Geology and Mineral Deposits of the Area South of Telluride Colorado

GEOLOGICAL SURVEY BULLETIN 1112-G

Prepared in cooperation with the Colorado State Geological Survey Board and the Colorado Metal Mining Fund Board

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By JOHN S. VHAY

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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By John S. Vhay

ABSTRACT

An area between Telluride and Ophir that has had considerable mineral production has been studied as part of the resurvey of the mineralized region of the San Juan Mountains.

The youthful topography, with a total relief of almost 5,000 feet between the peaks and the bottoms of the canyons, is the result of erosion that followed several periods of uplift of the San Juan peneplain, with repeated glaciations that formed a fretted upland. Melting of the frozen matrix of the extensive talus is an important factor in the formation of several types of rock streams. Considerable soil covers the old upland surfaces and the floors of the glacial basins.

Gently dipping sedimentary rocks of Permian, Triassic, Jurassic, and Cretaceous age are overlain with slight angular unconformity by nearly flat-lying Tertiary sedimentary and volcanic rocks. These layered rocks have been invaded by dikes, plugs, and stocks of rocks of intermediate composition.

The older sedimentary rocks are correlated with the upper part of the Cutler formation, the Dolores formation, the Entrada sandstone, the Wanakah and Morrison formations, the Dakota sandstone and part of the Mancos shale. The Telluride formation is at the base of the Tertiary section, and the remainder of the section is volcanic in origin. As this area is on the west flank of the great San Juan volcanic pile, west of the Silverton caldera, the section contains only a few of the volcanic units recognized farther east; the San Juan breccia, Eureka rhyolite, Burns latite, and Potosi volcanic series have been mapped. The San Juan breccia is the thickest unit of the section and consists of a few hundred feet of waterlaid tuff overlain by nearly 2,000 feet of volcanic breccia, much of which may have come into this area as volcanic mudflows. The Eureka rhyolite is represented by latite flows overlain by breccia. The Burns latite locally is a basal volcanic conglomerate, which is overlain by breccias and flows; in the eastern part of the area a few thin flows possibly representing the pyroxene andesite have been mapped with the Burns latite. The Potosi volcanic series consists of an alternation of quartz latite "flows," and rhyolite "flows," that may actually be welded tuff beds.

The intrusive rocks consist of: two stocks, one a composite intrusion of diorite and monzonite, the other composed only of diorite; several small plugs of diorite or monzonite; a number of andesite and latite dikes, concentrated especially in the southwestern part of the area; several small intrusive masses

and plugs of quartz-feldspar porphyry in the southeastern part of the area. Breccia pipes are associated with some of the porphyry plugs.

The structures in the area were produced by two main periods of diastrophism. Tilting to the northwest and some faulting took place in pre-Tertiary time, probably during the Laramide revolution. In late Tertiary time a slight tilting to the east and much fracturing took place; some of this fracturing is associated with the formation of the Silverton caldera, both as radial fracture zones and as fractures concentric to the caldera. Other fracturing is related to the intrusive bodies in the southwestern part of the area. Between the caldera and the general area of quartz-feldspar porphyry intrusions in the southeastern part of the area is a zone of horsts and grabens. A complex graben in the western part of the area and a few major faults elsewhere are not obviously related to either center of structural influence.

The first claims were staked in this region about 1875, and the early development of small mines in the near-surface oxidized ores was rapid. The advent of a railroad in 1890 further spurred development of the mines. Although only a few large mines were developed, there were many small operations.

In general gold has been produced from westward-trending veins in the north half of the area, and silver and base metals from veins of variable trends in the south half of the area; notable exceptions are the Gold King and Suffolk mines in the southwest part of the area, which yielded much gold. Gold has been produced from quartz veins, which generally contain pyrite and in places a little galena. The silver and base-metal veins contain galena, chalcopyrite, tetrahedrite, sphalerite, and pyrite in a gangue consisting of quartz, ankerite, barite, and, in places, fluorite, rhodochrosite, or gypsum. Sparse molybdenite and hubnerite are found at a few places.

The ore deposits are fracture fillings; most occur at the intersections of well-defined fracture zones with massive, moderately resistant rocks. The most important hosts for ore are the San Juan breccia and the Cutler and Telluride formations; less important hosts, because they are thinner, are the breccias of the Eureka rhyolite and of the Burns latite.

The relative amount of cover appears to have had little influence on the formation of ore bodies. Rich ore has been mined in Bear Creek and the valley of Howard Fork in pre-Tertiary rocks below an altitude of 10,000 feet and as high as 12,400 feet in the volcanic breccias around Gold King Basin and elsewhere. The Potosi volcanic series is an exception in that it fractured so thoroughly, probably because of a lesser load, that ore solutions entering the rock were diluted and few ore deposits formed.

INTRODUCTION

This report describes the geology and mineral deposits of parts of the Upper San Miguel and the Iron Springs mining districts, San Miguel County, Colo., the area that lies between the San Miguel River on the north and the Howard Fork of the San Miguel River on the south, and between the divide on the east side of the San Miguel drainage on the east and the area covered by the Silver Mountain landside (fig. 24). This area is called the South Telluride area in this report, and includes about 24 square miles that was mapped in detail. Most of the accessible underground workings of

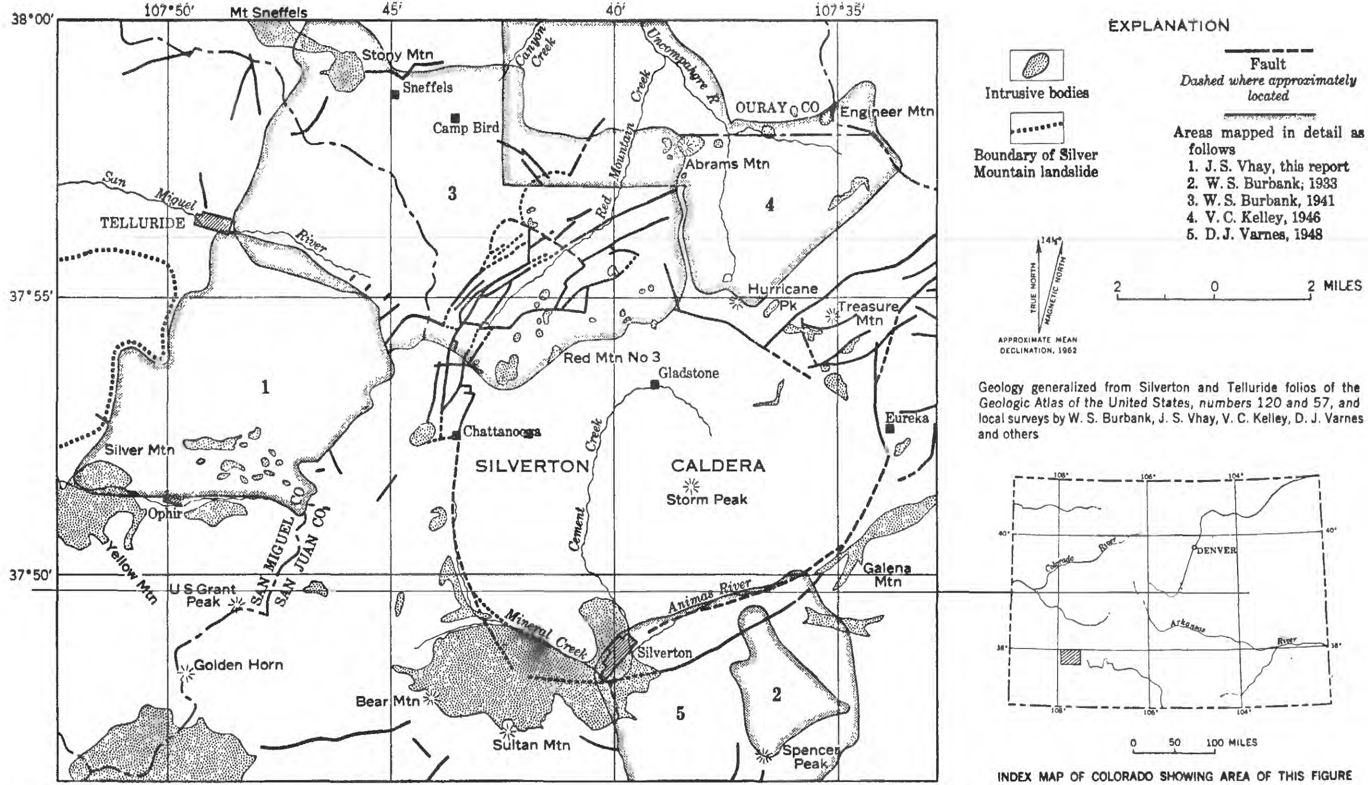

FIGURE 24.—Index map of Silverton caldera and vicinity, showing areas covered by reports by W. S. Burbank, V. C. Kelley, D. J. Varnes, and this report.

the mines were also mapped and studied. The drainage basins of Bridal Veil and Bear Creeks, as well as the slopes on the north and northeast sides of Howard Fork, and the headwater areas of Turkey and Prospect Creeks are in the area. Altitudes range from about 8,700 feet on the San Miguel River at the northwest corner of the map to 13,661 feet on Lookout Peak, at the southeast edge of the map. The whole region lies within the Montezuma National Forest.

