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Geology and Beryllium Deposits of the Lake George (or Badger Flats) Beryllium Area, Park and Jefferson Counties, Colorado

GEOLOGICAL SURVEY PROFESSIONAL PAPER 608-A

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By C. C. HAWLEY

GEOLOGY AND ORE DEPOSITS OF THE SOUTHERN TARRYALL REGION
PARK AND JEFFERSON COUNTIES, COLORADO

GEOLOGICAL SURVEY PROFESSIONAL PAPER 608-A

A study of the nonpegmatitic beryllium deposits, with special emphasis on their association with the late Precambrian Redskin Granite

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GEOLOGY AND BERYLLIUM DEPOSITS OF THE LAKE GEORGE (OR BADGER FLATS) BERYLLIUM AREA PARK AND JEFFERSON COUNTIES, COLORADO

By C. C. Hawley

ABSTRACT

The Lake George (or Badger Flats) beryllium area is a terrane of Precambrian rocks on the southwest side of the Front Range in Colorado. Its southeastern and southwestern parts are underlain mainly by the metasedimentary Idaho Springs Formation, the metaigneous Boulder Creek(?) Granodiorite, and the Silver Plume(?) Granite. The northern and central parts of the area are underlain principally by the Pikes Peak and Redskin Granites. Locally the Precambrian rocks are masked by thin tuffs and boulder deposits of Tertiary(?) age and by colluvium and alluvium of Quaternary age.

The oldest rocks—Idaho Springs Formation, amphibolite and hornblendite, and Boulder Creek(?) Granodiorite—were involved in a period of plastic deformation during which a major north-northeast-trending fold, the Round Mountain syncline, formed. Subsequently they were strongly deformed and regressively metamorphosed by the intrusion of the Silver Plume(?) Granite. The emplacement of the youngest Precambrian igneous rocks—the gabbro and monzonite, Pikes Peak Granite, and Redskin Granite—had little structural effect on the older rocks. Locally the rocks were cataclastically deformed sometime after the plastic deformation but before emplacement of the youngest igneous rocks. They were faulted in several episodes. Movement along the Badger Flats fault, a major structure of the area, possibly occurred before emplacement of the Silver Plume(?). Movement along most of the other faults first occurred in Precambrian time.

The principal ore deposits are nonpegmatitic beryllium deposits that occur in veins, pipes, and other forms generally encased in greisenized wallrocks. The greisens contain quartz, muscovite, topaz, and fluorite, and trace elements, such as lithium and tin, that are typical of greisens. The principal deposits are concentrated in four parts of the area that are in or very near the Redskin Granite. Small concentrations of beryllium minerals and greisen bodies that contain only trace amounts of beryllium are more widely distributed.

Most of the beryllium occurs in beryl, which forms hexagonal crystals and massive poikiloblastic grains. Some of the beryllium occurs in bertrandite, which may be the dominant beryllium mineral in some ore bodies or parts of ore bodies. Very small amounts of the beryllium occurs in euclase. The beryllium deposits locally contain arsenopyrite, wolframite, molybdenite, galena, and dark sphalerite, and these minerals and other sulfides and oxides are locally concentrated in small ore shoots near beryllium deposits or in greisenized rocks nearly free of beryllium. The gangue of most deposits is formed by the typical greisen minerals.

Though the deposition of ore minerals and the formation of greisens were nearly contemporaneous, the ore minerals are somewhat younger than the greisens. Quartz, muscovite, and fluorite, which form the bulk of the greisens, also occur with the ore minerals and were deposited during a long period of time.

The beryllium deposits and associated greisen are closely related genetically to the Redskin Granite, as shown by chronologic and chemical similarities and spatial association. The main deposits, those of the Boomer mine, seem to be a particularly good example of cupola-type mineralization.

INTRODUCTION

The Lake George (or Badger Flats) beryllium area is about 10 miles northwest of Lake George on the west side of the Front Range (fig. 1); it is a few miles east of South Park and is separated from it by the Puma Hills. The rugged Tarryall Mountains extend into the northern part of the area, and the parklike Badger Flats forms most of its southwestern part. The mapped area comprises most of the north half of the Tarryall quadrangle and most of the south third of the McCurdy Mountain quadrangle.

The main mineral resource of the area is beryllium-bearing greisen, which has been mined principally at the Boomer mine. The greisen and associated veins also contain local concentrations of tungsten, molybdenum, lead, zinc, tin, and silver minerals. Besides the greisen deposits, small amounts of scheelite occur in tactitelike calc-silicate gneiss, and fluorite forms fissure-vein de-

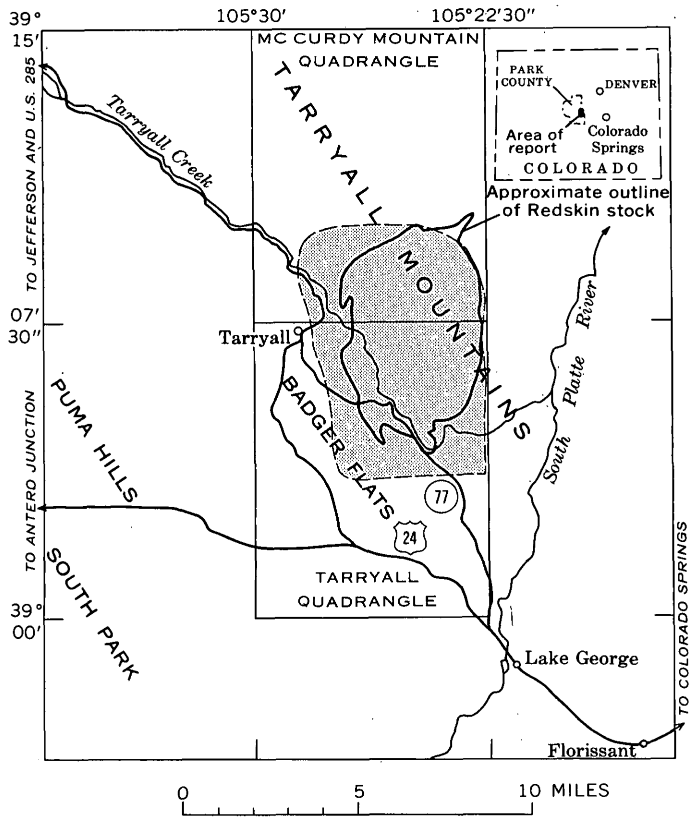


FIGURE 1.—Location of the Lake George (or Badger Flats) beryllium area (stippled).

posits from which small amounts of ore have been produced.

The Lake George beryllium project of the U.S. Geological Survey began in 1959, although considerable data had been accumulated previously by W. R. Griffitts of the Geological Survey, who closely followed activity in the district after the discovery of beryl in 1955. This report concentrates on the beryllium deposits.

I appreciate the assistance received from Mr. Griffitts, who helped start this investigation, and from W. N. Sharp, U.S. Geological Survey, who contributed some of the mapping and mineralogic data incorporated in this report. Mining men interested in the region were cooperative, especially D. H. Peaker of U.S. Beryllium Corp., Harlan Foresyth, former superintendent at the Boomer mine, and Bob Beal and the late William Van Couten, miners and excellent geologic observers.

GENERAL GEOLOGY

The Lake George beryllium area has had a long and complex history of folding, metamorphism, faulting, and igneous intrusion that is mainly recorded in Precambrian rocks. These rocks can be divided into three main groups according to age and conditions of formation or metamorphism (Hawley and others, 1966). Rocks of the first and oldest group consist of the Idaho Springs Formation, which is a metasedimentary unit; amphibolite and hornblendite of uncertain origin; and the Boulder Creek(?) Granodiorite, a metaigneous rock of catazonal type (Buddington, 1959). The intermediate-aged group is represented by the Silver Plume(?) Granite, a mesozonal igneous rock. The rocks of the youngest group are epizonal and are unnamed gabbro and monzonite, the Pikes Peak Granite, and the Redskin Granite.

The dominant rock unit of the area is the Redskin Granite of late Precambrian age, which forms the Redskin stock and two smaller bodies, the China Wall and Boomer cupolas (pl. 1). The beryllium deposits are closely associated with the Redskin Granite and probably are genetically related to it. The Redskin stock itself is an oval composite body, about 19 square miles in area, that lies partly in the somewhat older Pikes Peak Granite and partly in the appreciably older terrane of metasedimentary, metaigneous, and igneous rock exposed south of the Pikes Peak Granite.

The structure of the older Precambrian rocks was mainly determined by two events. In the first event, sedimentary rocks were metamorphosed and deformed into a broad northeast-trending syncline and the Boulder Creek(?) Granodiorite was emplaced. In the second, the Silver Plume(?) Granite shouldered the older rocks aside and caused recrystallization and retrograde metamorphism. The later Pikes Peak and Redskin Granites had little structural effect on the older rocks.

Faults, mainly of a northwest trend, formed in more than one episode, but nearly all first opened in Precambrian time. The oldest movement on the Badger Flats fault probably occurred before emplacement of the Silver Plume Granite, and surely before greisenization related to the Pikes Peak or Redskin Granite. Faults that cut the Pikes Peak or Redskin Granite are locally mineralized and are probably nearly as old as the granites.

PRECAMBRIAN ROCKS

Precambrian rocks, in order of decreasing age, are the Idaho Springs Formation, Boulder Creek(?) Granodiorite, Silver Plume(?) Granite, Pikes Peak Granite, and Redskin Granite. Small masses of amphibolite and hornblendite which occur in the Idaho Springs Formation and Boulder Creek(?) Granodiorite generally have indeterminate age relations with the enclosing rocks but probably are older than Silver Plume(?). Gabbro and monzonite occur near Redskin and Pikes Peak Granites and are younger than Silver Plume(?) and older than Redskin Granite. Pegmatites, locally abundant, are of several ages. Most pegmatites are related to the Silver Plume(?) or Boulder Creek(?), but a few are related to the Pikes Peak or Redskin Granite.

IDAHO SPRINGS FORMATION

The oldest rock unit in the mapped area is the Idaho Springs Formation (Ball, 1906), which underlies much of the southeastern and southwestern parts of the area. It was the country rock into which the Boulder Creek(?) and Silver Plume(?) bodies were intruded, and together with these units it forms most of the Precambrian complex lying peripheral to the Pikes Peak and Redskin Granites.

The formation varies widely in texture and mineralogy, but it is dominantly a fine- to medium-grained locally migmatitic biotite gneiss. Fine-grained gneiss is composed mainly of quartz, plagioclase, and biotite; it is light gray, has a salt and pepper aspect, and is only rarely migmatitic. Medium-grained biotite gneiss is composed largely of biotite, quartz, sillimanite, and, where affected by retrograde metamorphism, muscovite; it is commonly migmatitic. Idaho Springs Formation near the Boomer mine and in the southwestern part of the area is mainly fine-grained biotite gneiss. In the southeastern part of the area, it consists of migmatitic interlayered fine- to medium-grained gneiss.

Calc-silicate gneiss and associated quartzite units form scattered thin layers and pods in biotite gneiss and in amphibolite. Two main types of calc-silicate gneiss were recognized: a fine-grained hornblendic or diopsidic rock, and a medium- to coarse-grained tactitelike rock which consists mainly of garnet, epidote, quartz, idocrase, and, locally, calcite, and which is the host to small scheelite deposits.

AMPHIBOLITE AND HORNBLENDITE

Amphibolite and closely associated hornblendite are found principally in the western part of the beryllium area, where they form layers, lenses, and pods whose contacts generally conform to the foliation of the adjacent gneiss of the Idaho Springs Formation.

The amphibolite is a medium- to dark-gray poorly to moderately foliated rock composed mainly of hornblende and plagioclase. It is more massive than the fine-grained hornblendic calc-silicate gneiss of the Idaho Springs Formation with which it occurs locally. The hornblendite is a very dark green dense rock composed mainly of hornblende which characteristically weathers brown.

Locally, tactitelike calc-silicate gneiss was developed from amphibolite, as shown by garnet-quartz-epidote tactite bodies that cut across the foliation of the amphibolite. The tactitelike masses are separated from amphibolite by diopside-rich rock which also cuts across the structure of the amphibolite.

BOULDER CREEK(?) GRANODIORITE

The Boulder Creek(?) Granodiorite forms two main bodies in the southern and southeastern parts of the area. One is a small partly conformable pluton exposed in the NW¼ sec. 28 and the SW¼ sec. 21 (fig. 2).[1] The second is a much larger, apparently conformable body that trends northeastward from the southwest corner of the mapped area to the southwest edge of the Redskin stock. Prior to the intrusion of the Redskin stock the granodiorite was continuous with granodiorite exposed along strike at the southeast edge of the stock. Other, generalized mapping (Hawley and others, 1966) indicates that the larger of the two Boulder Creek(?) bodies is an phacolith asymmetric to the Round Mountain syncline.

The Boulder Creek(?) Granodiorite ranges in composition from quartz diorite to granite. The quartz diorite is a medium- to coarse-grained mesocratic biotite-quartz-plagioclase rock which contains phenocrysts or porphyroblasts of quartz and plagioclase. The more granitic types are fine- to coarse-grained mesocratic to leucocratic rocks, and locally they contain tabular or augen phenocrysts or porphyroblasts of microcline. In general, the Boulder Creek(?) is gneissic; mineral lineations generally plunge northeastward, or subparallel to the dominant trend of mineral lineations in the Idaho Springs Formation.

Tentative correlation of Boulder Creek(?) Granodiorite with the Boulder Creek Granodiorite of the central Front Range is based on the average composition, relative age, and syntectonic origin indicated by the phacolithic form and metamorphic structures common to both deformed metasedimentary rock units.

SILVER PLUME(?) GRANITE

The Silver Plume(?) Granite forms an oval-shaped pluton about 2 miles long in the southeastern part of the area and numerous smaller sill-like and irregular bodies in the southern and western parts of the area.

The Silver Plume(?) Granite ranges from fine to medium grained and from massive to foliated. Most facies are leucocratic tan or gray granite (or quartz monzonite of some classifications) that consists mainly of quartz, oligoclase, and potassium feldspar. Both biotite and muscovite are present in most specimens, along with accessory amounts of magnetite, apatite, and

[1] A large part of the area is in T. 11 S., R. 72 W., and sections, unless noted otherwise, are in this township.

other minerals. Sillimanite is also generally present in small amounts and is found with the muscovite or with potassium feldspar; it forms linear zones, especially in potassium feldspar, that indicate fracture control.

The potassium feldspar is commonly carlsbad twinned, but it is grid twinned locally. Plagioclase is locally myrmekitic, and part of the muscovite is intergrown with plagioclase. In the foliated granites, structure is due to alined micas and potassium feldspar laths.

The Silver Plume(?) Granite of this area shows strong similarities to the Silver Plume Granite of the central Front Range in the following respects: Its pre-Pikes Peak post-Boulder Creek(?) intrusive relations, presence of both biotite and muscovite, seriate porphyritic texture, quartz monzonite modal composition, and common occurrence and local nearly trachytic alinement of lathlike potassium feldspar.

PIKES PEAK GRANITE AND ASSOCIATED ROCKS

The Pike Peak batholith of the Colorado Front Range is a composite pluton covering an area of more than 1,000 square miles. Major units within the batholith range in composition from granodiorite or quartz monzonite (Hutchinson, 1960; Peterson, 1964) to alkali granite. Minor rock units in the batholith or near its periphery range in composition from gabbro to peralkaline granite and include syenites and monzonites (Hutchinson, 1964; Stewart, 1964; Gross and Heinrich, 1965). Like the Pikes Peak Granite, the associated minor types are unmetamorphosed, posttectonic rocks that form dominantly discordant plutons. Several have been dated by rubidium-strontium or potassium-argon methods to be about 1 billion years old (Giffin and Kulp, 1960; Hutchinson, 1964; Gross and Heinrich, 1965), or about the same age of the main Pikes Peak Granite. It seems reasonable to assume that all the rocks 1 billion years old which are spatially related to the batholith are comagmatic with the Pikes Peak Granite, and here they are considered as units of a magma series whose chief unit is the Pikes Peak Granite. Other units of the magma series in the Lake George area are the Redskin Granite and gabbro and monzonite.

GABBRO AND MONZONITE

Mafic to granitic rocks, classed generally as gabbro and monzonite, occur mainly at the southeast end of the Redskin stock near Tarryall Creek and in the northeastern part of the mapped area. The unit includes olivine gabbro, granodiorite, monzonite, quartz monzonite, and quartz monzonite porphyry. A composite mass of gabbro, granodiorite, and quartz monzonite near Tarryall Creek is the remnant of a zoned funnel-shaped pluton that has been invaded by the Redskin Granite. The incomplete outer zone of the pluton is coarse-grained olivine gabbro which has a marked planar structure and which contains noticeable interstitial ilmenite. Locally olivine and other early ferromagnesian minerals are altered to biotite. The intermediate zone is medium- to coarse-grained biotite-hornblende rock which ranges in composition from granodiorite to quartz monzonite. The core is quartz monzonite porphyry. Quartz monzonite porphyry also forms dikes which cut the gabbro and the Silver Plume(?) Granite. The monzonite in the northeastern area is either a large inclusion in the Pikes Peak Granite or a small plug intrusive into it. Although its relations to the coarse-grained Pikes Peak Granite are not clear, the monzonite is cut by fine-grained granite dikes similar to those widely distributed in the Pikes Peak Granite. The composite gabbro and quartz monzonite body is not in contact with the Pikes Peak Granite, but it cuts the Silver Plume(?) Granite and is cut by the Redskin Granite.

PIKES PEAK GRANITE

The Pikes Peak Granite of the Tarryall Mountains batholith underlies the northern and northeastern parts of the mapped area. Typically the granite is a biotitic coarse-grained nearly massive pink rock composed mainly of microcline perthite, quartz, and sodic plagioclase, in order of decreasing abundance. The microcline perthite occurs mainly as coarse grains, locally as much as 8 cm across, which are enclosed in a medium- to coarse-grained granular matrix of quartz and plagioclase. Microscopic examination shows that the plagioclase is moderately sericitized and that fluorite and zircon are the main accessory minerals.

Two main facies and several minor facies of the Pikes Peak Granite can be distinguished. The two main types differ chiefly in average grain size, shape of potassium-feldspar crystals, and degree of granularity. They differ only slightly in mineralogy (table 1), and on the map they are combined as coarse-grained inequigranular granite. The minor facies forms dikes and irregular bodies in the batholith or in the adjacent country rocks. Porphyritic granite and fine-grained granite form the larger dikes and irregular masses in and near the batholith (pl. 1); a dark biotitic granite, aplite, and pegmatite form small dikes and irregular bodies.

TABLE 1.—*Average modal analyses, in volume percent, of coarse-grained inequigranular Pikes Peak Granite*

[Tr., trace]

	Subequigranular type	Porphyritic type
Perthitic microcline	50.1	44.1
Quartz	29.4	31.9
Sodic plagioclase	14.5	16.9
Biotite	5.2	5.7
Muscovite	.2	.7
Fluorite	.4	.4
Topaz	Tr.	.1
Zircon	.1	.1
Opaques	.1	Tr.
Kaolinite	Tr.	Tr.
Anatase	Tr.	Tr.
Apatite	Tr.	Tr.
Monazite(?)	Tr.	Tr.
Percent potassium feldspar in perthitic microcline	77	78
Number of samples	14	7
Number of thin sections	28	14
Total points counted	55,000	28,000

REDSKIN GRANITE

Redskin Granite, named by Hawley, Huffman, Hamilton, and Rader (1966) and previously described as an unnamed late facies of the Pikes Peak Granite (Hawley, 1963, 1964), forms the Redskin stock, the China Wall and Boomer cupolas, and numerous dikes at the west edge of the Pikes Peak batholith. The Redskin stock cuts across the batholith, indicating that the Pikes Peak Granite is older than the Redskin Granite, although similar compositions and radioactive ages show that the two are related genetically (Hawley, 1964; Hawley and others, 1966). The trace-element content, discussed in the 1966 paper, is an important criterion indicating affinity of the two granites. Both are enriched in fluorine, beryllium, lithium, tin, and rubidium relative to most granites.

The Redskin stock is a zoned oval-shaped pluton about 6½ miles long and 4 miles wide which is the dominant geologic body of the area (pl. 1). Adjacent to the west side of the pluton is the China Wall cupola, about three-fourths mile long. About 1 mile southwest of the stock is the Boomer cupola, which is only 500 feet across at the surface but widens at depth.

Petrography

In contrast to the Pikes Peak, which is dominantly coarse grained, the Redskin Granite is fine to medium grained. Previously (Hawley, 1963; Hawley and others, 1966) the Redskin was divided into three main facies—granular, porphyritic, and fine grained—on the basis of grain size and texture. Because additional study has shown that the fine-grained facies should be subdivided and that additional minor facies should be named, seven facies or units are herein proposed. Four of these—granular, porphyritic, fine grained (equigranular), and granite-aplite—form extensive parts of the Redskin, China Wall, and Boomer plutons; the other three—fine- to medium-grained equigranular granite, pegmatite, and fine-grained porphyritic granite—form dikes only. The porphyritic and granite-aplite facies of the three main plutons also form dikes. Although the subdivision proposed here is complex, it is based on differences observed in the field or through the microscope; furthermore, it has economic significance because only the porphyritic facies and the granite-aplite have thus far yielded beryllium-bearing greisen.

The granular facies of the Redskin Granite is a nearly white to pale-pink medium-grained equigranular biotite granite consisting mainly of microcline perthite, quartz, and sodic plagioclase (table 2). The porphyritic facies consists of a finer grained seriate porphyritic granite composed mainly of quartz, microcline perthite, and sodic plagioclase in nearly equal proportions; generally it is a pink biotite-muscovite granite. The fine-grained facies is different from the porphyritic facies mainly in that it has a finer average grain size and a larger content of sodic plagioclase. Microscopically, the granular, porphyritic, and fine-grained facies of the Redskin Granite are hypidiomorphic. Plagioclase began to crystallize before the quartz and microcline, as indicated by its tendency toward idiomorphism and its inclusion in quartz and microcline perthite. Though the plagioclase is dusted with sericite, it is less altered than the plagioclase of the Pikes Peak Granite of the batholith. As in the Pikes Peak Granite, fluorite and zircon are the main accessories in the Redskin Granite. The granite-aplite of the Redskin stock and China Wall and Boomer cupolas is a biotitic to muscovitic fine-grained facies characterized by micrographic intergrowths of quartz and albite that are younger than more euhedral potassic feldspar and sodic plagioclase (albite). Granite-aplite is represented in table 2 by the muscovitic rock of the Boomer cupola.

The granular facies is older than the porphyritic and fine-grained facies, which grade into each other and are probably about the same age. Locally, granular granite is cut by dikes of granite-aplite, but elsewhere granite-aplite appears to grade into both granular and porphyritic types, and the granite-aplite is probably about the same age as or very slightly younger than the other facies of Redskin Granite.

Minor facies of the Redskin Granite form dikes and small irregular bodies. Fine- to medium-grained equi-

TABLE 2.—*Average modal composition, in volume percent, of the main facies of the Redskin Granite*

[Tr., trace]

	Redskin stock			Boomer cupola
	Equigranular granite	Seriate porphyritic granite	Fine-grained granite	Granite-aplite
Quartz	31.9	29.6	29.4	37.1
Sodic plagioclase	23.6	33.0	35.2	32.2
Microcline perthite	40.6	32.4	[1] 29.4	[1] 24.0
Biotite	3.4	2.8	2.8	.1
Muscovite	.4	1.5	2.4	6.0
Fluorite	.5	.5	.5	.15
Topaz	.1	Tr.	Tr.	Tr.
Zircon	.05	Tr.	Tr.	Tr.
Opaques	.15	.1	.1	.15
Others	Tr.	Tr.	Tr.	[2] .3
Number of samples	50	53	15	12
Number of thin sections	100	53	15	12
Points counted (approximate)	100,000	53,000	15,000	12,000

[1] Only sparsely perthitic.
[2] Mostly carbonates.

granular granite forms dikes in and near the granular facies and is probably genetically related to it, differing mainly in a smaller average grain size. Fine-grained porphyritic granite is a sparsely porphyritic rock that contains microcline phenocrysts in a matrix resembling the main fine-grained facies. Pegmatite forms small segregations, mostly too small to be mapped, in the granular facies and also locally occurs with granite-aplite. The pegmatite is a homogeneous rock consisting principally of microcline perthite and quartz. Locally at the north end of the Redskin stock a granite breccia occurs near the contact of granular and porphyritic fragments. The fragments resemble fine-grained biotitic granite dikes found nearby in the Pikes Peak Granite, and the matrix resembles Redskin Granite.

Zoning of plutons

The Redskin stock and China Wall cupola are zoned, as shown on the geologic map (pl. 1). The granular facies forms the outer zone of the Redskin stock and the inner zone of the China Wall cupola. The porphyritic facies forms the intermediate zones of both these bodies and the local border zones on the Redskin stock. Fine-grained granite forms the inner zone of the Redskin stock. Granite-aplite forms the outer zone of the China Wall cupola, local border zones on the Redskin stock, and all the nearly homogeneous Boomer cupola.

