorite vein, Jacob Kole vein. |
| 288268  | S60-17 | 1.5| 1.5| 150 | 1,500| 30,000| 70 |N | L | Fluorite vein, Silver Dollar vein. |

---

1. Semiquantitative spectrographic or morin-fluorescent.
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, clinzoisite, 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 northwest-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:

<table>
<thead>
<tr>
<th>Element</th>
<th>Content, in parts per million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re</td>
<td>Sieved split</td>
</tr>
<tr>
<td>Be</td>
<td>16</td>
</tr>
<tr>
<td>Cu</td>
<td>11</td>
</tr>
<tr>
<td>Nb</td>
<td>66</td>
</tr>
<tr>
<td>Pb</td>
<td>44</td>
</tr>
<tr>
<td>Sn</td>
<td>27</td>
</tr>
</tbody>
</table>
EXPLANATION

- Greisenized rocks
  - Number shown in table 1

- Quartz vein with greisenized walls
  - Vein locally contains beryl, wolframite, and cassiterite. Dashed where inferred

- Fluorite or barite vein
  - Dashed where inferred

- Vein containing uranium minerals

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

Redskin Granite

Pikes Peak Granite

Silver Plume (?) Granite

Other rocks, undivided

Contact

Fault or barren vein

Quartz vein with greisenized walls
Vein locally contains beryl, wolframite, and cassiterite. Dashed where inferred

Fluorite or barite vein
Dashed where inferred

Vein containing uranium minerals

Scheelite

Approximate location of scheelite occurrence or scheelite prospect area

Stream-sediment sample locality
Showing tin concentration, in parts per million

<10
10-15
15-20
20-30
30-50
50-100
>100

Soil-sample traverse
Showing average tin concentration, in parts per million

<10
10-15
15-20
20-30
30-50

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.
**EXPLANATION**

- **q-Tv**: Welded tuff

- **rfa**: Redskin Granite
  - rfa, fine-grained granite aplite
  - rp, medium-grained brecciated porphyritic granite
  - rg, medium-grained equigranular granite

- **ICS**: Calc-silicate rock
  - Locally with scheelite

- **sm**: Silver Plume (?) Granite
  - Medium-grained granite

- **PRECAMBRIAN**: Granitic gneiss and biotite gneiss undivided

**FIGURE 6.**—Geologic and geochemical map of the Mary Lee mine area.
Contact, showing dip
Dashed where inferred or gradational

Inferred fault or barren vein

Vein, showing dip
Dashed where inferred

Greisenized rocks

Shaft Trench Pit Adit or incline

Sample location, table 2

Geochemical symbols
Showing metal concentration, in parts per million

Sn Be
<10 6
10 5
15 7
20 10

Value shown if $\leq 30$
Value shown if $> 15$

Example: Be=5, Sn=20, Ag=1

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:

<table>
<thead>
<tr>
<th>Element</th>
<th>Values, in parts per million, for indicated ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be</td>
<td>$\leq 2$  $3$–$5$  $7$–$10$  ($\geq 15$, value shown)</td>
</tr>
<tr>
<td>Sn</td>
<td>$\leq 10$  $15$–$20$  $30$–$50$  ($\geq 70$, value shown)</td>
</tr>
<tr>
<td>Cu</td>
<td>$&lt; 50$  $50$–$70$  $100$  ($\geq 150$, value shown)</td>
</tr>
<tr>
<td>Pb</td>
<td>$20$–$30$  $50$–$70$  $100$  ($\geq 150$, value shown)</td>
</tr>
</tbody>
</table>

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
Sample locality

Enlarged area in northwest corner of section 30

Figure 7.—Geologic map of the Tappan Mountain area.
EXPLANATION

- Welded tuff
- Redskin Granite
  - Granite-aplite
- Granite pegmatite
- Silver Plume(?) Granite
  - Medium-grained granite
  - Fine-grained gneissic granite
- Idaho Springs Formation
  - Calc-silicate rock, locally with scheelite
  - Migmatitic biotite-muscovite gneiss

Contact
- Dashed where inferred

Fault or barren vein, showing dip
- Strike and dip of foliation
- Direction and plunge of lineation
- May be combined with foliation symbol

Quartz vein with greisenized walls, showing dip
- Locally contains wolframite, scheelite, and pyrite

Greisenized rocks

4 Sample locality, table 3
  x O Prospect pit
  O Trench
  - Adit
  - Shaft

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 mine 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.

**TABLE 2—Semi-quantitative 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.]

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Field No.</th>
<th>Ag</th>
<th>Be</th>
<th>Cu</th>
<th>Mo</th>
<th>Pb</th>
<th>Sn</th>
<th>W</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
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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-
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.—Semi-quantitative spectrographic analyses of mineral deposits, Tappan Mountain area**

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<th>Sample locality No.</th>
<th>Lab No.</th>
<th>Field No.</th>
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<th>Cu</th>
<th>Mo</th>
<th>Pb</th>
<th>Sn</th>
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Limits of determination: 0.5, 1, 5, 10, 20, 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 1 1/4 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 aligned 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 1 1/3 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 Tapan
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 1 1/4 miles south of the Boomer cupula, 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.

REFERENCES