The work on which this report and map are based is part of a larger project by the U.S. Geological Survey in cooperation with the Colorado State Geological Survey Board and the Colorado Metal Mining Fund Board to restudy the geology and mineral deposits of the whole San Juan Mountains area.

FIELDWORK

A plane table and telescopic alidade were utilized in mapping the area, using the triangulation points shown on preliminary topographic maps for primary control. The smaller mines and prospects were mapped during the surface mapping. The accessible older parts of the Alta and St. Louis mines were mapped mostly in the fall of 1938, and mapping of the newer workings was brought up to date in 1941 and 1942.

E. H. Bailey assisted the author during the 1938, 1939, and 1940 field seasons; S. A. Feitler and L. A. Warner for part of the summer in 1939; and in 1941, H. P. Darley and G. R. Prichard served as assistants for the whole summer and Vincent Suarez-Horton for about a month. In 1942 the author assisted by D. J. Varnes, J. W. Odell, and J. W. Gabelman, started mapping the valley of Howard Fork; Varnes was left in charge of the party when the author found it necessary to devote his efforts to wartime investigation of strategic minerals. Fieldwork was resumed in 1947 when the author, assisted by L. T. Silver, filled in gaps in the map and checked some previous mapping.

ACKNOWLEDGMENTS

Many people of Telluride and vicinity were helpful to the party, and it is a pleasure to acknowledge our debt for their assistance. The officials of the Alta mine supplied living quarters and maps to the members of the party several times. Telluride Mines Inc. (then called Veta Mines Inc.) furnished quarters at their Blue Lake bunkhouse a part of one summer. Isaac Partenan supplied maps of many mines, some of them now inaccessible. Abe Wood assisted in underground mapping at the Alta mine. Mayor Noyes of Ophir supplied information on the local mines. Buck Lill shared his living quarters with the party in Jackass Basin in 1940 and 1941, as did Messrs.

Chenoweth and Loomis in 1947 when the higher part of the northeast end of the valley of Howard Fork was being mapped. Several other prospectors were helpful to the party at various times.

Within the Geological Survey, the author credits W. S. Burbank for general supervision of the project and for field conferences, D. J. Varnes for office compilation work on the map and for preparing the information on early work in the area (p. 296), and E. P. Kaiser for microscopic study of the intrusive rocks.

GEOGRAPHY

CLIMATE AND VEGETATION

The San Juan Mountains are well watered, although the San Miguel Plateau, an eastern part of the great Colorado Plateau immediately to the west, is semiarid. Precipitation in the mountains is as much as 40 inches per year (Cross and Larsen, 1935, p. 10). Deep snow accumulates in the higher regions, and, because of the steep treeless slopes, snowslides are frequent and are serious handicaps to mining operations throughout the whole area. The deep snow melts slowly and much is still present at late as early July. On the north-facing steep slopes, and especially in the narrow, steep chutes cutting them, some snow may remain throughout the year. The months of May, June, September, and October are fairly dry, but during July and August thunderstorms occur almost daily.

The daily temperature has a wide range, and the nights are always cool. According to Cross and Larsen (1935, p. 10),

> The summer temperatures are moderate, the average for July and August being a little over 60°. Temperatures as high as 100° have been recorded, but the altitude is so great and the air so dry that it is comfortable in the shade even on the hottest day * * *. The average temperature in January is from 13° to 20°, but temperatures as low as —34° have been recorded * * *. Frosts are not uncommon in June and September, and they have been recorded for every month of the year.

The types of vegetation in the area have a close relation to the altitude. The abundant moisture supports a heavy forest cover, especially on the north- and northwest-facing slopes. Spruce, intermixed with some pine and fir, is most common. Aspen grows in groves along the water courses, and, together with a thick cover of brush, has overgrown large areas where the coniferous trees have been removed by either forest fires, snowslides, or the intense logging which has been done in the area, especially near the mines. Near timberline the spruces become stunted, twisted, and sparse.

Timberline generally lies between 11,500 and 12,000 (Cross and Purington, 1899, p. 1), approaching the higher altitude only on the north-facing slopes and falling below the lower altitude on the drier south-facing slopes.

The north side of the valley of Howard Fork has relatively few conifers, except for a zone between 11,000 and 11,600 feet, where there are fairly dense growths of conifers on the small ridges between the gulches. The rest of the north side of the valley is covered with dense aspen groves and brush thickets up to an altitude of about 11,300 feet; grass and wild flowers grow abundantly between the thickets.

Stunted willows grow along the water courses for a considerable distance above timberline. The rest of the country, except for the cliffs and talus slopes, is covered by short grasses and alpine-type flowers; in places they grow in great profusion, and the variously colored Indian paintbrush and other wild flowers form beautiful carpets of brilliant color when in bloom. The alpine flowers become smaller and smaller at higher altitudes, but a few dwarfed plants are on even the highest peaks.

ACCESSIBILITY

The region is reached by State Highway 145, from Dolores through Rico, Ophir Loop, and Placerville to Naturita; State Highway 62 connects Placerville with U.S. Highway 550 at Ridgway. State Highway 108 goes from Highway 145 past Telluride to Pandora, and Highway 134 from Ophir Loop up the Howard Fork past Ophir, over Ophir Pass and connects with Highway 550 north of Silverton. There are less-traveled roads from Pandora to the top of Bridal Veil Falls, up Bear Creek as far as the Maryland mill, and into Palmyra and Gold King Basins.

Because of much mining activity in the past, there are fairly good trails up the canyon of Bridal Veil Creek and into the basins tributary to it and other trails wind up through La Junta Basin and along Bear Creek to its east fork. Trails follow the crest of Gold Hill and traverse Prospect Basin. There are also, of course, trails to all the mines or prospects of any size throughout the area; these trails are still generally passable, except in areas where talus movement has destroyed them.

Aerial trams were used a great deal by mining companies because the steep slopes, talus, and winter snowslides made road building and maintenance difficult. The only tram in operation as recently as 1947 goes from the top of Bridal Veil Falls to a point on the road to the falls at an altitude of about 9,450 feet; the Palmyra-St. Louis tram to the Alta mill, and one from that mill to Ophir Loop were in operation as late as World War II. The cables of the tramway from the Carbonero mine to the mill were still up in 1947.

DEVELOPMENT OF WATERPOWER

This area has the distinction of being one of the first places where electrical power was transported fairly long distances. As Chester Purington wrote in 1897 (Cross and Purington, 1899, p. 15) under the heading "Recent Progress."

> The electric transmission of power generated by water has attained important development. Stamp mills are operated by electric power at distances of more than 10 miles, in a straight line, from the generating station, near Ophir Loop, and at elevations of 2,000 or 3,000 feet above the source of the power.

A powerplant that uses water from both Howard Fork and Lake Fork of the San Miguel River is still in operation below Ophir Loop.

The Telluride Mines, Inc., has an extensive system of dams and pipelines for water conservation and use in Bridal Veil Basin. Power generators are located at the top of Bridal Veil Falls and at the mill at Pandora. Dams to conserve water for use during low-water periods have been built at Lewis Lake, Mud Lake, and Silver Lake. A tunnel, located on the next flat below the rock lip of Blue Lake, taps the lake at considerable depth and serves as the starting point for the pipeline to the power plant at the head of Bridal Veil Falls. Blue Lake itself is further supplied with water by pipelines from Lewis Lake and from the west branch of Bridal Veil Basin (locally called Double Eagle Basin). The vertical drop from the surface of Blue Lake to the generator at Bridal Veil Falls is roughly 1,900 feet; from Bridal Veil Falls, where the water from the tailrace of the generator and also from Bridal Veil Creek enters a large pipe, down to the generator at the mill is another drop of 1,200 feet.