In gross aspect, the zoning of the China Wall cupola is the opposite of that of the Redskin stock; that is, the Redskin stock becomes generally finer grained inward and the China Wall cupola becomes finer outward. But the zoning of the China Wall cupola does correspond directly to a local gradation observed at the south edge of the Redskin stock in secs. 14 and 23 and is similar to the zoning observed on the small southward protrusions of the pluton east of there. At these places, the dominant granular facies of the stock grades outward and upward into the finer grained porphyritic granite or granite-aplite. It is inferred from this that the granite of the China Wall pluton grades downward into dominantly granular granite, texturally like that of the outer zone of the Boomer stock, and also that granite-aplite of the Boomer cupola grades downward into similar equigranular rocks, as is shown diagrammatically in sections *B–B′* and *C–C′*, respectively (pl. 1).

The zoning is significant economically. Most beryllium deposits, including those at the Boomer mine, occur in granite-aplite. A few deposits, including those at the Redskin mine, occur in the seriate porphyritic granite. Thus, zones containing granite-aplite and porphyritic granite facies should be closely prospected for beryllium-bearing greisen.

TERTIARY(?) AND QUATERNARY DEPOSITS

Boulder deposits overlain by welded tuff, both of Tertiary(?) age form scattered outcrops on Badger Flats. Similar deposits closer to Lake George fill valleys cut in the Florissant Lake Beds of Oligocene age.

Quaternary deposits, which are more extensive than the Tertiary(?) deposits, locally cover the upland surface on Badger Flats and cover north-facing slopes and other timbered areas of part of the Tarryall Mountains. Recent alluvium fills the valley of Tarryall Creek and its tributaries, but remnants of older gravel or boulder deposits are found above the present stream level. Remnants of gravel also occur on a local erosion surface cut on the Badger Flats, and these deposits may correspond in age to the boulder deposits found as remnants along Tarryall Creek.

STRUCTURE

The structure of the area is mainly due to folding, faulting, and igneous intrusion in Precambrian time, and it mainly reflects two events, an older plastic deformation caused tectonically and a younger largely plastic deformation caused by the intrusion of Silver Plume(?) Granite. The rocks were also locally deformed cataclastically; this deformation occurred after the tectonic plastic deformation but before or during the late stages of the emplacement of the Silver Plume(?) Granite. Faulting probably occurred in several Precambrian episodes.

The present Rocky Mountains formed in the Laramide orogeny in Late Cretaceous and Paleocene time, but this orogeny had little apparent effect on the Precambrian rocks other than uplift.

OLD FOLDS AND METAMORPHIC STRUCTURES

The most characteristic features of the older deformation are folds and lineation, of dominant north-northeast trend, and bedding foliation. The Round Mountain syncline (pl. 1) is the dominant structure of the complex of older metasedimentary and metaigneous rocks. Its axis plunges steeply north-northeast toward the Redskin stock. East of the axis the foliation generally strikes northeast and dips northwest; west of the axis it strikes northwest and dips northeast, defining the locally tight but open fold. Many subsidiary folds and mineral lineations in Idaho Springs Formation and Boulder Creek(?) Granodiorite are subparallel to the axis of the fold; they cluster in an area that plunges N. 10° W. to N. 40° E. at 10°–60°.

YOUNGER FOLDS AND METAMORPHIC STRUCTURES

The gneissic rocks were deformed later by the emplacement of the Silver Plume(?) Granite and by minor tectonic forces. The Silver Plume Granite shouldered aside the gneisses, formed folds, and at the same time caused recrystallization, migmatization, and retrograde metamorphism of the gneisses. Minor tectonic forces caused local fracture cleavage and small folds.

The deformation caused by Silver Plume(?) was strong, especially near the larger plutons. An excellent example of the deformation is the northwesterly trending syncline in the Idaho Springs Formation which was caught between two Silver Plume(?) plutons in secs. 34 and 35 at the south edge of the mapped area (pl. 1). Reverse drag folds whose axes parallel Silver Plume(?) contacts are common in biotite gneiss near the plutons, as are migmatite and muscovite poikiloblasts.

Fracture cleavage and small sharp folds of east-northeast trend are found in the gneissic rocks in the southwestern part of the mapped area. The folds cut across Boulder Creek(?) bodies characterized by foliation of the old period, but their relation to the Silver Plume(?) is uncertain. Possibly the cataclasis was nearly contemporaneous with Silver Plume as indicated by the alinement of sillimanite along incipient fractures in the Silver Plume. Harrison and Wells (1959) described a somewhat similar relation near the type Silver Plume area where secondary mica and chlorite formed in minute fractures in cataclastically deformed granite.

FAULTS

The main faults belong to a steep northwesterly trending set; minor faults belong principally to the northwesterly trending set or to a steep northeasterly trending set. Faults of both sets are locally mineralized. The faults originated in Precambrian time but may have been reactivated later.

Badger Flats fault

The Badger Flat fault is a prominent structure that strikes north-northwest and dips steeply, possibly to the east. The fault is poorly exposed but can be traced through the western part of the area for about 4 miles (pl. 1). Other faults of the same set can be traced northward from near the north end of the Badger Flats fault.

Locally the Badger Flats fault is composite, consisting of two or possibly more branches; it consists of two branches in the SE¼ and in the northern part of sec. 28 and in the southern part of sec. 22. In the Boomer mine area (pl. 3) east of the Badger Flats fault, a set of fractures occurs that strikes more northwest and dips less than the Badger Flats fault and possibly is related to it. The fractures contain granite-aplite dikes of the Redskin Granite and, locally, beryllium veins.

South of the Boomer mine, parts of the Badger Flats fault can be closely located, and the lithologic trend is at an angle to the fault; so some estimate of displacement can be made on the basis of facies offset. Apparent left-lateral displacement along the fault ranges from a few feet at the south end to about 200 feet in the Boomer mine area (pl. 3) and about 1,000 feet in the SE¼ sec. 28.

A small Silver Plume(?) pluton, mainly in the NE¼ sec. 28, lies along the projected trace of the fault, and a part of the pluton extends in a dikelike zone parallel to and within the fault zone. Although the shape of the pluton might be explained by postpluton faulting, two lines of evidence suggest that the pluton is younger than the fault. One is the dikelike projection of the pluton to the northwest; the second is that the fairly large apparent displacement (1,000 ft) in sec. 28 can be easily explained if the granite pluton were emplaced after the faulting and this Silver Plume(?) body noticeably raised the block of ground east of the fault.

Northwesterly trending faults and shear zones

Faults and shear zones also cut through the Pikes Peak or Redskin Granite (pl. 1). The longest structures are a fault in the northwestern part of the area and shear zones near Redskin Gulch. These structures locally contain trace amounts of fluorite. Shorter faults, which locally contain fluorite veins, form a crudely defined belt that trends northwestward from the NE cor. sec. 23 to the NE cor. sec. 9.

Although there is little evidence to indicate movement, small displacements seem to have occurred on both long and short faults or vein fissures of the granite.

Northeasterly trending faults

Faults (vein fissures) of the steep northeasterly set are prominent in the S½ sec. 22 and in the Boomer mine (pl. 4). At these localities the faults locally contain beryllium-bearing veins. Steep northeasterly trending faults, locally with greisen, also occur in secs. 19 and 30, T. 10 N., R. 71 W., at the east edge of the mapped area. Displacements are probably very small on the northeasterly trending faults.

Age of faulting

Several episodes of faulting occurred in Precambrian time. The oldest movement on the Badger Flats fault could be pre-Silver Plume, as discussed previously, and many faults were formed or reopened during the intrusion of the Pikes Peak and Redskin Granites, as shown by the fact that they are now occupied by granite dikes. Other faults and shear zones cut these granites and so are younger, but they are probably not much younger than the granites because they locally contain greisen bodies or fluorite veins.

Movement must have occurred on some of the faults in more recent time, but the only direct evidence of post-Precambrian movement is in a small body of Tertiary(?) tuff in the NW¼ sec. 22 that appears to to be cut by faults too small to be shown on plate 1.

GEOLOGIC HISTORY

Geologic history in the Lake George beryllium area is largely recorded in Precambrian rocks and is thus only fragmentary. The oldest event that can be inferred from the Precambrian rocks was the deposition of a thick sequence of sediments. Younger recognizable events in the Precambrian were regional metamorphism and nearly synchronous folding of the layered rocks and catazonal emplacement of the Boulder Creek(?) Granodiorite. These events were followed by the forcible mesozonal emplacement of the Silver Plume(?) Granite and, still later, by the epizonal emplacement of the Pikes Peak and Redskin Granites.

The oldest rocks of the district are the complexly interlayered paragneisses constituting the Idaho Springs Formation which formed dominantly from shales and pelitic sandstones, possibly graywackes, during high-grade regional metamorphism. The quartz diorite and granitic orthogneisses tentatively assigned to the Boulder Creek(?) Granodiorite were intruded as sheetlike or phacolithic bodies and were metamorphosed and folded plastically along north-northeast-trending axes during this early period. The metamorphic grade attained was that of the almandine-amphibolite facies. The high grade of regional metamorphism, conformable contacts of paragneiss and orthogneiss, and the phacolithic and sill-like shapes of the orthogneiss plutons suggest a metamorphic environment typical of the catazone.

During a later deformation these rocks were locally folded along axes trending east-northeast and were cataclastically deformed. This event cannot be dated except to say that it followed the regional metamorphism and plastic folding.

The emplacement of the Silver Plume(?) Granite probably followed movement along northwest-trending faults, such as the Badger Flats fault. Conditions were approximately mesozonal, but, near the Silver Plume(?) plutons where rocks were heated, deformation caused by the plutons was plastic. Deformation near the plutons was accompanied by recrystallization and retrograde metamorphism in which large muscovite poikiloblasts formed, partly at the expense of sillimanite and potassium feldspar.

Gabbro and monzonite and the Pikes Peak and Redskin Granites are sharply discordant to the older rocks and have not been metamorphosed. They were emplaced in a pressure-temperature environment typical of the epizone.

Age determinations on Boulder Creek and Silver Plume rocks in the Front Range and on the Pikes Peak Granite, summarized by Hawley and others (1966), indicate that more than 700 m.y. of Precambrian time is represented by the rocks of the area. Periods of igneous activity culminated 1,650–1,700 m.y. ago (Boulder Creek), more than 1,350 m.y. ago (Silver Plume), and about 1,000 m.y. ago (Pikes Peak).

Radiometric (Antweiler, 1966) or geologic data suggest that ore deposits formed in each of these epochs. The beryllium deposits of the area represent a late hydrothermal stage of the Pikes Peak Granite magma series that was related specifically to the Redskin Granite.

ORE DEPOSITS

The ore deposits of the Lake George beryllium area include fissure-vein deposits of fluorite, barite, and pyrite in slightly altered rocks, scheelite deposits in calc-silicate gneiss, and the deposits of beryllium, tungsten, and other metals in greisenized rock that are the subject of this report. All are of Precambrian age.

The fluorite deposits occur in discontinuous fissure veins that cut the Pikes Peak and Redskin Granites. In addition to the dominant fluorite, they contain barite and quartz and small amounts of galena, sphalerite, and copper sulfides. Rare earths are characteristically present in trace amounts in these deposits, but most fluorite veins have a low content of beryllium, generally <3 ppm (parts per million). Most fluorite deposits occur in the Redskin stock, where they fill fissures belonging to a steep northwest-trending set and to minor low-angle northwest- or northeast-trending sets. The area of greatest concentration of fluorite veins in the Redskin stock includes the Redskin Gulch area, which also contains beryllium deposits (pl. 2). Because of this spatial association with deposits known to be Precambrian and their confinement to the fluorite-rich Pikes Peak and Redskin Granites, the fluorite deposits are believed to be Precambrian in age and to be genetically related to the granites. They are, however, younger than the berylliferous greisens, which they locally cut.

The scheelite deposits (Tweto, 1960) occur in calc-silicate gneiss that mineralogically resembles typical contact metamorphic tactite. The ore-bearing rock consists mainly of garnet, epidote, idocrase, quartz, calcite, and diopside; it also contains local concentrations of scheelite, sparse amounts of sulfides, and sparse manganese silicates. Small metalliferous deposits in calc-silicate rocks are scattered throughout the mapped area, but to the south of the area they occur mainly in or near plutons of Silver Plume(?) Granite, where they probably were formed by the contact metamorphism of calcium-rich metamorphic rocks.

The most economically important ore deposits are the beryllium ores which have been mined extensively at the Boomer mine and on a small scale elsewhere in the area. These deposits form veins, pipes, pods, and complex irregular bodies which are encased in altered rock termed "greisen." Although greisen is widely distributed, it is not common in the better known ore deposits of the United States and so is described briefly here.

GREISEN

Although a few greisen bodies have been described as igneous rocks of exceptional composition, the great bulk of greisens are altered rocks formed from granitic hosts. They are characterized by distinctive mineralogy, trace-element content, and rock association. The most common variety is a granular rock composed dominantly of quartz and lithian muscovite or related mica. Greisen also contains topaz and fluorite, and locally either of these minerals may predominate and form, for example, topaz greisen. The characteristic trace elements are lithium, molybdenum, tin, and tungsten, which occur with more common trace elements such as copper, lead, and zinc. Greisen is associated with granitic intrusives, particularly with late highly acid differentiates, many of which share the trace-element suite of the associated greisen. Evidently greisens form at temperatures above the stability range of the clay minerals characteristic of mesothermal or epithermal alteration (Sainsbury, 1960).

The greisen of the Lake George area is in many respects typical of greisens. It is composed of quartz and lithian muscovite and locally topaz and fluorite and contains small amounts of tungsten, molybdenum, and tin. The beryllium content of deposits associated with greisen in the Lake George area is somewhat high compared with that of well-known greisen areas such as Cornwall and Saxony, but beryllium minerals are known from these areas, and beryllium-rich deposits associated with greisen have recently been found at many other places.

Almost all the beryllium deposits have greisenized wallrocks, and some, such as the quartz-muscovite-bertrandite rocks, are beryllium-bearing greisens. Because of this association of altered rock and mineral deposits and because of the close paragenetic relations of minerals in each, greisen and ore are discussed together. The reader should, however, realize that ore and greisen are not necessarily synonymous. Although virtually all ore has associated greisen, many greisenized rocks are not ore bearing.

DISTRIBUTION OF BERYLLIUM DEPOSITS AND GREISEN

Beryllium deposits and greisen are concentrated in four areas, all of which are in or very near masses of the Redskin Granite (pl. 2). These are the Boomer mine, China Wall, Mary Lee mine, and Redskin Gulch areas. Small beryllium deposits or greisen bodies occur singly or in clusters outside these four areas. Greisen containing only trace amounts of beryllium but some tin and tungsten is also abundant in the Tappan Mountain area, where it appears to be associated with the Silver Plume(?) Granite.

DISTRIBUTION OF BERYLLIUM DEPOSITS RELATIVE TO THAT OF THE REDSKIN GRANITE

Most beryllium deposits are associated with Redskin Granite, and specifically with its porphyritic and granite-aplite facies. Small beryl-bearing veins occur as much as several thousand feet from any known occurrence of Redskin Granite, but these veins are largely composed of quartz, and they have not been productive. Greisens with only trace amounts of beryllium occur in the granular facies of the Redskin Granite, the Pikes Peak Granite, and the Silver Plume(?) Granite. In the Boomer mine area the beryllium deposits are associated with granite-aplite of Redskin type in the Boomer cupola or dike rocks related to the cupola; in the Redskin Gulch area they are in the porphyritic granite of the Redskin stock; in the China Wall cupola they are in or adjacent to granite-aplite very similar to that of the Boomer cupola; and in the Mary Lee mine area the deposits occur near granite-aplite which forms a local border of the Redskin stock.

Anamolous concentrations of beryllium also occur in altered Silver Plume(?) Granite and calc-silicate gneiss associated with Redskin granite-aplite dikes near the center of sec. 16, but the mineral that contains the beryllium has not been identified. Another occurrence is in sec. 23, where quartz-beryl vein is found within a granite-aplite border-zone rock of the Redskin stock.

In summary, present information on the distribution of beryllium-bearing greisen indicates that in the Redskin stock the porphyritic granite and granite-aplite are favorable for prospecting; near the Boomer mine and in the China Wall cupola the granite-aplite is the favorable unit.

DISTRIBUTION OF BERYLLIUM DEPOSITS RELATIVE TO THAT OF OTHER ROCK UNITS

Beryllium deposits associated with the Boomer and China Wall cupolas and those in the Mary Lee mine area have been mined partly from the Redskin Granite and partly from older rocks of granitic composition in contact with the granite. Silver Plume(?) Granite, the more granitic parts of the Boulder Creek(?) Granodiorite, and pegmatite seem to be particularly favorable as hosts. In the Boomer mine area, replacement deposits have been mined from greisen in pegmatite and Silver Plume(?) Granite adjacent to Redskin Granite; in the China Wall cupola all known beryllium deposits occur essentially at the contact between the Redskin Granite-aplite and the included masses of the Silver Plume(?) Granite; and in the Mary Lee mine area the one shoot mined was in granitic orthogneiss cut by Redskin Granite. Biotite-rich schistose rocks seem to be generally unfavorable, but some ore has been mined at the Boomer mine from steeply dipping veins in biotite gneiss (Idaho Springs Formation).

Several small mineralized bodies, as yet virtually unprospected, were found by W. N. Sharp (oral commun., 1962) near the center of sec. 16. These deposits occur in metasomatically altered Silver Plume(?) Granite and calc-silicate gneiss within an area cut by several granite-aplite dikes. The altered Silver Plume(?) contains as much as 0.015 percent beryllium. The altered calc-silicate gneiss contains about 0.0015–0.007 percent beryllium and 0.007–0.015 percent tin, suggesting that calc-silicate gneiss could, under some circumstances, be a favorable host rock for deposits.

DISTRIBUTION OF GREISENS

Although most beryllium deposits are associated with greisens, many greisens contain only trace amounts of beryllium, and nearly barren greisens are much more widely scattered than the beryllium-bearing types. The known occurrences of beryllium-bearing greisen suggest that most greisens associated with favorable facies of the Redskin Granite contain at least small amounts of discrete beryllium minerals. In contrast, most greisens associated with the unfavorable granular facies of the Redskin Granite, the Pikes Peak Granite, or greisens in older igneous and metamorphic rocks contain only trace amounts of beryllium and only sparse concentrations of beryllium minerals.

The main concentration of beryllium-poor greisen is in the Tappan Mountain area (p. A35; fig. 14). Greisen nearly barren of beryllium is also concentrated in the granular facies of the Redskin stock in a small area in the SE$\frac{1}{4}$ sec. 15 and in the southern part of sec. 14 and the adjacent part of sec. 23. Greisen also appears to be fairly abundant in Silver Plume(?) Granite and metamorphic rocks in the E$\frac{1}{2}$ sec. 28 and the contiguous part of sec. 21, where greisen bodies are localized in part by the Badger Flats fault.

Some greisen with low beryllium content contains anomalous amounts of other metals. Thus, several low-beryllium greisens of the Tappan Mountain area contain 0.01–0.07 percent tin, and one vein of the area has been prospected for tungsten.

GENERAL CHARACTER OF THE BERYLLIUM ORES

The beryllium ores of the Lake George area are variable in texture and mineralogy. Some of them are readily recognized as ore, but some beryllium-rich rocks have been overlooked because the valuable minerals were unfamiliar or because the rocks resembled barren greisen or granite.

The first beryllium ore discovered in the Lake George area consisted of subhedral to euhedral beryl crystals in complexly intergrown aggregates accompanied by small amounts of quartz and muscovite. The beryl crystals were first noted on the dump of the Boomer mine, and the first beryllium production was from beryl crystal aggregates sorted from the dump rock, and mined from veins rich in well-crystallized beryl. The miners call this type of ore crystal beryl. A short time after the initial discovery an almost white granitic-textured rock noted in the Boomer vein was found to consist largely of beryl in anhedral poikiloblastic form; this material has been referred to as massive beryl ore. Ores composed of well-crystallized and poorly-crystallized beryl can occur in the same vein, and apparently they intergrade. In general the well-crystallized beryl forms sharp-walled veins in greisenized rocks; the ore that contains poorly crystallized beryl grades into barren greisen.

A third type of beryllium ore was discovered in a surface cut at the Boomer mine by L. G. Moyd with a beryllium detector. The ore occurred in a shallow pit partly under an outbuilding to the mine, and the ore body mined has generally been referred to as the Outhouse lode. This type of ore is composed principally of bertrandite, muscovite, and quartz (Sharp and Hawley, 1960). Much of the muscovite is pale yellow; it is abundant enough to mask the pale pink of the bertrandite and to impart a yellowish cast to the ore. Close inspection, however, shows that bertrandite is very abundant and forms small disseminated grains and veinlets in the micaceous greisen. Very similar ore is also found in greisens in Redskin Gulch. The bertrandite ore at both places forms podlike or pipelike ore bodies encased in barren gray mica-rich greisens. Like the so-called massive beryl ores, the bertrandite ore grades into barren greisen.

Another type of bertrandite-bearing rock was subsequently recognized in the Redskin Gulch area by W. N. Sharp. It consists of fine-grained euhedral quartz, euhedral pink bertrandite, and sparse yellow-green mica. In hand specimen it resembles a slightly altered, vuggy aplite.

Minor varieties of beryllium-bearing rocks are vuggy white topaz-quartz-beryl-muscovite greisens found at the Boomer mine, and quartz-topaz-wolframite-beryl veins found at the Mary Lee mine and other prospects of the Mary Lee mine area.

A few beryllium occurrences have a pegmatitic aspect, but the feldspars that are characteristic of most pegmatites do not occur in strongly greisenized rocks or in beryllium ores. Deposits in the China Wall cupola in the north part of the area are small irregular bodies of medium- to coarse-grained greisen accompanied by pods of massive and crystalline milky quartz similar to quartz segregations found in pegmatites. At the Boomer mine, barren parts of the Boomer vein are locally composed of quartz and perthitic potassic feldspar, and thin pegmatitic zones accompanied by greisenized rock locally are found in granite-aplite dikes. Quartz and beryl, greisen, and pegmatite are associated in a small deposit in the NE¼ sec. 23.

Metallic minerals are not abundant in most of the beryllium ores but do occur locally; they also tend to occur in concentrations in other parts of the deposits. Of the metallic minerals, molybdenite, arsenopyrite, galena, and wolframite appear to be most closely associated with the beryllium minerals. At the Boomer mine arsenopyrite formed nodules in beryllium ore in the Boomer vein and also formed a zone on the footwall of a beryllium-bearing greisen pipe which branches off the Boomer vein. This latter mode of occurrence (fig. 2)

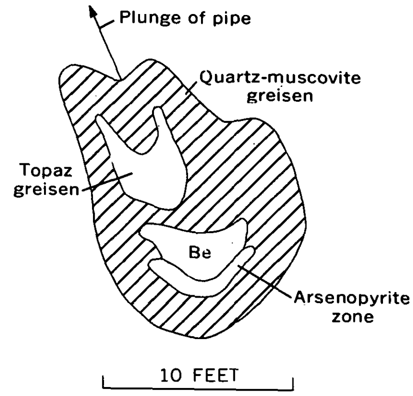


FIGURE 2.—Beryllium-bearing greisen pipe, Boomer mine, showing arsenopyrite "footwall gutter." Be, ore (berylliferous) greisen.

is apparently similar to the "footwall gutters" of metallic minerals reported from greisen pipes of the Australian tin province (Blanchard, 1947, p. 272; Garretty, 1953, p. 964). Elsewhere in the Boomer mine, beryl locally occurs with galena, dark sphalerite, and wolframite. Galena and sphalerite fill the interstices of ores composed of nearly euhedral beryl; wolframite tends to occur with topaz and is locally found in quartz-topaz-muscovite-beryl greisen at the Boomer mine.

Almost all the beryllium deposits have greisenized wallrocks. In many places the wall greisens are gray medium-grained equigranular quartz-muscovite rocks, but locally they include topaz- or fluorite-rich types which grade into quartz-muscovite greisens and beryllium-bearing ore greisens. Beryllium deposits are generally found in the central part of greisens, although the amount of alteration and the types of greisen present may not be exactly symmetrical with reference to the beryllium deposit. For example, some ore bodies have a quartz-topaz greisen on the footwall but only a quartz-muscovite greisen selvage on the hanging wall. The only beryllium occurrences without greisenized wallrocks found thus far are quartz-beryl veins in granite-aplite dikes. The dikes, however, are of unusual composition, as they consist mostly of quartz, albite, and muscovite and contain only sparse remnants of potassic feldspar.

