Sugar Loaf and St. Kevin Mining Districts Lake County, Colorado

By QUENTIN D. SINGEWALD

A CONTRIBUTION TO ECONOMIC GEOLOGY

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By Quentin D. Singewald

ABSTRACT

The Sugar Loaf and St. Kevin districts of Lake County, Colo., adjoin along Lake Fork in the eastern foothills of the Sawatch Mountains, 4 to 7 miles west of Leadville. Most of the terrain is nonglaciated, but Lake Fork occupies a wide and deep glacial valley. Unconsolidated glacial and alluvial deposits, four different types of which were mapped, effectively conceal bedrock over an aggregate of about one-sixth of the mapped area. Float rock and soil obscure the bedrock, yet do not effectively conceal it, over much of the remainder.

Pre-Cambian schist, gneiss, granite, and pegmatite constitute the bulk of the bedrock; they are cut locally by dikes, by narrow zones of small discontinuous dikes, and by small irregular-shaped bodies of Tertiary igneous rock that resembles the White porphyry of Leadville. Schist and gneiss were mapped together as a single unit, which probably may be correlated with the Idaho Springs formation of the Front Range; biotite schist, quartz-mica schist, and quartz-mica gneiss, mostly injection gneiss, are the prevailing facies. Areas mapped as schist and gneiss contain many pegmatites and small masses of granite. The rock mapped as granite, although it approaches quartz monzonite in composition, has been correlated with the Silver Plume granite of the Front Range.

All types of bedrock in proximity to fissures have been intensely sericitized and locally silicified. In granite, sericitization commonly reaches out far enough from two or more fissures to coalesce and form irregular zones of alteration. Chert "dikes," dike zones, and innumerable chert veinlets within irregularly shaped areas represent particularly noteworthy products of silicification.

Pre-Cambrian orogeny, according to Stark and Barnes, compressed the schists and gneisses of the Sawatch Mountains into isoclinal folds, whose axes prevailingly trend N. 60°–65° E., and whose overturned axial planes dip steeply to the northwest. Structural details within the Sugar Loaf and St. Kevin districts cannot be deciphered because outcrops good enough to determine the attitude of foliation are scarce. During the Laramide orogeny, from Late Cretaceous to early Tertiary time, the area that is now the Sawatch Mountains was uplifted into a broad anticlinal arch trending north-northwest. At that time, the area comprising the Sugar Loaf and St. Kevin districts was broken by many faults, which now are disclosed by veins, chert dikes, and sericitized rock whose prevailing trends are north-northwest and east-northeast.

Nearly all productive veins in the area were discovered during the eighties, and the period of maximum output for most of them was prior to 1893. As production statistics are not available for years prior to 1914, the value of the aggregate output from the two districts can only be estimated as 10 to 15 million dollars.

The veins have been mined primarily for silver. Gold has been a subordinate product of most veins. Zinc and lesser quantities of lead occur in the northeastern part of the Sugar Loaf district and in the central part of the St. Kevin, but are scarce or absent elsewhere. Insignificant quantities of turquoise have been shipped from prospects within a small area in the southeast-central part of the St. Kevin district. In 1951, uranium-bearing minerals were discovered by the U. S. Geological Survey, but no occurrence was of commercial grade.

The veins occupy strong fissure zones, normally less than 10 feet thick, having steep dips. Within the fissure zones are broken and crushed rock, gouge, and quartz-sulfide vein substance in the form of streaks, layers, pods, lenses, and veins. The wall rocks, which are greatly shattered, are intensely altered by hydrothermal action. Vein quartz normally is exceedingly fine grained and therefore resembles chert: in part it is light colored, in part moderately dark. Pyrite is mostly fine grained; it is irregularly intergrown with quartz as a subordinate constitutent of most veins. Massive sulfides as well as sulfide-free quartz, however, are found locally. Where sphalerite and galena occur, they may either be intimately intergrown with pyrite or apart from it. Sandberg found traces of tetrahedrite and argentite in polished sections of ore specimens from the north-central part of the Sugar Loaf district. Native silver was present in some veins, and some of it must have been a hypogene constituent. Many are shoots bottomed at depths of 100–200 feet below the surface; their shallow depth may be due at least in part to hypogene distribution of the silver minerals, rather than to supergene enrichment by surface water. Data regarding individual mines are meager, for very few underground workings were accessible.

INTRODUCTION

The Sugar Loaf and St. Kevin districts adjoin in the eastern foothills of the Sawatch Mountains in Lake County, Colo. Together they comprise an area of about 10 square miles that is 4 to 7 miles west and west-northwest of Leadville on the west side of the Arkansas River (see fig. 40). The geographic boundary between the Sugar Loaf district to the south and the St. Kevin district to the north is a wide deep valley occupied by Lake Fork and Turquoise Lake. The mine workings are at altitudes ranging from 9,700 feet to 11,100 feet. Timberline is at an altitude of about 11,500 feet. Details as to latitude and longitude, township and range, drainage pattern, and access roads are apparent from plate 26.

The valley of Lake Fork has a broad U-shaped profile with precipitous walls, typical of a glaciated valley. The remainder of the area is decidedly less rugged, and it shows rounded peaks and ridges between V-shaped ravines and valleys characteristic of nonglaciated terrain. Actually, a small tract north of Temple Gulch was overridden by glacial ice, but ice erosion there was negligible.

A summary of the regional geology of the Sawatch Mountains, accompanied by a generalized geologic map on a scale of nearly 5 inches to the mile, has been published by Stark and Barnes (1935, p. 467–479). It is recommended to the reader as background information helpful in appreciating details of the Sugar Loaf and St. Kevin districts.

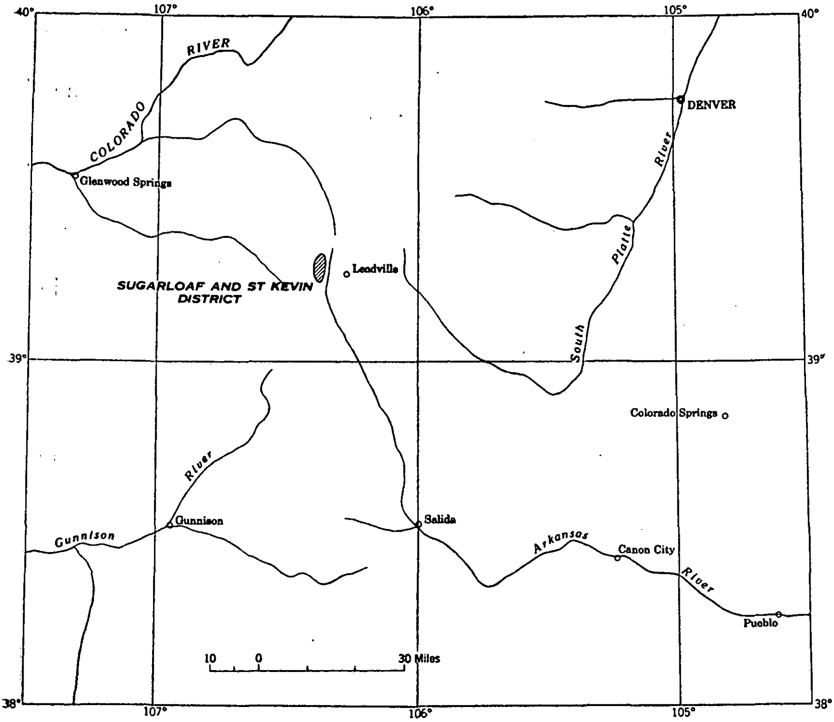

FIGURE 40.—Index map of part of Colorado showing location of Sugar Loaf and St. Kevin districts.

A rapid geologic reconnaissance of the Sugar Loaf and St. Kevin districts was undertaken during the summer of 1936 by the U. S. Geological Survey as a project of its cooperative program with the Colorado State Geological Survey Board and the Colorado Metal Mining Fund Board. Attention was focused mainly on ascertaining which mines had been notably productive, acquiring information about them, and studying the coarser features of their geologic setting. However, the work could not quite be completed within the 2 months then available. In 1951, part of the area was reexamined by the Geological Survey on behalf of the Atomic Energy Commission, because torbernite was found in several specimens collected in 1936; simultaneously, the original reconnaissance was completed. A more detailed and comprehensive study of the Sugar Loaf and St. Kevin districts is now being made by Ogden L. Tweto, of the Geological Survey, as part of a project begun in 1945 to map in detail the geology of the Holy Cross quadrangle. Meanwhile, the present report sets forth results of the rapid reconnaissance. A more specialized report discussing the occurrences of radioactive minerals has already been published (Pierson and Singewald, 1954).

Time has not been available to the author for petrographic or polished section studies of the veins and their wall rocks. However, Mr. John G. Broughton, who assisted the author during the field season of 1936, made a preliminary petrographic study [1] of the bedrock.

Prior to 1936 Mr. Charles H. Behre, Jr., acquired a considerable amount of information about the area for the U. S. Geological Survey, and all his data were given to the author, for which grateful acknowledgment is tendered herewith. Mr. Charles T. Pierson assisted in the fieldwork of 1951.

The generous cooperation of many residents of Leadville has been of inestimable value, as they supplied much of the data given for inaccessible mines. Especial thanks are due Messrs. Edward P. Chapman, J. Marvin Kleff, and the late Fred J. McNair for technical data and Mr. George S. Casey for general information.

UNCONSOLIDATED DEPOSITS

Unconsolidated deposits were mapped wherever they effectively conceal the bedrock over sizeable areas. They likewise conceal any ore deposits that may exist. Plate 26 shows the distribution of four types of unconsolidated deposits that in this report are designated as moraine, outwash gravel, alluvium, and gravel. Mixtures of float rock and soil that form a veneer over the bulk of the area have not been mapped, because they do not effectively conceal the bedrock, even though they may obscure the geologic details.

Materials constituting the unconsolidated deposits are derived from the same rock types as now crop out—that is, pre-Cambrian igneous and metamorphic rocks, and minor amounts of Tertiary igneous rocks. Detrital minerals likely to be worked as placers are not present.

Moraine is composed of unassorted materials ranging in size from a fine powder to huge boulders, and it tends to form hummocky topography. All the moraine shown in the central part of plate 26 was deposited during the Wisconsin stage of glaciation by ice that occupied the valley of Lake Fork. The bulk of it is lateral moraine. Toward the east the lateral moraine merges with terminal moraine that continues beyond the area of plate 26, to border the entire eastern half of Turquoise Lake. On the valley floor of Lake Fork, half a mile west of Turquoise Lake, is a relatively small area of recessional moraine that represents a halt or slight readvance of the ice during its retreat. The moraine shown north of Temple Gulch was deposited by a glacier which in its lower reaches spilled over from the valley to the north.

[1] Broughton, J. G., 1938, Petrology of the Sugar Loaf-St. Kevin mining districts, Lake County, Colo.: 184 p., unpublished thesis, available in the library of the University of Rochester, Rochester, N. Y.

Outwash gravel along the southern part of the eastern margin of the Sugar Loaf district was deposited by water issuing from the Lake Fork glacier. The material is crudely sorted, but otherwise rather similar to the adjoining moraine.

Deposits mapped as alluvium are mostly silt or sand, but some contain gravel. Some are normal stream deposits. Others accumulated in swampy areas where small streams became clogged, first by ice that flowed transverse to their courses and then by moraine deposited by the ice. The alluvium in two areas in the valley bottom of Lake Fork is relatively fine grained material that accumulated in broad, rather flat basins formerly occupied by glacial lakes impounded by moraine; this material may in part be reworked ground moraine.

Crudely bedded material ranging from fine sand to pebble size is designated merely as gravel. Deposits of such material occur in two areas in the valley bottom of Lake Fork. This gravel probably represents the shoreline facies of the alluvium deposited within the former glacial lakes impounded by moraine.

BEDROCK

PRE-CAMBRIAN ROCKS

The pre-Cambrian rocks of the Sugar Loaf and St. Kevin districts include schist, gneiss, granite, and pegmatite. Their relations, as determined in outlying areas where bedrock is well exposed, have been described by Stark (1935, p. 6–8, 12–21).

Schist and gneiss together constitute one map unit of plate 26. Granite constitutes another. Pegmatite could not be mapped in reconnaissance because it appears in many occurrences that range from mere films to tabular and irregular bodies many feet in width; it is especially abundant within schist and gneiss.

Most of the area is covered by a thin layer of soil and float rock. In general, where fragments of schist and gneiss are fairly abundant in the float the bedrock was mapped as schist and gneiss; where fragments of these rocks are scarce or absent the bedrock was mapped as granite.

SCHIST AND GNEISS

Biotite schist, quartz-mica schist, and quartz-mica gneiss, including injection gneiss (migmatite), are the types of rock most abundant in the unit mapped as schist and gneiss. Sillimanite is visible in them at many places. Within the part of the Sawatch Mountains that includes the Sugar Loaf and St. Kevin districts these rocks were named the "Sawatch schist and migmatite" by Stark and Barnes (1935, p. 472). They probably may be correlated with the Idaho Springs formation of the Front Range.

The schist and gneiss are prevailingly medium grained. Mica flakes commonly are slightly larger than quartz or feldspar grains. The rocks, which have a lustrous appearance due to reflected light from cleavage surfaces of mica, are medium gray except where chloritization has imparted a green tone or weathering has developed a rusty-brown or reddish stain. The rocks tend to weather to slabby fragments ranging from less than an inch to several feet in length and having irregular or jagged outlines.

Throughout the schist and gneiss are sizable layers and masses of granite and pegmatite. In fact, within areas mapped as schist and gneiss are many small mine dumps containing nothing but granite. These local granite masses are too numerous and too lenticular to be mapped in reconnaissance. They are particularly abundant near the Tiger and Shield mines, east of the Dinero mine, and near the St. Kevin mine. Schist and gneiss commonly grade into the main granite bodies—toward conformable contacts by an increase in the number of intercalated granite layers, and toward transverse contacts by lateral tapering of schist layers into granite.

Schist and gneiss have been bleached and rendered soft and friable by hydrothermal alteration in proximity to many fissures, particularly veins. In most places, the original fabric is retained well enough to permit ready identification, but in some places the altered product seems to be a fine-grained crumbly rock of doubtful derivation. Sporadic occurrences of chlorite in subordinate amounts may represent less intense effects of the same solutions that produced bleaching elsewhere. In general, hydrothermally altered schist and gneiss are much less widely distributed than altered granite.

The strike and dip of the schistosity could be determined at only a few places, which are too scattered to reveal clearly defined structural features. They vaguely suggest a prevailingly northeast strike which changes to northwest in the northern part of the area; the dip is mainly eastward. A zone of anomalous strikes and dips may extend northwestward from Turquoise Lake.