Some additional waterpower is available in the district from Bear Creek and smaller streams like Deertrail, La Junta, Prospect, and Turkey Creeks, but, although the fall is great, the water supply is extremely variable, ranging from flood conditions every spring and early summer to very low stages in the fall and winter. Because of these conditions, Telluride Mines, Inc., has made an effort to conserve water in Bridal Veil Basin.

TOPOGRAPHY

The country between the San Miguel River and the Howard Fork of the San Miguel River is extremely rugged. About 17 peaks in this small area stand at altitudes between 13,000 and 13,661 feet (the altitude of Lookout Peak), whereas the altitude of the San Miguel Plateau to the west ranges from 10,000 feet near the mountains to 8,000 feet farther west.

The two main drainage lines are the nearly straight valleys of the Howard Fork and the San Miguel River, which trend westward out of the mountains. From an altitude of 10,517 feet (Beaver Lake) at its east end, the valley of Howard Fork descends to about 9,200 feet at its west end at Ophir Loop. Only a number of steep talus-filled gulches cut the north side of the valley, but two larger tributaries, Swamp Creek and Waterfall Creek, do enter the Howard Fork from south of the map area.

The valley of the San Miguel River descends from an altitude of about 9,000 feet at its head, east of Pandora, to 8,600 feet 6 miles west, where the river plunges down to join the South Fork, cutting the deep canyon that continues through the San Miguel Plateau. The two large tributaries, Bridal Veil and Bear Creek, flow northward into the San Miguel River, and Prospect and Turkey Creeks flow northwestward out of the mapped area.

This whole mountainous region has been glaciated into a fretted upland. Only a few small patches of probable remnants of the preglacial topography remain. Among these are the high rounded areas south of the Gold King Basin, the upper part of Gold Hill and the area around Green Cone, the east side of La Junta Peak, the area southwest of Bridal Peak between altitudes of 13,100 and 13,200 feet, and the hill north of Silver Lake Basin (altitude 12,270 feet). These small areas appear to have somewhat more soil cover and have not been deeply scoured by ice. Some of them may be parts of the San Juan peneplain or of the landscape formed during the Florida erosion cycle, older erosion surfaces now represented only by gently sloping remnants in the higher mountains (Atwood and Mather, 1932, p. 21–29).

In the whole region most of the ridges around the cirques are aretes, with cols between them at altitudes between 12,840 and 13,160 feet. Most of the high points in the area are typical horns; the more prominent ones are listed below together with their altitudes (asterisks indicate triangulation points):

	Altitude (feet)
Lookout Peak*	13, 661
Unnamed peak, north of Lookout Peak	13, 614
Wasatch Mountain*	13, 555
Bridal Peak*	13, 510
Three Needles*	13, 481
La Junta Peak	13, 472
Silver Mountain*	13, 470
Palmyra Peak	13, 319
Ballard Mountain	12, 804

In addition to these peaks, at least seven more horns in the mapped area stand above 13,100 feet.

GEOLOGY

SUMMARY

The bedrock in the area south of Telluride can be classified into three main types—sedimentary rocks, volcanic rocks, and intrusive igneous rocks (pl. 16). Most of the sedimentary rocks are pre-Tertiary (late Paleozoic and Mesozoic) in age: one sedimentary formation and all the igneous rocks are Tertiary in age.

The pre-Tertiary sedimentary rocks comprise the Cutler formation (Permian), the Dolores formation (Triassic), the Entrada sandstone and the Wanakah and Morrison formations (Jurassic), and the Dakota sandstone and Mancos shale (Cretaceous). Most of these formations crop out along the bottom and lower sides of the canyons of Bear Creek and the San Miguel River. Some are also on the lower part of the west side of the Ophir Needles, and in the valley of Howard Fork as far east as Beaver Lake. The rocks are much metamorphosed around an intrusive body that comprises the Ophir Needles.

The Telluride formation is at the base of the Tertiary section, between the pre-Tertiary sedimentary rocks and the Tertiary volcanic rocks. Unless covered by landslide material, the formation crops out in an imposing cliff almost everywhere, except in the eastern part of the valley of Howard Fork where intense hydrothermal alteration has weakened it.

Except for a relatively small area underlain by dikes and stocks, the Tertiary volcanic rocks form the bedrock of the remainder of the mapped area. The San Juan breccia at the base consists in large part of pyroclastic material; the Eureka rhyolite contains some flows but is more than half pyroclastic material; the Burns latite consists mostly of flows, and the Potosi volcanic series is made up mostly of thick "flows," some of which may be welded tuffs.

Most of the intrusive plugs, stocks, and similar intrusive bodies are found only in the valley of Howard Fork or in an area within a relatively short distance north of it. Diorite intrusions occur as two fairly large stocks, 6,000 to 8,000 feet in greatest diameter, and several smaller bodies are in the western half of the valley and in the area to the north. Quartz-feldspar porphyry occurs as one or more poorly exposed but fairly large bodies and small plugs in the valley of Howard Fork east of the diorite masses. Breccia pipes are associated with some of the small plugs.

Many dikes, a few feet to several tens of feet wide, are present in the South Telluride area. They are most abundant in the west half of the valley of Howard Fork, around Gold King, Palmyra, Prospect and Lena Basins, and on the south side of the basin of the East Fork of Bear Creek. A few are scattered throughout the rest of the area.

The dikes are generally composed of dark greenish-gray andesitic rocks, which show a wide variety of textures and contain a variety of minerals as phenocrysts. Contact metamorphism of the enclosing rocks consists only of a slight baking, which changes the color and usually increases the resistance to erosion slightly. Many dikes were injected along faults, or were the sites of later faults. Most dikes are hydrothermally altered along their contacts.

Not much is known about the pre-Tertiary structure of the area. Around Telluride the pre-Tertiary formations dipped northwest at the time the Telluride formation was deposited, for it rests on eroded Dolores formation at Bridal Veil Falls and along Bear Creek just north of the Nellie mine, whereas it rests on part of the Morrison formation at Telluride. In the valley of Howard Fork, the metamorphosed Pony Express(?) limestone member of the Wanakah formation not far below the Telluride formation dips northwest, whereas north of Ophir Loop, farther west, intensely metamorphosed Mancos shale underlies the conglomerate. Only two pre-Tertiary faults were recognized although they may be more common. A northeastward-striking fault, exposed in the south wall of the canyon of the San Miguel River southwest of the Smuggler Union mill, had two periods of movement—one in pre-Tertiary time and one during the Tertiary.

In general it appears as though the volcanic section dips eastward between 5° and 10°, even allowing for the fact that many of the formational contacts in the volcanic section are irregular surfaces, and probably none of the contact surfaces were flat when the overlying units were deposited.

In Tertiary time the faulting and mineralization in the area may have been controlled by events that occurred in two distinct and separate centers. Just east of the area (see fig. 24), a large subsided block that has been called the Silverton caldera (Burbank, 1933, p. 160; 1940, p. 246) apparently had a strong influence on the structural features in the eastern and northern parts of the mapped area. Forces associated with the intrusive center along the valley of Howard Fork had a strong influence on the structures in the southwestern and southern parts of the area.

The radial faults from the caldera cross the north half of the area, striking a little north of west. The young northeastward-striking faults are concentric to the caldera, and trend more to the south as they approach the valley of Howard Fork. These faults have downward movement on the east side. There are also a few north- and northwestward-trending faults.

The structure and ore deposits in the southwestern part of the area presumably are greatly influenced by the diorite intrusion at

Ophir Needles and by the other diorite stock in Spring Gulch. Here the dikes, faults, and veins are in zones that trend west-northwest, northeast, and north. On the west side of the mapped area there is a graben wherein the Potosi volcanic series is downfaulted between San Juan breccia, but most of this structure is covered by landslide material.

There are many northeastward-trending fracture zones throughout much of the valley of Howard Fork, and a zone of weakness lies between the group of quartz-feldspar porphyry intrusions in the eastern part of the valley and the Silverton caldera. There several grabens and horsts are bounded by eastward- and northwestward-striking faults.