FORM, SIZE, AND STRUCTURAL RELATIONS OF THE BERYLLIUM ORES

The beryllium deposits and their enveloping greisens are largely replacement deposits in the form of veins and pipes and complex irregular bodies. They are partly localized by fissures, contacts, and rock units of favorable composition or orientation. In the vein deposits the ore solutions clearly were guided by fissures. In the pipe deposits and complex deposits, controls are less well defined, although in most of the pipes a part of the ore control appears definite. For example, a pipe may be parallel to the plane of dip of an obvious fracture, but a second fracture inferred as necessary to control the direction of plunge of the pipe may not be well developed if it is present at all.

GREISEN PIPES

Greisen pipes like those of the Lake George area are apparently very common in many greisen areas, as in the Australian tin province (Blanchard, 1947). In many places their manner of formation, particularly with reference to structural control, is uncertain.

Most greisen pipes of the Lake George area, first described by Butler and Riley (1940), are in the Redskin Granite and particularly are in the porphyritic facies of the granite in the Redskin stock. Some pipes are in the granite-aplite forming the Boomer cupola, and one pipe, which contains only small amounts of beryllium, is at the contact of the granular type of the Redskin Granite and Idaho Springs Formation at the Happy Thought mine. A quartz-rich greisen pipe was noted in the Pikes Peak Granite above Spruce Grove, formerly Spruce, campground.

The greisen pipes range from about 1 foot to more than 10 feet in width. Most pipes are oval in cross section, some are lenslike or irregular, and a few are almost circular. The maximum length of pipes is unknown, but the main pipe at the Redskin mine has been followed down an irregular course for more than 160 feet, and pipes at the Minerva J and Black Prince mines (fig. 13) have been followed, respectively, about 160 and 100 feet. The upper parts of all three of these pipes, and nearly all other pipes of the area, were eroded; therefore, originally they may have been much longer than they are now. Greisen pipes elsewhere in the world are known to be much longer. According to Hall (1932, p. 487–489), the greisen pipes of Potgietersruet, South Africa, are commonly 5–8 feet across, and some have been followed for as much as 2,500 feet. Some pipes of the Kingsgate district, New South Wales, Australia, have been followed for more than 500 feet (Garretty, 1953, p. 962–965).

The pipes of the Lake George area tend to occur in clusters, as in Redskin Gulch (fig. 13), and pipes in any one cluster tend to have a subparallel plunge, although the pipes follow irregular courses, as illustrated by diagrammatic views of the Redskin and Minerva J pipes (fig. 3).

The beryllium deposits and deposits of other valuable minerals occur as irregular disseminations and veinlike zones in the central part of the pipes. In general the beryllium ore grades outward into nearly barren dark-gray muscovite-rich greisen which in turn is in abrupt contact with a thin selvage of quartz greisen (fig. 4). In places where the greisen has been removed

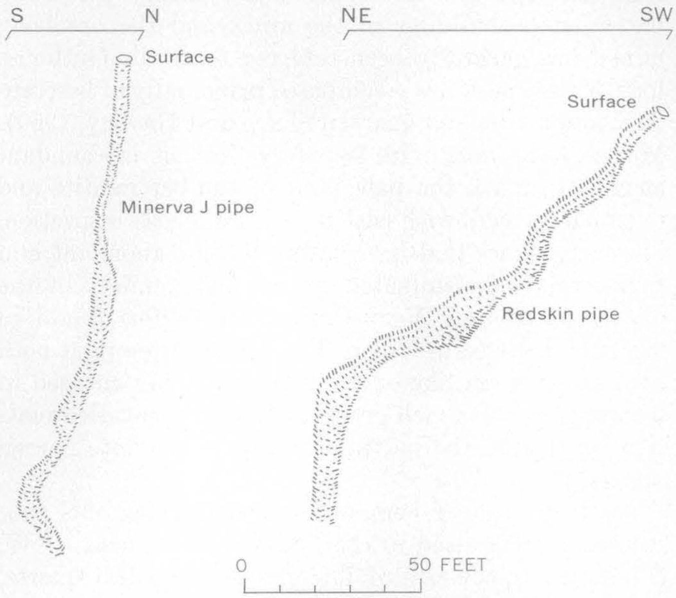


FIGURE 3.—Diagrammatic view of Minerva J and Redskin greisen pipes. Pipes sketched along the cross sections made by W. N. Sharp in 1960. Uppermost 40 feet of Redskin pipe plunges north and was projected into plane of cross section.

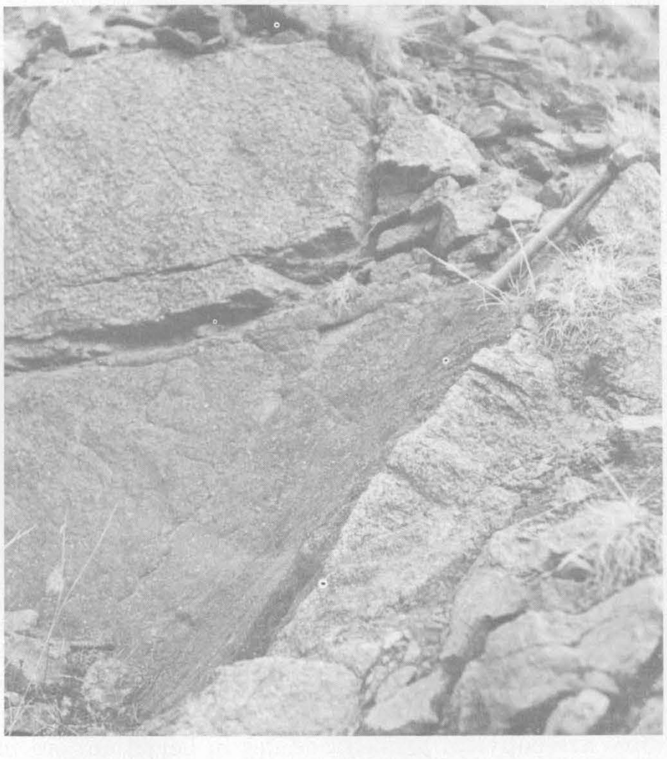


FIGURE 4.—South edge of main Redskin pipe. Hammer is about on quartz greisen-muscovite greisen contact. Quartz greisen grades to the right into granite. Dark-gray material is micaceous greisen. Hammer parallels plunge of greisen pipe.

in mining, the prospect pits clearly show the cylindrical shape of the pipes. In nearly vertical pipes, like the Minerva K and O (fig. 13), the contacts of greisen and granite are uniformly sharp. In the upper part of the main Redskin pipe, which plunges at about 40°, only the footwall contact is sharp, and the hanging wall greisen grades into granite.

At the Boomer mine, pipes form small parts of complex ore bodies. One pipe, which is as much as 10 feet across, has been traced to the surface from the hanging wall of the Boomer vein, and at least two other pipes were traced shorter distances from the hanging wall of the vein (pl. 4). Another pipe, part of which is shown near the east end of section *B–B′* (pl. 4), was traced from an irregular ore body to the surface. Both of these pipes were ore bearing; the beryllium ore zone was approximately in the center of the pipes and was as much as 2 feet across in both pipes. The Outhouse lode ore body was also pipelike in form.

The relation of greisen pipes to fracture zones is shown diagrammatically in figure 5. In all the pipes shown, the fractures are partly in greisen and partly in barren granite; in other pipes, such as the almost perfectly circular Minerva O pipe, no discernible fracture extends from pipe to wallrock.

VEIN DEPOSITS

Tabular fissure veins filled with quartz, topaz, and smaller amounts of beryl and wolframite in greisenized wallrock are typical of deposits found in the Mary Lee mine area (fig. 11), and similar veins containing more beryl are found in the Boomer mine. A wolframite-bearing vein occurs in the Tappan Mountain area. The generally nonberylliferous fluorite deposits are also a fissure-vein type.

In the Mary Lee mine area the fissure-vein deposits range in width from less than 1 inch to about 2½ feet and can be traced along strike for distances ranging from a few tens of feet to more than 1,000 feet. The veins fill a set of high-angle fractures which strike northeast. The area of greatest concentration of veins is just south of a small lobate mass of granite which extends southeastward from the Redskin stock, and the veins are oriented approximately at right angles to the trend of the small granite mass (pl. 1 and fig. 11). The veins appear to have an en echelon arrangement and to occur in zones in which the individual veins are separated by several feet of nearly barren rock. The major vein of the area, the Mary Lee, which has been traced with reasonable certainty for about 1,400 feet, probably is a lode zone consisting of nearly parallel mineralized fissures. Ore shoots within the vein structures apparently have a limited extent. In most places the beryl is too scattered to be mined, but a small ore body composed mainly of crystalline beryl was mined from the lower Mary Lee adit.

In the Boomer mine, fissure veins are mostly contained in two fracture sets, both of which extend from the cupola into older igneous and metamorphic country rocks. One vein set strikes northeast and is nearly vertical; the other strikes north-northwest and dips northeast at a low angle. Neither set has appreciable amounts of vertical or horizontal displacement.

The northeast-striking set contains quartz-beryl veins, most of which are too thin to mine, and fine-grained granite dikes which locally contain greisen and beryl veinlets. The main northeast-trending vein in the mine is best exposed on the 8,516-foot level (fig. 6), where it has been followed for about 120 feet. The southern part of the vein is a simple vein as much as 8 inches wide in sparsely greisenized gneissic wallrocks. In places the vein filling is an aggregate of interlocking beryl crystals. The northern part of the vein is partly in extensively greisenized rocks and partly in nearly fresh granite-aplite. The fissure, as such, cannot be traced directly through the extensively greisenized area but is apparently marked by discontinuous beryl veins, some of which have been mined.

On the low-angle north-northwest-striking vein fissure set the major mineralized zone is the Boomer vein. At various places in the Boomer mine the fissure is marked by pegmatitic material in unaltered granite, by sharp-walled quartz-crystalline beryl veins as much as 2 feet wide in greisenized rock, by massive beryl replacement ores at least 6 feet across grading outward from beryl-bearing fissures, and by partly greisenized granite dikes in the metasedimentary rocks. The vein is exposed on three levels in the mine, but it is most strongly mineralized on the 8,533-foot level (fig. 7); the main ore body in the vein probably has a flattened pipelike shape.

DEPOSITS LOCALIZED BY FAVORABLY ORIENTED ROCK UNITS AND CONTACTS

Greisens, locally containing economically important amounts of beryllium, are localized along the contacts of the Redskin Granite with older granitic rocks at several places in the Lake George area. Examples of contact or wallrock control of mineralization, some noted earlier, are found in the Boomer mine, at several prospects in the China Wall cupola area, and possibly at the Happy Thought and Tennessee mines in sec. 22.

The south edge of the Boomer cupola is in contact with an older pegmatite that is typical of those in the metamorphic complex. At the surface the contact is nearly vertical, but at a depth of about 50 feet the contact

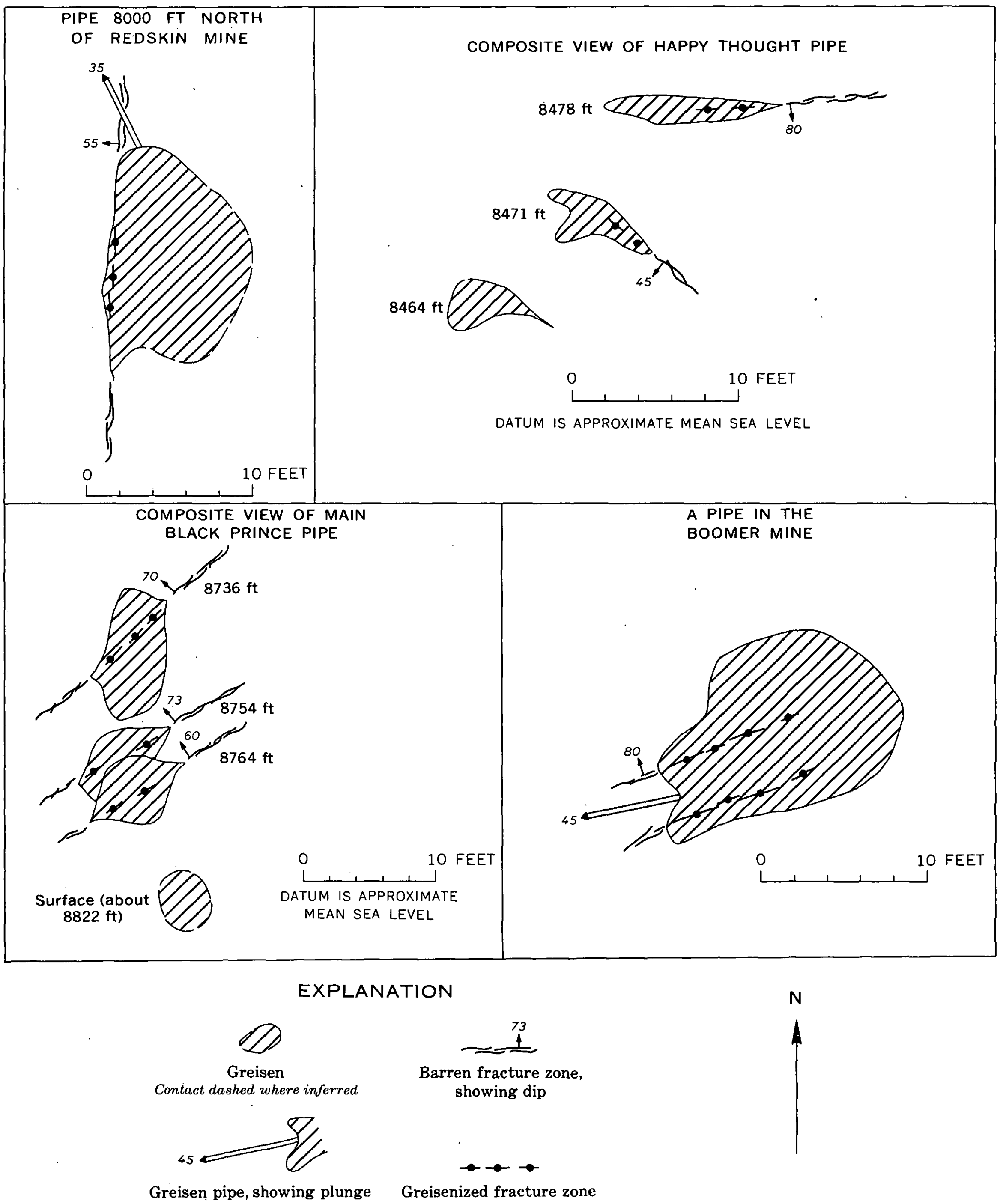


FIGURE 5.—Relations of greisen pipes to fractures.

flattens abruptly. In cross section (pl. 4, sections A–A' and B–B') the pegmatite appears to be a remnant, which contains a horse of gneiss, lying between granite-aplite and gneissic rocks and completely underlain by the granite-aplite. The contact of the granite-aplite and pegmatite is mineralized at several places, but most extensively at the collar of the Boomer shaft, on the 8,565-foot level (now in the main opencut) and on the 8,516-foot level. The very small remnant mass of pegmatite exposed on the 8,516-foot level has been almost completely replaced by beryllium-bearing greisen forming an ore body about 35 feet long.

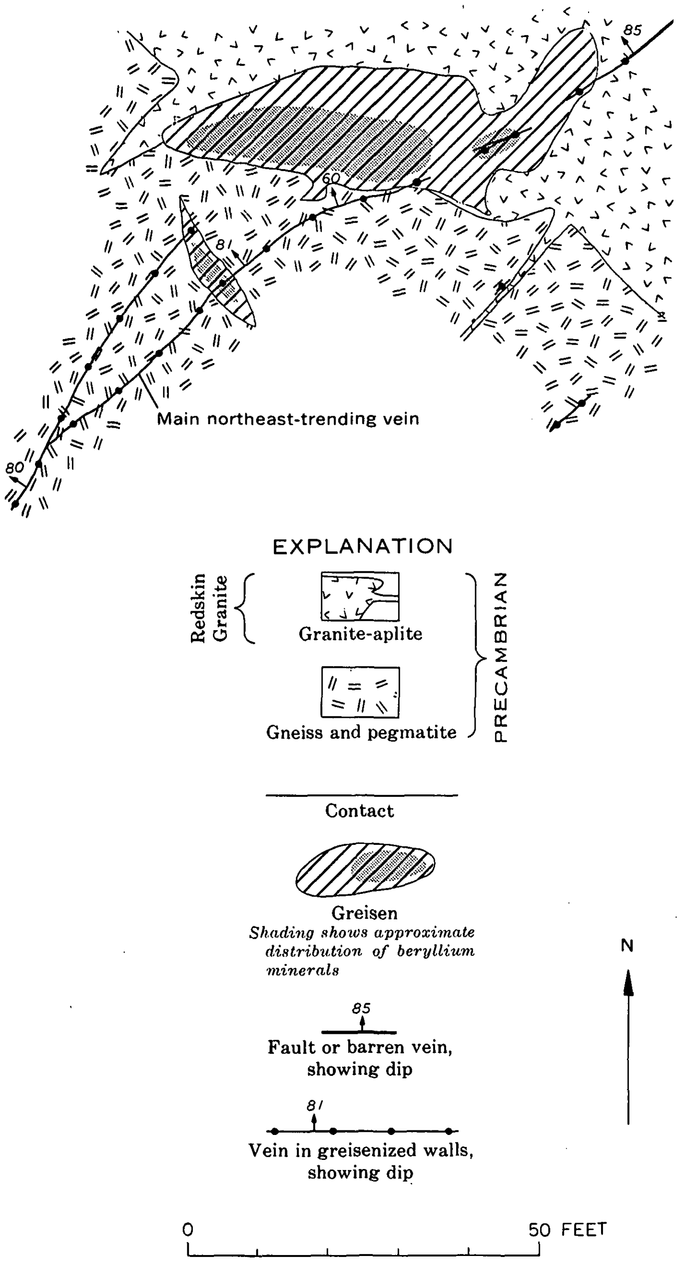


Figure 6.—Part of the 8,516-foot level, Boomer mine, showing northeast-striking veins and ore along granite-aplite contact.

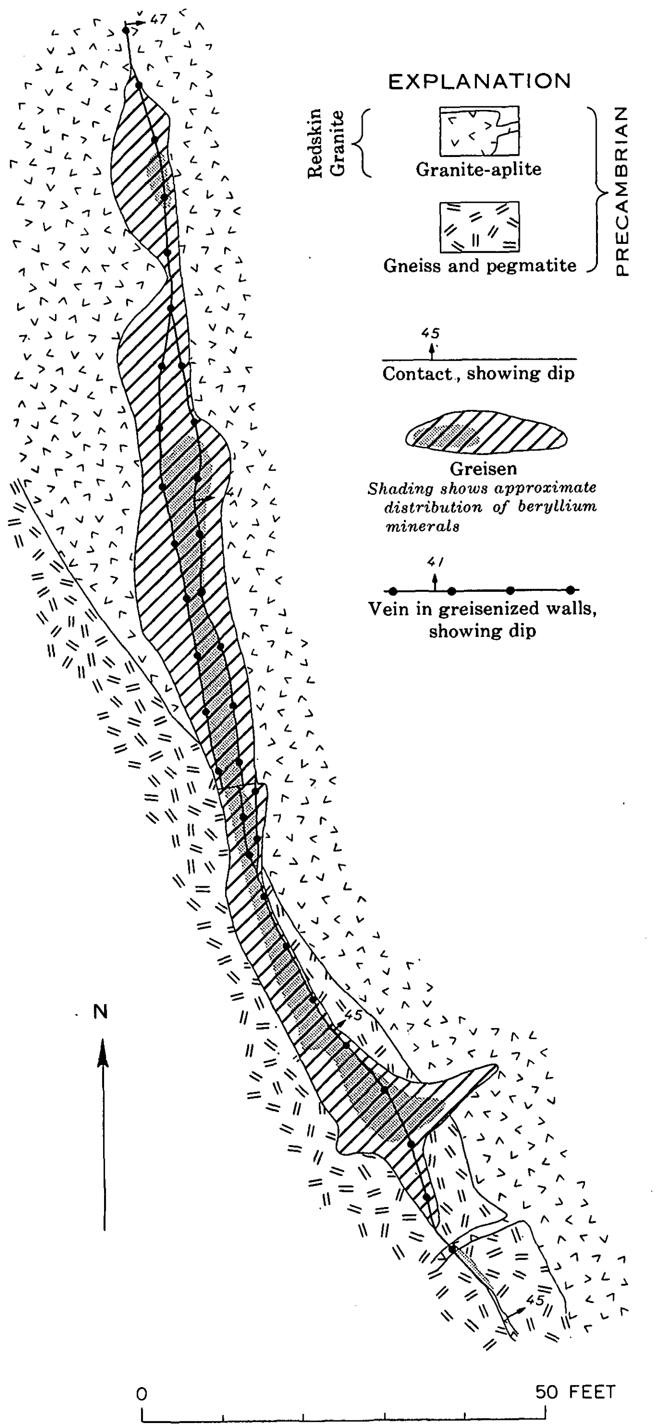


Figure 7.—The Boomer vein, 8,533-foot level, Boomer mine.

The granite of the China Wall cupola was emplaced between the Redskin stock and a body of the Silver Plume(?) Granite, and it contains numerous inclusions of Silver Plume(?) Granite, particularly near the west edge of the pluton. The beryllium-bearing greisens are found near or at the contacts of the inclusions with granite-aplite of the Redskin Granite or, as at the A & C mine in the China Wall area, in a thin dike of granite-aplite which cuts a large inclusion of the Silver Plume(?) Granite.

A greisen pipe which contains trace amounts of beryllium at the Happy Thought prospect (fig. 11) lies nearly on the contact of the Redskin stock with the Idaho Springs Formation and the old pegmatites and in part is apparently controlled by the contact. A few hundred feet south along the contact, beryl-bearing veins and greisens are found in the Tennessee prospect. Still farther along the same contact, the beryl shoot in the Mary Lee vein deposit lies in Boulder Creek(?) Granodiorite within 50 feet of the Redskin stock.

MINERALOGY

The beryllium ores are generally composed of only a few minerals. Most consist of beryl or bertrandite and other silicates typical of greisen such as quartz, muscovitic mica, fluorite, and topaz. The associated greisens and related deposits of other metals, however, may be complex mineralogically. In addition to common sulfide minerals, the deposits contain arsenopyrite, molybdenite, wolframite, and rarely cassiterite and uraninite. Euclase is a sparse component of some of the beryllium ores.

The minerals found in the deposits are divided into two groups: (1) ore minerals comprising the beryllium-bearing silicates and the metallic minerals, and (2) nonmetallic gangue minerals including topaz, fluorite, and muscovite. Supergene minerals are sparse and are not discussed as such; cerussite is found with galena in the Boomer mine, and some limonite after iron-bearing sulfides or siderite is present in many deposits.

ORE MINERALS

SULFIDES

The sulfides found in the greisens and associated ore deposits are, in approximate order of abundance, galena, sphalerite, arsenopyrite, molybdenite, pyrite, chalcopyrite, and covellite. The sulfides most closely associated with the beryllium minerals are probably arsenopyrite, molybdenite, and galena.

Galena is found at the Boomer, Happy Thought, and Black Prince mines. At the Boomer it occurs as disseminated grains and aggregates in greisens and granite and as massive pods and veins in greisenized rocks. Solid masses of galena as much as several inches across were found in places such as the raise between the Boomer vein and the Outhouse lode opencut and in the greisen on the hanging wall of the Boomer vein on the 8,533-foot level. Semiquantitative spectrographic analyses, by J. C. Hamilton, indicate that the galena contains about 0.3–0.7 percent silver, and 0.3–1.5 percent bismuth, 0.007–0.7 percent copper, and only very small amounts of other trace elements. The silver content is appreciable, and it is assumed that galena-rich deposits were the silver ores sought by the early miners at the Boomer.

Disseminated galena in the greisen is found with sphalerite in the Happy Thought pipe, in small amounts at the Black Prince pipe, and in several places at the Boomer mine. Galena and sphalerite are found in a quartz-beryl-mica zone forming the footwall of the Boomer vein on the 8,533-foot level near one occurrence of massive galena.

Sphalerite is found with galena or chalcopyrite and is probably most abundant at the Boomer mine and in the main Black Prince pipe. The sphalerite is a dark iron-bearing variety and contains minute exsolved blebs of chalcopyrite. (A semiquantitative spectrographic analysis, by J. C. Hamilton, of sphalerite from the Boomer mine showed 7.0 percent iron, 0.7 percent copper, and 0.15 percent manganese.) Disseminated sphalerite accompanied by chalcopyrite and pyrite is also found in granite-aplite in the northern part of the 8,533-foot level and on the 8,494-foot level of the Boomer mine and also at the Redskin mine.

Arsenopyrite has been observed only at the Boomer mine. It occurs there as nodules and crystals 1–2 inches across in greisen fragments on the dump and in place in the Boomer vein on the 8,533-foot level and in the footwall of the pipelike ore body connecting the Boomer vein with the Outhouse lode greisen mined at the surface.