GRANITE

Rock that may be designated under the general term "granite" predominates in the southern half of the area, as shown by plate 26 and by figure 41, but is less abundant than schist and gneiss in the northern half. This rock has been correlated with the Silver Plume granite (Stark and Barnes, 1935, p. 474).

Two varieties of granite are distinguishable on the basis of grain size, though they are not shown separately on plate 26. The most widespread variety ranges from medium grained to coarse grained, whereas the other is prevailingly fine grained. The finer grained

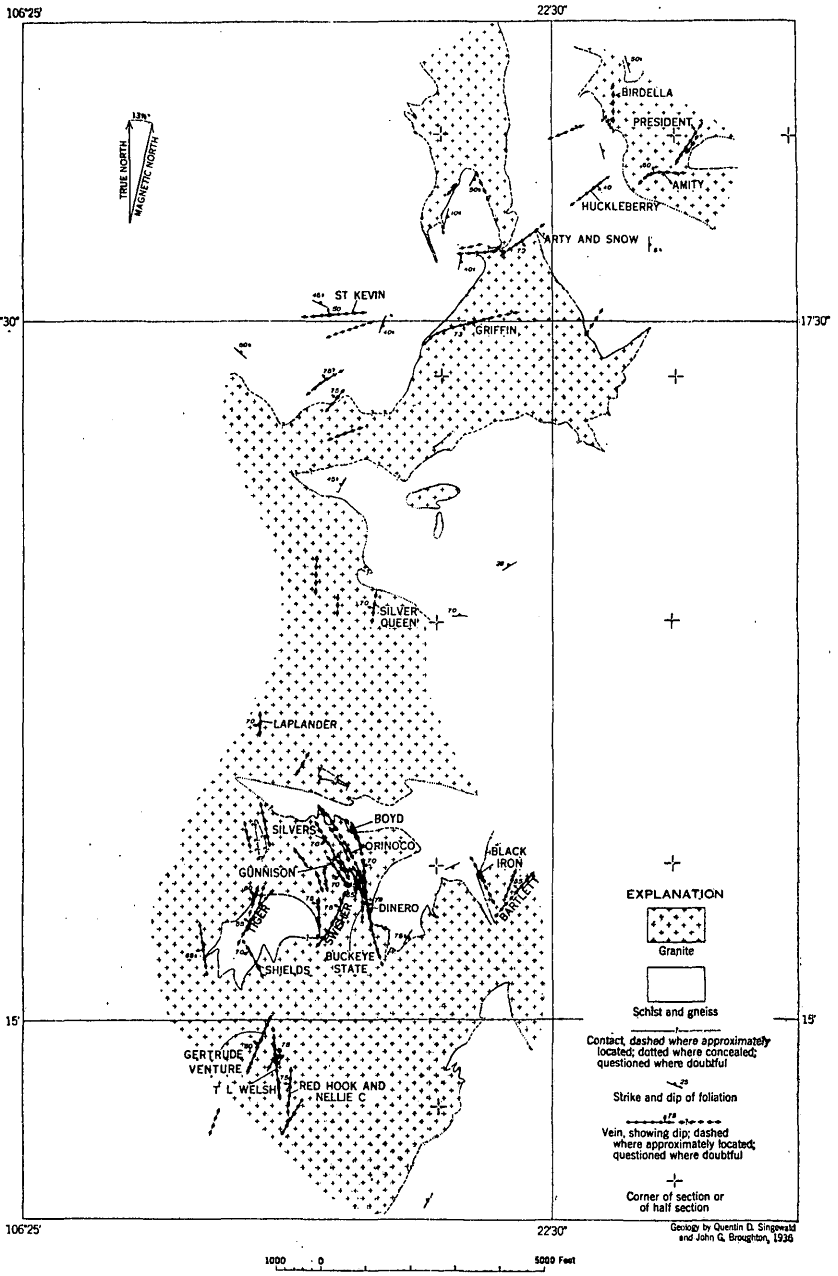

FIGURE 41.—Vein pattern in Sugar Loaf and St. Kevin districts, Lake County, Colo.

granite crops out over a large area to the west of Turquoise Lake, including the cliffs north of Lake Fork, and continues westward beyond the area of plate 26; it also crops out within a small area near the Birdella mine. Its age relations to the coarser grained granite were not determined, because nearly everywhere the two varieties are separated by schist and gneiss, and in the few places where they may adjoin, the contact is covered by moraine, alluvium, or weathered debris.

The prevailing rock of the coarser variety is medium grained, gray, and conspicuously granular, though locally the fabric may become either coarse grained or nearly fine grained. As the grain size increases the rock becomes inequigranular and the larger feldspars assume subparallel arrangement. A few of the feldspars are as much as an inch in length. In the freshest specimens, small flakes of biotite and subordinate muscovite are scattered among larger grains of feldspar and quartz; the feldspar ranges from gray to faintly pink. The rock weathers to pinkish-brown subrounded boulders, which disintegrate first into smaller fragments and eventually into a coarse angular sand. In specimens of weathered rock the feldspar is bleached, the biotite remains dark, and rusty-brown iron stain permeates the rock, particularly along fracture surfaces.

At places, particularly near the contacts, the granite shows conspicuous foliation due to dark films of mica, doubtless inherited through incomplete assimilation of schist. The foliation is especially well developed in two prongs of the intrusive body northwest of the Wilkesbarre workings.

The fine-grained variety of granite has a more glassy feldspar and is slightly richer in biotite than the medium-grained variety. Grain size ranges at different places from very fine grained to medium grained. Where intensely altered by hydrothermal processes, very fine grained granite may be difficult to distinguish from later formed porphyry.

Over large areas both varieties of granite show the effects of sericitic hydrothermal alteration; this altered granite grades almost imperceptibly into fresh rock. Feldspars have been partly or wholly converted to claylike aggregates, biotite has been bleached, and the rock as a whole has been rendered relatively soft and friable, generally without destruction of the original fabric. Within the central part of an area of particularly intense alteration that extends southeastward from the Griffin mine, however (see pl. 26 and fig. 41), microcrystalline alteration products have developed locally between grains of original feldspar to impart a pseudoporphyritic fabric. Moreover, along the north side of Lake Fork, immediately west of the area of plate 26, according to Schwartz (1933, p. 539–545), an extreme end product is sericite schist. It is not known whether clay minerals accompany sericite where alteration has been especially intense, as in proximity to vein fissures. A second type of hydrothermal process—namely, silicification (p. 260)—has yielded product unlike the one now under consideration.

A definite relationship between intensity of sericitization and distance from fissures is clearly evident in the Dinero Tunnel and along the road cut south of Turquoise Lake, the only two places where continuous exposures may be seen over a considerable distance transverse to structure. Along the road cut are numerous fissures and narrow shear zones, adjacent to which the granite is intensely altered. In general, the intensity decreases gradually away from each fissure but does not die out before reaching a zone extending out from the next fissure. Within the Dinero tunnel near its portal, on the other hand, fissures are less closely spaced and alteration is less intense, so fresh rock intervenes. These two localities give a clue to conditions elsewhere. The granite areas may, therefore, be pictured as irregularly permeated by sericitized zones, large and small, with closely spaced zones coalescing to form extensive, irregular areas having gradual boundaries. Although all veins occur within intensely sericitized rock, the converse is not true; and so the intensity of alteration is not a reliable guide to ore in granite.

Sericitization followed or perhaps in part was contemporaneous with the Tertiary porphyries, for the porphyries themselves are sericitized. On the other hand, it preceded ore deposition, for the rock within vein fissures as well as the walls thereof are intensely sericitized, and in places gouge derived from sericitized rock constitutes ore.

TERTIARY IGNEOUS ROCKS

In the Sugar Loaf and St. Kevin districts rocks that resemble some of the early Tertiary porphyries of the Mosquito and Tenmile Ranges form dikes and, much less commonly, small irregular elongated bodies. Individual dikes can rarely be traced more than a few hundred feet along the strike. Although this may be due partly to lack of outcrops, and perhaps partly to concealed faults, it also indicates that the dikes themselves are characteristically noncontinuous. On the other hand, a cluster of small discontinuous dikes may form a narrow zone half a mile or more in length. Plate 26 shows the more continuous dikes and the largest irregular-shaped bodies, but does not show all occurrences of porphyry.

The porphyry is grayish white and fairly soft. One facies shows rare phenocrysts of quartz, dark muscovite, and bleached feldspar in a dense homogeneous groundmass having rather smooth fracture. Another facies shows more numerous, though never abundant, phenocrysts of hexagonal-shaped sericite aggregates, quartz, and bleached feldspar in an exceedingly fine grained, sugary groundmass. The phenocrysts in both are medium sized. The former facies is identical in appearance with typical early White porphyry of the Mosquito Range. The latter might be late White porphyry, a slightly coarser facies of the early White porphyry, or an intensely altered facies of the Gray porphyry group, but it does not closely resemble any of them.

CHERT ZONES AND DISSEMINATIONS

A distinctive feature of the Sugar Loaf and St. Kevin districts is the widespread occurrence of chert, forming well-defined "dikes" or zones in some places, and innumerable discontinuous veins and veinlets in other places. Plate 26 diagrammatically shows the principal chert occurrences. The chert reminds one of the well-known jasperoid bodies found in limestone in many districts—though here it is in igneous and metamorphic rocks. It does not closely resemble "breccia reefs" (as used by Lovering and Goddard, 1950, p. 237) of the Front Range of Colorado.

Chert is particularly conspicuous on Sugar Loaf Mountain. There, a sinuous chert zone or "dike" more than a hundred feet wide extends northeasterly for nearly a mile (see pl. 26). The chert is white or gray except where locally permeated by red hematite stain. Pure chert in the central part of the zone grades outward into silicified country rock, predominantly granite. Slickensides are preserved at a few places on chert and on silicified granite. To the northeast the chert zone fades away soon after passing into schist. To the southwest it opens irregularly into a broad area of granite that is silicified along innumerable fractures. The gradation from chert to silicified rock and the preservation of slickensides together suggest that the chert formed mainly by replacing preexisting rock along faults.

North of Saw Mill Park a chert zone attains a maximum width of 350 feet. It contains, in places, silicified fault breccia in addition to slickensides. Other prominent but smaller chert zones are indicated on the geologic map. In general, they trend east or northeast, occur mainly in granite close to a schist contact, and terminate within granite by spreading into a broad area of mild silicification, but fade away when they enter schist.

Several of the chert zones are closely associated with White porphyry. Some consist of alternating porphyry, chert, and silicified country rock; or porphyry dikes may grade rather abruptly along the strike into chert "dikes." At places, the White porphyry is converted to chert.

Areas of innumerable chert veins and veinlets may perhaps be designated as chert disseminations. They lack definite boundaries, and so are difficult to portray on a geologic map, but an attempt has been made to indicate the general locations of the principal disseminations on plate 26. Most disseminations are near chert zones.

Hot solutions doubtless account for the chert zones and disseminations. The solutions postdate the porphyries, which in places are converted to chert, yet the close geographic association of porphyry and chert in many places suggests a genetic relationship. Perhaps the processes of silicification and sericitization were essentially contemporaneous, the former representing a more intense phase of hydrothermal alteration than the latter. On the other hand, fragments of sericitized granite on the dumps of many mines are transected by veinlets of an early-formed, light-colored, chertlike vein quartz. Therefore, the possibility that chert zones and disseminations postdate sericitization must be entertained. Neither by direct observation nor by conversation with miners could the age relations between chert zones and ore-bearing veins be ascertained.

GEOLOGIC STRUCTURE

The structural features of the Sawatch Mountains disclose two distinctive periods of major orogeny—one during the pre-Cambrian era, and the other, named the Laramide orogeny, during Late Cretaceous to early Tertiary time. The pre-Cambrian structural features have been described by Stark and Barnes (1934, p. 475–478), who state:

> The schists in all parts of the range are tightly compressed into isoclinal folds with axial planes overturned, dipping steeply to the northwest. This is clearly shown in the drag folding.* * * The drag fold structure of the schists is accentuated by the lighter colored pre-Cambrian lit-par-lit stringers and sills. What appeared at first to be simply irregular contortions in pegmatitic intrusions were found on closer inspection to parallel the schistosity of the darker host rock in all its most intricate and complex folding. * * * In hundreds of measurements * * * less than 10 per cent vary more than five degrees from the general average of N. 60° to 65° E. The greatest variations occur at the crests and troughs, where the igneous material breaks across in complex masses. But within a distance of a few inches or a few feet along the limbs, the strike of the beds and the axial trend of the drags swing back to accord with the regional direction of N. 60° to 65° E.
>
> The schistosity in all the mapped areas is apparently parallel to the bedding. * * * The parallelism might be explained in part by the isoclinal folding. * * * The differences between schistosity and bedding from such folding would probably be slight and may be masked in this region by the generally coarse texture of the schists. * * *
>
> The igneous material is not badly fractured. It is thought probable that emanations with accompanying heat from the advancing magma of the Silver Plume massive slowly permeated the schists or sediments from which the schists were formed, that recrystallization may have been in progress as the lit-par-lit stringers were intruded, and that folding occurred while the entire mass of host rock and intruded material was in a plastic condition. The igneous activity did not entirely cease after the folding is shown by the last series of pegmatites which follows the schistosity in part but more commonly cut across both the schist and the earlier pegmatites. The lamprophyres, which may possibly represent complementary dikes of the Silver Plume massive, also post-date the period of complex folding.

The Sawatch Mountains were uplifted during the Laramide orogeny to form the crest of a broad regional arch (Butler, 1929, p. 28). To the east, in the Mosquito and Tenmile Ranges, the limb of the arch was broken by countless faults. The major faults, which are associated with long and relatively narrow anticlines, strike north-northwest, have upthrown eastern walls, and for the most part dip to the east. They are readily recognized where bounded on one or both sides by sedimentary rocks, and the more persistent ones have been traced for many miles. On the contrary, tracing is difficult or impossible where they pass into pre-Cambrian metamorphic or igneous rocks along both walls, even where exposures are good. Similar faults may exist but they remain unrecognized in the pre-Cambrian terrane of the Sawatch Mountains, and beneath the unconsolidated deposits of the Arkansas River valley. In fact, Tweto (1952, written communication) recently found a strong reverse fault, upthrown to the east, heading down the Arkansas River valley from Tennessee Pass.

That the area of the Sugar Loaf and St. Kevin districts has been extensively broken by faulting is attested by numerous minor faults, by the widespread sericitization and silicification, and by the ore deposits themselves. Details of the pattern are imperfectly known, however, for it is reasonably certain that many faults remain undiscovered. Over much of the area, only the faults that are revealed by exposed fillings of porphyry, chert, or vein minerals could be recognized during the rapid reconnaissance. The longest fault known in the district is occupied by a chert "dike" on the eastern spur of Sugar Loaf Mountain (see pl. 26). Other prominent faults that are filled with chert or porphyry or both are shown on the geologic map. They strike either northeast or northwest, but in general have a larger east-west component that a north-south component. Most veins, on the other hand, have a more northerly trend. The longest is the Dinero, which has been traced more than half a mile along the strike. Where the Dinero vein crosses the chert "dike" on the eastern spur of Sugar Loaf Mountain, neither seems significantly to offset the other.