Gold is present along the westward-trending radial faults in the north part of the mapped area and along a few northward-trending zones in the southwest part. Base metals and silver are present in some of the northward-trending fault zones in the eastern part of the mapped area and in zones of several trends all across the south half.

PRE-TERTIARY ROCKS

The pre-Tertiary sedimentary rocks are exposed only in the lower parts of the larger canyons and have a total thickness of about 1,330 feet. The thicknesses given in the following table are approximate, for the pre-Tertiary rocks, being in the lower slopes of the canyons, are, in general, heavily covered by talus, landslide material, soil, and vegetation. The age relations shown on this table are those given by Burbank (1941).

CUTLER FORMATION

The upper part of the Cutler formation, of Permian age, is exposed on the south side of the canyon of the San Miguel River and for about 2.3 miles up Bear Creek. It consists of more than 500 feet of alternating beds of conglomerate, sandy conglomerate, coarse arkosic sandstone, sandstone, thin-bedded sandy shale, shale, and mudstone. The sandstone beds contain some thin micaceous shale partings, and much of the sandy conglomerate and arkosic sandstone is crossbedded and contains lenses of conglomerate. The beds are maroon, reddish gray, and dull red. The sandstone is locally mottled light gray and red, but the mottling is not everywhere parallel to the bedding. The more shaly beds are usually dull red. Along lower Bear Creek a cliff-forming conglomerate bed, 10 feet thick and about 320 feet below the top of the formation, seems to be fairly persistent and was used as a key bed. On the whole, however, the individual units of this formation are not very persistent; most of the conglomerate appears to be in large lenses. The formation in general is fairly resistant and forms many outcrops.

Pre-Tertiary sedimentary formations

Age		Formations	Thickness (feet)	Description
Mesozoic	Upper Cretaceous	Mancos shale	380+	Thinly bedded black and gray shale, some sandy or calcareous shale, calcareous nodules, few beds of fine sandstone.
		Dakota formation	193	Upper 111 ft gray shale, siltstone and some sandstone. Lower 82 ft medium- to fine-grained yellow sandstone.
	Upper Jurassic	Morrison formation: Brushy Basin member.	278+	Mostly shale, in places calcareous, and minor amount of sandstone.
		Morrison formation: Salt Wash member.	(?)	Only few feet of irregularly bedded sandstone exposed in this area.
		Wanakah formation: Undivided upper section.	110	Top 20 ft, well-bedded sandstone, possible equivalent to Junction Creek sandstone. Middle 60 ft, calcareous shale and weak sandstone beds. Bottom 30 ft, medium-grained yellow sandstone, more massive lower half; topped by "carnelian sandstone" (18 in.), Bilk Creek sandstone member.
		Wanakah formation: Pony Express limestone member.	18–28	Dark-gray finely laminated limestone overlain by limestone breccia and knobby, massive limestone.
		Entrada sandstone	32–40	Yellow to buff, medium- to coarse-grained quartz sandstone; in part crossbedded.
	Triassic	Dolores formation	300–320	Top 50 ft, yellowish-gray sandy mudstone, calcareous sandstone and limestone conglomerate (Wingate equivalent?). Mostly thick-bedded red mudstone, in part calcareous or sandy; many thin beds of micaceous sandstone, sandy shale and red shaly limestone. Bottom 5–10 ft, conglomerate with limestone pebbles, grading upwards into white sandstone.
Paleozoic	Permian	Cutler formation (upper part).	500+	Interbedded pinkish-gray and maroon-gray mottled coarse arkosic sandstone, conglomeratic sandstone and conglomerate; some thin beds of dark-red micaceous shale and shaly sandstone; many lenses of conglomerate and much crossbedding in the coarse sandstone.

DOLORES FORMATION

The Dolores formation of Triassic age (Larsen and Cross, 1956, p. 48) is exposed along the canyons of the San Miguel River and lower Bear Creek, above the outcrops of the Cutler formation. It is also probably present along Howard Fork, but it was not definitely recognized there because of the color change due to metamorphism, and because of poor exposures; it probably comprises the lower part of the area mapped at metamorphosed Mesozoic rocks.

The base of the Dolores formation commonly consists of a white to light-gray conglomerate layer, 10 feet thick. This bed contains some limestone pebbles that serve to differentiate it from the conglomerate in the Cutler formation. This conglomerate layer is less than 10 feet thick in many places and may be missing locally; where it is missing, its place is taken by a white sandstone bed a few feet thick. More than half of the main part of the Dolores formation characteristically consists of bright-red thick-bedded mudstone with some interlayered thin-bedded shale and sandy shale. Distributed throughout the mudstone, and next in abundance to it, are red thin-bedded micaceous, calcareous, or shaly siltstone and fine-grained sandstone beds. Limestone conglomerate is fairly common and thin beds of buff or pink limestone are sparse throughout the section. The bright-red color, the large amount of mudstone, and the highly calcareous nature of much of the rock appear to be characteristic of the middle part of the formation.

The top of the formation is marked by about 40 feet of buff or yellow calcareous beds that appear closely related lithologically to the Dolores, although more detailed mapping of the Mesozoic rocks might show that they could be treated as a separate formation, possibly an equivalent to the Wingate sandstone. These beds consist, from the bottom up, of limestone conglomerate, calcareous sandstone, calcareous sandy mudstone containing limestone pellets, and a calcareous sandstone containing greenish-gray limestone pellets. In places this part of the formation may have been mapped with the overlying Entrada sandstone where it forms the bottom part of cliffs of Entrada sandstone.

The Dolores formation probably is separated from the overlying Entrada sandstone by a disconformity. This is indicated by a few inches of thinly bedded light greenish-gray shale at the top of the Dolores, which appears to the author to represent a slightly reworked soil zone lying on the top of the Dolores. The total thickness of the Dolores formation is between 300 and 320 feet.

ENTRADA SANDSTONE

The distribution of the Entrada sandstone is similar to that of the Dolores formation except that it is more restricted. It not present east of a point approximately a thousand feet west of Bridal Veil Falls, and south of about the latitude of the Silver Chief mine along Bear Creek. Typically it forms a low yellow cliff at the top of the Dolores outcrops.

The Entrada is 32 to 40 feet thick where exposed in the area south of Telluride. It consists of yellow medium- to coarse-grained quartz sandstone beds. The thicker beds in places have crossbedding. At the top it has a sharp contact with the Pony Express limestone member of the Wanakah formation.

WANAKAH FORMATION

The Wanakah formation is more limited in occurrence than the older formations. It does not occur east of approximately the longitude of the Smuggler Union mill along the south side of the valley of the San Miguel River, nor south of the latitude of the Canton mine along Bear Creek, except for the Pony Express limestone member at the base, which extends a little farther east and south. (See pl. 16.) At least part of the formation is probably included in the metamorphosed Triassic and Jurassic rocks in the southwestern part of the area, but, because of intense metamorphism, it was not definitely recognized. Except for the Pony Express member, the formation is poorly exposed, and the subdivisions described below were recognized only in a few gulches a short distance east of Bear Creek on the south side of the valley of the San Miguel River.

The formation can be divided into four members: the Pony Express limestone member at the base, the Bilk Creek sandstone member, the so-called marl, and, at the top, a sandstone that is possibly the equivalent of the Junction Creek sandstone (Eckel, 1949, p. 27–29). The members above the Pony Express are combined into a single unit on the map. The total thickness of the formation is about 135 feet.

The Pony Express limestone member is 25 to 28 feet thick in most places. The bottom is 9 feet of thinly laminated platy black to dark-gray limestone; this is overlain in places by about the same amount of dark-gray limestone breccia formed by the leaching of gypsum from a gypsum-limestone complex (Burbank, 1940, p. 195, 211), and this is in turn overlain by 8 to 10 feet of gray, massive, somewhat sandy limestone that weathers with a knobby surface because of patches of recrystallized calcite and gypsum.

The overlying Bilk Creek sandstone member consists of about 30 feet of yellow sandstone in fairly massive beds in the lower half and thinner, somewhat shaly beds in the upper half. It is topped by the so-called carnelian sandstone, which is about 18 inches of resistant sandstone containing red chalcedony grains.

The next member above consists of about 60 feet of calcareous shale, mudstone, thin beds of shaly sandstone, and shaly limestone. Some of the beds contain small pieces of red chalcedony, and some mudstone contains crystals of gypsum. This unit has been called the marl member of the Wanakah.