Molybdenite occurs principally in the Redskin Gulch area, but it has also been reported from the Boomer mine. Only small amounts of molybdenite are found on the Redskin mine dump, but veinlike zones of solid molybdenite as much as 2 inches thick were found during the exploration of the mine for beryllium in 1961, and it is assumed that similar material was mined and shipped during the molybdenum activity about the time of World War I. Some of the molybdenite found at the Redskin mine was intimately associated with bertrandite.

Pyrite occurs sparsely in the Boomer mine ores and in the greisens from the Redskin Gulch area, generally in disseminated form. Massive pyrite was noted only at the Lucky Boy mine, a tungsten (wolframite vein) prospect east of Tappan Mountain. Chalcopyrite is found with pyrite or sphalerite and is nowhere abundant. Covellite is found as thin late veinlets cutting sulfide-bearing materials in the Boomer mine.

OXIDES

Oxide minerals found in the greisens are cassiterite, uraninite, and the iron oxides hematite, goethite, and limonite.

Cassiterite occurs in at least one and probably two veins near the Mary Lee mine (fig. 11) and was found in a prospect in the northeastern part of the Tappan Mountain area (fig 14). It probably occurs as a microscopic component of the gray muscovite-quartz greisens at the Boomer mine and elsewhere which generally contain about 100 ppm tin. Cassiterite was also identified in altered granite from the dump at the Redskin mine, where it occurs with wolframite and pyrite.

Uraninite has been found in small amounts at the Redskin, Black Prince, and Boomer mines. Apparently most of the uraninite is of the sooty variety; in the only locales currently accessible, sooty uraninite is found in a 1- to 2-inch-thick galena-rich vein with greisenized walls on the 8,494-foot level of the Boomer mine and with bertrandite and molybdenite in the Redskin mine (sample loc. 13, fig. 13).

Hematite, which is very finely disseminated, appears to be a characteristic associate of most greisens in the older pegmatite and granite wallrocks, and small amounts of specular hematite are locally found in the greisens themselves. The pegmatite and Silver Plume (?) Granite, which generally are almost white, become distinctly reddish near a greisenized zone. Goethite was identified by chemical composition and X-ray powder pattern from the Mary Lee vein where it forms small needlelike crystals in vugs in apparently fresh vein material; most of the hydrated iron oxides are, however, confined to partly oxidized ores and seem definitely supergene. Limonite, which locally has pseudomorphically replaced an older carbonate mineral assumed to have been siderite, fills spaces between beryl crystals and other crystalline components of the greisens.

SILICATES—BERYL, BERTRANDITE, AND EUCLASE

The silicate minerals classed as ore minerals are the three beryllium minerals thus far identified from the deposits. Beryl is the major component of most of the ores, but bertrandite is widely distributed and contains most of the beryllium in certain ore bodies or parts of ore bodies. Euclase has been found in small amounts at the Boomer mine and in deposits in the Redskin Gulch area.

Beryl is commonly represented by the formula $Be_3Al_2Si_6O_{18}$. Natural beryls deviate from this formula because of the substitution of other chemical elements for beryllium, aluminum, and possibly silicon; the substitutions involved are strongly influenced by the unusual ringlike structure of beryl which has been summarized by Schaller, Stevens, and Jahns (1962, p. 685–687):

> Beryl has a fundamentally columnar, honeycomblike structure * * *. Each column is hollow, and consists of stacked hexagonal rings that are formed by linked silicon-oxygen tetrahedra. * * * the columns are arranged in a hexagonal pattern, and their long axes are parallel to the c-axis of the crystal. Each ring * * * is bonded by means of beryllium and aluminum ions to the rings above and below it in the column, and to other rings in adjacent columns, as well.
>
> Each beryllium ion occupies a position of tetrahedral coordination between two columns and is surrounded by four oxygen ions from four different rings. * * * Each oxygen ion not involved in linkage of the silicon-oxygen tetrahedra is bonded to one Be^{2+} ion, one Al^{3+} ion, and one Si^{4+} ion.

Most beryls deviate from the ideal composition by substitution of alkali elements which are, commonly, lithium, cesium, and sodium, and, less commonly, potassium and rubidium. Cesium, sodium, and potassium are very large cations and probably can only be accommodated in the beryl structure in the open spaces within the silicon-oxygen rings. Lithium is slightly smaller and probably substitutes for aluminum (Schaller and others, 1962, p. 685–692; Beus, 1959), as indicated by a generalized formula:

$$(R^{+1})\ (Be_2Al)\,(Li\ Al)\,Si_6O_{18},$$

where (R^{+1}) represents the large alkali cations.

The beryllium contents of common beryls (as used by Schaller and others, 1962, table 6) can be estimated from measurements of the N_ω refractive index of beryl. The index ranges from about 1.570 to 1.590 in common beryls, corresponding to BeO contents of about 13.7 to 11.8 percent (Norton and others, 1958, p. 23). It has also been proposed that the unit cell edges (particularly a_0) determined from X-ray measurements reflect composition. Schaller, Stevens, and Jahns (1962, p. 683) stated that a_0 increases with increasing alkali content, and that c_0 is nearly constant.

Refractive indices, d-spacings, and cell edges were determined on four beryl samples from the Lake George area. The refractive-index measurements indicate a BeO content of about 13.5 percent, which is similar to that of beryl from tin- and molybdenum-bearing vein deposits investigated by Adams (1953, p. 108, 117). The d-spacings and cell edges were obtained from four powder photographs made with CuKα radiation. Two photographs (samples B2–8 and BJ–1 from the Boomer and Blue Jay mines, respectively) had sharply defined back reflections showing doublets, and, for these, extrapolated a_0 values were calculated graphically and are 9.212 and 9.222, respectively. The other two photographs had diffuse back reflections, but measured d-spacings on them correspond closely to those on the better samples.

The conclusion that the beryl is a high beryllium type is proved by the low alkali content of samples submitted by W. N. Sharp, and by analyses as shown in table 3.

TABLE 3.—*Spectrographic analyses (in percent) of beryl from the Boomer mine*

[Tr., trace; ----, not looked for]

Sample No.	[1] 287928	[1] 287929	[2] B39	[3] B39
Si	>10	>10	----	----
Al	>10	>10	----	----
Fe	.7	.7	0.15	0.3
Mg	.007	.007	.007	.005
Ca	.015	.007	<.005	.01
Na	.15	.3	.15	.1
K	0	0	<.7	.2
Mn	.003	.003	.0015	.002
Ti	0	0	.0003	----
Ba	.0003	.0003	.0003	----
Be	7	7	----	----
Cr	0	0	<.0001	.0001
Cs	<.02	<.02	----	<.1
Cu	.0003	.0007	.0007	----
Ga	.003	.003	.0003	----
Li	0	0	<.005	.02
Rb	<.006	<.006	----	<.02
Sc	.03	.015	.015	.014
Sn	.03	.015	----	----
V	0	0	<.0050	<.0005
Zn	Tr.	Tr.	.03	----

[1] Semiquantitiative spectrographic analysis by J. C. Hamilton; data submitted by W. N. Sharp.
[2] Semiquantitative spectrographic analysis by P. R. Barnett (in Staatz and others, 1965).
[3] Quantitative spectrographic analysis by P. R. Barnett (in Staatz and others, 1965).

The trace-element content in beryl from the Boomer mine is typical of nonpegmatite beryls in general (Staatz and others, 1965). Particularly characteristic features of the trace-element suite are the low content of lithium and the relatively high content of scandium.

The beryl occurs in both massive and crystalline external form; it ranges in color from almost white to pale blue, yellowish green, and bluish green. Some of the blue beryl is aquamarine, although practically none is of gem quality. The beryl crystals range in size from almost microscopic to about 10 by 3 inches; probably most are less than 1 inch across. Nearly all beryl crystals have striated prism faces, and on close inspection striated faces can be seen on some nearly massive, poikiloblastic crystals disseminated in greisen. Many of the crystals from veins in the Boomer mine show zoning; the interior of the crystals is clear and pale bluish; the outer parts are nearly white. In part the difference in color is due to the presence of minute abundant fluid inclusions in the white less clear material.

Beryl in topaz-bearing ores at the Boomer mine forms very pale bluish or greenish crystals, which typically occur in porous aggregates of very small well-formed crystals.

Beryl commonly occurs with quartz and muscovite; it also forms nearly monomineralic aggregates, and in a few places it is associated with quartz and topaz. Bertrandite and yellow mica occur, in part, as pseudomorphic replacements after beryl, and very locally bertrandite occurs with unaltered beryl. In a few places beryl is associated with metallic minerals. Beryl was found in pods of wolframite-topaz greisen on the 8,565-foot level of the Boomer mine (now in the main open-cut of the mine, pl. 4), and at other places it was found with arsenopyrite, galena, and sphalerite. The galena and sphalerite fill interstices in mats of beryl crystals and thus seem definitely younger than the beryl.

Bertrandite, a hydrous beryllium silicate ($Be_4(OH)_2Si_2O_7$), is the major beryllium mineral in the Outhouse lode ore body at the Boomer mine and in the greisen pipes of the Redskin area. It also occurs with beryl in the Boomer vein. Most natural varieties of bertrandite probably approach the ideal formula which contains about 42 percent BeO.

The bertrandite forms flesh-colored to pink subhedral to euhedral crystals, some of which are easily visible in hand specimen. Much of the bertrandite, however, occurs in apparently massive form as disseminations and veinlets in the greisen. Thin sections show that most of the apparently massive material is composed of aggregates of minute well-formed crystals.

Bertrandite is generally associated with quartz and mica. It has not been noticed in association with topaz. At the Redskin mine molybdenite and other sulfides are locally found in very rich bertrandite-bearing ore. The closest associate of bertrandite is fine-grained yellow mica which appears either to replace the bertrandite or, in vugs, to be deposited on it. Both the bertrandite and the yellow mica are younger than the coarser white mica which is a major component of the barren greisen. In hand specimens of most of the bertrandite-bearing ores, the pink color of the bertrandite is masked by the yellow mica.

Bertrandite also occurs in beryl-bearing ores where it and mica are found as pseudomorphic replacements of beryl and also in disseminated crystals. Most of the bertrandite in this association is interpreted as a hypogene alteration product of beryl. Bertrandite also occurs in some ores as the earliest hypogene beryllium mineral. This type of ore shows no remnants of beryl or the elongate zones of bertrandite-mica diagnostic of pseudomorphic replacement of beryl. One example of a possibly primary bertrandite ore is that from the Minerva N pipe in the Redskin Gulch area. Here euhedral bertrandite crystals were deposited on quartz crystals (fig. 8). Similar ore was also found in the Redskin pipe.

FIGURE 8.—Quartz-bertrandite-muscovite ore, Minerva N prospect. Crossed nicols, × 35. Q, quartz; B, bertrandite; M, muscovite.

Euclase ($BeSiAlO_4(OH)$) has been found in small amounts in ore mined from the Boomer vein and in the deposits of the Redskin Gulch area (Sharp, 1961). It typically occurs as minute euhedral crystals deposited on quartz and fluorite crystals in vugs. It is interpreted as a late hypogene mineral.

TUNGSTATES

Wolframite occurs sporadically in massive topaz-bearing greisens and in quartz-beryl-topaz veins in greisenized wallrocks. It is accompanied by small amounts of scheelite which form coatings on, or veinlets in, the wolframite; scheelite is probably a late hypogene or supergene alteration product.

At the Mary Lee mine the wolframite forms crystals as much as 2 inches across in a vein composed of quartz and topaz in greisenized wallrocks; it is most abundant in the upper adit. At the Boomer mine, wolframite occurs in disseminated plates about one-fourth inch long in topaz greisens exposed at the surface and in somewhat coarser form with topaz and beryl in pods on the 8,565-foot level (now in the main opencut) of the mine. Wolframite also occurs at the Lucky Boy prospect in the Tappan Mountain area.

The wolframite of the mapped area is closer to the ferberite end of the wolframite series than to the huebnerite end because it contains more iron than manganese, as shown in table 4.

TABLE 4.—*Semiquantitative spectographic analyses, in percent, of wolframite from the Boomer and Mary Lee mines*

[Analyst: Nancy M. Conklin]

Mine	Boomer	Mary Lee
Lab	[1] 280555	280556
Al	0.15	0.15
Fe	>10	7
Mn	3	3
Ca	.15	.15
Ti	.015	.015
Ba	.003	0
Bi	.015	0
Cr	<.002	<.002
Cu	.003	.003
Mo	0	.03
Nb	1.5	1.5
Pb	.7	1.5
Sc	.3	.07
Sn	.15	.07
V	.015	0
W	>10	>10
Y	.015	.015
Zr	.03	.015

[1] From topaz greisen.

GANGUE MINERALS

The gangue is composed dominantly of quartz, muscovite, fluorite, and topaz; siderite, now largely altered to limonite, is locally abundant, and barite, apatite, and monazite are present very locally.

HALIDES

The halide group is represented by fluorite, which occurs in most of the greisens and which is the major component of the fluorite fissure veins of the area.

Fluorite forms small disseminated grains in the barren quartz-muscovite greisens, massive aggregates or veins in greisens near ore, and euhedral cubes in vugs; it is generally less abundant in the beryllium-bearing greisen than in barren greisen. It is very abundant in a central muscovite-rich greisen in a barren part of the Boomer vein on the 8,516-foot level and in the greisen exposed in the opencut 60 feet east of the Boomer shaft; a quartz-fluorite vein formed the hanging wall of the bertrandite ore body in the Outhouse lode opencut.

Most of the fluorite found as disseminated grains or as massive or veinlike bodies is green and poorly crystalline. The euhedral fluorite found in vugs is a zoned type that contains clear fluorite in the central part of the crystal and purple fluorite in the outer part.

Fluorite disseminated in the greisens is inferred to be younger than the quartz and muscovite because it is interstitial to them. The zoned fluorite crystals are found in vugs in barren and ore-bearing greisen, and are probably among the youngest hypogene minerals. The green fluorite at the Boomer mine contains a higher concentration of rare earths than do either the purple or the white varieties, as shown in table 5.

TABLE 5.—*Semiquantitative spectrographic analyses, in percent, of fluorite from the Boomer mine*

[Analyst: J. C. Hamilton]

Lab. No.	287934	287935	287936
Color of fluorite	White	Purple	Green
Si	0.15	0.15	<0.01
Al	.3	.15	.007
Fe	.15	.15	<.001
Mg	<.001	.0015	<.001
Ca	>10	>10	>10
Mn	.0003	.0007	.0007
Ag	.0003	.0015	0
Be	.015	.0007	.0003
Ce	<.05	<.05	<.05
Cu	.015	.15	.0015
Dy	0	0	.03
Er	0	0	.015
Gd	0	0	.015
La	0	0	.015
Mo	.0015	.007	0
Nd	<.05	<.05	<.05
Pb	.03	.07	.0015
Sn	.0015	.0015	0
Sr	.007	.007	.07
Y	.015	.15	.15
Yb	.0007	.003	.03

CARBONATES

Siderite or a closely related iron-bearing carbonate is a characteristic accessory mineral in metasomatically altered granites near greisens. Siderite, now altered to limonite, occurs in beryl-bearing greisens at the Boomer mine and in several bodies in the China Wall pluton. Siderite in greisens of the area is interstitial to well-formed crystals of beryl or topaz.

SILICATES

Quartz and muscovite are commonly the most abundant constituents of the greisens; locally greisens are made up mainly of either topaz, a hydroxyfluosilicate, or the beryllium silicates previously described.

Kaolinite is found in some greisens, but it is generally not abundant. It formed by the late hypogene or supergene alteration of topaz and possibly muscovite. Quartz in greisen commonly occurs as gray equigranular medium-grained crystals that locally have strongly sutured outlines; it also occurs in vuggy greisens as clear medium- to coarse-grained euhedral crystals and in 1- to 2-inch-thick veins as a cryptocrystalline variety. The cryptocrystalline quartz cuts across the more crystalline minerals of the greisens.

At least two types of muscovite occur. The most common type is white to gray mica which forms pseudohexagonal crystals and is paragenetically early. Somewhat less abundant is a pale-yellowish green mica which forms fine-grained aggregates; it is characteristic of the bertrandite-bearing ores and some barren greisens, and it formed partly by the replacement of the gray muscovite. Both types are nearly nonpleochroic in thin section. A third mica, noted only in thin section, is green and pleochroic and occurs in poorly crystalline aggregates along the partings of the gray muscovite.

The gray muscovite possibly is a $2M_1$ polymorph. Reflections were found at about 31.2° 2θ and 32.0°2θ, and these probably arise from characteristic $2M_1$ planes—115 and $11\overline{6}$, respectively. Observed 2θ values from diffractometer measurements of gray muscovites from the Boomer mine are compared with observed values from synthetic $2M_1$ muscovite (Yoder and Eugster, 1955, table 4) below:

Gray muscovite in greisen from Boomer mine		Synthetic $2M_1$ muscovite (Yoder and Eugster, 1955)	
Observed 2θ	I [1]	Observed 2θ	I [2]
8.9	>70	8.830	>100
17.8	20	17.665	55
19.8	15	19.825	55
		19.915	65
22.9	5	22.865	37
23.7	10	23.820	32
25.4	15	25.450	44
26.8	>75	26.60	>100
27.8	15	27.810	47
29.8	20	29.795	47
31.2	15	31.160	35
32.0	10	31.925	22
		34.640	50
34.8	20	34.770	45
		35.025	90
36.0	20	35.720	20
		36.555	19
		37.545	10
42.0	8	42.045	10
		42.390	23
45.5	50	45.100	75

[1] Relative intensity; height above diffractometer background.
[2] "Relative intensity based on arbitrary linear scale" (Yoder and Eugster, 1955, p. 247).

The gray muscovite of the greisen is an iron-rich phengitic variety which is more similar to gilbertite than to any other variety of muscovite cited by Foster (1956, pp. 59–66, table 2). As seen in the analyses below, the greisen muscovite is similar to sericite in its high content of silica and of divalent cations.

	1	2
SiO_2	46.20	48.8
Al_2O_3	28.01	28.8
Fe_2O_3	1.98	1.6
FeO	7.63	5.7
MgO	.05	.2
CaO	.06	0
Li_2O	N.D.	.1
Na_2O	.42	1.1
K_2O	10.59	10.2
H_2O+	3.35	2.9
H_2O-	.05	------
TiO_2	.08	------
P_2O_5	.00	------
MnO	.22	------
Cl	.02	------
F	1.95	0.6
Subtotal	100.61	------
Less oxygen	.82	------
Total	99.79	100

SAMPLE NOTES

1. Sample No. B1-22 (Lab. No. D 101506). Chemical analyses of gray greisen muscovite from the Boomer mine by Vertie C. Smith. Spectrographic analysis of sample B1-22 shows the following trace elements, in percent: B, 0.003: Ba, 0.007; Be, 0.0007; Cu, 0.007; Ga, 0.015; Li, present; Nb, 0.007; Pb, 0.05; Sc, 0.005; Sn, 0.02; Sr, 0.001; Y, 0.003; Yb, <0.0007; Zn, 0.05; Zr, 0.007.
2. Samples IV-10a-g and B2-7-2. Calculated chemical composition of gray greisen muscovite from the Boomer mine is based on chemical and modal analyses of these two samples.

Half-cell formulas for the two samples were calculated using Foster's method (1960, p. 13–14) and neglecting relative amounts of F and OH:

1. $[(Al_{1.51}Fe^{3+}_{0.10}Fe^{2+}_{0.45}Mg_{0.01}Mn_{0.02})_{2.09}(Si_{3.22}Al_{0.78})O_{10}(OH,F)_2](K_{0.94}Na_{0.05}Ca_{0.01})$
2. $[Al_{1.56}Fe^{3+}_{0.08}Fe^{2+}_{0.33}Mg_{0.02}Li_{0.04})_{2.03}(Si_{3.28}Al_{0.72})O_{10}(OH,F)_2](K_{0.88}Na_{0.16})$.

The yellowish-green mica lacks several of the characteristic 2*M* X-ray peaks, and the diffractometer data are inadequate to resolve its structure. Semiquantitative spectographic analysis of the yellowish-green mica indicates that it contains much less iron than the gray mica.

Topaz is found in some Redskin and Pikes Peak Granites as an accessory mineral, in miarolitic facies of both granites as coarse euhedral crystals, and in the greisens and beryl-bearing veins. At the Boomer mine it occurs sparsely in the barren quartz-muscovite greisens, but it is the most abundant mineral in some less widely distributed greisens. Most of the topaz at the Boomer mine is in medium-grained cloudy to white subhedral grains, and the topaz-rich greisens are almost white rocks, typically more porous than the muscovite-rich greisens. The topaz-rich greisens are apparently more abundant in the surface and near-surface greisens at the Boomer mine than they are in the deeper levels of the mine. They tend to be located centrally in barren quartz-muscovite greisen envelopes in nearly symmetrical pipes and veins, but locally they occur on the footwall portions of asymmetric pipes and irregular tabular deposits and in small pods in slightly altered granite.

Coarse-grained topaz is found in greisens of the China Wall area and in the Mary Lee vein. According to Bob Beal (oral commun., 1962), topaz in greisens of the China Wall area is as much as 2 inches across; most of it is iron stained and fractured, but a few pieces of gem quality material have been recovered in mining. Coarse-grained topaz also is found as a rock-forming mineral in pegmatite dikes exposed near the China Wall cupola. At least locally topaz is more abundant than muscovite in wall greisens at the Mary Lee mine.

Minerals typically associated with topaz are quartz, muscovite, beryl, and wolframite.

OTHER MINERALS

The barium sulfate, barite, was found in small amounts in the Outhouse lode at the Boomer mine; it also occurs with fluorite and small amounts of metallic minerals in vein deposits west of the mapped area near Tarryall.

Apatite occurs in the greisen at the Little John No. 1 claim, and in small euhedral crystals in another greisen in the same area. Both of these greisens are in a mafic facies of the Boulder Creek(?) Granodiorite, which, in this area, locally has megascopically visible apatite.

A mineral tentatively identified as monazite occurs in microscopic crystals in some ores from the Boomer mine.

PARAGENETIC SEQUENCE

Certain minerals of the greisens, such as beryl, gray muscovite, and topaz, are consistently early; others, such as fluorite, yellow mica, euclase, and galena and sphalerite, are consistently late. Still other minerals do not show consistent relations, and probably do not occupy a definite place in any general paragenetic scheme. Bertrandite, for example, forms pseudomorphs after beryl and is in turn replaced by yellow muscovite; in places, however, it was the first and perhaps the only beryllium mineral deposited. Quartz and, to some extent, fluorite and muscovite have several distinctive modes of occurrence that indicate deposition continued over a long period of time; diagnostic contacts have not been found between certain pairs of minerals, therefore their paragenetic relations are unknown.

The crystalline beryl ores typically fill fissures encased in barren greisen; contacts between the ore and barren greisen are sharp. Beryl was the first mineral deposited along the greisenized walls in the veins and was succeeded by one or more of the following minerals: Quartz, topaz, siderite, bertrandite, muscovite, and rarely galena and sphalerite. In many places beryl was extensively replaced by quartz, mica, or bertrandite. Its contacts with topaz show little or no evidence of replacement, but the topaz is partly interstitial and probably is slightly younger.

In the massive ores, beryl forms poikiloblastic grains partly in vein fissures and partly in the walls of the fissures; replacement of early barren greisen by beryl is indicated by the megascopic and microscopic relations between the beryl and the fissures. Megascopically replacement is suggested by the distribution and pattern of ore-bearing and barren greisens. The ore-bearing greisens are centrally located in an envelope of barren greisen; beryl occurs at the extreme edge of the beryl-bearing zone as anhedral poikiloblasts scattered through barren greisen. The amounts of barren greisen decrease as the beryl poikiloblasts coalesce toward the high-grade central beryl-rich zone, as clearly shown in the Boomer vein on the 8,533-foot level. The relations can be interpreted to indicate that the massive beryl and the well-crystallized beryl formed at about the same time in different parts of the vein structure; beryl replaced the barren greisen walls in the massive ores and filled fissures in the well-crystallized ores.

As seen microscopically, quartz-muscovite remnants partly replaced by beryl are scattered through the massive ore. Microscopic examination also shows, however, that some quartz and mica fill vugs in the ore and are younger than the beryl. The apparent sequence, therefore, in both crystalline and massive ores was quartz and muscovite, in either their adjacent wall or host greisen, beryl, and then more quartz and muscovite. The greater abundance of late quartz and muscovite in well-crystallized ores compared with that of massive ores is probably related to the greater porosity of the fissure host compared with that of the greisen.

Beryl at the Boomer mine and other places is locally replaced pseudomorphically by bertrandite and muscovite. In the ores richest in bertrandite, however, beryl is absent, and the sequence of formation is quartz, bertrandite, and yellow mica.