According to a generalized geologic map by Stark and Barnes (1935, p. 472), the Sugar Loaf and St. Kevin area lies immediately to the east of a large embayment of schistose rocks. This embayment extends southward from a large area of schistose rocks and penetrates westward into an extensive area of granitic rocks. The differences in physical properties of these two types of rocks would have caused them to yield differently to stresses during the Laramide revolution. Rocks of the area near the contact, particularly in proximity to a large embayment, would be expected to have fractured more extensively than those elsewhere. In turn, such an area located within the transverse belt of Tertiary igneous rocks and ore deposits that extends southwestward from Boulder County theoretically would have become a locus of ore deposition. Even so, other geologic features, such as northward-trending major faults, as yet undiscovered, may have helped to localize ore deposits specifically within the Sugar Loaf and St. Kevin area.

ORE DEPOSITS

HISTORY AND PRODUCTION

Nearly all the productive veins of the Sugar Loaf and St. Kevin districts were discovered back in the eighties. In fact, one man, Tom Walsh, is credited with having located most of the veins that subsequently became the large producers.

The period of maximum output for most mines was during the last century, prior to the drastic drop in price of silver in 1893. However, some mines maintained more or less continuous production until the first World War, and at least one, the Dinero mine, operated continuously into the 1920's. Minor, intermittent work at one or another of the mines has been done by lessees, particularly during a second flurry of activity that lasted from the early years of the present century until about 1912.

Silver has been the main constituent won from ores throughout the district. Gold has been a minor product of some, but has been negligible in others; nowhere have veins been worked primarily for gold, except in a few prospects and very minor producers along the north bank of Lake Fork. Zinc and subordinate amounts of lead have been noteworthy constituents of ore in the northeastern part of the Sugar Loaf district and at the Griffin and St. Kevin mines (see pl. 26), but were absent or scarce elsewhere. Turquoise occurs in several prospects in the southeast-central part of the St. Kevin district, where insignificant quantities actually have been mined and shipped. Apparently turquoise does not occur in silver veins, nor vice versa. In 1951, the U. S. Geological Survey discovered many occurrences of uranium in the St. Kevin district, though none had immediate commercial possibilities.

Reliable production statistics for years prior to 1914 are not available, either for individual mines or for the area as a whole. Fragmentary records for a few of the mines were obtained confidentially to supplement estimates made by mining men who have been actively interested. From these sources, a "guess-estimate" may be made that the aggregate value of output from the two districts has been of the order of 10–15 million dollars.

The Dinero mine, generally regarded as the largest in either district, probably produced at least a million dollars worth of ore, and perhaps as much as two million. The Gunnison, St. Kevin, Birdella, President, Gertrude-Venture, Griffin, and Tiger-Shields mines probably each produced between half a million dollars worth of ore and one and a half million. Comparable production may also have come from workings along the Silvers vein, and perhaps from other veins closely associated with the Dinero. Among the mines that probably had an aggregate output of $100,000–$500,000 each are the Amity, Red Hook and Nellie C., Arty and Snow (including the Wilkesbarre tunnels), T. L. Welsh, Black Iron, and Huckleberry. Some of the foregoing mines are described in the pages that follow; others are not described because no specific data concerning them could be obtained.

GENERAL FEATURES OF SILVER VEINS

The pattern of the main veins in the Sugar Loaf and St. Kevin districts is depicted by figure 41. The difference between prevailing trends in the northern part of the area and those in the central and southern parts is obvious. Presumably this reflects differences in the direction of maximum stress at the time of deformation, but the underlying cause is not apparent from data procured within the mapped area.

Most of the veins are in granite but near a contact with schist and gneiss, two are along a contact, one crosses a contact, two are within areas of prevailing schist and gneiss but associated with small unmapped granite bodies, and one (the Huckleberry) is almost wholly within schist and gneiss. Thus, the veins tend to be in the brittle granite rather than the more plastic schist and gneiss, yet seem to be localized near contacts.

The veins occupy strong fissure zones having steep dips. Generally, the fissure zones are several feet thick where productive, but locally they attain 10 feet or more in thickness, and elsewhere pinch to less than a foot. Within them are broken and crushed rock, gouge, and quartz-sulfide vein material. The gouge commonly occurs as films and seams following surfaces of movement within the zone. One or both walls of the fissure zone may be well defined, yet at many places a gradual decrease in abundance of individual fissures outward from the central part of the zone into the wall rocks precludes a precise determination as to where the fissure zone ends and wall rock begins. In either case, the wall rocks are greatly fractured and permeated by randomly oriented gouge films. Major and minor auxiliary fissures commonly branch from the main zone.

Rock within and adjoining vein fissures has everywhere been intensely altered by hydrothermal action. The dominant process has rendered the rock as a whole relatively soft and friable, converted the feldspars to claylike aggregates, bleached the biotite, and developed accessory pyrite. This process has been tentatively designated sericitization but no petrographic study has been made to determine whether clay minerals or other products are locally present along veins. Locally, silicification seems to have been superimposed upon sericitization.

The quartz-sulfide vein material forms streaks, stringers, layers, lenses, and veins within the fissure zones. Composition ranges from massive sulfide minerals on the one hand to quartz devoid of sulfide minerals on the other. Most widespread is an intimate intergrowth of very fine grained, chertlike quartz with subordinate, though considerable, quantities of fine-grained pyrite. When extracted, this material may be in large solid chunks containing numerous vugs, or more commonly, may be broken into small angular fragments. Two varieties of chertlike quartz may be seen with the unaided eye in many specimens, an earlier light-colored variety and a later moderately dark gray variety. In addition, red jasper is a minor constituent of some veins, particularly in the Sugar Loaf district. Pyrite is distributed unevenly through the quartz. Sphalerite and galena, where present, may either be intimately associated with pyrite or occur apart from it. In general, sphalerite is more abundant than galena.

The distribution of zinc and lead may reflect a zonal pattern. Sphalerite or galena, or both may readily be found on dumps from the St. Kevin, Griffin, Laplander, Dinero, Gunnison, Buckeye State, Silvers, Orinoco, Boyd, and Bartlett veins (see fig. 41), but these minerals are absent or extremely scarce on mine dumps farther to the southwest, west, and north. An apparent lack of sphalerite or galena in the St. Kevin district to the south of the Griffin mine may not be conclusive, because relatively little mining has been done in this ground. Smelter settlement sheets and other incomplete records of production for some of the mines reveal that the St. Kevin, Griffin, Dinero, Silvers, Orinoco, Swisher, and Black Iron ores contained several percent of combined zinc and lead, whereas the Amity, Wilkesbarre, Tiger, and Gertrude-Venture ore contained little or none. Thus, zinc and lead as essential constituents of veins may be restricted to the northeastern part of the Sugar Loaf district and the central part of the St. Kevin district. One exception may be the President mine, where lead is said to have been a noteworthy constituent of ore mined many years ago.

Data are meager regarding the mineralogy and physical aspect of ore that was shipped. At the Amity mine, and perhaps at many others, dark gouge as well as dark quartz-pyrite vein substance constitutes ore; the dark gouge bleaches when exposed to air. Yellow-stained material consisting of clay, granules of quartz and feldspar, grains of pyrite, and small fragments of quartz-sulfide vein substance is abundant on most mine dumps; but this material presumably was below grade and therefore does not represent ore. Vein specimens that Sandberg (1935, p. 495–504) apparently collected from the Dinero and nearby mine dumps a decade after mining ceased exhibit sphalerite, pyrite, quartz, galena, and microscopic quantities of chalcopyrite, tetrahedrite, argentite, and rhodochrosite. Native silver, of which specimens remain in the hands of private collectors in Leadville, may have been widely distributed in some veins of the Sugar Loaf district, including veins that did not contain sphalerite or galena. In the Dinero vein, native silver persisted to a depth of about a thousand feet below the surface, which would indicate that it was a hypogene mineral. On the other hand, E. P. Chapman (1936, oral communication) found that silver minerals rarely can be recognized in polished sections of ore from the St. Kevin district, even in material that assays as much as 100 ounces per ton.

The paragenesis of sulfide minerals in the Dinero and nearby veins have been described by Sandberg (1935). Comparable data do not exist for the veins that lack sphalerite or galena in the Sugar Loaf district, nor for any veins in the St. Kevin district. Sandberg (1935, p. 495–504) states:

The ores are pitted and vuggy, with numerous well-formed crystals of sphalerite, pyrite, quartz, and galena in the vugs. The specimens contain the following minerals in order of abundance: sphalerite, pyrite and quartz, galena, chalcopyrite, tetrahedrite, and argentite. * * *

The first mineral to crystallize was pyrite, in small amount. This was followed by dark brown sphalerite, chalcopyrite (as inclusions in sphalerite), and galena, these being closely associated and probably in part contemporaneous, though galena appears to outlast the sphalerite. * * *

The next minerals to be introduced were pyrite and quartz in close association, as veinlets, embayments, and crusts. Some light-colored sphalerite is closely associated here with quartz. * * *

Galena occurs in part overlapping with, though apparently outlasting, pyrite and quartz, and is associated with minor amounts of chalcopyrite, tetrahedrite, and argentite.

Tetrahedrite occurs in small amounts in a few of the specimens examined. Its principal occurrence is in close association with galena with which it forms intergrowths * * * without apparent relation to crystallographic directions or fractures. These intergrowths contain a few rounded and smoothly-curving patches of chalcopyrite, and occur as shapeless areas in dark sphalerite. * * * It is likely that some silver occurs with the tetrahedrite. Polished surfaces of ore from the Gunnison mine, which has been cited as producing the richest silver ore in the district, show considerable tetrahedrite as a minor constituent. * * * Argentite appears on etched galena surfaces * * * as sparsely and irregularly distributed rods and dots, occasionally showing a faint suggestion of orientation, but no discernible relation to fissure or veinlets.

* * * The chief gangue mineral is quartz * * * The only carbonate which occurs in sufficient quantity to be accurately identified is a pink rhombohedral mineral which quantitative analysis shows to contain approximately 67 percent of $MnCO_3$ to 33 percent of $CaCO_3$. This material came from the dump of the Fanchon shaft. The carbonate surrounds isolated areas of galena which it cuts in veinlets, and occurs as well-formed crystals in vugs.

Especial interest is attached to the paragenesis of silver minerals, particularly as to whether they are of supergene or hypogene origin. * * * In view of their close intergrowth association with galena, a mineral rarely if ever formed in noteworthy quantity by secondary enrichment, and their lack of definite relationship to veinlets, cleavage directions, and grain boundaries, they are regarded as hypogene. The rich silver ore mined in the early operations, as at the Gunnison mine, together with field evidence, indicate that there was an oxidized zone. If there was a secondary sulphide zone, no evidence of it was seen in the specimens studied.

Many, though not all, ore shoots bottomed at depths of 100 to 200 feet. To what extent the shallow ore shoots reflect an enrichment of veins near the surface by descending (supergene) water, rather than the distribution of hypogene silver minerals, is not known. The present water table at the very few places observed is not more than 50 feet below the surface. Its depth could not be determined in the leading mines, even the accessible ones, because in general the upper workings are drained by lower adits. Unaltered pyrite, according to Chapman (1936, oral communication), extends to within less than 50 feet of the surface at many places. However, in at least some fissure zones, limonite extends downward along only one or several of a multitude of fractures tens of feet below otherwise unoxidized material, including pyrite. Hence, the veins may be intensely oxidized only to a maximum depth of about 50 feet, and yet be partly oxidized along a few selected fractures to a decidedly greater depth. Where even partly oxidized, the veins may be enriched. In fact, if supergene sulfide minerals exist, the veins may be enriched a little deeper than they are oxidized. On the other hand, Sandberg's specimens revealed no supergene sulfide minerals, and ore shipped from the oxidized zone of the Dinero vein (p. 272), where part of the zinc had been leached, apparently was not enriched in silver. The negative evidence for the Dinero and nearby veins, of course, does not necessarily apply elsewhere in the districts. In conclusion, the veins may have been enriched by descending water, but neither the amount, nor the maximum depth of enrichment may be surmised.

OCCURRENCES OF URANIUM

Occurrences of uranium that were discovered by the U. S. Geological Survey in 1951 are described in another publication (Pierson and Singewald, 1954), which includes a map showing specific localities and a table summarizing data for each locality. Therefore, only a brief résumé is given here to round out the picture of mineralization in the area.

In 1951, radioactivity anomalies were found at 122 localities in the St. Kevin district and at 8 in the northern part of the Sugar Loaf district. None is a showing of commercial uranium ore. Most of the anomalies are concentrated within an area of about 3 square miles in the central part of the St. Kevin district. At 24 localities in the St. Kevin district the anomalies were greater than 3 times background count; at all other localities the anomalies were less. At only one locality could a uranium-bearing mineral be identified with the unaided eye—namely, torbernite, at the Josie May prospect (see pl. 26). Analyses of samples from other localities gave contents of chemical uranium ranging from 0.001 to 0.07 percent and ratios of uranium to total radioactive material ranging from 0.05 to 0.93 percent. In addition, a rather strong concentration of radon gas was found in the Wilkesbarre adit (see pl. 26). Further prospecting doubtless would disclose more radioactivity anomalies.

The host rock is hydrothermally altered wherever radioactivity anomalies have been found. By far the most common host rock is intensely sericitized granite. Inasmuch as altered granite in the St. Kevin district prevailing exhibits low radioactivity (0.03–0.05 mr per hr), whereas unaltered granite exhibits rather high radioactivity (about 0.12 mr per hr), the anomalies may represent material that was leached, concentrated, and redeposited during hydrothermal alteration.

Most of the radioactivity anomalies were found in material from the zone of weathering in nonglaciated terrain. Such anomalies result from secondary minerals that developed during a long period of weathering in a humid climate—conditions favorable for chemical leaching of uranium. Small quantities of secondary uranium minerals giving small anomalies near the surface therefore might lead downward into larger quantities of hypogene uranium minerals below the zone of weathering. Of course, this does not imply that the hypogene minerals will necessarily be either abundant enough or continuous enough to be profitably mined.