About 20 feet of fairly massively bedded cliff-forming sandstone lies at the top of the Wanakah formation as mapped in this area. This member may be the equivalent of the Junction Creek sandstone mapped farther south (Eckel, 1949, p. 27).

MORRISON FORMATION

The Morrison formation west of the South Telluride area consists typically of two parts: the lower Salt Wash member, predominately sandstone, and the overlying Brushy Basin member, mostly shale. The Salt Wash member is probably present only on the slopes on each side of the mouth of the canyon of Bear Creek. It crops out in few places and, except for the bottom few feet above the Wanakah formation exposed in steep gulches, was not recognized during the mapping.

The Brushy Basin member is present only on the west side of the Ophir Needles, where the rocks are intensely metamorphosed. At this place there is about 278 feet of hornfels and minor amounts of quartzite, which probably was shale, calcareous shale, shaly sandstone, and a few beds of sandstone before being metamorphosed.

DAKOTA SANDSTONE

The Dakota sandstone also is exposed in the South Telluride area only in the cliffs on the west of the Ophir Needles. Here, about 82 feet of yellow quartzite is overlain by 111 feet of dark-gray hornfels, gray siliceous hornfels, and a few quartzite beds. The top of the formation is assumed to be the highest quartzite bed, which is 7 feet of gray fine-grained quartzite.

MANCOS SHALE

Only the lower part of the Mancos shale is present in this area. About 380 feet of thinly bedded black and dark-gray hornfels is present on the west side of the Ophir Needles between the Dakota sandstone and the overlying Telluride formation. A few doubtful *Gryphea* molds and fairly abundant *Inoceramus* imprints near the top of the exposed section served to identify these rocks as Mancos shale.

TERTIARY SEDIMENTARY AND VOLCANIC ROCKS

To identify and correlate the formations in a complex volcanic area is generally difficult. In the long period of time during which a large volcanic pile like that found in the San Juan Mountains is forming, many different volcanic centers or craters are active either successively or concurrently. Recurrent activity is possible, with the extrusion of different types of lava at different times. Conversely, similar-appearing lavas may come from different craters. Moreover, volcanic formations may be lenticular in cross section and may interfinger with, or overlap, other formations. Thick breccias may form in one place while flows are being piled up elsewhere. Calderas may form in any large volcanic field (Williams, 1941) and may sink repeatedly. As a result of subsidence, a rock unit may be thousands of feet of massive flows within a caldera, but be absent, or consist of only thin flows or breccias, outside the caldera. Moreover, breccias similar in general appearance and composition may be separated by major disconformities, with or without separating flow units. Such breccias should not be grouped as one formation where there are major disconformities or intervening flow formations.

It is very difficult, therefore, to correlate volcanic formations across any considerable distance in an old volcanic pile without actually mapping the units in the area between. Some previous correlations in the San Juan region, especially those made during reconnaissance examinations, may be in error because of the possible relations pointed out above. This is probably true of at least part of Burbank's Picayune volcanic group (Burbank, 1941, pl. 1). This unit was correlated from the southeast side to the northwest side of the Silverton caldera, without detailed mapping of intervening areas. Some of the correlations proposed in this report leave much to be desired, as the author has neither seen all the type areas nor mapped the intervening country. Moreover, he feels that some of the original definitions and descriptions of the units by Cross and Purington (1899) and by Cross, Howe, and Ransome (1905) are not adequate for modern geologic use.

The area described in this report lies on the west flank of the large compound San Juan volcanic center. In this center, many volcanoes erupted different types of lava over a long period of time. The west edge of the Silverton caldera, first described by Burbank (1933, p. 160), lies about 2 miles east of the east side of the mapped area. The caldera sank at different times during its long history, and flows that are as much as several thousand feet thick in the caldera are represented in the South Telluride area by flows a few tens or hundreds of feet thick, which came out over the rim. Moreover, much pyroclastic material accumulated in this flank area while flows accumulated in the caldera; also, much erosion took place in the flank area. Certain formations that are fairly thick in the caldera did not reach some parts of the flank areas. Elsewhere, pyroclastic formations of younger age may have been deposited on much older deposits, and it may be difficult to distinguish the two pyroclastic units.

Of the Tertiary formations described by Cross and Larsen (1935) in the San Juan Mountains, equivalents or partial equivalents of the following units are believed to be present in the mapped area: The Telluride conglomerate, the San Juan tuff, some units of the Picayune volcanic group, flows and breccias of the Eureka rhyolite, volcanic conglomerate, breccia, and flows of the Burns latite, a very little of the pyroxene andesite, and part of the Potosi volcanic series. These rocks have been mapped as the following units: Telluride formation; San Juan breccia; the Silverton volcanic series, which consists of Eureka rhyolite (including andesite of the Picayune volcanic group, typical Eureka rhyolite and the overlying breccias) and Burns latite (including underlying volcanic conglomerate, breccias, Burns-type flows, and one pyroxene andesite flow); and the Potosi volcanic series. These formations are shown in the following table:

Tertiary sedimentary and volcanic formations

Age	Series and (or) formation	Members	Thickness (feet)	Character
Upper or middle Tertiary	Potosi volcanic series	Andesite flow	40	Massive dark-gray flow; found only on Lookout Peak.
		Rhyolite flows	175–250	Massive light-gray flows.
		Quartz latite flow and breccia	75–100	Red flows and breccia.
		Rhyolite flows	250–300	Thick flows of glassy banded rhyolite.
		Quartz latite flows	50–100	Gray quartz-latite flow with dark bands or hard balls of similar rock.
		Quartz latite flows	300–350	Pinkish-gray massive flows with brown biotite phenocrysts.
Miocene, Silverton volcanic series	Burns latite	Pyroxene andesite flow and breccia	40	A few lens-shaped flows associated with breccia.
		Latite flows	70–200	Dark-greenish and reddish-gray flows; massive flows in upper part, fissile-weathering flows in lower part of unit; typical Burns latite.
		Latite breccia	0–150	Breccia and tuff, with volcanic conglomerate at base in places.
	Eureka rhyolite	Breccia and tuff	250–400	Contains many rock types, but very little like underlying flows.
		Latite flows	10–100	Reddish and greenish-gray flows, characterized by numerous flattened vesicles; typical Eureka rhyolite.
		Andesite flows and breccia	0–25	Dark-gray vesicular flow overlain by a little breccia; may be equivalent to part of Picayune volcanic group farther east.
Miocene(?)	San Juan breccia	Breccia and tuff	1,200–2,100	200 ft of well-bedded tuff at base overlain by fairly massive beds of breccia and local lenses of tuff.
		Andesite flow	0–20	Dark-green flow 450 ft above base of formation.
Oligocene(?)	Telluride formation		300–400	Massive conglomerate composed mostly of Precambrian and Paleozoic rocks; bottom few feet characterized by immediately underlying rocks; top 15 ft is a pinkish-gray, coarse arkose.

Much more detailed fieldwork and petrographic studies will be required before definite correlations can be made and the proper geologic sequence be established for this ancient volcanic pile.

TELLURIDE FORMATION

The Telluride formation [1] in the South Telluride area consists mostly of a massive cliff-forming conglomerate. In the canyons of the

[1] Formerly called Telluride conglomerate. The change to formation is suggested because of the variable lithology of this unit from place to place. In the southwestern part of the South Telluride area it has considerable sandstone and farther west the "formation is [at Mount Wilson] a succession of fine conglomerates, grits, sandstones, sandy shales, calcareous shales, sandy limestones, and dark, or even black, shales." (Cross and Purington, 1899, p. 4.)

San Miguel River and Bear Creek it forms a continuous, nearly vertical cliff except in the northeast corner of the mapped area, where it is covered by talus from Ingram Basin, and on the east side of the lower part of Bear Creek, where it is buried by two landslide masses. Along the west side of the mapped area the Telluride formation is covered by the Silver Mountain landslide and some of the smaller slides near the mountain front, except for one small area south of the mouth of Gold King Basin. It forms a cliff along the northwest side of the Ophir Needles extending southward to a place where it is cut out by the Ophir Needles intrusion. Along the north side of the valley of Howard Fork it crops out continuously enough to be mapped, though rarely forming cliffs, from the east edge of the Ophir Needles intrusion as far as Spring Gulch. East of Spring Gulch the Telluride formation, like all the other formations apparently is weakened by hydrothermal alteration and weathers so easily that there are few outcrops; as shown on the map (pl. 16), exposures were found at only three places, the easternmost being just west of Chapman Gulch.