Quartz, in particular, gives every indication that it continued to form over a long period of time. It is replaced by beryl in the massive greisens, and it replaces beryl or fills vugs in both massive and well-crystallized ore. It also lines vugs, where it is succeeded only locally by other minerals, all of which are late types: yellow, fine-grained mica, well-crystallized fluorite, and euclase. Finally, cryptocrystalline quartz forms veins cutting through the ore-bearing vein fissures in the the central parts of the greisens.

Muscovite and fluorite both are present in more than one form, indicating that deposition occurred at several different times. Fluorite is a late mineral in barren greisens, forming interstitially to quartz and muscovite; it is not generally abundant in ore-bearing greisens so its relations there are uncertain. Cubic crystals of clear and purple fluorite in vugs are, however, among the youngest minerals of the deposits.

The gray muscovite of the deposits is partly older than some beryl, as it is replaced by massive beryl ores; it is also locally replaced by bertrandite in very rich bertrandite ores. The yellow mica replaces gray muscovite, beryl, and bertrandite, and it forms on euhedral quartz crystals in vugs. It is older than at least some of the fluorite and euclase.

ORIGIN OF THE BERYLLIUM DEPOSITS

The beryllium-bearing greisen deposits of the Lake George area are linked to the Redskin Granite by age, chemical composition, and spatial association. The deposits are proposed to be directly related to the granites; they are regarded as end members of the crystallization of a volatile-rich peraluminous granite magma under epizonal plutonic conditions.

The age of the deposits is about 1,000 m.y., or nearly the same age as the Redskin and Pikes Peak Granites (Hawley and others, 1966). This age is indicated by potassium-argon analyses of greisen muscovite and lead isotope analyses of galena (Antweiler, 1966) and potassium feldspar (B. R. Doe, written commun., 1965). The dating methods used are not precise enough that an estimate can be made of the time involved in mineralization—in fact, the apparent age of lead in galena and the calculated potassium-argon date for greisen muscovite are older than calculated potassium-argon and rubidium-strontium ages for the host granites.

A genetic relation between the Redskin Granite and most of the ore deposits is indicated by a suite of trace elements—including fluorine, tin, lithium, rubidium, and beryllium (Hawley and others, 1966)—that is common to both granite and greisen and by the fact that the Redskin Granite closely associated with the deposits contains a higher concentration of elements typical of greisens than the slightly older Pikes Peak Granite. The Pikes Peak Granite itself contains more of these trace elements than most other granite, and it is proposed that the processes that caused trace-element enrichment in the magma series which includes both the Pikes Peak and Redskin Granites were ultimately responsible for the ore deposits.

Spatial association of beryllium-bearing greisen with the Redskin Granite is the most direct evidence of a genetic relation between granite and greisen, especially greisen associated with beryllium ores.

The spatial association of beryllium deposits at the Boomer mine, the China Wall cupola, and the Mary

Lee mine area is interesting because it can be explained by what can be called the cupola concept of mineralization. The term "cupola" was originally used by Daly (1911) for upward protrusions from the roofs of large igneous intrusives, and it has also been used, as here, for small outlying igneous bodies which probably connect at depth with larger masses. Many geologists, among them Butler (1915), have observed that ore deposits tend to be clustered around these upward projections rather than within the deeper granite. This has been found particularly true of the greisen deposits, as recognized many years ago by Ferguson and Bateman (1912). This type of ore occurrence has led to the concept that volatiles and metals tend to concentrate in the cupolas and form the clustered ore deposits (Kennedy, 1955, p. 496–498).

The greisens at the Boomer mine and in the China Wall area both are related to circular or crudely oval cupolas of granite. Most of the veins of the Mary Lee mine area lie south of a protrusion of the Redskin stock which is structurally the highest part of the stock exposed in this area: thus the cupola theory seems to apply there also.

The greisen occurrences in the Redskin Gulch area of the Redskin stock cannot be explained fully by this cupola theory because they are concentrated in the southern part of the stock and are structurally deep in the intrusive. Possible they resulted from the concentration of volatiles and entrained metals in the inner part of the body after the earlier crystallization of the outer granular zone of the stock; this theory is very similar to that suggested by Vance (1961) to explain major zoning patterns of some plutons.

A few greisen deposits are associated with and probably genetically related to the Silver Plume(?) and Pikes Peak Granites. Although enriched in beryllium relative to granite, these greisens do not appear to contain appreciable concentrations of beryllium minerals.

The main greisen occurrence of apparent Silver Plume affinity is near Tappan Mountain where quartz-rich greisens with local concentrations of tin and tungsten minerals occur. Elsewhere in the area, scheelite-bearing calc-silicate deposits are associated with the Silver Plume(?) Granite. As pointed out in the descriptive section on the Silver Plume(?) Granite, it was a relatively wet granite, and the occurrence of greisens and other deposits marginal to the Silver Plume(?) plutons could be predicted.

GREISEN AREAS AND REPRESENTATIVE MINES

BOOMER MINE AREA

The Boomer mine area (pl. 3) is near the center of sec. 21, T. 11 S., R. 72 W., on Badger Flats. It is underlain mainly by gneisses of the Idaho Springs Formation, which are cut successively by a quartz diorite facies of the Boulder Creek(?) Granodiorite, Silver Plume(?) Granite, and pegmatite and granite-aplite of the Boomer cupola and associated dikes. Nearly conformable lenticular bodies of amphibolite are interlayered with the biotite gneiss of the Idaho Springs Formation, and amphibolite is also cut by the granites. Tertiary(?) welded tuff covers the bedrock in the northern part of the area.

ROCKS

The Idaho Springs Formation of the mapped area is mostly fine-grained biotite gneiss. Locally, fine-grained fieldspar-rich units, as near the east side, and conformable amphibolite units serve as markers. One prominent amphibolite layer has been traced for about 1,000 feet from the northwest side of the Boomer cupola; a second layer is exposed in and near the Blue Jay mine. Small bodies of Silver Plume(?) Granite and pegmatite cut the Idaho Springs(?) Formation and the Boulder Creek(?) Granodiorite. One small concordant mass of the Silver Plume(?) Granite is exposed near the Champell mine along the contact between the Idaho Springs Formation and Boulder Creek(?); a second body is exposed as a lenticular, discordant unit southwest of the Boomer mine. Light-colored pegmatites, of homogeneous or simple type, that in part are associated with the Silver Plume(?) Granite are numerous. One of these pegmatites occurs along the south contact of the Boomer cupola; another body, sharply discordant to the metamorphic foliation, crops out adjacent to the west boundary of the cupola. Locally, both pegmatite and Silver Plume(?) Granite are altered and mineralized, especially near granite-aplite.

The granite-aplite of the Redskin Granite forms (1) the Boomer cupola, (2) a dike which trends northwest from a point near the northwest edge of the cupola, and (3) numerous small dikes. The Boomer cupola is about 500 feet across; exposed contacts dip steeply outward. The contact flattens abruptly, however, on the south side of the cupola at a depth of about 50 feet. Below about 100 feet, the shape or extent of the body is unknown, although the body is probably much wider at a depth of several hundred feet than at the surface.

The main dike of granite-aplite of the Boomer area can be followed northwestward from a point near the contact of the Boomer cupola for about 750 feet, where it appears to split into two dikes. The branch that appears to be the direct extension of the main dike can be traced north-northwestward for about 400 feet more. Locally the dike is approximately concordant to the strike of the intruded strata, but it generally dips at a lower angle than the gneissic layers.

Small dikes of granite-aplite, most of which fill fractures belonging to sets striking northwest, north-northwest, and northeast, are exposed in other parts of the Boomer area. No dikes have thus far been found in the part of the area west of the Badger Flats fault. Dikes appear to be fairly abundant in a small area south of the Blue Jay mine.

The granite-aplite dikes are locally greisenized and beryllium bearing. Beryllium-bearing dikes are locally exposed in the Boomer mine, J & S Nos. 1 and 2 mines, the Blue Jay mine, and in the long trench about halfway between the Blue Jay and Boomer mines.

STRUCTURE

The gneisses of the Idaho Springs Formation and the Boulder Creek(?) Granodiorite strike northwestward and dip steeply to the northeast except where modified by small-scale fold structures. They are cut by the Badger Flats fault and by smaller faults, some of which are filled with granite or with vein materials. The Badger Flats fault crosses the western part of the Boomer mine area a few hundred feet west of the J & S No. 1 mine; it is probably exposed in a trench south-southwest of the mine, but in general its position has been inferred from slight topographic depressions, sparsity of outcrops, and offset of rock units. The fault has an apparent left-lateral movement of about 200 feet, as shown by the displacement of the contact between the Idaho Springs Formation and the Boulder Creek(?).

GREISEN

Greisens, some of which are beryllium bearing, are found mostly in the granite-aplite of the Redskin Granite or in Silver Plume(?) Granite or in pegmatite near the granite-aplite. Locally as at the Champell mine, pegmatites associated with Silver Plume(?) Granite and the Silver Plume(?) Granite itself are greisenized but are not near a known body of Redskin Granite. The most extensive greisen zones of the area are in the southern part of the Boomer cupola.

All the beryllium deposits are closely associated with the granite-aplite that is in either the Boomer cupola or in the dike rocks; all deposits except those in a quartz-albite-muscovite granite-aplite found locally in the main dike also have greisenized walls. Small occurrences of beryllium minerals or chemically anomalous amounts of beryllium have been found away from known granite-aplite near the Champell mine and in the area southeast of the Blue Jay mine.

BOOMER MINE

The Boomer mine (pl. 4) is near the center of sec. 21, T. 11 S., R. 72 W., in the southwestern part of the Lake George beryllium area. The mine was located, probably before 1895, as a silver prospect, and some silver-lead ore was shipped. About 1917 the mine was known as a molybdenum prospect (Worcester, 1919, p. 73), but as far as is known no molybdenum ores were produced. After these early mining and prospecting ventures the mine was abandoned and apparently lay idle until the uranium boom after World War II. In the early 1950's anomalous radioactivity was noted on the mine dump, and in 1955 the mine was partly rehabilitated as a uranium prospect. Only small amounts of uranium were found, but beryl was found on the dump. The mine was operated as a beryllium producer much of the time from October 1956 until July 1965.

The total production of beryllium ore cannot be given exactly because some ore, including high-grade material, was stockpiled. It seems likely, however, that the Boomer mine has produced more beryllium ore than any other mine in the United States. The production data are given below.

Beryllium ore production of the Boomer mine, 1956–60[1]

Year	*Tons*	*Grade (Percent BeO)*
1956	78	11. 2
1957	282	10. 2
1958	141	7. 3
1959 [2]	177	6. 6
1960	197	≈8
1960	211	≈5
1960	1, 028	2–4
Total	2, 114	

[1] Published with permission of U.S. Beryllium Corp.
[2] Does not include any ore produced in November and December.

The average grade of the 678 tons mined in the period 1956–59 was 8.77 percent, and at $40.00 per ton this ore would have had a value of about $238,000. A total production of about 3,000 tons of beryllium ore through 1965 seems to be a conservative estimate.

Analyses of samples taken from the mine are given in table 6.

TABLE 6.—*Analyses, in percent, of samples from the Boomer mine*

[----, not looked for; Tr., trace. Analyses were semiquantitative spectrographic analyses unless otherwise noted. Analysts: J. C. Hamilton and R. G. Havens]

Locality	Sample loc. (Pl. 4)	Lab. No.	Description	Ag	Be[1]			Cu	Ge	Li[2]	Mo	Nb	Pb	Sn	W	Zn
					1	2	3									
Outhouse lode opencut.	IV-10a-2	G-2953	Sheeted greisenized granite footwall of ore.	0.0015	0.007	----	----	0.07	0	----	0.03	0.007	1.5	0.007	0	0.15
	IV-10a-1	278803	Quartz-topaz greisen	.0015	.0003	----	----	.15	.015	0.024	.0007	.007	.07	.003	Tr.	.07
	S60-Bo-155	288291	do	.0015	.00015	----	----	.007	.007	----	.0007	.015	.03	.003	.7	0
	IV-10a-g	H-3610	Gray quartz-muscovite greisen.	0	.001	----	----	.0015	0	----	0	.007	.02	.01	0	0
	S59-Bo-122g	288289	do	Tr.	.015	----	----	.0007	0	----	0	.007	.003	.03	0	.007
	IV-10a-5	H-3611	Yellow quartz-bertrandite-muscovite greisen.	.00015	5	----	----	.001	.003	----	0	.0015	.01	.003	0	0
	S59-Bo-122y	288290	do	Tr.	3	----	----	.0007	.003	----	0	.003	.007	.007	0	.015
	IV-10a-3	278804	do	.0015	1.5	0.88	0.79	.15	<.005	.023	.0007	.015	.7	.007	Tr.	.07
	IV-10a-4	G-2954	Granite adjacent to IV-10a-2.	.0003	.0007	----	----	.007	0	----	.007	.003	.07	.0015	0	.007
Upper greisen pipe section C-C′.	C2-D	293626	Galena-bearing greisen	.015	1.5	2.1	----	.03	0	----	.005	.002	>10	.005	0	.3
8,565-ft level, now in main opencut Bo-2 (not shown on plate).	BO-1	289731	Quartz-topaz-wolframite greisen.	.00015	.0015	.0022	----	.015	.007	----	0	.15	.3	.03	>10	.03
	BO-2	289732	Quartz-beryl vein	0	3	1.6	----	.015	0	----	0	.003	.07	.0015	.03	.03
8,533-ft level	B1-13	289733	Beryl-quartz-muscovite greisen, footwall of B1-14.	.003	3	2	----	.07	0	----	.007	.007	3	.007	0	.3
	B1-14	289734	Beryl vein	.0003	3	3.1	----	.07	0	----	0	.003	.07	.007	.03	.03
	B1-15	278780	Muscovite greisen, hanging wall of B1-14.	.0007	1.5	.56	.57	.15	0	----	.003	.007	.3	.007	0	.3
	B1-16	278781	Greisenized pegmatite 6-ft-long chip sample.	.0015	.07	.07	.07	.07	<.005	----	.0015	.007	.7	.015	.015	.15
	B1-18	281310	Bertrandite-rich vein	0	3	6.20	----	.015	.003	----	0	.003	.03	.0015	0	.07
	B1-19	281311	Beryl vein	0	3	4.43	----	.007	Tr.	----	0	Tr.	.007	.0015	0	0
	B1-20	281312	Muscovite greisen between B1-18 and B1-19.	0	.007	.0035	----	.015	0	----	0	.003	.07	.007	0	.07
	B1-21	281313	Beryl greisen, hanging wall B1-19.	0	3	4.24	----	.007	Tr.	----	0	.003	.015	.003	0	0
	B1-22	281314	Barren gray quartz-muscovite greisen, footwall B1-18.	0	.007	----	----	.003	0	----	0	.003	.015	.007	0	.015
	B1-26-1	288149	Muscovitic greisen	0	.0015	.0015	----	.003	0	----	.0007	.003	.03	.03	0	.03
	B1-26-2	288150	Quartzose greisen, hanging wall B1-26-1.	.0007	.0015	.0012	----	.0015	0	----	.0015	.003	.03	.003	0	Tr.
	B1-27	288151	Quartz-muscovite-fluorite vein.	.00015	.015	.032	----	.03	0	----	.0007	.007	.15	.003	0	.07
	B1-28	288152	Chalcedonic quartz vein.	.0003	.0007	.0014	----	.015	0	0	0	.003	.07	.0015	0	.07
	B1-31	293624	Greisen	.0001	.02	.029	----	.015	.005	----	0	.005	.1	.007	0	.05
	B1-32	293625	Quartz-beryl greisen	.0005	5	4.9	----	.03	.005	----	.002	.007	.7	.003	0	.15
8,516-ft level	B2-4	278782	Boomer vein, sparse sulfides.	.015	.15	----	----	1.5	.007	.031	.015	.003	3	.007	Tr.	.7
	B2-5	278783	Boomer vein	.0015	.07	----	----	.15	.007	.12	.003	.003	.7	.0015	Tr.	.7
	B2-7-1	H-3242	Quartz-muscovite greisen, hanging wall B2-7-2.	.00007	.0007	----	----	.007	0	.009	0	.007	.03	.003	0	.07
	B2-7-2	H-3243	Boomer vein, muscovite-fluorite greisen.	Tr.	.0015	----	----	.03	0	.051	.003	.003	.15	.015	0	.15
	B2-7-3	H-3244	Quartz-muscovite greisen, footwall of B2-7-2.	.0007	.0007	----	----	.007	0	.018	.0007	.003	.15	.007	0	.07
8,486-ft level	B3-3	288023	Altered granite	.003	.0003	----	----	.015	0	----	.003	.003	.15	.003	0	.07
	B3-5	278786	do	.0015	.0003	----	----	.007	0	----	.03	.007	.15	.007	0	.15
	B3-6	278784	Quartzose greisen	0	.0007	----	----	.007	.003	----	.0007	.007	.03	.015	0	.03
	B3-7	278785	Muscovite greisen, 3-ft-long chip sample.	0	.0007	----	----	.003	<.005	----	0	.007	.03	.03	0	.03
	B3-9	278787	Quartz-muscovite greisen.	0	.0007	----	----	.003	.007	----	.0015	.007	.07	.015	.015	.03
	B3-10	278788	Fluorite-rich greisen	0	.0015	----	----	.007	0	----	.03	.007	.15	.015	0	.07
	B3-12	278789	Muscovite greisen, 2.5-ft-long chip sample.	0	.0007	----	----	.0015	0	----	0	.007	.03	.03	.015	Tr.
	B3-13	278790	Granite, disseminated sulfides.	.007	.0003	----	----	3	.015	----	.0007	.003	.3	.007	0	.15
	B3-14	278791	Quartz-muscovite greisen.	.0007	.0007	----	----	.07	0	----	.0015	.015	.15	.015	.015	1.5

[1] Separate analyses: 1, semiquantitative spectrographic analysis by J. C. Hamilton and R. G. Havens; 2, morin-fluorescent analysis by L. F. Rader; 3, gamma-neutron analysis by Wayne Mountjoy.

[2] Quantitative spectrographic analysis by J. C. Hamilton and R. G. Havens.

Mine workings consist of one main shaft and short irregular levels which are interconnected by open stopes and raises and also connect with opencuts or small glory holes. The main or Florman shaft is nearly vertical and about 185 feet deep. The main opencut (pl. 4) partly coincides with a shaft (the Boomer) that was used in the early part of beryllium mining. The main levels are at altitudes of about 8,556 (adit level), 8,533, 8,516, 8,494, 8,486, 8,440, and 8,398 feet, and the levels are referred to by altitude in this report. Nearly all the ore was found above an altitude of 8,500 feet, and the lowest level, perhaps by coincidence only, contains neither ore nor altered rock.

The mine is near the south contact of the Boomer cupola. Opencuts at the surface are mostly confined to the granite-aplite of the cupola, but some of the underground workings are partly in granite and partly in pegmatite, amphibolite, and in gneisses belonging to the Idaho Springs Formation. The 8,486-, 8,440-, and 8,398-foot levels are entirely in granite-aplite.

Fracture sets that strike northeast or north-northwest contain beryllium veins and granite-aplite dikes. The northeast-striking set dips steeply, and most of the veins are small. The main mineralized fissure, the Boomer vein, belongs to the north-northwest-striking set. In most places the Boomer vein is localized by a single fissure which has an average dip of 40° NE.; locally the vein-fissure splits into two main fractures. A third set of fractures, which strikes north-northwest and dips at low angles to the southwest, is locally mineralized in a very wide and complex greisen zone on the 8,533-foot level of the mine. Unmineralized shear zones that belong to an almost flat fracture set are exposed at several places.

Bodies of greisenized rock are exposed on all levels of the mine except the deepest (8,398-ft level). Most are composed dominantly of barren quartz-muscovite greisen, and all greisens exposed on the deeper levels (8,494-, 8,486-, and 8,440-ft) contain only trace amounts of beryllium. Topaz- or fluorite-rich greisens and ore-bearing greisens, both distinguished on the map (pl. 4) by patterns, are locally distributed within quartz-muscovite greisen zones on the surface and on the 8,533- and 8,516-foot levels.

Beryl is dominant in all ore bodies except the Outhouse lode, in which bertrandite is the major ore mineral. Bertrandite is also abundant in the northern part of the ore body mined from the Boomer vein, particularly in the northern part of the 8,533-foot level, and it is locally abundant as pseudomorphs after beryl in the main body mined on the 8,516-foot level. Small amounts of euclase occur in the ore mined from the Boomer vein.

The beryllium-bearing ores locally contain sulfides and other metallic minerals. Small amounts of galena and sphalerite occur in beryllium ore on the footwall of the Boomer vein near sample locality B1–13 (8,533-ft level) (pl. 4 and table 6), and arsenopyrite is found in the ore about 50 feet to the north along the vein, and also in a footwall mass in contact with ore in a pipelike extension of the Boomer vein ore body. Disseminated galena and sphalerite occur in the same pipe near the surface. Beryl was found with wolframite in a quartz-topaz greisen that occupied part of the area of the main opencut.

Larger concentrations of metallic minerals are scattered through the greisens away from the beryllium ores. Pods of argentiferous galena as much as 6 inches across are found in the greisen body lying between the Boomer vein and the abandoned Boomer shaft on the 8,533-foot level, and galena and sphalerite were found in a low-beryllium part of the Boomer vein exposed in a shallow winze just south of the shaft. Sulfides also occur in a partly mined greisen body exposed (but not mapped) just above the 8,486-foot level near the bottom of the abandoned Boomer shaft.

Beryllium ore bodies have been mined from surface workings and from the 8,565- (now in the main opencut), 8,533-, and 8,516-foot levels. It seems certain that most of the apparently separate ore bodies are actually interconnected and form one large complex body localized by the combined influence of the Boomer vein, fractures of the steep northeast-trending set, and the southern contact of the Boomer cupola. The ore bodies mined at different places in the mine are discussed separately, and relations indicating possible or probable connections are pointed out.

The two most productive ore bodies have been mined from the 8,533- and 8,516-foot levels of the mine. One is largely controlled by the Boomer vein fissure, the other is partly controlled by the contact of the Boomer cupola with a pegmatite body. The Boomer vein is exposed on the 8,533-, 8,516-, and 8,486-foot levels, but is strongly mineralized only on the 8,533-foot level where it has been followed for about 200 feet and where it contains beryllium ore for about 100 feet. The vein has been overhand stoped in one place to within a few feet of the surface and also mined in shallow underhand stopes; it is about 1–8 feet wide. The vein is appreciably narrower and less well mineralized on the 8,516-foot level; it has been stoped at one place between the 8,516- and 8,533-foot levels, but there the ore zone was much thinner than that found along the upper level. In general the relations suggest that the ore body was a nearly horizontal flattened pipe lying along the vein fissure.

As exposed on the 8,486-foot level, the vein consists of a few inches of unaltered pegmatite, but it is greisenized in a raise driven from near the north end of the level.

In the widest and most productive part of the ore shoot the Boomer vein is compound and has two main splits; beryllium minerals fill both and replace greisen between them and, locally, replace the wall greisen. Near the south end of the ore shoot the most abundant component of the vein is well-crystallized beryl; northward the beryl becomes anhedral and bertrandite becomes abundant, although less abundant than beryl. At a sampled locality the footwall vein is dominantly bertrandite and the thicker hanging wall vein and replacement ore are mostly beryl. Euclase forms small crystals in vuggy zones on the hanging wall of the vein.

On the 8,533-foot level, a mineralized zone is widest, about 15 feet, where the Boomer vein crosses the cupola contact and also nearly coincides with a low-angle fracture set striking parallel to the vein but dipping southwest. The relations of the contact, the Boomer vein and southwest-dipping fracture set, and ore are shown in cross section (*A–A′*, pl. 4). At another strongly mineralized zone (*C–C′*, pl. 4), a pipelike ore body intersects the hanging wall of the Boomer vein. Exposures in the raise driven along the pipe show that the bearing of the pipe locally follows steeply dipping fractures which strike about N. 70° E.

The second main ore body was mined between the 8,516- and 8,533-foot levels. As exposed on the lower level it is a podlike body about 35 feet long and 10 feet wide elongated along the contact of the Boomer cupola and granite pegmatite. The footwall of the zone is formed by greisenized granite-aplite that has a marked sheeted structure lying parallel to the base of the ore. The hanging wall is greisenized pegmatite. Between the two levels, the ore body enlarged into an irregular body mined from the 8,523-foot bench level just north of the body (pl. 4, 8,516-ft-level map). The ore was composed largely of massive quartz and beryl which was locally pseudomorphically replaced by bertrandite. Some gem aquamarine was found in vugs in the greisen. A small amount of beryllium ore has been left on the floor of the 8,516-foot level, but thinning of the ore zone and thickening of the basal sheeted zone probably mark the limit of the ore body to the east. A small podlike extension of the ore zone in the floor was formed at the junction of the pegmatite contact with the main northeast vein fissure, and some ore was mined from this minor pod in the winze sunk about 35 feet northeast of the Florman shaft on the 8,516-foot level.