DESCRIPTIONS OF MINES

SUGAR LOAF DISTRICT

DINERO AND NEARBY MINES

By far the most productive local area within the Sugar Loaf and St. Kevin districts has been the ground along the Dinero vein and several closely associated veins—the Gunnison, Silvers, Buckeye State, Orinoco, and Boyd (see fig. 42)—in the north-central part of the Sugar Loaf district. The precise pattern of veins in this local area is now indeterminate because shafts and prospect pits at places are too numerous to delineate individual veins. Plate 26 and figure 42 give the author's best guess at a reconstruction made after a careful field consideration of possible alinements and a study of the locations of shafts and pits on claim maps. Branch veins and auxiliary fissures doubtless were mined in addition to the veins named above.

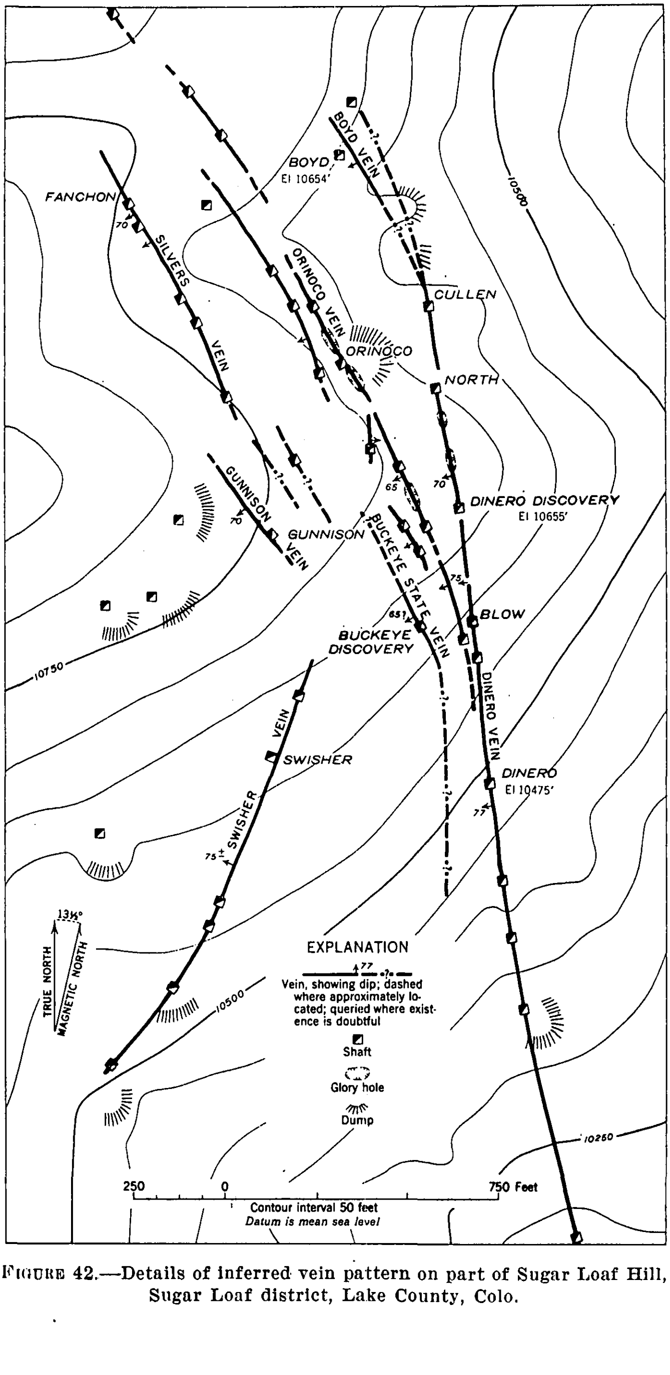

FIGURE 42.—Details of inferred vein pattern on part of Sugar Loaf Hill, Sugar Loaf district, Lake County, Colo.

MINE WORKINGS

All the veins at first were worked from shafts, mostly inclined, along the outcrop. Later, the Dinero tunnel was driven about 3,300 feet northwestward across barren ground to reach the Dinero vein at depth. Figure 42 gives the names and locations of the main shafts, shows the locations of some other shafts, but omits many of the lesser shafts and pits. Plate 26 locates the portal of the Dinero tunnel, at altitude 9,771 feet, immediately to the northwest of the intersection of Sugar Loaf and Little Sugar Loaf Gulches, in the east-central part of the Sugar Loaf district.

Mining done from the shafts doubtless extended to maximum depths of several hundred feet. No specific information about the underground workings could be procured, other than sketchy data about workings along the Dinero vein and a map showing part of a "2nd level down," 157 feet deep along the Gunnison vein. Most of the workings probably were never surveyed.

The Dinero vein was prospected by shafts and pits along an outcrop length of more than 3,000 feet, and it may have yielded at least minor amounts of ore near the surface throughout this distance. The most productive part of this vein, however, lay between the Dinero and North shafts (see fig. 42), which are about 1,100 feet apart. Six levels were worked northward from the inclined Dinero shaft, the sixth level being 365 feet, and the third level about 240 feet in vertical distance below the shaft collar. At least the three upper levels, and likewise a tunnel at the level of the shaft collar, connect with workings from the Blow shaft, which in turn connect with those from the Dinero Discovery and North shafts. It is uncertain whether essentially the entire vein above the third level was stoped all the way from the Dinero shaft to the North shaft, or whether two unstoped lean stretches, each about 100 feet in strike length and plunging 80° north, intervene between the Blow and Dinero Discovery shafts and the Dinero Discovery and North shafts, respectively. By contrast, much of the vein between the sixth and third levels may remain unstoped.

The Dinero tunnel workings include 2,200 feet of drift along the Dinero vein on the tunnel level, 1,300 feet along two levels below the tunnel, and at least 1,600 feet along diverse levels above the tunnel. In addition, 250 feet of drift follows the Buckeye State vein along a level 200 feet above the tunnel. A 700-foot crosscut that passes directly beneath the collar of the Gunnison shaft apparently cuts at least one nonproductive vein west of the Dinero vein on the tunnel level, but did not extend far enough to reach the Gunnison vein. Figure 43 shows in part the location of veins in the Dinero tunnel workings as inferred from an incomplete mine map. The aggregate length of stopes at the tunnel level probably does not exceed 1,200

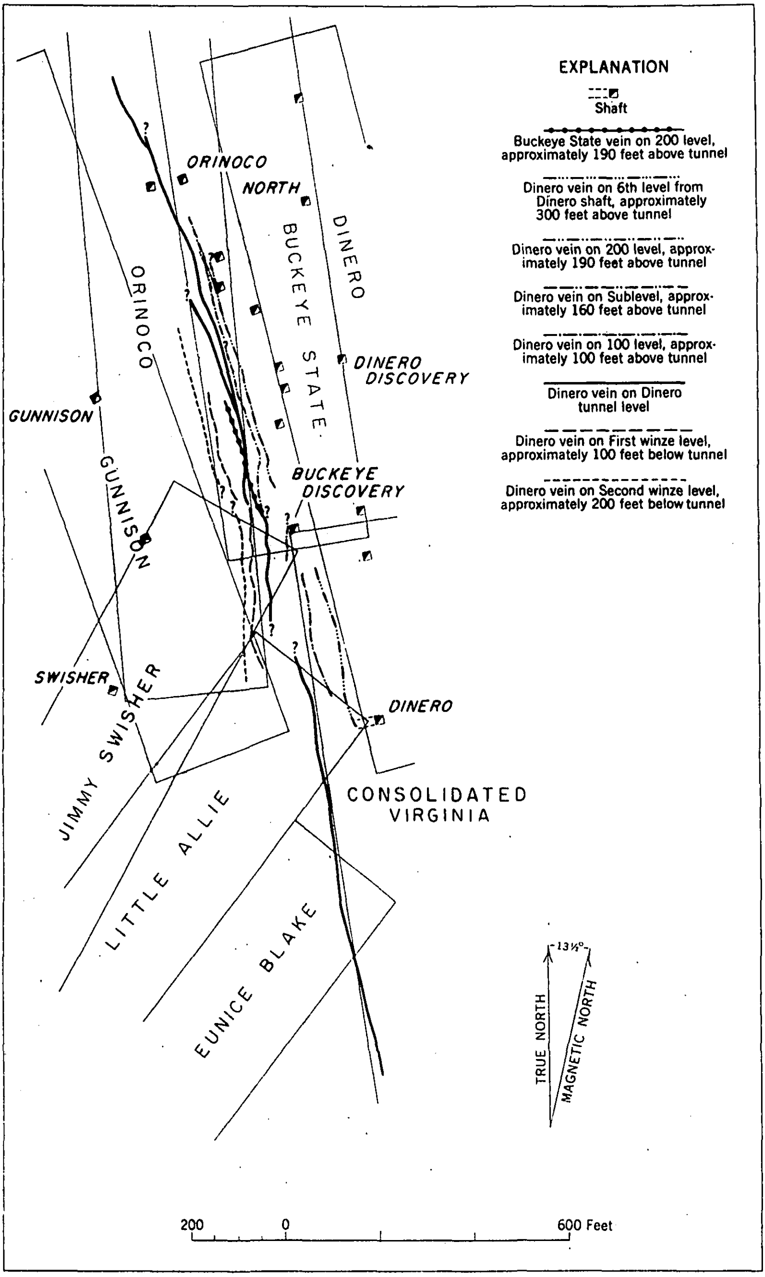

FIGURE 43.—Inferred positions of veins in Dinero tunnel workings, Sugar Loaf district, Lake County, Colo.

feet; as in the workings above, the bulk of them lie north of the Dinero shaft. All ore shoots apparently bottomed above the deepest winze level, that is, 1,000–1,050 feet in vertical distance below the surface at the Dinero Discovery shaft.

RECORDS OF ORE SHIPMENTS

The Dinero mine during the period 1914–48 reported an intermittent output aggregating 9,259 tons of ore, of which 939 tons were mined primarily for manganese, the remainder primarily for silver. The manganese content of the 939 tons averaged only about 12 percent. The silver ore averaged 0.155 ounce of gold per ton, 62.7 ounces of silver per ton, 0.12 percent copper, and 1.88 percent lead; its zinc content is not known. Most, if not all, of this ore must have come from the Dinero vein.

An anonymous compilation of records for more than 25 thousand tons of ore, valued at more than $800,000, shipped by the Dinero mine between 1891 and 1923 may include some ore from veins other than the Dinero. Although not a complete record of production, and perhaps not precisely accurate, the compilation provides data valuable for generalizations that the author regards as reasonably reliable. The prevailing range in gold content of individual shipments is from 0.04 to 0.5 ounce per ton, and in silver content from 11 to 140 ounces per ton; less than 10 percent of the shipments had either a gold or a silver content not within these ranges. The prevailing range in zinc content is from none to 14 percent. The overall averages are 0.167 ounce of gold per ton, 63.0 ounces of silver per ton, 4.3 percent zinc, and about 9 percent sulfur. Lead probably was not determined in all shipments, so a computed overall average of 0.4 percent lead may be too low. The true overall average for lead must not exceed one percent, nevertheless, because the ratio of zinc to lead of shipments in which both are reported averages more than 5 to 1.

A comparison of contents of zinc and of silver in ore shipped during three successive periods when mining presumably attained progressively greater depth suggests that descending water leached zinc near the surface but did not enrich silver. Zinc is reported in only 2 of 54 shipments during 1891–92, in 46 of 172 shipments during 1893–1904, and in 284 of 361 shipments during 1905–23. The average zinc content is 0.3 percent for 1891–92, 2.0 percent for 1893–1904, and 5.2 percent for 1905–23. The average silver content in ounces per ton for these same periods is 62, 43, and 67, respectively.

Only for the Silvers vein could other records of shipments from the Dinero local area be gleaned. Settlement sheets for five small shipments of ore made by Ralph Snedden, lessee, during 1935–36, from the 80-foot level of the Fanchon shaft on the Silvers vein showed: gold, 0.3–0.7 ounce per ton; silver, 84–167 ounces per ton; zinc, 12.3–15.9 percent; lead, none to 7.9 percent; iron, 10–21 percent; manganese, none to 1.7 percent; insoluble, 29–46 percent. Seventeen shipments aggregating 510 tons, allegedly from the Silvers vein during 1891–92, averaged about 0.15 ounce gold per ton and 48 ounces silver per ton; none reported zinc or lead.

GEOLOGIC SETTING

Granite is the prevailing wall rock of the Dinero and associated veins, as shown by plate 26. In the vicinity of the Dinero shaft, however, the Dinero vein adjoins a contact between granite and schist, and nearly all the veins enter schist country rock at their northern terminations. The veins locally cut White porphyry and zones of chert. A particularly well defined zone of chert trending sinuously east-northeast (see pl. 26) crosses the belt of veins about 300 feet north of the Dinero Discovery shaft. This may be what some old-timers called the "blow out fault." It would be interesting indeed to be able to observe whether the veins change in physical character in passing through the chert, or are offset along it. Furthermore, perhaps there is some significance in the fact that productive veins closely associated geographically with the Dinero are restricted to an area of abundant minor chert veins that may be auxiliary to the main zone, and to ground immediately to the north. All the rocks except chert are intensely sericitized in proximity to productive veins, and locally considerably silicified.

DETAILS OF VEINS

Accessible exposures of veins of the Dinero grouping are rare. In the Dinero tunnel, the vein itself has been mined out within the accessible workings. The vein fissure walls in some places are fairly well defined, in other places are transitional owing to a gradual decrease outward in the number of individual fracture surfaces and in the intensity of crushing shown by the rock between them. In either case, the rock in the walls is extensively shattered and contains many gouge seams randomly distributed.

A vein thought to be the Silvers was well exposed in 1936 at the breast of a drift, 67 feet south of the Fanchon shaft (see fig. 42), on a level 80 feet vertically below the collar. The vein was 3–4 feet thick. Both walls were fairly well defined, though thin films of gouge parallel to the vein actually provided a transition zone into shattered wall rock. Within the vein fissure were the following zones, from hanging wall to footwall: 6 inches of rotten, oxidized rock, with several partings of brown gouge; 2–2½ feet of unoxidized gray gouge, soft mud, and crushed rock; discontinuous films and veinlets of sulfide minerals; 6 inches to 1 foot of crushed rock, slightly oxidized, with films of gouge; a ½-inch layer of sphalerite. The uppermost zone of oxidized material constituted the ore.

An opencut 80 feet long, located 130 feet west of the Dinero Discovery shaft, exposes the walls of a vein thought to be the Orinoco. The vein, 3–4 feet thick, trending N. 25° W. and dipping 65°–70° SW., has been mined out. At one place, seriticized lamprophyre, either a dike or an elongated inclusion, adjoins the vein. Elsewhere, the wall rock is intensely sericitized granite that locally has been partly silicified, especially along fractures. A thin layer of strongly silicified rock forms a distinct wall on the foot, whereas the hanging wall is not well defined. A strong branch fissure extends about N. 5° E., 75° NW. into the footwall, and a sheeted zone about S. 30° W. vertically into the hanging wall.