From a distance the massive conglomerate of the Telluride formation is light reddish gray or gray. In detail the color is influenced mainly by the color of the constituent boulders. These consist of a great mixture of relatively resistant rock types—red and gray sandstone, gray limestone, bluish-gray or gray quartzite, gray granite, gneiss, and dark-gray schist; the sandy matrix is stained somewhat reddish by iron oxide. The rock fragments range in size from a few inches to as much as 2 feet across and are generally well rounded. A light-pink to white coarse arkose 10 to 15 feet thick tops the formation and contrasts sharply with the overlying dark-gray fine-grained tuffs of the San Juan breccia.

The character of the bottom few feet of the formation changes considerably, depending on the formation that directly underlies it. Where it overlies the Dolores formation, the Telluride has the same bright-red color as the Dolores and contains many boulders of red sandstone and mudstone. Over the Entrada sandstone, the Telluride contains boulders of yellow sandstone, generally with a red matrix derived from the nearby Dolores. Over the Pony Express member, it contains limestone fragments; but over the rest of the Wanakah, it is generally a weak impure sandstone that grades upward into the typical conglomerate.

The Telluride formation is generally between 300 and 400 feet thick. South of the San Miguel River it thins eastward from about 400 feet to about 275 feet; at Bridal Veil Falls, the most eastern point where it is exposed, one doubtful measurement of 180 feet was made. At its most southwestern exposure in the South Telluride area, on the northwest side of the Ophir Needles, it is approximately 450 feet thick, and is in general finer grained than elsewhere in the mapped area, with considerable sandstone both at the base and at the top.

These measurements confirm the statements of Cross and Purington (1899) that the formation thickens to the west (approximately 1,000 feet in the Mount Wilson area) and thins to the east of the Telluride quadrangle. Burbank reports (written communication, 1955) that in Canyon Creek, about 5 miles northeast of the Smuggler Union mill, the conglomerate is locally 25 to 40 feet thick, whereas farther northeast the Telluride is missing altogether, although it may be represented only by an erosion surface on a weathered layer. The South Telluride area therefore was near the eastern shore of a great lake (Cross and Purington, 1899, p. 1, 13) where coarse lacustrine and possibly fluviatile (Cross, Howe, and Ransome, 1905, p. 21) deposits were forming. According to Burbank (1941, pl. 1) the age of the Telluride formation is Oligocene(?).

SAN JUAN BRECCIA

The San Juan breccia is by far the thickest formation exposed in the South Telluride area, and it is the most widely exposed unit in the section. (See plate 16.) The formation is called San Juan breccia rather than San Juan tuff in this area because of the great predominance of coarse pyroclastic material over finer grained material in this area. The formation is fairly resistant to erosion, and where it crops out in the sides of canyons and basins it generally forms steep slopes or cliffs.

The lower part of this formation is made up of 150 to 300 feet of tuff; overlying this lower part is a great thickness of usually thick-bedded breccia and tuff breccia. In part of the canyon of Bear Creek one andesite flow occurs about 450 feet above the base of the San Juan breccia. The thickness of the whole formation increases rather gradually from about 1,250 feet in the southwestern and southern parts of the area to 2,100 feet in its northeastern corner.

The tuff in the lower part of the formation is well-bedded and generally fine-grained. At the base, close to the top of the Telluride formation, there are a few coarse grains of quartz and feldspar in the tuff in places. At the top, the tuff grades rather abruptly into the overlying breccias. Except where hydrothermally altered, it has a dark-reddish or purplish-gray color. It represents the earliest volcanic debris deposited in the large lake in which the Telluride formation was formed (Cross and Purington, 1899, p. 5). The rest of the San Juan breccia, on the other hand, shows no indication of having been deposited in standing water.

The main part of the San Juan breccia consists mostly of fine to coarse breccia and tuff breccia beds ranging from a few feet to about 75 feet thick. Interlayered are scattered, discontinuous lenses of tuff from a few inches to about 10 feet thick. The blocks in the breccias are generally a mixture of as many as eight different types of volcanic rock, mostly andesitic or latitic in composition, and differing from each other slightly in texture, grain size, amount of phenocrysts, color, and presence or absence of flow structure. Little vitric or devitrified material has been seen. Phenocrysts are common. Most of the blocks are subangular to rounded. The tuff breccias contain scattered large blocks, in places as much as 10 feet in diameter in a matrix of fine tuff to lapilli tuff. The bedding planes, in many places rather indistinct except where tuff lenses are present, are generally rather plane surfaces, though local channels cut by intraformational erosion may be present. Most of the formation is dark gray, usually with reddish, purplish, or greenish tints.

The author believes that most of the pyroclastic material in the San Juan breccia came into this area as mudflows, perhaps locally reworked and sorted by running water. The lenses of bedded tuff presumably accumulated in local ponds, but most of the beds, and especially the tuff breccia beds, show no grading of size or crossbedding, as would be expected were they deposited by running water. Conversely, there are no wedges of angular breccia such as would be deposited on the slopes of a volcano by explosive eruptions or nuées ardentes. There are no bombs with glassy edges or similar evidence of direct deposition of material by eruption.

One dark greenish-gray andesite flow, 10 to 20 feet thick, lies about 450 feet above the base of the San Juan breccia in the middle part of the canyon of Bear Creek. A thin breccia consisting solely of small fragments similar to the andesite flow rock, is at the same stratigraphic horizon farther north. The andesite flow is the only key unit in this thick formation that can be used to measure the displacement on faults. Otherwise, displacements can be measured only in the overlying or underlying formations.

Fine-grained "dikes" of tuff from half a foot to about 2 feet wide are found at a few places in the San Juan breccia. These cut massive breccia beds that overlie lenses of tuff. Apparently the coarse bed came to rest as a unit over fine ash that was still wet and plastic; the coarse material, probably drying faster than the underlying ash, cracked and was then "intruded" by the wet ash under the load of the overlying breccia.

The San Juan breccia is the oldest volcanic formation in the South Telluride area and at least the lower part of the formation is probably approximately the same age (Miocene?) everywhere in the whole San Juan region.

SILVERTON VOLCANIC SERIES

The Silverton volcanic series was originally defined (Cross, Howe, and Ransome, 1905) as covering the section "* * * between the San Juan andesitic tuffs and the Potosi rhyolite series * * *," and included from the base up, "the Picayune andesite * * *, * * * the Eureka rhyolite * * *, * * * the Burns latite complex * * *, and * * * the pyroxene andesite flows and tuffs." Later Picayune andesite was changed to Picayune volcanic group by Cross and Larsen (1935), and the Henson tuff was added at the top of the section. Burbank (1941) grouped andesite (the Picayune as originally(?) defined) with rhyolite (the Eureka), latite, and pyroclastic rocks (the lower part of the Burns) as the Picayune volcanic group, which, with the Burns latite flows and the pyroxene andesite, he put in the Silverton volcanic series. Kelley (1946) shows the Silverton volcanic series as consisting of the Picayune volcanic group (subdivided into smaller units), the Eureka rhyolite, the Burns latite (also subdivided into smaller units), the pyroxene andesite, and the Henson tuff.

A somewhat different grouping of the formations in the Silverton volcanic series has been made in this report, as the South Telluride area is on the west flank of the San Juan volcanic pile, entirely outside of the Silverton caldera, and as the rocks of the Silverton volcanic series are in large part pyroclastic types, and the flows are almost entirely typical Eureka rhyolite and Burns latite.

EUREKA RHYOLITE

The Eureka rhyolite of this area consists of two, and in places three, distinct units. The base locally consists of flows and breccia of dark andesite. Overlying this unit, or forming the base of the formation where the andesite is absent, is a group of very distinctive flows and flow breccias that appear to be similar to the typical Eureka rhyolite. The uppermost unit consists of a group of breccia beds 250 to 450 feet thick that are separated from the overlying breccias or flows of the Burns latite by a disconformity having considerable relief.