The contact between pegmatite and the granite-aplite at the south edge of the cupola is also a major control of ore near the surface. The collar of the Boomer shaft, which is now in the main opencut area, was apparently in high-grade beryllium ore, which was discarded at that time as waste. Aggregates of crystalline beryl as much as 3 feet across and weighing several hundred pounds have been recovered from the dump rock within a few feet of the shaft, and these resemble the beryl ore left in place next to the shaft. East of the Boomer shaft, the contact was almost barren on an abandoned 8,565-foot level now within the main opencut, but the contact zone contained beryl-bearing veins west of a mineralized vein belonging to the steep northeast set. The pegmatite west of the vein contained disseminated beryl crystals and was extensively greisenized. Greisen associated with mineralized northeast-trending fractures exposed on the same level apparently led into a pipelike ore body that was mined to the surface (partly shown at the east end of section *B–B′*, pl. 4). Small pods of quartz-topaz-wolframite-beryl greisen were found near the lower end of the pipe exposed in the main opencut; at the eastern end of the pipe in the opencut the ore consisted of a veinlike mass of white to pale-green beryl associated with fluorite (on the footwall) and quartz and topaz.

Beryl veins localized by steep northeast-trending fissures are exposed on the upper three levels of the mine and have been mined near their intersections with the Boomer vein or with the contact between the pegmatite and granite-aplite on the south edge of the Boomer cupola.

Two ore bodies—the Mammoth and Outhouse lodes—have been mined chiefly from the surface. The Outhouse lode consists of a greisen pipe containing a central beryllium-rich zone which plunges a few degrees southeast. The pipe is somewhat asymmetric in cross section and consists of a sheeted micaceous greisenized granite on the footwall, quartz-topaz greisen mostly on the footwall, and quartz-muscovite-fluorite greisen on the hanging wall and surrounding a central quartz-bertrandite-yellow mica greisen. The sheeted zone on the footwall of the pipe is very similar to sheeted footwall granite observed underground on the 8,516-foot level. A quartz-fluorite vein which is exposed below and on the hanging wall side of the ore body is, perhaps, indirect evidence for a north-northwest fracture zone which acted as one control of the mineralization but has been mostly obliterated in the greisen.

The Outhouse lode was mined over a horizontal distance of about 40 feet, and although the ore-bearing greisen nearly pinched out southward, barren greisen continued farther southeast. About 20 feet south of the edge of the Outhouse ore body, another pipe was intersected on the west side of the same greisenized zone. This pipe, shown in section C–C′, plate 4, plunged S. 80° W.

at about 40°. The character of the ore is much different from that of the Outhouse lode. Most of the ore consists of massive poikiloblastic beryl crystals in the quartz-rich greisen gangue. The ore is also somewhat unusual in containing appreciable amounts of galena near the surface and in forming on the hanging wall of an arsenopyrite zone in the lower part of the pipe (fig. 2). The pipe appears to connect the hanging wall of the Boomer vein with the greisen pipe of the Outhouse lode.

The Mammoth lode also contained quartz-beryl ore; it appears to be a pipelike ore body elongated along a fissure which strikes north-northeast and dips 40° SE. The pipe appears to plunge toward the Boomer vein at the far north end of the 8,533-foot level, and it probably connects with the Boomer vein.

Two other pipes are exposed in the hanging wall of the Boomer vein. One, which produced low-grade beryllium ore, was mined from a raise on the 8,516-foot level. The other, which contained chalcopyrite and sphalerite, was prospected in a raise from the 8,533-foot level about 10 feet south of section C–C′, plate 4.

J & S GROUP

The J & S group of the Boomer mine area (pl. 3) consists of three mines opened by shafts and a total of about 700 feet of drifts or crosscuts. Shafts, and mines, have been numbered for purposes of discussion from northwest to southeast (pl. 3 and fig. 9). The Nos. 1 and 2 shafts explore greisens associated with the major granite-aplite dike of the Boomer area. The No. 3 shaft is collared in Idaho Springs Formation just west of the Boomer cupola and intersects the cupola underground. A few tons of beryllium ore have been produced from the J & S No. 1 mine. Table 7 gives analyses of samples from the group.

The No. 1 shaft opens into four levels; two very short levels at about 22 and 37 feet, and longer levels at 50 and 66 feet vertically below the collar of the steeply inclined shaft (fig. 9). The No. 2 shaft is essentially vertical; it opens into short levels at 39 and 59 feet below the collar. The No. 3 mine has an 80-foot-long drift driven west-southwest from the bottom of a 60-foot vertical shaft.

Workings from the Nos. 1 and 2 shafts are driven in biotite gneiss, amphibolite, and quartz gneiss of the Idaho Springs Formation, pegmatite of possible Silver Plume affinity, Silver Plume(?) Granite, and in the Redskin granite-aplite dikes. The Idaho Springs Formation has been intruded by almost concordant to sharply discordant masses of pegmatite and Silver Plume(?) Granite, and these rocks, in turn, are cut by the granite-aplite dikes.

TABLE 7.—*Spectrographic analyses, in percent, of samples from the J & S group of the Boomer mine area*

[Be is quantitative analyses by morin-fluorescent method; all others are semiquantitative; Tr., trace. Analysts: L. F. Rader and J. C. Hamilton]

Sample locality (fig. 9)	Lab. No.	Description	Be	Ag	Cu	Mo	Pb	Sn	Zn
J & S No. 1–1	289719	0.5-ft-long chip sample, greisen	1.7	0	0.030	0	0.15	0.015	0.07
1–2	289720	1.5-ft-long chip sample, greisen	.2	Tr.	.003	.0015	.07	.015	.03
3–1	288155	0.5-ft-long chip sample, altered pegmatite.	.0003	.0003	.015	0	.15	0	.03
3–2	288156	1.5-ft-long chip sample, greisen	.2	.0003	.03	0	.15	.015	.03

The main dike of the Boomer area is exposed on both levels of the J&S No. 2 mine and on the 66-foot level of the No. 1 mine near the east end. Two other dikes are exposed in the No. 1 mine workings; one is near the east face of the 66-foot level, and a second, larger dike is near the shaft on the 50- and 66-foot levels. This second dike is in the footwall of the main dike and probably joins it at depth (section *A–A′*, fig. 9).

Beryllium-bearing greisens occur in the J&S Nos. 1 and 2 mines as replacement bodies in old pegmatite or Silver Plume(?) Granite or in thin veins and pods in the Redskin granite-aplite. The workings of the No. 2 shaft were driven specifically to explore the granite dike because it contained thin beryl veins on the surface. The largest concentration of beryllium-bearing minerals, now largely mined, is in the No. 1 shaft. The beryllium ore was mined from a veinlike greisen traced down from the collar of the shaft to the 50-foot level. Near the collar the greisen replaces a thin pegmatite dike, and it is inferred that the greisen body formed mainly by replacement of pegmatite, although in the deeper workings nothing of the original character of the greisenized rock can be determined. The greisen is approximately concordant to the foliation of the gneissic wallrocks and dips 60°–70° NE.; the main body of beryllium-bearing greisen occurred just above the junction of the greisen and granite-aplite (section *A–A′*, fig. 9). The strike of the dike is nearly parallel to that of the greisen, but its dip is much flatter. A fault occurs along the footwall side of the greisen, and it was considered by the miners to be the ore control. It is not mineralized, however, and it is more likely a postmineral fault. The fault diverges from greisen below the 50-foot level.

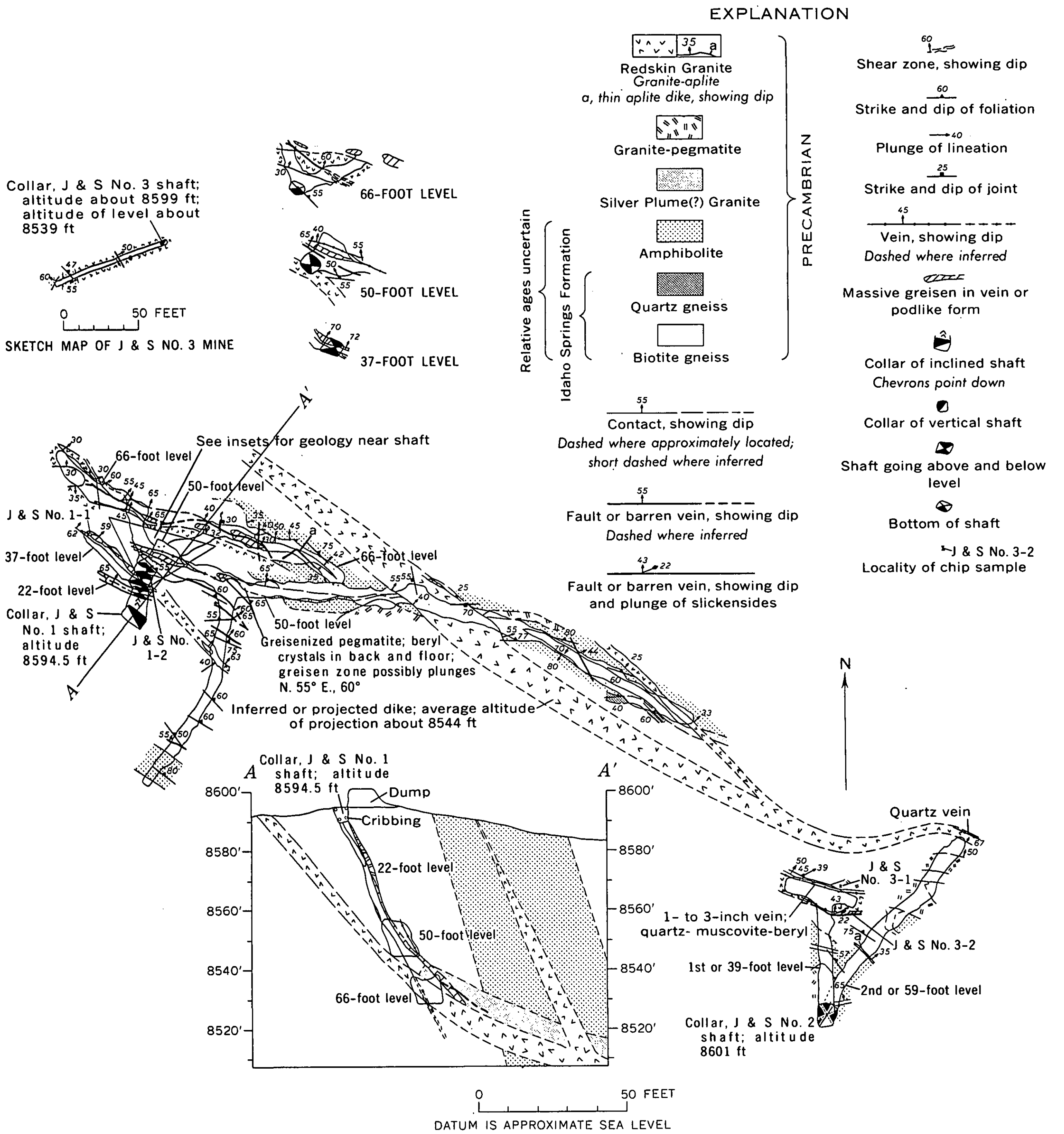


FIGURE 9.—Geologic maps and section of the J & S group mines.

Other beryllium occurrences in the J&S Nos. 1 and 2 shafts are also in or adjacent to granite-aplite dikes. Beryllium minerals are found in two zones on the 39-foot level of the No. 2 shaft; beryl is present in thin veins on the hanging wall of the dike, and a berylliferous greisen, as much as 1½ feet thick, occurs along the footwall of the dike.

The No. 3 shaft explores an apparently nearly barren part of the Boomer cupola. An irregular greisen body with only trace amounts of beryllium was intersected in the drift about 25 feet from the shaft.

CHINA WALL AREA

The China Wall area (fig. 10) is mostly in secs. 4 and 5, T. 11 S., R. 72 W., east of the village of Tarryall, near the China Wall cupola. The area is underlain mainly by rocks of the cupola, a granite body elongated northward along the east boundary of the Redskin stock. To the west, the granite of the cupola is in contact with older gneisses and with the Silver Plume(?) Granite;

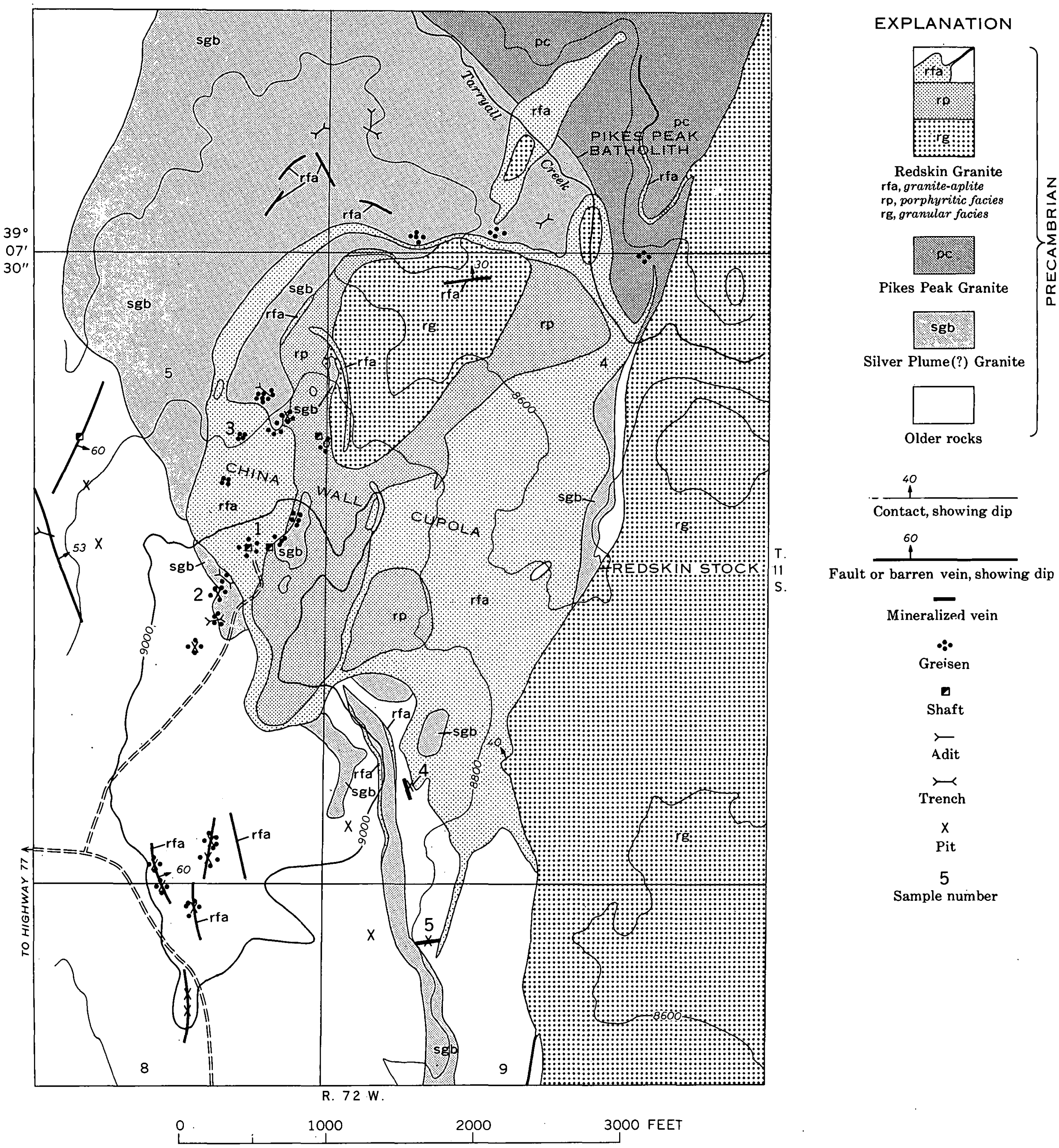


FIGURE 10.—Geologic map of the China Wall area. Contour interval 200 feet. Datum is mean sea level.

several masses of Silver Plume(?) are included in the granite of the cupola. Analyses of samples from the China Wall area are given below.

Semiquantitative spectrographic analyses, in percent, of samples from the China Wall area

[Tungsten looked for but not found. Analysts: J. C. Hamilton and P. R. Barnett. Tr., trace]

Sample loc. (fig. 10)	Lab. No.	Description	Be	Cu	Pb	Sn
1	288336B	Beryl-bearing greisen	0.7	0.003	0.03	0.0015
	288287	Greisen	.0015	.0007	.007	.015
	287983	Muscovitic greisen	.0007	.0007	.003	.015
	287984	Quartz-muscovite-fluorite greisen.	.007	.0003	0	.007
	287985	Hematitic greisen	.0015	.007	.15	.015
2	288280	do	.0007	.0007	.015	.007
3	293641	Vuggy quartzose greisen	.0005	.0007	.007	.005
4	288277	Quartz-muscovite greisen	.0007	.0015	.007	.015
5	288336A	Quartz-beryl vein	.07	.0007	Tr.	.003

Beryllium minerals occur in small podlike greisens on the west side of the cupola and in dikes of granite-aplite south of the cupola. The occurrences in the cupola are, seemingly without exception, at the contact of a block of the Silver Plume(?) Granite that is included in or cut by the granite-aplite facies of Redskin Granite which forms the outer part of the cupola.

The greisen of the area is commonly hematite stained and contains abundant topaz; it also contains coarse pods or layers of quartz which locally contain beryl. Beryl is the main ore mineral of the deposits prospected thus far, but bertrandite occurs pseudomorphically after beryl. Small amounts of beryllium ore have been mined in the area, and Bob Beal and Roy Monett sold a small lot of beryl ore to the Custer, S. Dak., buying station in 1962.

Besides the beryllium deposits, faults with altered wallrocks occur southwest and west of the cupola. These faults were prospected many years ago for gold or silver, but they must be nearly barren, judged by the small extent of mine workings.

MARY LEE MINE AREA

The Mary Lee mine area (fig. 11) is in sec. 22, T. 11 S., R. 72 W., about 1 mile east of the Boomer mine. The area is underlain partly by Redskin Granite and partly by older igneous and metamorphic rocks. Local layers and lenses of calc-silicate gneiss are indicated on the map because these have been prospected for scheelite.

The Redskin Granite of the Mary Lee mine area consists of the granular facies, which is predominant; granite-aplite, which forms a lobate cap on the granular rocks near the center of sec. 22; and porphyritic granite, which forms a local border zone of the Redskin stock in the northeast part. Exposures in the Mary Lee mine show that the granite-aplite lobe continues to the southeast a short distance in the subsurface, and the lobe is inferred to extend even farther (section *D–D′*, pl. 1).

Beryl, the main beryllium mineral of the area, occurs 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 (fig. 11). Greisen occurs along the walls of the beryl-bearing fissures, and it also is found in a pipe at the Happy Thought mine and in irregular masses and veins at the Tennessee mine. Analyses of samples from the Mary Lee mine area are given below.

Semiquantitative spectrographic analyses, in percent, of samples from the Mary Lee mine area

[Analyst: J. C. Hamilton]

Sample loc. (fig. 11)	Lab. No.	Description	Be	Cu	Pb	Sn	W
1 [1]	289735	Quartz-muscovite-fluorite greisen.	0.007	0.015	0.03	0.015	0
	289736	Quartz-topaz greisen	.003	.07	.3	.007	.03
	289737	Fine-grained greisen	.0015	.03	.07	.015	0
2	288013	Greisen	.0015	.0015	.007	.007	0
3	288003	Quartz vein, greisen walls	.0003	.015	0	.15	0
4 [2]	287994	Quartz-topaz vein	.0003	.015	.15	.003	0
5	288015	Beryl-bearing greisen	.015	.015	.15	.007	0
	288016	Same, 1-ft chip	.0007	.03	.3	.007	0
6	288017	Greisen	.0007	.003	.0015	.007	0
7	288010	Muscovite greisen	.0015	.0007	0	.03	0
	288011	Quartzose greisen	.003	.0007	0	.03	0
8	289726	1½-in.-thick quartz-beryl vein.	1.5	.003	.03	.007	0
9	288014	Hematitic quartz-muscovite-fluorite greisen.	.0007	.0007	0	.015	0
10 [3]	288336	Greisen	.0007	.015	.07	.015	.15
11	288008	do	.0015	.0015	.0015	.03	0

[1] On dump of Happy Thought mine.
[2] In Mary Lee vein (prospect shaft).
[3] In Little John 1 shaft.

MARY LEE MINE

The Mary Lee mine develops a fissure-vein deposit that is representative of most vein deposits of the area. The vein, which is most likely a lode zone of closely spaced fissures, can be traced with reasonable certainty for about 1,400 feet. The main workings are on the eastern part of the vein and comprise two adits and an incline (fig. 12); a shallow shaft, now inaccessible, was sunk near the west end of the vein. Claims covering most of the vein were located by Bob Beal and Roy Monett in 1957; the property was sold to the Mary Lee Mining Co. in 1958.

The Mary Lee incline (fig. 12) is about 140 feet long; it was driven about S. 50° W. for 120 feet, thence almost due south for 20 feet. Deep water prevented detailed examination of the workings beyond about 80 feet from the portal. The first 60 feet of the workings is in a granitic gneiss facies of the Boulder Creek(?) Granodiorite; at 60 feet the gneiss is in fault contact with the granite-aplite of the Redskin Granite, and the rest of the incline is in granite-aplite. The granite-aplite body is the subsurface part of the lobate extension of the Redskin stock in the Mary Lee mine area.

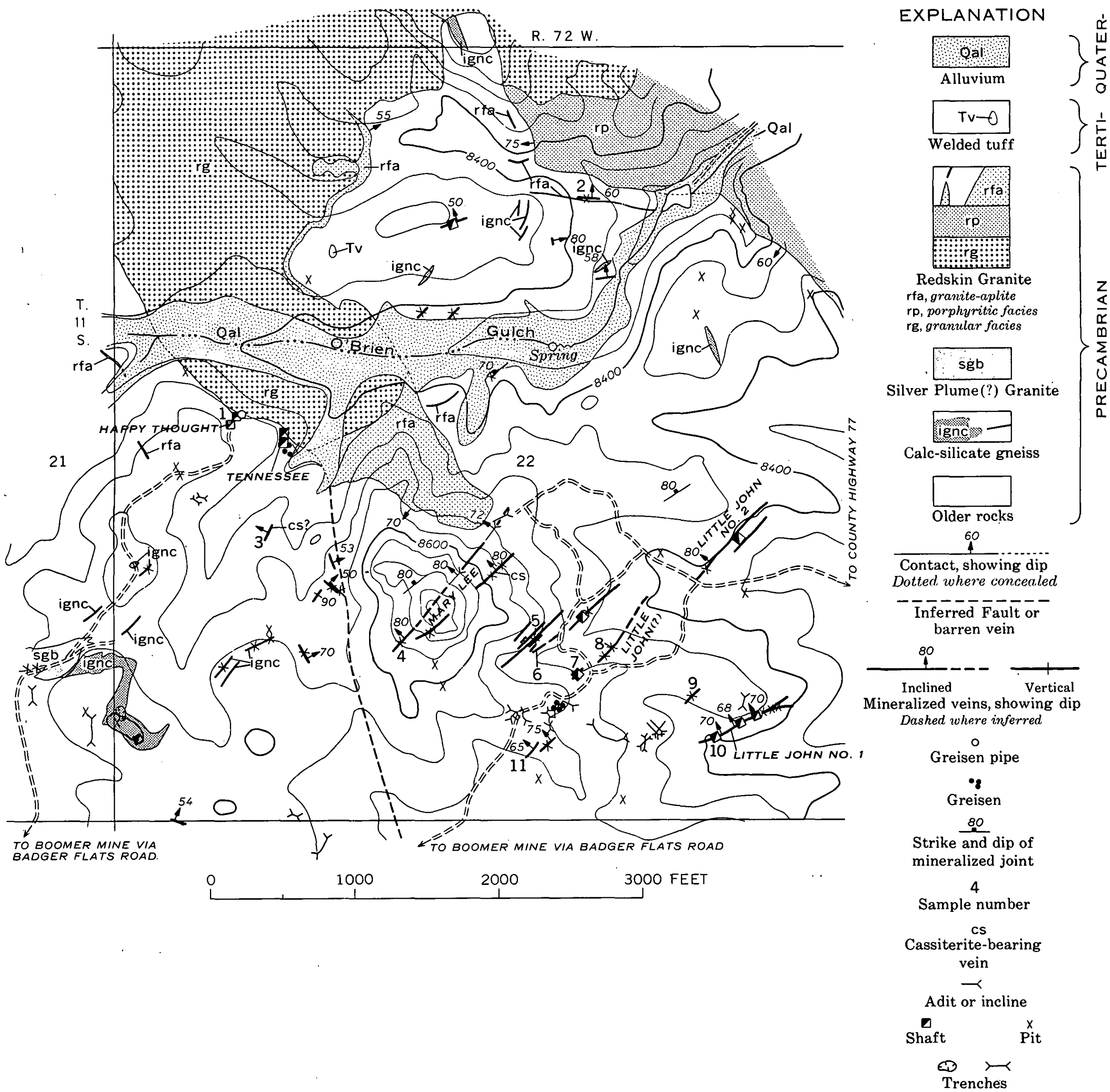


Figure 11.—Geologic map of the Mary Lee mine area. Contour interval 40 feet. Datum is mean sea level.