VEIN MINERALS

The bulk of the sulfide-bearing vein material exposed on the dumps is medium-gray, very fine grained quartz—almost chert—containing a considerable though decidedly subordinate quantity of fine-grained pyrite. Some of this material is in massive chunks derived from layers at least a foot thick, but most of it is in small angular fragments derived from thin streaks or from thicker layers that were somewhat broken by postmineral movement within the vein fissures. All the larger fragments contain numerous vugs; some are minute cavities and some are more than 6 inches in longest diameter. Nearly all the vugs are coated with small, clear to translucent quartz crystals. The pyrite is unevenly distributed, and commonly is concentrated in crude layers, concentric masses, or irregular patches. Sphalerite is decidedly less abundant than pyrite, and galena is still less abundant. Sphalerite and galena are irregularly distributed within quartz-pyrite material and also as crystals coating many vugs. All the sulfide minerals also impregnate silicified granite. A light-colored chert-like quartz, usually devoid of sulfide minerals, is found transecting granite and also intermixed with the medium-gray quartz-sulfide material.

An important constituent of ore from the Dinero vein was native silver. Inasmuch as it persisted downward at least to the tunnel level in quantities adequate to be readily detected by the unaided eye, according to Mr. J. Marvin Kleff of Leadville, the native silver was evidently a hypogene constitutent. Native silver probably also was found in the Gunnison, Silvers, Buckeye State, Orinoco, and Boyd veins. It is not surprising that no specimens remain on any of the dumps. Traces of argentite and tetrahedrite were seen under the microscope by Sandberg (1935, p. 504) in specimens collected mainly from the dumps of the Dinero and nearby mines.

Whether any of the gouge constituted ore in the Dinero group, as in mines in the St. Kevin district, could not be ascertained.

TIGER-SHIELDS MINE

The Tiger-Shields mine, in the west-central part of the Sugar Loaf district, ranked either second or third in value of output among the productive local areas of the Sugar Loaf district. It was greatly surpassed by the Dinero local area, and it may or may not have been surpassed by the Gertrude-Venture. Two veins were worked—the Shields, which strikes N. 37° W. and dips about 65°–75° SW., and the Tiger, which strikes N. 20° E. and dips about 55° NW. As shown by plate 26 and figure 41, the two veins form a very wide V, open to the east, but no data concerning their relations at the junction are available.

The veins apparently were worked first by means of a series of shafts along the outcrops of each, and later were opened by the Tiger tunnel. The portal of the tunnel, at an altitude of approximately 10,600 feet, is 4,550 feet S. 63½° W. of the northwest corner of sec. 19, T. 9 S., R. 80 W., at the head of a small ravine that trends southward to join Little Frying Pan Gulch.

A map of the Tiger tunnel, date and surveyor unknown, furnished the strikes and dips given above. The map shows that the Shields vein was continuously stoped through a strike length of 370 feet, southeastward from its junction with the Tiger, both above and below the tunnel level; presumably the stopes extend upward to grass roots, at a maximum vertical distance of 150 feet above the tunnel. The Tiger vein apparently was continuously stoped above the tunnel level along a strike length of 300 feet, northeastward from its junction with the Shields, and perhaps intermittently thereafter for another 300 feet—though data on the mine map do not clearly designate stoped areas along the Tiger vein. Two hundred feet north of the junction of the two veins, a winze on the Tiger vein suggests that some ore may have been mined below the tunnel level, which is about 180 feet vertically below the surface at that point.

The alinement of shafts and pits on the surface suggests that the Tiger vein may fork north of the Tiger shaft, and also that an auxiliary vein may exist about a hundred feet to the west.

Copies of only a few settlement sheets for ore shipped during 1904–5, 1910, and 1924 were available. These showed gold ranging from 0.06–0.11 ounce per ton and silver from 10.9–23.5 ounces per ton, with no zinc or lead. The average for 275 tons was 0.08 ounce of gold and 21.0 ounces of silver per ton. The ore mined during earlier days may have been richer.

Although the Tiger and Shields veins lie within an island of prevailingly schist bedrock, a great deal of altered and disintegrated granite is found on the dumps. Vein quartz containing considerable pyrite is abundant in chunks and as small angular fragments. The bulk of the vein quartz is medium gray and very fine grained, almost cherty; but light-colored chertlike quartz forms intergrowths with the medium-gray variety and also with veinlets transecting granite. Minor amounts of red chertlike quartz form irregular intergrowths with the medium-gray quartz, and form banded layers within it.

One specimen shows angular fragments of the light-colored variety enclosed in red, which in turn is transected and enveloped by the medium-gray variety. Pyrite is intimately associated only with the medium-gray quartz, in which it is irregularly distributed; pyrite-rich portions impart a crude banding to some specimens. All the pyritic quartz is somewhat vuggy. The abundance of this material on the dumps indicates that it did not constitute the ore. Occasional chunks of nearly pure pyrite, with remnants of gouge adhering, may also be seen.

Mr. George S. Casey, of Leadville, possesses a chunk of native silver about 8 inches in longest diameter, derived from the Tiger-Shields mine. According to Casey, native silver was not uncommon throughout the richer ore shoots.

GERTRUDE-VENTURE MINE

The aggregate value of output from the Gertrude and Venture claims, in Little Frying Pan Gulch, half a mile south of the Tiger and Shields, was of the same general order of magnitude as that from the Tiger and Shields. The bulk of the output came from the Gertrude-Venture vein which strikes about N. 20° E. and dips 50°–55° NW.; the dip is inferred from survey data, furnished by J. Fred McNair, giving the slope of the Venture shaft (see pl. 26) and the location of the Gertrude-Venture vein in the Siwatch tunnel. The main workings along the Gertrude-Venture vein were never surveyed, insofar as the author could ascertain. The distribution of the larger dumps suggests that the vein may have been stoped along a strike length of 300–500 feet, to an unknown depth. At 400–450 feet below the surface, apparently well below the main workings, a vein thought to be the Gertrude-Venture was cut in a long, crosscutting prospect adit named the Siwatch tunnel (see pl. 26). There it was explored along a strike length of 400 feet, but is said to have yielded only very small quantities of low-grade ore.

Three shipments aggregating 251 tons during 1916–21 averaged 0.25 ounce of gold per ton and 37 ounces silver per ton.

T. L. WELSH MINE

The T. L. Welsh mine was only a subordinate producer whose output was perhaps about a quarter of that of the Gertrude-Venture, but inasmuch as part of the adit was accessible for mapping in 1936, the pattern of veins and faults found there serves as a geological sample of mines in Little Frying Pan Gulch.

The mine workings comprise three shafts and an adit. The portal of the adit, at an altitude of 10,044 feet, is 3,500 feet N. 80° W. of the southwest corner of sec. 19, T. 9 S., R. 80 W. The shafts are north-northwest of the adit, the most distant one being 600 feet N.

19° W. of the portal. It may connect with the adit beyond the accessible part. The main T. L. Welsh shaft may connect with the adit via one of the two chutes located 400 feet from the portal (see fig. 44).

Figure 44 is a map of workings accessible in 1936. The wall rock is entirely granite, which has been considerably sericitized. The main vein is a zone that ranges from less than a foot to nearly 5 feet in thickness. It is composed of crushed rock, gouge, and pyritic, chert-like quartz that forms stringers, veinlets, and lenses; the gouge is

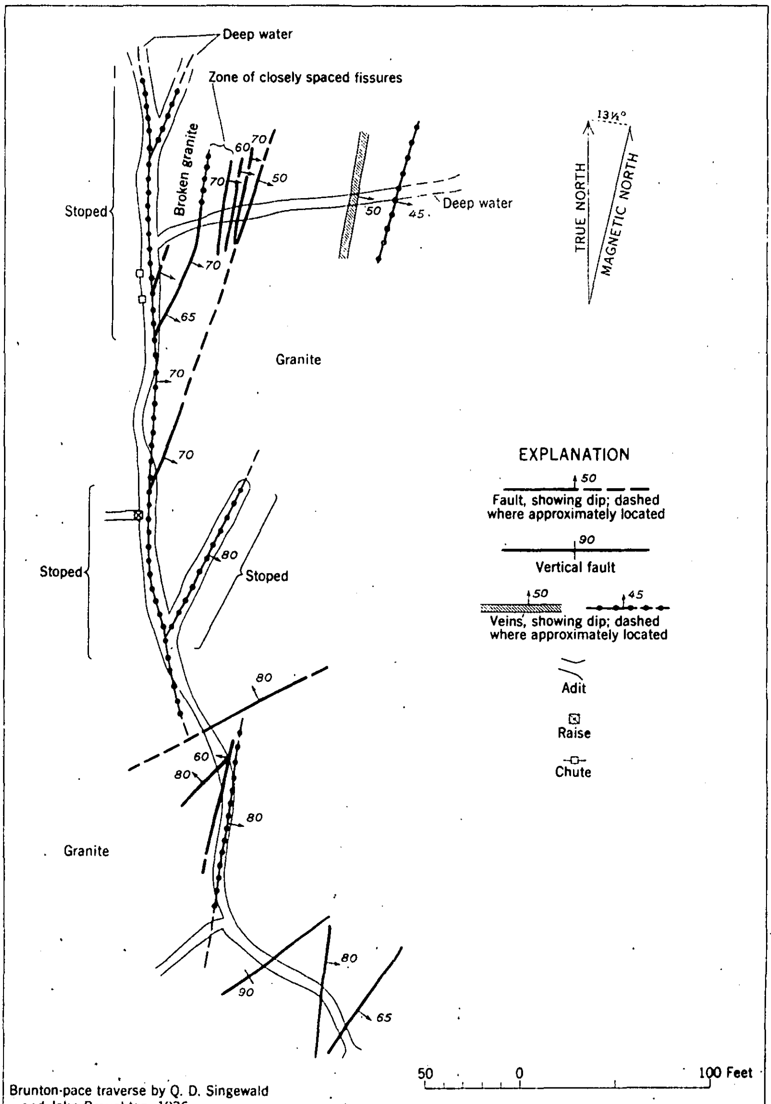

FIGURE 44.—Geologic map of T. L. Welsh adit, Sugar Loaf district, Lake County, Colo.

along many individual fault surfaces that lie within the vein fissure zone. The pyrite-bearing quartz commonly is along the hanging wall, but it also occurs both within the fissure and along the footwall. Rock adjoining the fissure is severely shattered, and contains many gouge films.

The bulk of the strong auxiliary veins and faults lie in the hanging wall of the main vein, as shown by figure 44, yet there are occasional strong transverse fissures. Both walls contain many minor fractures not shown on the map. The auxiliary veins, like the main vein, are fissure zones containing crushed rock, gouge, and pyritic quartz; they range from several inches to several feet in thickness. The easternmost vein, shown 135 feet from the main vein at the eastern accessible end of the crosscut near the northern end of figure 44, is a 3-foot zone of nearly parallel gouge seams with shattered rock between; along the hanging wall is a 1-inch seam of pyrite in soft gouge, and extending diagonally inward and downward from the hanging wall is a lens of pyrite-bearing quartz. The footwall break is heavily stained by limonite, and many fracture surfaces in the severely broken wall rocks are coated with limonite and very minor amounts of manganese stain. Twenty-two feet to the west is another fissure zone, 4 feet wide, that shows pyrite-bearing lenses and nests along the footwall. Both walls are heavily stained by limonite.

A vein fissure 2½ feet wide is exposed in one of the shafts; it trends N. 6° W. and dips 80° NE. The rotten granite walls of the shaft are cut by many minor fissures. Those in the footwall average about N. 20° W. in trend and 50° SW. in dip; those in the hanging wall about N. 75° W. in trend and 65° SW. in dip.

The mine dumps consist mainly of altered granite which is partly disintegrated, but they also contain vein material that is pyrite-bearing, moderately dark, chertlike quartz containing many small vugs. Much of the vein material shows specks and small masses of red chertlike quartz. Pyrite intergrown with the dark chertlike quartz is fine grained, but occasional pieces of nearly pure coarse pyrite also may be found. In the ore bin are specimens of soft white gouge that resemble talc, as well as pyritic dark chertlike quartz.

LAPLANDER ADIT

The Laplander adit was a very minor producer, but as it was accessible in 1936, it provides a geologic sample of veins on the steep slope south of Turquoise Lake. The portal is 4,500 feet S. 61½° W. of the northwest corner of sec. 18, T. 9 S., R. 80 W.

Figure 45 is a map of the adit. The wall rock is entirely granite, which is considerably sericitized and, adjacent to veins, somewhat silicified. The veins are in strong fissures that range from a few inches to 3 feet in thickness. Sphalerite and subordinate pyrite are the only

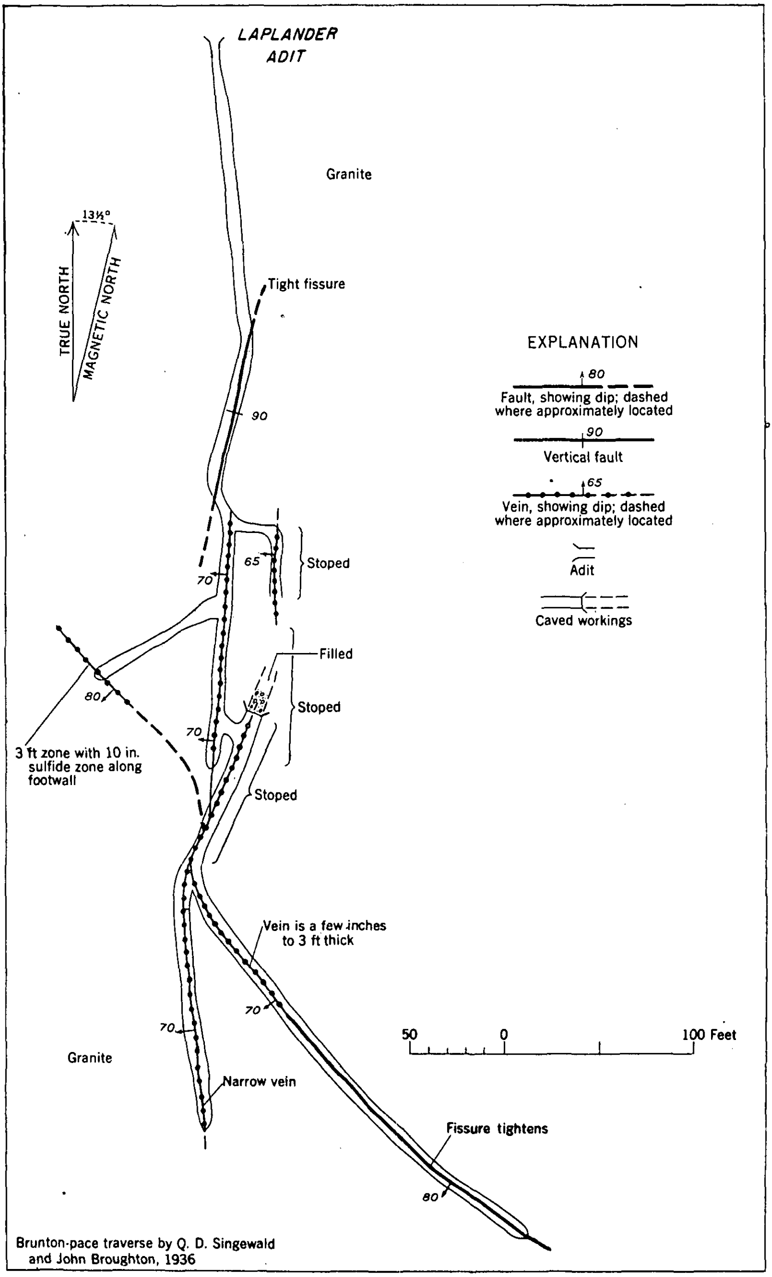

FIGURE 45.—Geologic map of Laplander adit, Lake County, Colo.

sulfide minerals seen. They occur intergrown with quartz and as granular masses and streaks within gouge. Pyrite also forms seams and impregnations in wall rock adjoining all veins. The ore is streaky and lenticular; in places, lenses more than a foot wide pinch out within a strike length of 50 feet. In a very general way, sulfide stringers and lenses are widest where the fissures are widest. The wall rock adjoining strong fissures is moderately broken by randomly oriented fractures.