The lowest member of the Eureka rhyolite is in a relatively narrow eastward-trending strip from Gold Hill, to the east side of La Junta Basin; eastward the strip widens, occupying the middle part of the west side of the canyon of Bridal Veil Creek and all the east side of the canyon from the Little Dorrit mine to the northeast corner of the mapped area. Recent erosion limits the unit to the north of this strip west of La Junta Basin. To the north between La Junta Basin and Bridal Veil Creek, and in the southern part of the map area, this unit either was not deposited or was removed by erosion before the flows of the middle member of the formation were laid down. About 1,000 to 2,000 feet west of the Little Dorrit mine a "fossil" hill of San Juan breccia is partly surrounded, but not covered by either the lowest or the middle members of the Eureka rhyolite.

This lowest member of the Eureka rhyolite consists of one or more very dark gray andesite flows overlain by a little breccia made up of fragments of the same rock type. The andesite is typically rather vesicular, and the vesicles are in most places filled with chalcedony, green chlorite, and calcite. The bearing of the elongation of the vesicles strongly suggests that the flows came from an east-northeastward direction. The unit is about 30 feet thick, and probably thickens to the east.

This andesite unit could be correlative with part of the Picayune andesite (Cross, Howe, and Ransome, 1905, p. 7), whose type section lies southeast of the Silverton caldera. The author has not seen this section, however, and it has seemed expedient to include the andesite with the overyling Eureka flows.

Several distinctive flows overlie the lower andesite unit where it is present and form the base of the Eureka rhyolite elsewhere. These flows are somewhat more resistant to weathering than the underlying and overlying rocks and so form cliffs more commonly. They apparently are everywhere except one locality about 2,000 feet northeast of the Suffolk mine, and another locality about 1,000 to 2,000 feet west of the Little Dorrit mine.

The surface on which these flows came to rest was in general fairly level, but in places it had shallow valleys as much as several hundred feet wide. In a few places in the central and eastern parts of the area, steep-walled canyons had been cut down through the underlying andesite flow and these were filled with the flows of the second unit. Apparently the compaction of the flows, which was produced by the flattening of vesicles, was greatest over these canyons, as the top surface of the canyon-filling flows was almost everwhere occupied by a valley, now filled with the breccia of the overlying member.

This middle unit of the Eureka rhyolite is as little as 6 feet thick in places around Palmyra Basin, because erosion removed some of it before the overlying breccias were deposited. Elsewhere, it is generally between 50 and 100 feet thick, and it becomes relatively thicker toward the east; in places as much as 200 feet of flow fills canyons cut into the underlying unit.

This unit of the Eureka rhyolite has conspicuous flow structure, contains many small inclusions, and is especially characterized by numerous flattened vesicles from a fraction of an inch to 3 or 4 inches in diameter, and from a knife edge to about a quarter of an inch thick. The vesicles generally are filled with a reddish or greenish-gray extremely fine grained clayey material. Small phenocrysts of feldspar, 1 to 3 millimeters long, are scattered in a felsitic groundmass. Mafic phenocrysts (augite or biotite) are relatively rare. In the southwestern part of the area the flows are a brick red to reddish gray, but eastward they become grayer, and at the eastern edge of the area are a mixture of greenish-gray and reddish-gray rocks. Some thin flow breccias and breccias of similar rock lie between flows of this unit.

A microscopic examination of thin sections of this flow unit of the Eureka rhyolite shows that the matrix is a thinly flow banded glass, generally devitrified. Most of the phenocrysts are laboradorite but a few may be andesine. Augite and lesser amounts of biotite (mostly somewhat altered), opaque minerals, and a few small crystals, possibly orthoclase, are present. No quartz phenocrysts were seen. No matter what the composition of the matrix, the phenocrysts scarcely suggest that the rock is a rhyolite. It is not worthwhile trying to classify this rock accurately without considerably more microscopic work and chemical analysis, but probably the rock is not more silicic than a latite. Correlation with the type Eureka rhyolite is based on its position in the section and on the fact that the rock is similar megascopically (that is, as to color, texture, and the presence of many flattened vesicles) to a rock identified to the author by W. S. Burbank, as typical Eureka, north of Animas Forks and near the type section of the Eureka rhyolite.

A group of breccia beds, shown as the breccia member of the Eureka on the map, comprises the uppermost unit of the Eureka rhyolite. Except near the base, where the breccia contains a few boulders of the underlying flow rocks, breccias of the Eureka are quite similar to the breccias of the San Juan, and the two units could not be differentiated where the intervening flows do not crop out or are not present. The breccia member of the Eureka may be reworked San Juan breccia for the most part (Burbank, 1933, p. 140, 143, 144; Kelley, 1946, p. 298).

The breccia member of the Eureka rhyolite is thicker on the west side of the South Telluride area than on the east side, in contrast with the underlying flows. Thus the combined thickness of the two or three units of the Eureka rhyolite is fairly constant; the whole formation is about 500 feet thick in the neighborhood of peak 13470 on Silver Mountain, about 400 feet thick around La Junta Basin, and 460 feet thick in the northeast part of the mapped area.

The Eureka rhyolite is quite different in the area on the west side of Lookout Peak. Here only the flows with the flattened vesicles (the second member) are present. These flows are between 50 to 90 feet thick and are overlain directly by massive flows of the Burns latite. Because of the poor exposures west of Chapman Gulch, it is not known how or exactly where the change in the section comes.

BURNS LATITE

The Burns latite overlies the Eureka rhyolite, and is separated from it by a disconformity having considerable relief, so that in different places different parts of the Burns latite are in contact with the underlying breccias or flows of the Eureka. This disconformity must represent a considerable time interval, as the pre-Burns erosion surface was formed on well-lithified breccia.

The most complete section of the Burns latite consists of the following parts, omitting consideration, for the present, of the local basic andesite at the top:

(*a*) As much as 20 feet of volcanic conglomerate containing, especially near the base, many well-rounded (presumably water-worn) and heavily iron-stained boulders that were deposited only in the lower parts of channels on the underlying erosion surface. This grades upwards into *b*.

(*b*) A breccia, with some tuffaceous layers, as much as 100 feet thick. Both this member and the underlying volcanic conglomerate contain some fragments similar to the overlying flows of the Burns latite; these fragments are the means of differentiating this breccia from the underlying breccia of the Eureka rhyolite in places where the disconformity cannot be seen. Overlying this is *c*.

(*c*) From 75 to 100 feet of thin fissile andesitic or latitic flows, containing abundant feldspar phenocrysts, and having some flattened vesicles filled with green chlorite. At the top is *d*.

(*d*) Thicker and more massive flows of approximately the same composition as the thinner, underlying flows. This unit is the most resistant to erosion, and generally forms cliffs where present in the section.

All the flow rocks (*c* and *d*) are dark greenish gray and reddish gray. They contain considerable hornblende and biotite in addition to the abundant feldspar phenocrysts, and apparently have the composition of andesite or hornblende latite.

The Burns latite is exposed only on the higher ridges and in the upper basins in the area of the report. It crops out around the higher ridges surrounding Palmyra and Gold King Basins, east on each side of the main ridge north of Howard Fork; in the ridges around La Junta Basin, around La Junta Peak, across the middle of Bridal Veil Basin, and around the three cirques East Basin, Mud Lake Basin and Grays Basin. It is cut out in places on the north side of the valley of Howard Fork by the Spring Gulch diorite intrusion and is unrecognizable because of intense hydrothermal alteration in the area north and northeast of the Carbonero mine where it presumably makes up the upper part of the area of hydrothermally altered Silverton volcanic series and San Juan breccia. It occupies a considerable area on the west side of Lookout Peak and in Ophir Pass. The only places where it is found at lower altitudes are on the ridges on the north and south sides of Palmyra Basin, where it is down faulted in a small graben; presumably it also underlies the Potosi volcanic series farther west on the ridge on the north side of Palmyra Basin, in the Palmyra graben (pl. 17).

The Burns latite is variable in thickness in the mapped area. At the west edge of the area, fissile flows aggregating 75 to 90 feet occur on a fairly level surface cut by local channels containing as much as 10 feet of breccia and about 15 feet of volcanic conglomerate. Eastward the relief of the underlying surface increases, the breccia is almost everywhere, and the massive flows overlie the fissile flows. Except for the area around Ophir Pass, the average thickness of the formation is about 300 feet. It thins over buried hills or "steptoes", and at a place about 900 feet east of the Little Dorrit mine, the whole formation is missing, as it wedges out against a buried hill of breccia of the Eureka rhyolite. At other places in the eastern part of the area, the total thickness is considerably more than 300 feet in the deep "fossil" valleys.