The incline follows a thin quartz-beryl vein from the portal to the faulted granite contact, where the vein is cut off. Apparently the vein was not found on the footwall of the fault, although a thin quartz-feldspar vein in granite about 100 feet from the portal could be the same vein.

The lower Mary Lee adit, about 120 feet southwest of the incline, follows a complex fracture zone in gneissic Boulder Creek(?) Granodiorite. The major vein fissure in the zone contains as much as 8 inches of crystalline beryl, now largely mined. Other subparallel fractures are marked mainly by the slight reddening and greisenization of the gneiss.

The vein zone is cut off near the portal of the adit by a fault which is almost certainly the same fault exposed along the granite contact in the incline (section A–A′, fig. 12). The vein of the lower adit is on the footwall of the fault and thus possibly is the faulted continuation of the quartz-beryl vein cut off in the incline, although the vein of the adit is much wider.

Southwestward from the fault in the lower adit, the vein can be traced for 30 feet, and it probably extends at least 20 feet farther, although the main vein in this latter part may be in the southeast rib, as shown by the queried vein (fig. 12). Where well exposed the vein strikes about N. 41° E., dips about 70° NW., and contains crystalline beryl. About 30 feet southwest of the fault the vein grades outward into hematitic greisenized gneiss containing small beryl crystals. The difficulty involved in tracing the vein in both the incline and the lower adit suggests that it is not actually continuous but instead is composed of en echelon veins.

The upper Mary Lee adit is about 400 feet southwest of the portal of the lower adit. The vein is exposed at several places in small prospects between the upper and lower adits. The upper adit is mainly in gneissic Boulder Creek(?) Granodiorite; it generally follows the vein, but in part the vein is probably in the southeast rib. In most places the vein is composed of quartz and topaz; locally it contains beryl and wolframite crystals as much as 2 inches across.

Production data have not been recorded, but beryl ore was mined from near the portal of the lower adit. The total production is estimated at less than 5 tons.

Analyses of samples from the mine are given in table 8.

REDSKIN GULCH AREA

Beryllium-bearing greisen pipes occur near Redskin Gulch in an area that includes the Redskin and Black Prince mine areas (pl. 2 and fig. 13). These areas are within the Redskin stock and are underlain by the porphyritic facies of Redskin Granite which forms the intermediate zone of the stock.

The greisen pipes, which are about 2–10 feet across, follow sinuous courses. The pipes generally occur in clusters, and within the clusters they generally have similar plunge directions. The most extensively explored pipes are the Redskin (main) and Minerva J, (figs. 3, 13), each of which has been followed in underground workings for about 160 feet. The Black Prince pipe has been followed for about 100 feet.

The pipes are composed mainly of a muscovitic greisen bounded by a selvage of quartzose greisen which grades outward into unaltered granite. The ore minerals—bertrandite, beryl(?), and molybdenite and locally galena, sphalerite, chalcopyrite, and sooty uraninite—occupy pipelike or veinlike zones within greisen envelopes. Pyrite with very sparse cassiterite and wolframite locally occurs in vuggy, but apparently little-altered, granite. The pipes are at least partly localized along discontinuous fissures or shear zones; more extensive and somewhat younger shear zones contain thin fluorite veins.

Analyses of samples from the Redskin Gulch area are given in table 9.

REDSKIN MINE

The Redskin mine is on the east side of Redskin Gulch about 3,000 feet from its mouth. Workings consist of an inclined shaft, which partly coincides with stopes on two greisen pipes, and a shallow prospect shaft or opencut on a third pipe. Greisens and surface workings are shown on the mine area map (fig. 13) which also shows generalized underground workings.

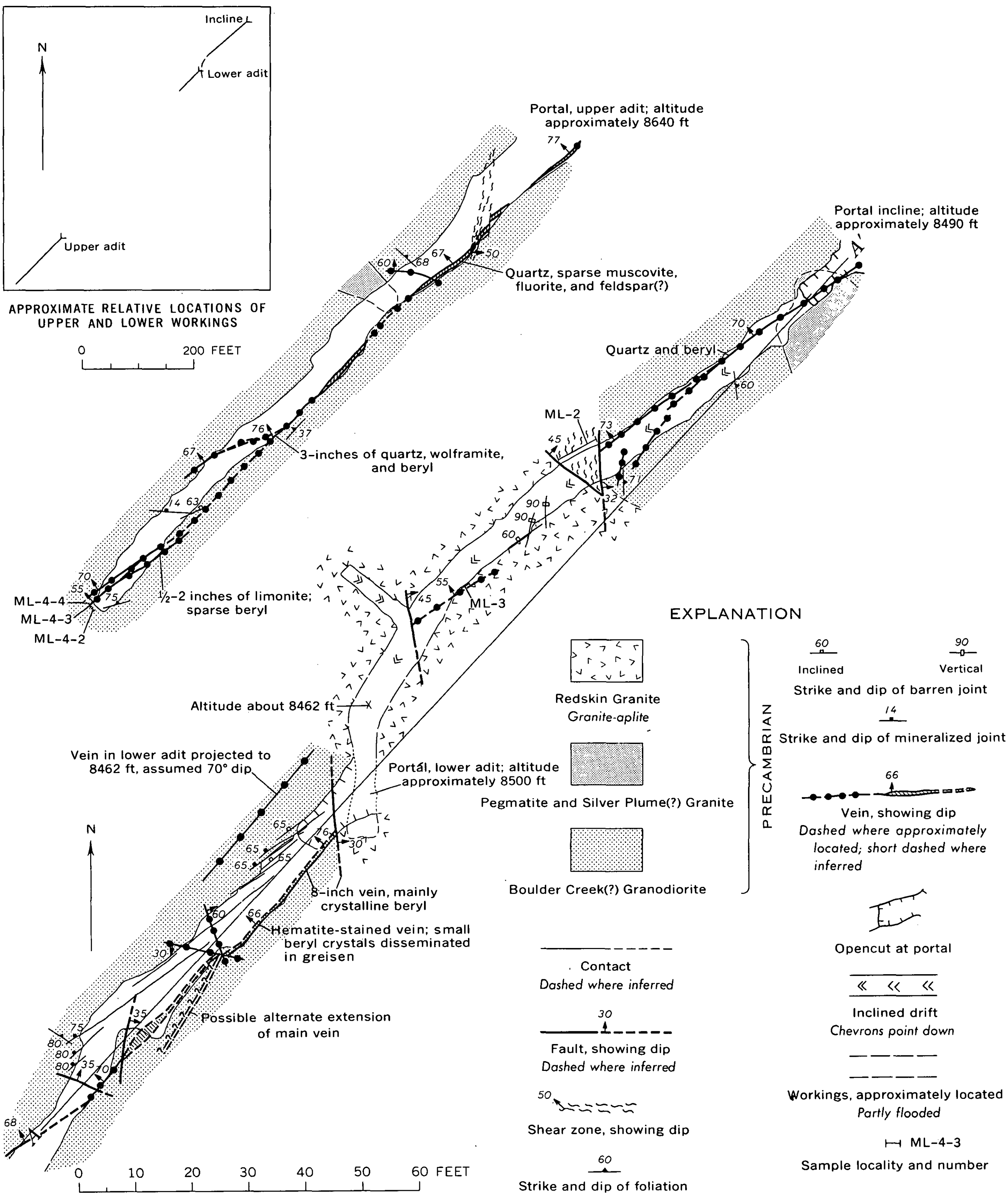
The Redskin mine was originally prospected for molybdenum (Worcester, 1919), and probably some molybdenum ore was shipped from the mine during or shortly after World War I. The mine was probably abandoned in the early 1920's and not worked again until the discovery of uraninite at the mine by Bill Wyble in about 1954. Mr. Wyble unwatered the mine but found only small amounts of sooty pitchblende in place. Beryllium minerals were discovered at the mine in 1959 by L. G. Moyd with a beryllium detector. Some low-grade beryllium ore has been mined.

The main Redskin pipe is exposed in an opencut a few feet south of the main shaft and there plunges about 40° almost due north. Most of the pipe has been removed from the cut, and all that remains of it is a smooth quartz-rich selvage on the footwall of the pipe and sparse beryllium-bearing greisen and barren greisen on the hanging wall of the pipe. The amount of dip of this segment of the pipe appears to be the same as that of a pregreisen fracture which also partly controls

TABLE 8.—*Semiquantitative spectrographic analyses, in percent, of samples from the Mary Lee mine*

[Analyst: J. C. Hamilton]

Sample loc. (fig. 12)	Lab. No.	Description	Be	Ag	Cu	Mo	Pb	Sn	Zn
ML–2	288153	7-ft-long chip sample, fault zone, altered rock.	0.0015	0	0.003	0	0.007	0.0015	0.03
ML–3	288154	Altered granite	.0003	0	.0015	0	.007	.003	.03
ML–4–2	H3238	Greisen	.0007	.00007	.015	0	.07	.007	.03
ML–4–3	H3239	Quartz-topaz vein	.0015	.0003	.07	.007	.15	.0007	.03
ML–4–4	H3240	Greisen	.0007	.00015	.07	.0015	.15	.007	.07


Incline
N
Lower adit
Upper adit
APPROXIMATE RELATIVE LOCATIONS OF UPPER AND LOWER WORKINGS
0
200 FEET
Portal, upper adit; altitude approximately 8640 ft
Quartz, sparse muscovite, fluorite, and feldspar(?)
3-inches of quartz, wolframite, and beryl
½-2 inches of limonite; sparse beryl
ML-4-4
ML-4-3
ML-4-2
Portal incline; altitude approximately 8490 ft
A
Quartz and beryl
ML-2
ML-3
Altitude about 8462 ft
Vein in lower adit projected to 8462 ft, assumed 70° dip
Portal, lower adit; altitude approximately 8500 ft
8-inch vein, mainly crystalline beryl
Hematite-stained vein; small beryl crystals disseminated in greisen
Possible alternate extension of main vein
N
0
10
20
30
40
50
60 FEET
EXPLANATION
Redskin Granite
Granite-aplite
Pegmatite and Silver Plume(?) Granite
Boulder Creek(?) Granodiorite
PRECAMBRIAN
Inclined
Vertical
Strike and dip of barren joint
Strike and dip of mineralized joint
Vein, showing dip
Dashed where approximately located; short dashed where inferred
Opencut at portal
Contact
Dashed where inferred
Fault, showing dip
Dashed where inferred
Shear zone, showing dip
Strike and dip of foliation
Inclined drift
Chevrons point down
Workings, approximately located
Partly flooded
ML-4-3
Sample locality and number

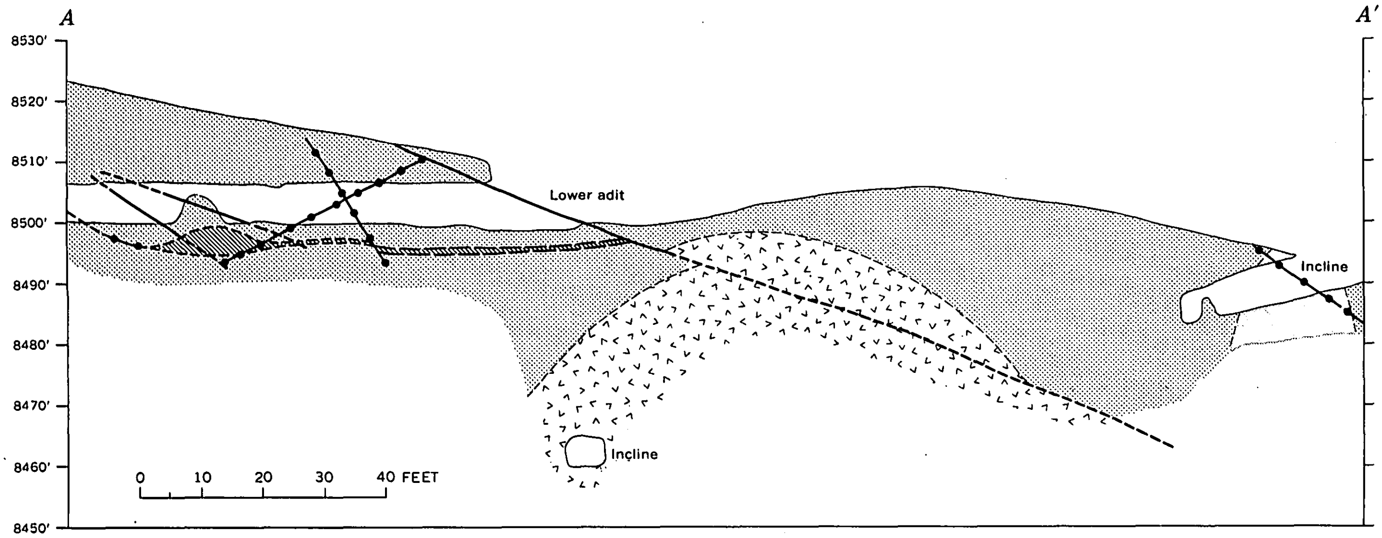


FIGURE 12.—Geologic maps (left) and section (right) of the Mary Lee mine. Datum is approximate mean sea level. Geology by C. C. Hawley and P. L. Williams, 1961–62.

the distribution of beryllium minerals within the pipe. About 30 feet horizontally from the cut, the pipe changes plunge direction to about N. 60° E. The main inclined shaft is mostly below the pipe and approximately parallel to the direction of plunge (N. 60° E.). High-grade beryllium ore occurs as small pods localized by steeply dipping fractures within the segment of the pipe plunging about N. 60° E., but the average grade of currently known parts of the pipe is low.

A second pipe (lower pipe) was exposed about 55 feet south of the main shaft; its surface position can only be inferred from the shape of the opencut. The pipe plunges northward, then flattens abruptly. This pipe was also intersected by the main shaft about 20 feet from the collar.

A third pipe is exposed in a shallow prospect shaft about 100 feet N. 70° E. from the main shaft. At the surface the pipe is a flattened lens lying parallel to a fracture zone; the pipe contains disseminated beryllium minerals and plunges northward at a high angle.

BLACK PRINCE MINE

The Black Prince mine is about 1,700 feet north-northeast of the Redskin mine (fig. 13). Workings consist of a shaft, which was recollared in 1961, a nearby caved shaft, and several opencuts. Some beryllium-bearing greisen, along with sulfide-bearing greisen, was noted on the dumps.

The main pipe is exposed in the rehabilitated shaft workings. It plunges steeply northward and is partly localized by a fracture zone which strikes northeastward. Several other pipes which plunge northward at low angles are exposed in opencuts south of the main shaft.

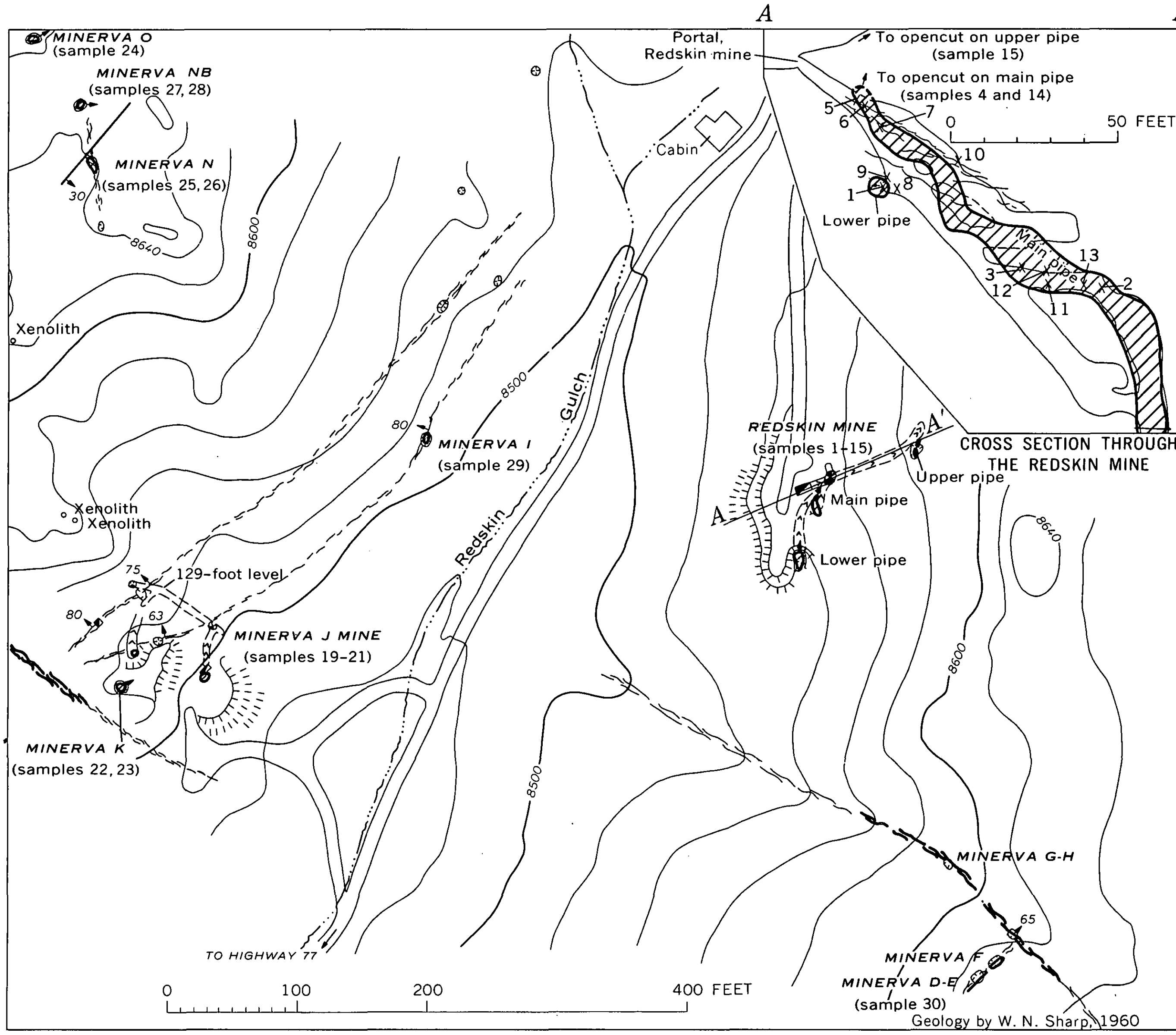
No beryllium ore has been produced from the Black Prince mine, but, according to James Smith (oral commun., 1965), of Tarryall, some sulfide ore was mined and shipped in about 1930.

TAPPAN MOUNTAIN AREA

The Tappan Mountain area (fig. 14) is in secs. 24 and 25, T. 11 S., R. 72 W., and secs. 19 and 30, T. 11 S., R. 71 W., and is underlain mainly by the Silver Plume(?) Granite and Idaho Springs Formation. The main mass of Silver Plume(?) Granite is part of the Tappan Mountain stock, a body about 2½ miles long which is elongated in the northeasterly strike direction of its gneissic host rocks. The body tapers to about one-fourth mile across at its northeast edge, and probably plunges at a moderately steep angle to the northeast in the subsurface. Both the Silver Plume(?) Granite and the Idaho Springs Formation are cut by steeply dipping, northeasterly striking faults which are locally mineralized.

The mineral deposits in the area are disseminated and pipelike greisens, veins with greisenized walls, and scheelite-bearing calc-silicate rocks. Most of the deposits are clustered near the northeast end of the Tappan Mountain stock of Silver Plume(?) Granite although a small group of deposits are found about one-third mile north of the stock in sec. 24, and a cluster of deposits are found in the SE¼ sec. 25. A cassiterite-bearing greisen is exposed in sec. 19 about one-half mile northeast of the stock and is approximately on projection of the long axis of the stock.

The greisen of the area is rich in quartz, but contains muscovite and fluorite. No discrete beryllium minerals have been found in the greisen, but it at least locally



contains cassiterite and scheelite. The Lucky Boy vein deposit contains some wolframite and scheelite and abundant pyrite. Copper ranges in concentration from a trace (7 ppm) to about 0.3 percent in veins or greisens as shown by the spectrographic analyses in the table below.

Semiquantitative spectrographic analyses, in percent, of samples from the Tappan Mountain area

[Analysts: A. L. Sutton, J. C. Hamilton, and P. R. Barnett; Tr., trace]

Sample locality (fig. 14)	Lab. No.	Description	Be	Cu	Pb	Sn	W
1	D114212	Vein,[1] greisen walls, limonitic	0.003	0.05	0.03	0.015	0
2	D114211	Vein [2]	.0003	.3	.1	.001	.1
3	D114215	Quartzose greisen, hematitic clay	.0002	.0015	0	.003	0
4	D114209	Quartzose greisen	.0005	.001	0	.01	0
5	D114226	Greisen	.0007	.005	.01	.015	0
6	D114214	Calc-silicate gneiss	.0003	.02	0	0	0
7	288285	Greisen [3]	.0007	.0007	Tr.	.03	0
8	D114213	do	.0002	.01	.0015	.03	0
	288286	do	.0003	.007	.0015	.07	0
9	278768	do	.0007	.007	.0015	.07	0

[1] Also contains 0.01 Ag and 0.007 Mo.
[2] Also contains 0.001 Ag, .002 Mo., .02 Co, and .07 Zn.
[3] Also contains 0.15 Ce.

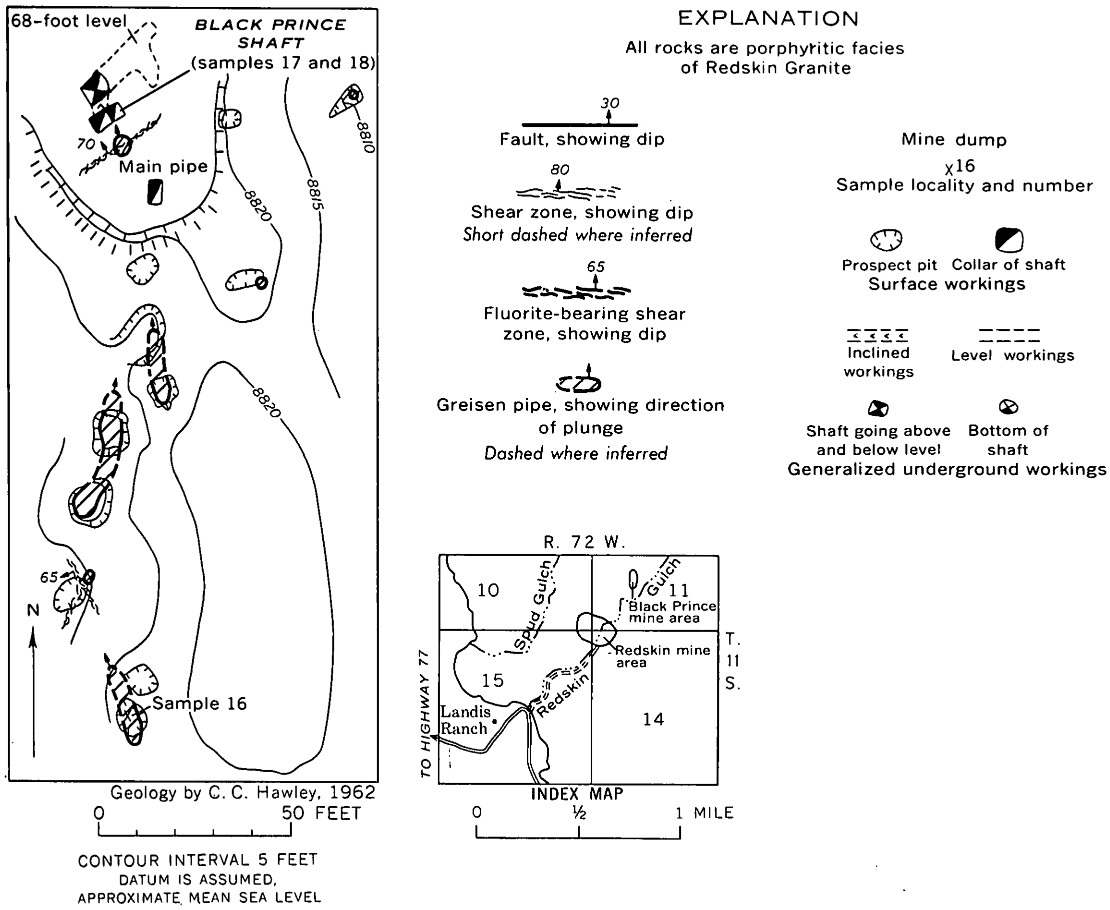


FIGURE 13.—Geologic maps of the Redskin (right) and Black Prince (left) mine areas in the Redskin Gulch area.