BARTLETT MINE

The Bartlett mine is more than half a mile east of the Dinero; it probably was one of the subordinate producers of the Sugar Loaf district, yet not even a guess as to its aggregate output could be obtained. The early workings from the inclined Bartlett shaft (see pl. 26) remain unmapped, insofar as the author could ascertain, but a map of the underground workings of the Bartlett tunnel, made by J. Fred McNair, was available. This map shows a sinuous vein that averages about N. 40° E. in strike and 55° NW. in dip throughout its productive length of more than 300 feet. Ore apparently continued downward below the tunnel level, which is some 220 feet vertically below the collar of the main shaft.

Meager specimens of vein material on the dump of the Bartlett tunnel reveal an early-formed, light-colored chertlike quartz and also minor amounts of moderately coarse vein quartz transected by moderately dark chertlike quartz containing pyrite, sphalerite, and sparse galena. In addition, copper stain was seen on a few pieces of oxidized vein substance.

OTHER MINES

The Red Hook and Nellie C. vein in Little Frying Pan Gulch, according to Leadville information, yielded an aggregate output of about the same amount as the T. L. Welsh mine. This vein probably strikes a few degrees east of north; it may dip 75° NW., concordant with the inclination of the Nellie C. shaft.

The Black Iron vein, half a mile east of the Dinero, according to George S. Casey yielded noteworthy though now unkown quantities of ore from shallow workings during the early days. Later, the Black Iron shaft was sunk to the northwest of the formerly productive area; little success resulted from this venture. Two smelter settlement sheets for shipments aggregating $740 in net value, from the Black Iron property, averaged approximately: 0.15 ounce gold per ton, 50 ounces silver per ton, 2.4 percent lead, and 5.5 percent zinc. Material on the dump of the shaft is coated with moderate amounts of manganese stain.

Essentially no information could be obtained about either the Swisher vein or a more northerly trending vein located a few hundred feet to the west (See pl. 26 and figs. 41 and 42). The sizes of dumps suggest that both may have been productive, and the Swisher may even have been a medium-sized producer. Three shipments aggregating 70 tons from the Swisher mine about 1914–16 averaged 0.1

ounce gold per ton, 22 ounces silver per ton, 0.08 percent copper, and 0.9 percent lead; the zinc content is not known.

ST. KEVIN DISTRICT

ST. KEVIN MINE

The St. Kevin mine, in the west-central part of the St. Kevin district, is reported to have been one of the largest producers in that district. Its output may have totalled as much as a million dollars in value.

The earliest workings presumably were from shallow shafts along the outcrop of the St. Kevin vein. By 1890, as disclosed by a mine map of that date attributed to Jay A. Wilcox, the vein had been mined along two levels from the inclined St. Kevin shaft (see pl. 26), at depths of 217 feet and 256 feet, respectively, and also from a level at the bottom of the Grandview shaft (see pl. 26) which is 355 feet below the collar of the St. Kevin shaft. In 1914, the St. Kevin shaft was sunk another 60 feet or so, to explore below the 256-foot level in ground east of the Grandview workings, but neither the extent nor the result of this exploration is known to the author. The Rosse tunnel (see pl. 26) was driven, probably at about the same time, with intent to crosscut to the St. Kevin vein at a depth of more than 400 feet below the collar of the St. Kevin shaft; a survey made by McNair in August 1917 discloses that the Rosse tunnel had not reached the vein at that time, but it may have done so later.

It seems likely that the most productive part of the St. Kevin vein increased from a strike length of about 100 feet on the Grandview (355-foot) level to nearly 300 feet on the 256-foot level, and perhaps to as much as 700 feet close to the surface, and that the eastern margin of the shoot raked westward whereas the western margin was nearly vertical. This is inferred from the length and relative positions of levels shown by the map of 1890. The 217-foot level extended 60 feet eastward from the St. Kevin shaft and 360 feet westward; the 256-foot level extended 460 feet westward. The Grandview level extended only 120 feet along the vein westward from a point located 210 feet west of the St. Kevin shaft. About 350 feet west of the St. Kevin shaft, near the western margin of the main ore shoot, the strike of the vein in the mine workings curves from N. 80° E. to due east; about 40 feet west of the shaft it again curves to N. 65° E. The inclination of the St. Kevin shaft, which may represent the approximate dip of the vein, decreases from 50° near the surface to 36° at the 217-foot level, but then increases again to more than 40°, and the average dip from the 256-foot level to the Grandview level is about 55°.

An intermittent output aggregating 1,412 tons of ore reported from the St. Kevin mine during 1914–46 averaged 0.07 ounce gold per ton, 29 ounces silver per ton, 0.025 percent copper, and 0.4 percent lead. The zinc content is not known.

The mine is located well inside an area mapped as schist and gneiss, yet granite bodies less than 100 feet thick and numerous small pegmatite masses crop out in the vicinity. Intensely sericitized schist and gneiss, subordinate amounts of sericitized and silicified granite, and very minor amounts of altered White porphyry are found on the dump of the St. Kevin shaft. These rocks commonly are impregnated with accessory pyrite. The chief vein substance is chertlike quartz—in part light colored, in part moderately dark—which forms vuggy masses that replace and transect the rocks. Pyrite is widely distributed, commonly in the interior of the quartz veinlets. Sphalerite and galena are very scarce in material remaining on the dump but may possibly have been more widespread in the ore. A few pieces of vein material containing red, chertlike quartz were also found.

At two shafts along the St. Kevin vein and at several prospect pits 250 feet to the south, several pieces of limonite-stained, intensely altered rock were found to have anomalous radioactivity. The strongest anomaly, however, was only 3½ times background count.

GRIFFIN MINE

The Griffin mine is half a mile east of the St. Kevin mine, on the south side of St. Kevin Gulch. The aggregate output of the Griffin mine has been large—perhaps of the same order of magnitude as the St. Kevin, President, and Birdella mines, perhaps somewhat less. The mine workings include two main adits and a host of shafts and prospect pits, mostly up the hill from the upper adit. The portal of the upper adit is at altitude 10,588 feet, as shown by plate 26, and of the lower adit at approximately 10,390 feet. Still another adit, 150 feet below the lower main adit, apparently followed a vein 300 feet north of the Griffin and may have a crosscut extending over to the Griffin vein. All the mine workings were inaccessible during 1951, but the author gained access to part of the lower adit in 1936. No geologic map was made, because most of the accessible workings were timbered and the remainder were in severely broken, heavy ground; but observations made at that time to supplement a mine map showing most of the underground workings, provide considerable detail.

The bulk of the output apparently came from the main Griffin vein along a 750-foot stretch that extends westward from a point about 25 feet east of the portal of the upper adit. Within this stretch are many disconnected stopes of diverse sizes between the surface and the lower adit level, a vertical range of 370 feet. The mine map, which was made about 1917, shows stopes and sublevels within an aggregate of only a quarter of this area, but probably a great deal more of the ground actually had been mined in workings not accessible at that time. The largest individual stope has a maximum strike length of 160 feet and a vertical range of 280 feet. The strike of the vein in its most productive part averages about N. 75° E., but it seems to curve slightly at each end, as shown by plate 26. The average dip is about 73°.

Some output came from branches and auxiliary veins. For example, the mine map shows a stope 125 feet long and 90 feet high along an auxiliary vein trending N. 23° E., into the footwall of the main vein immediately east of its productive part. Moreover, the distribution of surface workings along the western part of the vein suggests that a branch may have been mined there.

An intermittent output aggregating 12,844 tons of ore shipped from the Griffin mine during 1915–39 averaged 0.09 ounce gold per ton, 19 ounces silver per ton, 0.02 percent copper, 2.9 percent lead, and 6.6 percent zinc. Smelter settlement sheets for less than a hundred shipments made during 1916–17 and aggregating some 30,000 dollars in value disclose the following ranges: gold, trace to 0.13 ounce per ton; silver, 6.6–107.7 ounces per ton; lead, none to 6.6 percent; zinc, 5–20 percent.

The vein fissure is as much as 6 feet wide within the limited area observed underground. Granite forms both walls, except at the western end, where the vein cuts at least one schist and gneiss outlier before it enters a main area of schist and gneiss and dies out. Rock within the fissure zone is severely shattered and in part pulverized to gouge; seams of the sticky gouge attain thicknesses of several inches. Slickensides seen on individual surfaces within the fissure zone mostly dip conformably with the fissure. Rock adjoining the fissure is broken by a myriad of randomly oriented fractures and numerous branching, transverse, and parallel faults, and is permeated by gouge films. Both within and adjoining the fissure zone, the rock is intensely sericitized and, locally, silicified.

Fine-grained chertlike quartz, mostly light colored, vuggy, and containing irregularly distributed fine-grained pyrite, forms streaks, layers, lenses, and veins within the fissure zone. Locally this vein material contains sphalerite and galena. Inasmuch as the light-colored, pyritic quartz is abundant on the dumps, it probably does not represent the ore that was shipped.

Radioactivity anomalies not exceeding four times background count were found on scattered pieces of oxidized material at places on the dumps.

PRESIDENT MINE

The President mine, near the mouth of Temple Gulch, may have had a total output of nearly a million dollars in value. Besides silver, lead is said to have been at noteworthy constituent of the ore. The only information available regarding the President mine was obtained from Mr. E. P. Chapman, of Leadville, who had pieced together bits of information from many local sources.

The President property was located in 1889 and worked until 1893. Most of the mining was done through the President shaft, said to be 175 feet deep; the shaft is located 400 feet S. 37° E. of the northwest corner of sec. 5, T. 9 S., R. 80 W. About 1892, the Reed shaft (see pl. 26) was sunk to a depth said to be 265 feet before a crosscut at the 175-foot level was driven to the President vein. Most of the high-grade ore came from the ground between these two shafts, a lateral distance of 550 feet, and above the 175-foot level.

The alinement of shafts and prospect pits suggests that the President vein strikes approximately N. 35° E. and that a secondary vein may exist about a hundred feet to the southeast. According to Chapman, the vein dips steeply to the southeast. The wall rock is prevailingly granite. The present water level in the President shaft is about 60 feet below the surface.

Feeble radioactivity anomalies were found only on limonite-stained surfaces of a few pieces of rock in a prospect trench south of the main President shaft.

AMITY MINE

The main Amity shaft, at altitude 10,085 feet between Gleason and Temple Gulches, is 890 feet S. 27° E. of the northeast corner of sec. 6, T. 9 S., R. 80 W. Extending to a distance of some 500 feet eastward and east-northeastward from the main shaft are a host of lesser shafts and prospect pits.

Mr. E. P. Chapman, of Leadville, who was working the mine in a small way in 1936, gave the following historical information. The Amity vein was discovered about 1887. The first work was done from a vertical shaft of unknown depth. A few years after the discovery, an inclined shaft was sunk to a vertical distance of about 160 feet. In 1907, the main shaft was sunk vertically to a depth of about 165 feet. From it, the Amity vein and also another vein about 50 feet south of the Amity were worked. Both veins were nonproductive, however, where cut by the Birdella tunnel, driven in 1916 from the mouth of Gleason Gulch. A 25-foot winze connected the bottom level of the shaft with the Birdella tunnel.

The aggregate value of output from the Amity mine, as estimated by Chapman, was about $350,000. Intermittent output reported for 1915–39 totaled 2,019 tons that averaged 0.25 ounce gold per ton and 10.7 ounces silver per ton. According to Chapman, the ratio of gold to silver, in ounces, in Amity ore has ranged from 1:20 to 1:200, in general somewhat higher than the average for the district.

The Amity vein is in an intensively sheared zone that ranges from about 1 foot to several feet in thickness; locally, it becomes a compound zone having even greater thickness. The trend is arcuate, as shown by plate 26, and the average dip is about 60° NW. Within the fissure zone, seams and layers of soft gouge alternate with crushed rock and with stringers, lenses, pods, and layers of pyritic quartz (essentially chalcedony). Both walls consist of shattered and intensely altered granite that readily crumbles. The hanging wall of the main fissure is fairly well defined, but the footwall in many places is obscure, owing to gradual decrease outward in the intensity of shearing.

Numerous films and layers of gouge, some as much as several inches in thickness, extend at oblique angles into the walls, though they are considerably more abundant in the footwall than in the hanging wall. In general, those in the hanging wall dip more steeply than the main fissure, those in the footwall dip less steeply. Many of these minor auxiliary fissures are mineralized. In fact, a substantial though subordinate part of Chapman's output during 1933–38 came from ore streaks in the footwall.

The best exposure of vein seen by the author was at the breast of the workings in 1936. It is not certain whether the vein exposed there was the Amity or a branch vein in the footwall. The fissure zone dipped 45° to the northwest and had rather well defined walls of moderately soft, highly altered, and shattered granite. Within the fissure zone was a layer of slightly broken, dark quartz and pyrite, 4 to 7 inches thick, underlain by 11 inches of dark-gray, soft gouge. The quartz-pyrite layer was bordered, both on the top and on the bottom, by a seam of pure pyrite less than an inch thick. A film of yellowish-gray gouge, in turn, separated the upper pyrite seam from granite of the hanging wall. Three streaks of dark-gray, mineralized gouge extended into the footwall, with strikes ranging from N. 75° E. to N. 80° W. and dips of 35°–40° to the north.