SUMMARY OF ECONOMIC ASPECTS OF THE DEPOSITS AND SUGGESTIONS FOR PROSPECTING

The size of the beryllium deposits of the area range from those containing 1 ton or less of ore to the deposit at the Boomer mine, which contained several thousand tons of ore. The deposit at the Boomer mine was partly eroded, and it seems possible that it originally contained 5,000 tons or more of medium- to high-grade beryllium ore. The beryllium deposits, or nearby mineralized rocks of the area, also locally contain silver, tungsten, molybdenum, and tin, and these elements are rare enough that they should be considered along with beryllium in appraising the economic potential of the area. Other elements present are copper, lead, and zinc, but they are not concentrated in bodies of sufficient size to be mined. The lead occurs in galena that at least locally contains as much as 230 ounces of silver per ton; so the small galena bodies encountered in mining could have value as byproducts.

The known mineral deposits have little areal extent, and they are scattered through the area. These negative factors are partly counterbalanced by the presence of geologic guides that narrow prospecting targets and by the fact that another Boomer-type deposit could be exploited profitably. The fact that a previously almost unknown area only 100 miles from Denver has deposits containing fairly rare and strategic elements does appear significant. The most recent prospecting in the area was almost entirely for beryllium ores, and apparently there never has been a prospecting effort directed toward the tin occurrences of the area.

GENERAL GUIDES TO ORE

The beryllium deposits of the area are associated with greisenized rocks and occur in or near granite-aplite or porphyritic facies of the Redskin Granite. The occurrences associated with granite-aplite tend to occur marginally to plutons and can be prospected using the

TABLE 9.—*Semiquantitative spectrographic analyses, in percent, of samples from Redskin Gulch area*

[Analyst: P. R. Barnett. Tr., trace]

Sample loc. (fig. 13)	Lab. No. 288–	Description	Be	Ag	Cu	Mo	Nb	Pb	Sn	W
		Redskin mine								
1	294	Greisen	0.7	0.00015	0.0015	0	0.003	0.015	0.007	0
2	295	do	1.5	.0007	.015	.15	.007	.03	.03	0
3	296	do	.7	Tr.	.0015	.0007	.003	.007	.007	0
4	297	do	.0015	Tr.	.007	.0007	.003	.003	.03	Tr.
5	298	do	.003	.0007	.0015	.0007	.003	.03	.03	0
6	299	Altered granite	.003	.0015	.07	.003	.003	.3	.007	0
7	301	Greisen	.07	.015	.07	.0007	.0015	7	.007	0
	302	do	.0007	.0015	.003	.007	.007	.3	.003	0
8	304	do	.15	0	.0015	0	.003	.007	.0015	0
9	305	do	.0015	0	.0007	.0007	.003	.003	.03	0
10	306	Vein in shear zone on hanging wall of pipe.	.03	.0003	.03	.0007	.03	.03	.003	.03
11	307	Greisen	.0015	.015	.07	.007	.003	.3	.015	.015
12	308	Quartz vein in greisen	.07	.0007	.007	0	.003	.015	.007	Tr.
13	309	Bertrandite-molybdenite greisen	7	.0007	.015	1.5	0	.03	.015	0
	312	Bertrandite-bearing greisen [1]	7	.0015	.15	.15	.003	.07	.007	0
14	310	Bertrandite-bearing greisen	7	.003	.07	.15	.003	.3	.007	.007
15	311	Beryl(?)-bearing greisen	.3	.0003	.015	.015	.003	.07	.015	0
		Black Prince mine								
16	322	Greisen	0.0007	0.0003	0.0007	0	0.003	0.003	0.003	0
17	323	Chalcopyritic greisen	.003	.015	1.5	0	.007	1.5	.015	.15
18	324	Greisen	.0007	.0015	.7	0	.0015	.3	.007	0
		Minerva J and small prospects								
19	313	Altered granite	0.003	0	0.0007	0	0.003	0.003	0.007	0
20	314	Bertrandite(?)-muscovite greisen	.03	.015	.07	.0007	.007	.15	.003	0
21	315	Greisen	.03	Tr.	.0015	.003	.007	.007	.007	0
22	316	Fluorite-rich greisen	.03	Tr.	.0015	.0015	.007	.015	.003	0
23	317	Muscovite greisen	.0007	0	.0003	0	.003	.0015	.003	0
24	325	do	.0015	0	.0015	0	.003	.003	.015	0
25	318	Greisen	.015	.00015	.03	0	.003	.007	.003	0
26	319	Quartz-bertrandite-muscovite greisen	7	0	.0007	0	.0015	.003	.007	0
27	320	Greisen	.003	0	.0003	0	.003	0	.007	0
28	321	Fine-grained greisen cut by quartz-euclase veinlets	.7	0	.0015	0	.0015	.0015	.0015	0
29	292	Greisen	.0015	.03	.15	.0003	.003	>10	.015	0
30	293	do	.007	.0007	.007	.003	.003	.07	.015	0

[1] Contains 0.7 percent U.

cupola concept of mineralization—essentially that ore tends to occur in or near the structurally higher parts of intrusive bodies of igneous rock. Thus, on the flanks of the Redskin stock another Boomer-type deposit might be sought in a cupola not yet exposed by erosion. Such bodies might be indicated by concentrations of dikes, and, because igneous emplacement was likely influenced by pregranite faults, they might tend to lie near prominent premineral structures such as the Badger Flats fault.

The beryllium occurrences of the Redskin stock itself are in the porphyritic facies of the Redskin Granite and lie within a crude northwesterly trending belt of shear zones and fluorite veins. Other greisens in the Redskin stock seem to be fairly abundant near the south end of the stock and in the central part of the stock near the southern contact of the fine-grained core and the porphyritic facies, and these places should also be prospected further for beryllium and other greisen elements.

The occurrence of greisen with Silver Plume(?) Granite at Tappan Mountain and of scheelite-bearing calc-silicate rock with Silver Plume(?) at many places indicates that this unit is also locally an ore-bearing granite. An average of approximately 500 ppm tin in Silver Plume(?) related greisen at Tappan Mountain, one occurrence of cassiterite, and the general occurrence of tungsten with the Silver Plume(?) suggests an association of these elements rather than beryllium with the Silver Plume(?).

BOOMER MINE AREA

The beryllium ores of the Boomer mine are closely associated with greisens and with the granite-aplite; most of the ore occurs either in the granite-aplite or in the older pegmatite or Silver Plume(?) Granite near granite-aplite contacts. Most of the ore has been produced from the Boomer mine near the south edge of the Boomer cupola, although small shoots of ore have been found and partly mined in the J & S No. 1 and Blue Jay mines in association with granite-aplite dikes. At the Boomer mine, all the beryllium ore has come from the upper three mine levels or from open cuts on the surface.

Favorable combinations of lithology and structure are found on the southwest and northwest sides of the Boomer cupola (pl. 3). In those areas discordant masses of Silver Plume(?) Granite and pegmatite crop out a few feet west of the cupola, and they almost certainly intersect the granite-aplite of the cupola at shallow

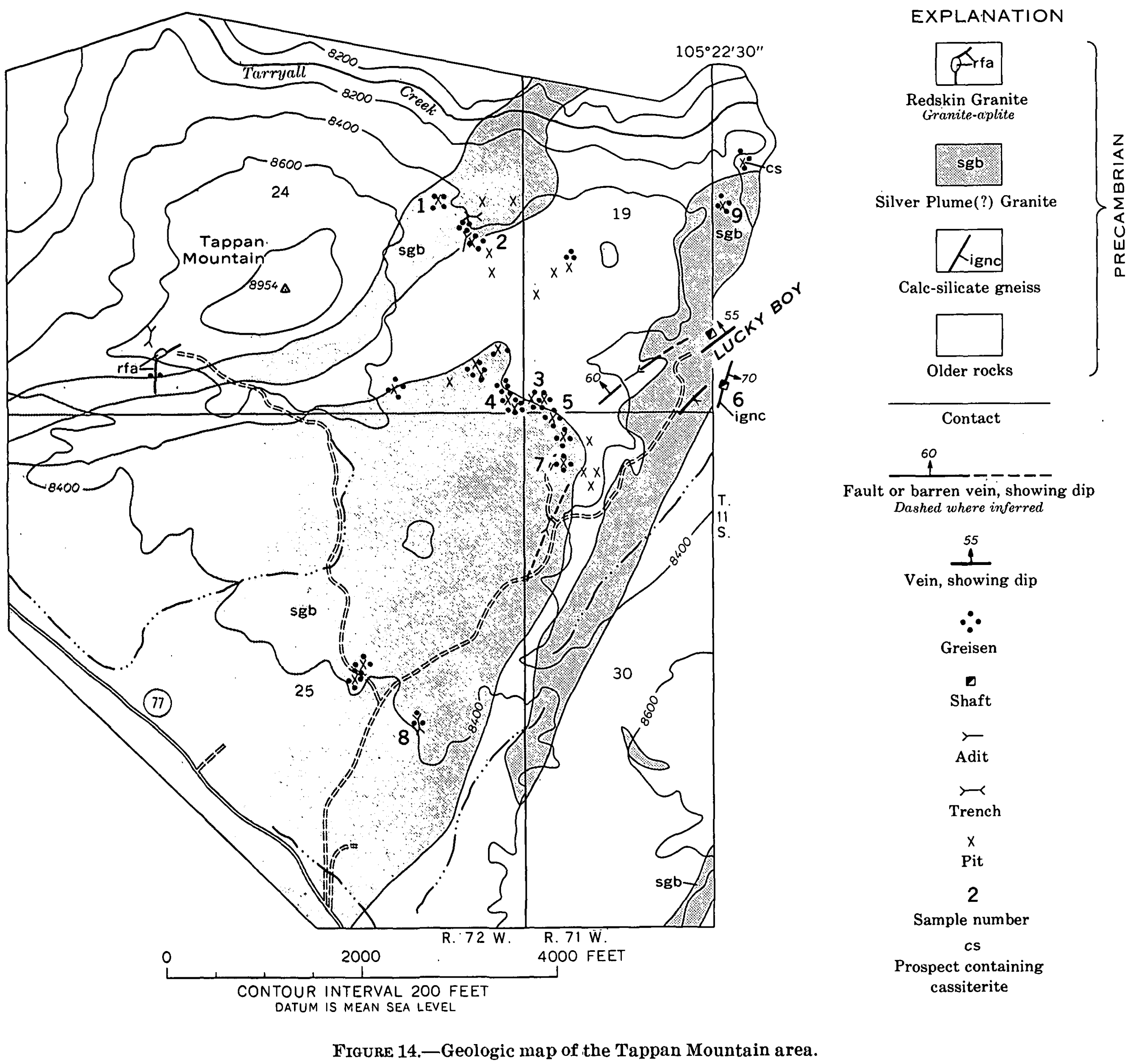


FIGURE 14.—Geologic map of the Tappan Mountain area.

depth. The Silver Plume(?) Granite and pegmatite bodies formed along northeast-striking fractures, and the combination of a granite-aplite contact with older granitic rocks and a fracture zone offers a possible locale for ore deposition.

Somewhat similar structural and lithologic conditions occur at the northwest edge of the cupola, where the main granite-aplite dike of the Boomer area, which was localized by a fissure striking northwest, is separated from the stock by a thin older discordant body of pegmatite. The dike and stock possibly join at a shallow depth and truncate the pegmatite.

The shallow dip of the south contact of the Boomer cupola suggests that minor cupolas may occur on the southern extension of the main pluton. Prospecting for minor cupolas may be more successful in finding new ore bodies than deep exploration of the Boomer cupola, because ore seems more abundant in the upper part of the cupola.

Favorable areas for subsurface prospecting in the area south of the cupola might be marked on the surface by a concentration of veins and dike rocks like that found several hundred feet south of the Blue Jay mine (pl. 3).

CHINA WALL AREA

Beryllium occurrences thus far known in the China Wall area consist of podlike greisens in the cupola itself and thin beryl veins in granite-aplite dikes south of the cupola. The deposits in the cupola occur adjacent to included masses of Silver Plume(?) Granite. The known occurrences of beryllium minerals in the cupola are on the west side of the cupola, away from the Redskin stock.

Deposits in the area found thus far are small, and because of their scattered mode of occurrence they would be difficult to find by drilling. There are greisen bodies in the cupola that have not been prospected, and trenching of these bodies should disclose small bodies of beryllium ore. The favorable Silver Plume(?) Granite host rock pinches out on the west side of the body; so prospecting for small replacement masses should probably be confined to the western and northwestern parts of the cupola. The beryl-bearing aplite dikes south of the cupola, however, were intruded on a steep northerly trending fracture set. This fracture set is related to the en echelon zone of faults at the north end of the Badger Flats fault and is of pre-Redskin Granite age. Because of the pregreisen age of the fracture set and the close spatial association of ore with the intrusive bodies, faults of this set could be more strongly mineralized and closer to the Redskin Granite of the cupola at depth than they are at the surface. There is, therefore, some justification for exploring faults and dikes south and southwest of the cupola.

MARY LEE MINE AREA

The occurrence of a small body of beryllium ore at the Mary Lee lower adit, scattered pods of ore at the Tennessee and Little John claims, the length of some of the vein fissures, and the proximity of the Redskin Granite indicate that the area has some potential as a beryllium area.

The granite-aplite of the Mary Lee mine area is considered favorable for prospecting because it is similar to the granite of the Boomer cupola and the outer zone of the China Wall cupola, both of which have associated beryllium deposits. The attitude of the granite-aplite body in the Mary Lee incline suggests that the front of the lobelike extension of the Redskin stock plunges southeastward at a low angle and possibly underlies much of the area southeast of the lobe at a shallow depth (as shown on pl. 1, section *D–D′*). Because all known beryllium ore bodies of the Lake George area occur in or very near such favorable facies of the granite, the vein fissures lying above the postulated projection of the lobe apparently are favorable for prospecting at depth. Some of these veins also contain wolframite, and at least one contains cassiterite; therefore, shoots of rare metals besides beryllium may exist in the veins.

REDSKIN GULCH AREA AND OTHER PARTS OF THE REDSKIN STOCK

The beryllium deposits of the Redskin stock are small bodies in greisen pipes which apparently are confined to a rather small area. The pipes also contained small bodies of molybdenum ore and lead-zinc ore which were mined many years ago.

Pipes with small beryllium content and irregular greisen zones are apparently concentrated in two broad areas in the southern part of the stock. One area trends northwestward from near the south edge of the stock and includes most of the fluorite deposits as well as the pipes of the Redskin area (pls. 1, 2). The second area is near the southern contact of the fine-grained granite that forms the core of the stock.

Stream-sediment samples from Redskin Gulch below known beryllium-bearing greisen pipes contained markedly anomalous beryllium values, therefore streams coming from other parts of the stock were also sampled (pl. 2). The sampling showed that the Redskin Gulch anomalous area is larger than previously realized and that there are two other, smaller, anomalous areas.

The beryllium content of a −100 mesh portion of the stream-sediment sample was determined either by semiquantitative spectrographic analysis or by a morin-fluorescence method; the average content of 145 samples, excluding one sample showing 300 ppm beryllium, was almost 9 ppm beryllium, which is also close to the median value. This compares with an average value of about 7 ppm beryllium in the Redskin stock determined by analysis of rocks (Hawley and others, 1966). Fewer than 20 percent of the sediment samples showed 15 ppm or more beryllium; these samples are considered anomalous and probably were derived from greisen bodies.

Stream sediments in lower Spud Gulch, west of Redskin Gulch, show anomalous beryllium content of as much as 50 ppm beryllium. Although no deposits have yet been found in lower Spud Gulch, the area is apparently part of the Redskin Gulch anomalous area (fig. 19). An isolated sample in upper Spud Gulch also shows anomalous amounts of beryllium, and possibly reflects a small greisen pipe about two-thirds of a mile northeast of the sample locality.

A small part of the Reader Creek drainage in the east part of sec. 3 and a small area southwest of Pilot Peak in secs. 1 and 12 also contain samples with more than 15 ppm beryllium.

The Spud Gulch area is easily accessible from Tarryall Creek or Redskin Gulch, and more detailed sampling is recommended there. Although the small areas in Reader Creek and near Pilot Peak are of difficult access, they may be worth further prospecting because small greisen bodies are known to occur within about half a mile of each area.

TAPPAN MOUNTAIN AREA

The Tappan Mountain area contains no discrete beryllium minerals, but it does contain numerous small greisen bodies, veins mineralized with tungsten, and cassiterite-bearing greisens. Besides the one cassiterite-bearing prospect noted (fig. 14), several of the greisen bodies sampled—1, 4, 5, 7, 8, and 9 of figure 18—contained 0.01–0.07 percent tin as shown by semiquantitative spectrographic analysis. Both scheelite and wolframite have been found at the Lucky Boy prospect.

The occurrences of anomalous amounts of tin and tungsten suggest that the Tappan Mountain area should be studied in more detail, along with limited prospecting. In particular, residual surficial deposits near the greisen occurrences and gravels of Tarryall Creek should be examined for cassiterite. The creek flows between canyon walls in the northern part of the Tappan Mountain area and for about 1½ miles farther northeast. From that point to the junction with the South Platte River, 1 mile farther downstream, the creek flows across a flood plain which could contain placer deposits. (See the U.S. Geological Survey Hackett Mountain 7½-minute quadrangle topographic map.)

Within the area itself, greisens are most numerous near the northeast end of a Silver Plume(?) Granite pluton, which probably plunges northeastward. The tungsten veins belong to a northeast-trending fissure set, and possibly the combined effects of the granite contact and the northeastern fissuring locally could result in mineralized bodies having greater continuity than the greisens thus far discovered.

OTHER AREAS

Greisen bodies are relatively abundant near the center of sec. 16 and in the E½ sec. 28 (pl. 2). In sec. 16, the greisens occur in very small Silver Plume(?) Granite bodies near granite-aplite dikes; associated weakly mineralized bodies exist in calc-silicate gneiss. Granite-aplite dikes are very abundant (pl. 1), and possibly these reflect a cupolalike extension of the Redskin stock at shallow depth.

In sec. 28, the greisen bodies lie along or in the hanging wall of the Badger Flats fault. This fault was almost certainly in existence prior to the intrusion of the Redskin Granite and could have localized granite cupolas. The greisen along the fault in the NE¼SE¼ sec. 28 (pl. 2), although nearly barren of beryllium, is strongly metallized with pyrite, and the fault near this greisen offers a possible exploration target at depth.

REFERENCES CITED

Adams, J. W., 1953, Beryllium deposits of the Mount Antero region, Chaffee County, Colorado: U.S. Geol. Survey Bull. 982–D, p. 95–119.

Antweiler, J. G., 1966, Isotopic evidence of Precambrian episodes of mineralization in Colorado [abs.]: Geol. Soc. America Spec. Paper 87, p. 270–271.

Ball, S. H., 1906, Pre-Cambrian rocks of the Georgetown quadrangle, Colorado: Am. Jour. Sci., 4th ser., v. 21, p. 371–389.

Beus, A. A., 1959, The position of the alkali metals in the structure of beryl: Geokhimiya, no. 3, p. 278–281.

Blanchard, Roland, 1947, Some pipe deposits of eastern Australia: Econ. Geology, v. 42, no. 3, p. 265–304.

Buddington, A. F., 1959, Granite emplacement with special reference to North America: Geol. Soc. America Bull., v. 70, no. 6, p. 671–747.

Butler, B. S., 1915, Relation of ore deposits to different types of intrusive bodies in Utah: Econ. Geology, v. 10, p. 101–122.

Butler, R. D., and Riley, L. B., 1940, Ore-bearing pipes in the Tarryall Range, Colorado [abs.]: Geol. Soc. America Bull., v. 51, no. 12, pt. 2, p. 1923.

Daly, R. A., 1911, The nature of volcanic action: Am. Acad. Arts Sci. Proc., v. 47, no. 3, p. 47–122.

Ferguson, H. G., and Bateman, A. M., 1912, Geologic features of tin deposits: Econ. Geology, v. 7, p. 209–262.

Foster, M. D., 1956, Correlation of dioctahedral potassium micas on the basis of their charge relations: U.S. Geol. Survey Bull. 1036–D, p. 57–67.

——— 1960, Interpretation of the composition of trioctahedral micas: U.S. Geol. Survey Prof. Paper 354–B, p. 11–49.

Garretty, M. D., 1953, Bismuth-molybdenite pipes of New England: Empire Mining and Metall. Cong., 5th, Australia and New Zealand 1953, Pub., v. 1, p. 962–967.

Giffin, C. E., and Kulp, J. L., 1960, Potassium-argon ages in the Precambrian basement of Colorado: Geol. Soc. America Bull., v. 71, no. 2, p. 219–222.

Gross, E. B., and Heinrich, E. W., 1965, The granites, pt. 1 *of* Petrology and mineralogy of the Mount Rosa area, El Paso and Teller Counties, Colorado: Am. Mineralogist, v. 50, no. 9, p. 1273–1295.

Hall, A. L., 1932, The Bushveld igneous complex of the central Transvaal: South Africa Geol. Survey Mem. 28, 560 p.

Harrison, J. E., and Wells, J. D., 1959, Geology and ore deposits of the Chicago Creek area, Clear Creek County, Colorado: U.S. Geol. Survey Prof. Paper 319, 92 p.

Hawley, C. C., 1963, Geology of the Pikes Peak Granite and associated ore deposits, Lake George beryllium area, Park County, Colorado: U.S. Geol. Survey open-file report, 287 p.

——— 1964, Genetic relation of Pikes Peak Granite and beryllium-bearing greisens, Lake George area, Park County, Colorado [abs.]: Geol. Soc. America Spec. Paper 76, p. 276.

Hawley, C. C., Huffman, Claude, Jr., Hamilton, J. C., and Rader, L. F., Jr., 1966, Geologic and geochemical features of the Redskin Granite and associated rocks, Lake George beryllium area, Colorado, *in* Geological Survey research 1966: U.S. Geol. Survey Prof. Paper 550–C, p. C138–C147.

Hutchinson, R. M., 1960, Structure and petrology of north end of Pikes Peak batholith, Colorado, *in* Rocky Mountain Assoc. Geologists, Guide to the geology of Colorado: Denver, p. 170–180.

——— 1964, Time span and field-time relations of Pikes Peak batholith and its wall rocks, Colorado [abs.]: Geol. Soc. America Spec. Paper 76, p. 277.

Kennedy, G. C., 1955, Some aspects of the role of water in rock melts, *in* Poldervaart, A. A., ed., Crust of the earth—a symposium: Geol. Soc. America Spec. Paper 62, p. 489–504.

Norton, J. J., Griffitts, W. R., and Wilmarth, V. R., 1958 Geology and resources of beryllium in the United States, *in* United Nations, Survey of raw material resources: Internat. Conf. Peaceful Uses Atomic Energy, 2d, Geneva, 1958, Proc., v. 2, p. 21–34.

Peterson, W. L., 1964, Geology of the Platte Canyon quadrangle, Colorado: U.S. Geol. Survey Bull. 1181–C, p. C1–C23.

Sainsbury, C. L., 1960, Metallization and post-mineral hypogene argillization, Lost River tin mine, Alaska: Econ. Geology, v. 55, no. 7, p. 1478–1506.

Schaller, W. T., Stevens, R. E., and Jahns, R. H., 1962, An unusual beryl from Arizona: Am. Mineralogist, v. 47, nos. 5–6, p. 672–699.

Sharp, W. N., 1961, Euclase in greisen pipes and associated deposits, Park County, Colorado: Am. Mineralogist, v. 46, nos. 11–12, p. 1505–1508.

Sharp, W. N., and Hawley, C. C., 1960, Bertrandite-bearing greisen, a new beryllium ore, in the Lake George district, Colorado, *in* Short papers in the geological sciences: U.S. Geol. Survey Prof. Paper 400–B, p. B73–B74.

Staatz, M. H., Griffitts, W. R., and Barnett, P. R., 1965, Differences in the minor element composition of beryl in various environments: Am. Mineralogist, v. 50, p. 1783–1795.

Stewart, D. D., 1964, The geology and petrology of the Lake George syenite stock, Park and Teller Counties, Colorado: Golden, Colorado School Mines Master's thesis.

Tweto, Ogden, 1960, Scheelite in the Precambrian gneisses of Colorado: Econ. Geology, v. 55, no. 7, p. 1406–1428.

Vance, J. A., 1961, Zoned granitic intrusions—An alternative hypothesis of origin: Geol. Soc. America Bull., v. 72, no. 11, p. 1723–1727.

Worcester, P. G., 1919, Molybdenum deposits of Colorado: Colorado Geol. Survey Bull. 14, 129 p.

Yoder, H. S., and Eugster, H. P., 1955, Synthetic and natural muscovites: Geochim. et Cosmochim. Acta, v. 8, nos. 5–6. p. 225–280.

[Italic page numbers indicate major references]

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