The ore mined at the Amity during the 1930's consisted in part of hard, pyrite-bearing, dark-colored chalcedony, and in part of soft, dark gouge. Generally, both the light-colored, pyrite-bearing chalcedony and white or yellow gouge are too lean to mine. However, the dark gouge becomes light colored after exposure on the dump. An extreme scarcity of sulfide minerals other than pyrite is characteristic.

The vein about 50 feet south of the Amity, cut on the 112-foot level, about 6 feet south of the main shaft, according to Chapman, was said to consist of 4 feet of gouge, with ore along both walls. This vein dips to the north, converges westward toward the Amity, and has one noteworthy branch into the footwall, diverging eastward, that was mined laterally at least a hundred feet.

Oxidation, according to Chapman, extended downward to depths of 25–65 feet. Pyrite in the veins extends upward to within 25 feet of the surface.

Feeble radioactivity anomalies were found on a few limonite-stained surfaces of altered granite apparently derived from the wall rock well away from a vein.

BIRDELLA MINE

The Birdella mine was a leading producer of the St. Kevin district, but no other information could be procured about it. In fact, the author is not even certain the trend of the vein is correctly depicted by plate 26 and figure 41.

WILKESBARRE MINE, INCLUDING ARTY AND SNOW WORKINGS

The Wilkesbarre adit, the Arty and Snow adit, a small intermediate adit, several shafts to the northeast, and a group of prospect pits constitute a single group of mine workings whose production came mostly from the Arty and Snow vein. The Wilkesbarre adit portal, at altitude of approximately 10,165 feet, in Shingle Mill Gulch, is 3,170 feet N. 28° E. of the southwest corner of sec. 6, T. 9 S., R. 80 W. The Arty and Snow adit, at altitude of approximately 10,300 feet, is about 330 feet northeast of the Wilkesbarre.

The Arty and Snow vein was located in 1884. No record of early output exists, nor is even a guess available, except that it probably was decidedly less than the early output of the Griffin, President, Birdella, and St. Kevin. From 1920 to 1923 work from the Arty and Snow adit yielded a gross output valued at about $15,000. Shipments averaged 8–30 ounces silver per ton, with gold, lead, and zinc essentially none.

The distribution of bedrock and float rock at the surface reveals a zone of chert along the southeastern boundary of a wedge of schist, which may possibly be along a major fault. This chert zone seems to die out southwestward within the main productive area of the mine workings, as shown by plate 26. Material on the dumps indicates that granite forms the immediate wall rock of veins throughout nearly all the underground workings.

A considerable part of the Wilkesbarre adit was accessible during 1951. Plate 27 is a geologic map of the workings. The granite wall rock is everywhere considerably broken by short, randomly oriented fractures, many of which contain gouge films. All the rock cut by the adit is intensely sericitized, but not very much silicified. The main vein was well exposed at only one locality, in a large chamber produced by caving at the northeast limit of accessibility. There it trends N. 55° E. and dips 70° SE. A central zone of crushed granite averages about a foot in thickness. Along the footwall is a 2–4 inch zone of dark-gray chert, only slightly broken. Along the hanging wall is a continuous seam of soft dark gouge, about a quarter of an inch thick, which is overlain by 1–4 inches of yellow gouge that interfingers with reentrants from the dark gouge; locally, the yellow gouge in turn is overlain by a film of dark gouge. A strong branch vein trends N. 15° E. and dips 55° SE. into the hanging wall. Granite between the main fissure and the branch is greatly crushed and moderately silicified. Elsewhere the walls are moderately firm. The exposure here described is at a nonproductive part of the vein; doubtless the vein is more complex elsewhere.

At a distance of about 170 feet from the portal (see pl. 27) is a strong fissure trending N. 50° E. and dipping 75° SE. The footwall is moderately firm granite, but the hanging wall is relatively soft and crumbly. This may be the southwestern continuation of the main vein. Neither the sulfide stringer located 24 feet to the southeast, nor the strong fissure 48 feet to the southeast were within access in 1951.

From data in the accessible adit supplemented by information from Mr. George S. Casey, of Leadville, by study of the mine map, and by observation of material on dumps, the following was deduced. The average trend of the Arty and Snow vein is about N. 57° E.; its dip 70° SE. The most productive part did not exceed 600 feet in length, nor extend much below the level of the Arty and Snow adit. The ore probably consisted partly of gouge, partly of somewhat crumbly pyrite-bearing chertlike quartz. Perhaps, as in the Amity vein, the darker varieties of gouge and quartz were richest.

Radon gas in the lower Wilkesbarre adit gave readings up to 10 times the background count outside the mine. In addition, anomalies were found on several types of materials on the dump and in the adit. The strongest anomalies were in rather friable vein substance and intensely altered fine-grained rock that may be a schist-granite hybrid, both found on the dump.

LAKEWOOD MINE

The Lakewood mine, on the Silver Queen vein, north of Lake Fork Creek, has been a very minor producer, but it was being worked intermittently during 1951, and therefore provided a sample of veins on the north side of Lake Fork. Like the Haphazard mine, 2½ miles to the west, but unlike the bulk of the mines in the Sugar Loaf and St. Kevin districts, the Lakewood ore is more valuable for gold than for silver—though the gold-silver ratio in ounces perhaps was only about 1:20.

The workings comprise three short adits, a shaft, and several prospect pits. The portal of the middle adit is 1,430 feet N. 76½° W. of the southwest corner of sec. 7, T. 9 S., R. 80 W. Figure 46 is a map of workings accessible in 1951—the lower adit is caved. The wall rock is an intensely sericitized, fine-grained facies of granite. The vein at the breast of the upper adit, where it is too lean for commercial exploitation, showed a 2-foot zone of somewhat broken, heavily py-

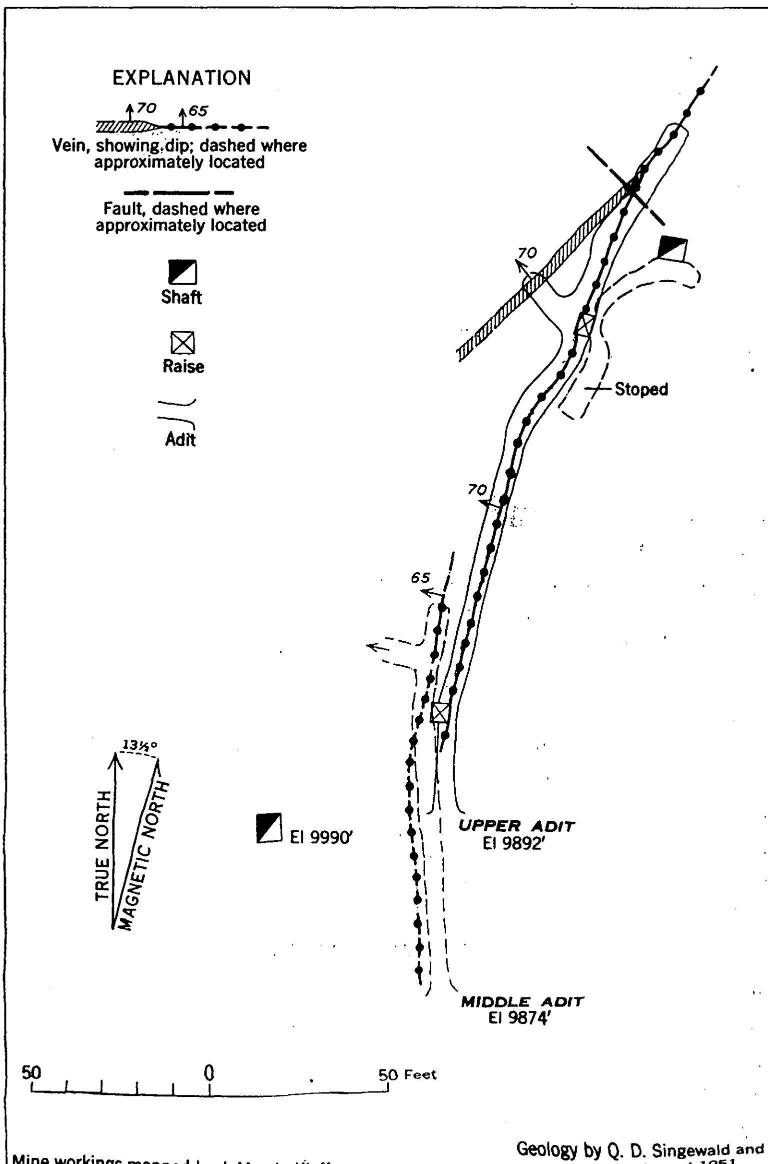

FIGURE 46.—Geologic map of Lakewood mine, St. Kevin district, Lake County, Colo.

ritized quartz, crushed rock, and gouge. The hanging wall is a well-defined fracture filled with gouge, whereas crushed rock extends for a foot into the footwall beyond the vein proper. At the breast of the middle adit is a fissure zone about one foot wide, composed of crushed rock, gouge seams, and disseminated pyrite. Both the rock and the gouge within the fissure, and also in the walls, are stained by limonite. A branch vein exposed in the short crosscut of the upper adit is a

3-foot zone of crushed and broken rock between seams of gouge; it contains pyrite seams and kidneys, and limonite-stained material along the footwall has a small content of gold.

Feeble radioactivity anomalies were found at only two spots, in limonite-stained soft material adjoining the vein.

HAPHAZARD MINE

The Haphazard mine, located near the foot of the cliffs north of Lake Fork 1¼ miles west of the boundary of plate 26, produced very minor amounts of ore more valuable for gold than for silver. About 1907 a shaft was sunk, and later an adit driven. The portal of the adit is about 200 feet north of the power line.

Neither the shaft nor the adit was accessible to the author. Information from a source believed reliable suggests that the vein was a well-defined fissure trending about N. 15° E. and ranging from a few inches to 2 feet in thickness. It was stoped for a strike length of about 110 feet northward from the shaft. About a hundred feet north of the shaft a nonproductive branch vein extended into the west wall. Most of the ore was limonite stained but contained pyrite. Numerous pyrite-bearing fissures are in the west wall, but none was productive.

TURQUOISE PROSPECTS

Turquoise has been found at four localities within a relatively small area in the northwestern and north-central parts of sec. 7, T. 9 S., R. 80 W., on the ridge between St. Kevin Gulch and the gullies draining into Saw Mill Park.

The Josie May prospect is 1,380 feet S. 24½° E. of the northwest corner of sec. 7. In 1936, there was an inclined shaft, 25 feet deep, and scattered small prospect pits in the immediate vicinity. By 1951, the shaft had been deepened, several pits immediately to the northwest had been enlarged, and a bulldozer trench extending 190 feet N. 74° E. from a point located 90 feet N. 10° W. of the shaft had been cut to a maximum depth of about 6 feet. The inclined shaft was filled with water to within 50 feet of the surface, measured along the 40° incline, in 1951. Judging by the volume of material on the dump, the shaft probably is not more than a hundred feet deep along the incline.

As shown by plate 26, the Josie May shaft is on a main contact between granite to the northwest and schist and gneiss to the southeast. A well-defined zone of chert that locally grades into silicified White porphyry lies several hundred feet to the south. Highly altered granite and somewhat less altered schist and hybrid granite-schist are found on the dump of the shaft, whereas only granite is exposed in the bulldozer cut. At the bottom of the shaft in 1936, turquoise was observed as films, blebs, veinlets, and irregular masses along fractures and also as impregnations within seemingly solid rock along a zone apparently trending about N. 65° E. and dipping 50° NW. Schist formed the hanging wall of the zone, granite and hybrid rock the footwall; hence, the zone is not the main granite and schist contact, or the relative positions of the rocks would have been reversed. The turquoise occurs within all three types of bedrock.

Along the center of the bulldozer cut is a concentration of rock fragments containing turquoise, but the remainder of the cut is essentally barren. In addition, turquoise was found in several small pits south of the cut. In these occurrences, the bulk of the turquoise occurs as gash veinlets and films along fracture surfaces.

The turquoise is accompanied by an abundance of a pale-green mineral (chrysocolla?) and, in some places, by small quantities of visible torbernite. Radioactivity anomalies ranging from 2–5 times the background count may be detected by Geiger counter on much of the rock associated with the turquoise.

An unnamed prospect, 750 feet N. 30° E. of the Josie May, is a cut that probably was excavated by bulldozer to a maximum depth of nearly 20 feet; the cut is about 200 feet long and curves from northeast to southwest, down the hill. Granite, considerably sericitized, is the only bedrock exposed. Turquoise and chrysocolla(?), not very abundant, show essentially the same mode of occurrence as in the Josie May cut. In 1936, two adits and one shaft, all caved, were alined to suggest that the turquoise zone trends about N. 10° E. One specimen collected then contained specks of torbernite. In 1951 the adits and shaft had been destroyed by a bulldozer cut and no torbernite was found. Radioactivity anomalies of rock in the cut rarely exceed 2–3 times the background count.

The Turquoise Chief prospect is approximately 2,000 feet N. 65° E. of the Josie May. In 1936, the prospect consisted of an inclined shaft 20 feet deep, a short adit, and a small opencut; in 1951, a wide opencut more than a hundred feet long, extending S. 20° W. down the hillside, had obliterated the former workings. Intensely sericitized and partly weathered granite is exposed. Turquoise and chrysocolla(?) are abundant in material on the dump and may be seen locally in place. They occur most commonly as gash veinlets and films along fracture surfaces, but they also impregnate the granite. The turquoise seen in 1936 was concentrated along a minor fault trending approximately N. 10° E. and dipping 40° SE., and in the wall rock to a distance of 10 feet from the fault. In 1951, exposures were too poor to decipher any structural setting; the trend of the main turquoise zone may possibly be east-northeast. The highest radioactivity anomaly found at the Turquoise Chief was in the east side of the cut in disintegrated granite that contains disseminated turquoise; an analysis of this material gave 0.017 equivalent uranium and 0.009 uranium.

The northeasternmost turquoise locality is 2,900 feet S. 76½° E. of the northwestern corner of sec. 7, or about 2,350 feet N. 76° E. of the Josie May. Turquoise and chrysocolla(?), as gash veinlets and films, and less commonly as impregnations, occur on most of the granite fragments on the dumps of a short adit and a shallow shaft, both caved. The granite is seriticized and partly weathered. Radioactivity anomalies greater than 3 times background count were exceedingly rare.

PETROGRAPHY OF THE BEDROCK

By John G. Broughton

A petrographic study of the bedrock of the Sugar Loaf and St. Kevin districts was made during 1937–38 in partial fulfillment of requirements for the Master of Science degree at the University of Rochester. Additional details may be obtained from the thesis itself.[2] Approximately 55 thin sections were prepared from more than a hundred hand specimens collected during the summer of 1936. The veins and their immediate wall rocks were not studied.

SCHIST AND GNEISS

A diversity of facies, ranging from relatively pure schist to injection gneiss (migmatite) containing as much as 50 percent admixed pegmatite, granite, and aplite, constitutes the bulk of the schistose rocks of the Sugar Loaf and St. Kevin districts. The admixed material is interlaminated with schist in layers ranging from paper thin to more than an inch thick. Other types of rock, such as quartzite and metalamprophyre, are scarce.

Biotite schist and related facies containing muscovite, quartz, and sillimanite represent the relatively pure schist. Abundance and alinement of brown biotite determines the foliation. Where the schist has been mildly altered by hydrothermal action, brown biotite has been converted to green biotite and chlorite, the latter commonly being impregnated by leucoxene. Muscovite commonly replaces biotite, but in some places forms microscopic bands parallel to it. Clusters of sillimanite needles and aggregates of minute grains of zoisite interweave with the micas in contorted schist, but form parallel interlaminations in noncontorted varieties. Quartz occurs as anhedral grains, which commonly contain inclusions of the other essential

[2] Broughton, J. G., 1938, Petrology of the Sugar Loaf-St. Kevin mining districts, Lake County, Colo., 184 p., unpublished thesis, available in the library of the University of Rochester, Rochester, N. Y.

minerals; in places, planes of the inclusions conform with adjoining foliation as to strike and dip. Zircon, in rounded grains, is the most abundant accessory mineral. Other minerals noted in one or more thin sections are albite, apatite, magnetite, sericite, and epidote, and the lithium minerals spodumene and eucryptite.

In typical gneiss, laminae composed of quartz, plagioclase, microcline, and, locally, orthoclase, in grains averaging about 0.5 millimeter in diameter, alternate with laminae of biotitic schist. The ratio of plagioclase to potash feldspar differs greatly in different specimens. Most of the plagioclase has a composition of about An_{25}.

Spotted schist represents a hybrid rock found in places near the contact of schist and gneiss with granite. As seen with the naked eye, the rock has a dark-gray, fine-grained matrix containing scattered poikiloblasts of labradorite, alone or intergrown with quartz, and flakes of biotite. Under the microscope, large grains of labradorite, biotite, and hornblende, as much as 2.5 millimeters in length, are seen embedded in a matrix of quartz and labradorite. The labradorite poikiloblasts tend to be greatly corroded by quartz. Some contain inclusions of apatite, zircon, hornblende, and biotite. Accessory minerals, besides apatite and zircon, include magnetite, titanite, and allanite.

Only a few specimens of quartzite were studied. They range in color from white to gray; in all, biotite is visible, and several show tiny grains of garnet. Microscopically, the quartzites are seen to be feldspathic. In some, the predominant feldspar is plagioclase (oligoclase-andesine), whereas in others microcline and orthoclase predominate. Muscovite, biotite, and chlorite normally are present. Especially characteristic is spessartite (garnet), in subhedral to rounded grains 0.15–0.45 millimeter in diameter. Quartz has evidently been partially recrystallized, as it corrodes feldspars.

One specimen of an unusual schistose rock probably is a metalamprophyre. It is a soft massive schist, dull green in color, containing large crystalloblasts of rusty muscovite. It is stained by limonite. In thin section, the groundmass is seen to be a felty mixture of chlorite, sericite, and minor amounts of quartz. Muscovite forms large crystalloblasts, and in addition replaces chlorite of the groundmass. Other minerals are apatite, which is very plentiful, zircon, sericite, and hematite.

GRANITE

The relative proportions of the feldspars, as determined by modal analyses, indicate that the rock mapped as granite is more truly a quartz monzonite than a granite. This accords with a statement by Stark (1935, p. 8) that "In the majority of the sections studied, the proportion of the feldspar indicates a quartz monzonite." However,

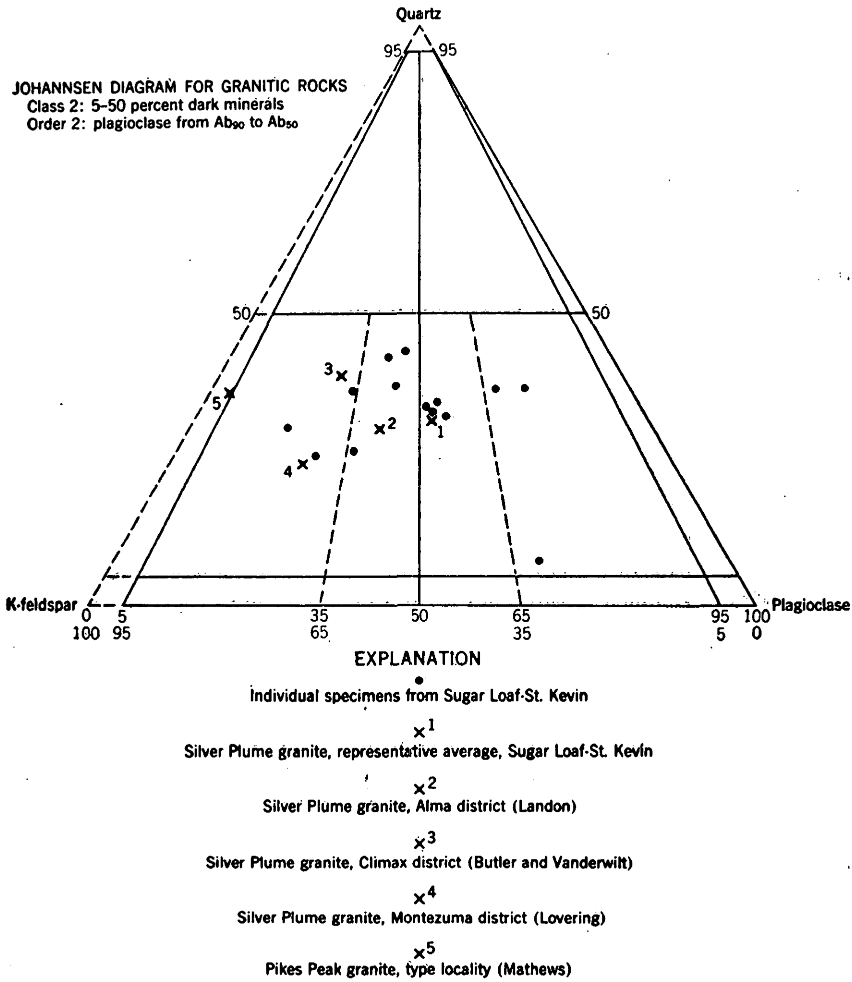

FIGURE 47.—Modal composition of some Colorado granites.

since the rock is correlated with the Silver Plume granite by Stark, the name "granite" is here retained.

Fourteen thin sections of fresh specimens of the granite were analyzed quantitatively by means of a Wentworth mechanical stage. Each analysis has been plotted on a Johannsen (1931, p. 140–158) diagram, figure 47. In addition, the average of the most representative analyses has been plotted on the same diagram and compared with approximate analyses of the Silver Plume granite from neighboring localities and with the Pikes Peak granite as described by Mathews (1900, p. 219) from the type locality. Compared with typical Silver Plume granite, the rock of the Sugar Loaf and St. Kevin districts has less potash feldspar, correspondingly more plagioclase feldspar, and approximately the same content of quartz and mafic minerals.

The potash feldspars include microcline, orthoclase, and microperthite, listed in order of their abundance. Microcline commonly occurs in Carlsbad twins, 4–5 millimeters long. Orthoclase, in general, is in smaller grains. Several different types of microperthite were noted, but the slender spindles "string" type (Alling, 1938, p. 162) and the S-shaped blebs type are most common. The potash feldspars contain scattered inclusions of biotite and plagioclase. Small ovoid blebs of quartz occur as replacements in many grains, especially in the larger Carlsbad twins. None of the potash feldspars is heavily sericitized.

Plagioclase commonly lies in the andesine range (An_{30-35}), although more albitic types are found in some specimens. Albitic rims are not infrequently found. Most grains range from 0.5–1.5 millimeters in longest diameter, although some grains were found as much as 2.5 millimeters in diameter. Myrmekite usually is found where plagioclase protrudes convexly into potash feldspar. In certain localities plagioclase is replaced by potash feldspar and quartz. The albitic rims normally have not been sericitized, whereas the more calcic cores may be intensely replaced.

Quartz forms interstitial grains of about the same size as plagioclase. Little cataclastic effect was noted in the normal facies, but undulatory extinction is the rule. Most inclusions are too minute to be determinable, but rutile occurs in long hairlike needles. Other inclusions commonly are alined in streaks, though they show no particular orientation. A few small cavities with liquid inclusions show Brownian movement.

Essential mafic minerals are biotite and magnetite. Biotite, the first essential mineral to have crystallized, ranges from 0.5–1.5 millimeters in length. Although fresh brown biotite is found here and there, most flakes have been altered to the green variety or to chlorite, with release of minor titaniferous minerals. Some of the magnetite crystalized early, in euhedral grains, intergrown with biotite; but most of it crystallized late, in irregular grains, interstitial to all the other essential minerals.

Accessory zircon forms slender prisms or short, stout grains, both with pyramidal terminations. Apatite forms hexagonal prisms. Muscovite replaces biotite, is localized at biotite contacts, and forms randomly distributed, large corroded flakes in which fluorite fills some of the holes. Topaz is found in rounded grains 0.5 millimeters or less in diameter; never do more than four or five grains appear in one thin section.

Apparently the first and most widespread stage in hydrothermal alteration of the granite resulted in gradual conversion of brown biotite to green biotite and then to chlorite. Shredded flakes of intergrown chlorite and green biotite are characteristic of this stage. They contain titanite and titaniferous magnetite in aggregates and lenses; sagenitic mats of tiny rutile needles are less common. Leucoxene, developed by weathering, now coats most grains of these three minerals.

Not a single granite specimen collected either on Sugar Loaf or St. Kevin is entirely free from sericitic alteration. The most prominent effect is noted in the plagioclase feldspars. They become more and more altered to sericite as a zone of more intense alteration is approached, until determination of the original composition becomes impossible. Intensely altered plagioclase grains seem to have acted as centers from which alteration then spread in all directions. However, albitized rims remain fairly clear even where the remainder of the plagioclase has been completely altered. Microcline has likewise resisted alteration, for it normally is quite fresh except along grain borders, around inclusions, and along fractures.

Concurrently with development of sericite in plagioclase, chlorite and biotite became bleached. In some flakes, the presence of released titanite and titaniferous magnetite and a somewhat ragged "older" appearance of the bleached mafic minerals offer the only criteria by which they may be distinguished under the microscope from original muscovite. Where sericitization and bleaching have been most intense, aggregates of small euhedral grains of pyrite commonly are found.

Silification perhaps represents a still more extreme process of alteration, localized adjacent to fractures. It transforms the dull, soft white sericitized rock to a dense, brittle, light-gray rock containing glassy quartz pseudophenocrysts and quartz-lined vugs. This rock usually is shattered and iron stained. In thin section, preexisting minerals are seen to be shattered and replaced by chalcedony. Plagioclase feldspar has been broken into small angular fragments and to a great extent replaced by chalcedony. Residual quartz, though showing no evidence of recrystallization prior to shattering, nevertheless seems to be coarser than in the unaltered granite and also has more prominent lines of inclusions. Biotite has been completely bleached. The secondary quartz ranges in grain size from chalcedony 0.01 millimeter in diameter to comb quartz about 0.1 millimeter in length, which lines the vugs.

PORPHYRY

Only one general type of rock, designated as White porphyry, has been found in the Sugar Loaf and St. Kevin districts to represent the early Tertiary igneous rocks of the northeasterly belt of intrusive porphyries first recognized by Ball (Spurr and Ball, 1908, p. 67 and pl. 11). The typical rock is intensely jointed, and where fresh shows a dense groundmass having light-gray, faintly greenish color, in which phenocrysts of feldspar, white mica, and quartz are scarce. Hydrothermal alteration has produced at some places a soft, nearly white rock that resembles limy sandstone and at other places a hard chert. Weathered surfaces commonly show small pits or yellowish-white spots where phenocrysts formerly existed. Dendrites of black manganese stain on weathered surfaces, though abundant at Leadville (Emmons, Irving, and Loughlin, 1927, p. 44 and pl. 35C), are not common in the Sugar Loaf and St. Kevin districts.

As seen under the microscope, the groundmass consists of anhedral grains of quartz and orthoclase, most of which range in grain diameter from 0.05–0.1 millimeter but a few of which are as small as 0.02 millimeter in diameter. Both minerals contain inclusions of fine-grained sericite. This sericite probably represents original microlites of plagioclase. In addition, coarser grains of sericite are liberally scattered throughout the groundmass, in part interstitially. Identification of the constituent minerals of the groundmass is difficult, because the grains are so small and so beclouded with inclusions. However, contrasts in relief between minerals of different indices suggest that quartz is much more abundant than orthoclase, in some specimens perhaps nine times as abundant.

In several slides a distinct "flow" banding is caused by segregations of clearer, finer grained groundmass material (quartz?). In one thin section, however, quartz in segregated bands is slightly coarser than in the remainder of the groundmass. This banding is supplemented in another section by subparallelism of the coarse sericite of the groundmass and of the lathlike biotite phenocrysts.

Phenocrysts of plagioclase are common in most thin sections. They range from 0.3–3.0 millimeters in length, and average 1 millimeter. Some are subhedral, but most are euhedral. All are intensely sericitized. In spite of the alteration, faint twinning and zoning may be seen here and there. An extinction angle of 11° was obtained on one crystal. Assuming, from the total mineralogy, that the plagioclase is albitic, such an angle would suggest a composition of about An_{10}. In one thin section, two clear untwinned crystals of albite were noted.

Biotite mostly occurs in long lath-shaped phenocrysts 0.5–1 millimeter in length. They have been rather completely bleached with the release of titanite, sagenitic rutile, and titaniferous magnetite. These titanium minerals have become coated with leucoxene. Textural relations indicate that the crystallization of biotite overlapped that of plagioclase, but in general lasted longer.

Quartz crystallized in clear, subround phenocrysts averaging 0.5 millimeter in diameter. These phenocrysts now have borders of optically continuous quartz, heavily impregnated by sericite, that are

0.1 millimeter or less in width. Very rarely does the sericite impregnate the interiors of these composite grains. According to Patton (1912, p. 74), in White porphyry of the Alma district

> a definite relationship exists between the width of the border and the size of the grains constituting the groundmass. The larger the grains of the groundmass, the wider is the border around the quartz phenocrysts.

He also states that the quartz phenocrysts have been corroded and that the groundmass material is all secondary, the result of recrystallization.

Zircon is a common accessory mineral. Apatite was occasionally noted. One small euhedral crystal of pigeonite was identified. Jarosite(?), carbonate, and limonite are secondary.

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