In the Ophir Pass area and on the west side of Lookout Peak, the Burns latite changes both in character and in thickness. Here it consists almost entirely of thick flows of massive rock which are, however, still recognizable by the abundant feldspar phenocrysts. The latite appears to be about 900 feet thick, and both the underlying Eureka rhyolite and the lowest member of the overlying Potosi volcanic series are much thinner than elsewhere.

This greater thickness of massive flows, plus the fact that steeply dipping and even vertical flow lines were observed at places on the north side of Ophir Pass, suggests that this area is quite close to at least one of the extrusive centers from which the material of the flows issued.

At the south and east sides of a small subbasin around the Lewis mine, in Bridal Veil Basin, lenses of very dark flow rock, underlain and overlain by a little dark breccia, are between the typical massive flows of Burns latite and the overlying Potosi volcanic series. This flow has a maximum thickness of 40 feet, and probably is mafic andesite; the rock contains small phenocrysts of pyroxene and altered olivine (probably iddingsite or iron oxides (Larsen and others, 1936, p. 701)). Quite likely it represents the westernmost extent of the pyroxene andesite unit of the Silverton area. The flow and the accompanying breccia occurs in such small amounts in the mapped area, however, that it has been included as a member of the Burns latite.

POTOSI VOLCANIC SERIES

The youngest of the Tertiary volcanic formations in the South Telluride area is the Potosi volcanic series. These rocks are generally found only on the higher ridges and peaks, and their distribution is similar to but slightly more restricted than that of the Burns latite. The rocks appear to have been laid down on a fairly even surface marked by only a few minor depressions or valleys. The contact with the Burns latite is a disconformity representing a considerable time interval, during which most of the pyroxene andesite, the Henson tuff, and the Sunshine Peak rhyolite were laid down farther east (Cross and Larsen, 1935). The maximum thickness of the formation, as shown on the east side of the area, is approximately 1,100 feet. It can be subdivided into six units in the report area; in much of this area, however, only the bottom three units are present.

The lowest unit, 300 to 350 feet thick, consists of one or two layers of pinkish-white weathering quartz latite. It is possible that these rocks may be welded tuffs rather than flows. Although somewhat fissile where weathered, this unit forms some of the most prominent cliffs in the area; these cliffs usually present the greatest obstacle for those who climb the high peaks in the area. The unit is a light-gray rock on fresh surfaces that contains prominent phenocrysts of potash feldspar and sodic plagioclase (the latter usually extremely altered) as well as many phenocrysts of black to light-bronze-colored biotite and many generally small (½ to 2 inch) inclusions of andesite and latite.

The next unit of the Potosi volcanic series consists of several gray quartz latite flows, 50 to 100 feet thick, which, almost everywhere, form a talus-covered ledge above the cliff formed by the underlying quartz latite. It was called the Cannonball unit during fieldwork, because in places it contains rather unusual hard concentric masses, from a few inches to several feet in diameter, which weather out from the flow; the name Cannonball, however, is preempted and so cannot be used for this unit. Each mass has a small foreign inclusion at the center, but consists for the most part of rock identical with the rest of the flow except that it is slightly harder. Where these "cannonballs" are not present, the quartz latite has thin black flow streaks. In places the rock has spherulitic structure or may contain large blocks of reddish-gray quartz latite that appear to be pieces of the top crust that rolled down into the lava. Except for some phenocrysts of potash feldspar and altered plagioclase, this unit consists almost entirely of devitrified glass.

On top of the gray quartz latite is another cliff-forming unit consisting of one or more layers of glassy banded rhyolite, aggregating 250 to 300 feet in thickness. This unit weathers to a dirty white or light gray, but in many places is rather heavily iron-stained to a reddish or brownish gray by the oxidation of disseminated pyrite, which was deposited during the hydrothermal alteration that affected much of the Potosi volcanic series. The glassy-appearing bands, one-eighth to one-quarter inch wide, alternate with more felsitic bands. This unit is highly siliceous; potash feldspar phenocrysts are present in a completely devitrified glass, now made up apparently of fine-grained quartz and orthoclase which may contain relict flow-banded structures.

A red to purplish-gray member, 75 to 100 feet thick, overlies this rhyolite member; it is relatively nonresistant to weathering and is generally poorly exposed, forming a talus-covered ledge between the rhyolite cliffs. It consists of some flows with spheroidal structures and some tuff and breccia, all probably close to quartz latite in composition.

The second cliff-forming rhyolite member, 200 to 300 feet thick, is similar to the lower one except that the glassy banding is less evident.

The top of the Potosi volcanic series in this area is a dark-gray andesite flow about 40 feet thick that appears only as a capping at Lookout Peak.

For the members of the Potosi volcanic series, thicknesses are given only in round numbers and with a large possible range because the members are usually in steep cliffs around the higher peaks and ridges, the less resistant members are heavily covered with talus, and the actual contacts are rarely seen.

TERTIARY VOLCANIC HISTORY

A provisional Tertiary volcanic history for the flank of the San Juan volcanic pile as exposed in the South Telluride area is as follows:

After the deposition of the Telluride formation in Oligocene(?) time, volcanoes erupted somewhat to the east, and relatively fine-grained tuff was washed into the lake in which the Telluride formation had been deposited. The tuff was covered by a thick unit of coarse pyroclastic material, which the author believes was derived from several different volcanoes to the east and came into this area mostly as volcanic mudflows (Anderson, 1933). At one time an andesite flow reached this area from one of the volcanoes and was buried by more breccia. At times running water reworked the material, and lenses of tuff were formed in local ponds on the surface of the mudflows. All this material makes up the San Juan breccia. At the end of San Juan time, one or more flows from a distant volcano, whence the andesite of the Picayune volcanic group poured out, reached part of this area, probably after erosion had cut some relief on the San Juan breccias.

Vigorous erosion followed deposition of the San Juan and Picayune formations, and some steep-walled canyons were formed. To the east, one or more volcanoes began erupting the lava of the Eureka, and some flows reached this area. Probably the Silverton caldera started subsiding at this time, and as its floor sank, about 2,000 feet of flows were accumulated in it, whereas only about 200 feet of similar rock were deposited in this flank area. These flows are overlain by several hundred feet of breccia, probably laid down soon afterwards. A considerable length of time then elapsed, during which the breccias of the Eureka were lithified, and erosion cut an irregular surface with a relief of several hundred feet.

Then, somewhere to the east, volcanoes began erupting the flows of the Burns latite. At first only water-transported material reached the mapped area, and was deposited in valleys as volcanic conglomerate. Coarser, more angular material, perhaps carried mainly by volcanic mudflows, covered the conglomerate. Then the fissile flows of the Burns, followed by the more massive flows, came into this area, burying all the surface of the country except the higher hills, which protruded through the younger flows as partly buried hills, or steptoes. During this time the Silverton caldera to the east continued to sink, and the Burns latite accumulated in greater thickness in it. It is suspected that at least one of the centers of eruption for these lavas was near what is now called Ophir Pass.

The Silverton caldera continued to sink, and a great thickness of pyroxene andesite formed within it. Only when the caldera was filled, perhaps, did one thin flow of this mafic andesite reach out as far on the flank as Bridal Veil Basin.

Then followed a long period of erosion during which the mapped area, as well as probably the whole San Juan region, was reduced to a great plain on which there were only a few shallow valleys. The whole region was then covered by the Potosi volcanic series. In the South Telluride area, this formation consists of three relatively silicic (quartz latite or rhyolite) members in thick, evenly distributed units, alternating with thinner units of more mafic composition (quartz latite or andesite). As silicic lavas are generally rather viscous and tend to form flows that are lenticular in cross section, the wide distribution in this region of silicic volcanic rocks of fairly uniform thickness suggests that all these rocks may be welded tuff.

This is the end of the volcanic history in the South Telluride area. To the east more volcanic formations were laid down (Cross and Larsen, 1935), and then the whole area was subjected to a long and complicated history of erosion as described by Atwood and Mather (1932).

TERTIARY INTRUSIVE ROCKS

Intrusive rocks are rare in the north half of the mapped area, but become increasingly abundant to the south. Three larger intrusive masses, as well as some smaller plugs and many dikes, are on the north side of the valley of Howard Fork. Several dikes crop out along the west side of the mountains as far north as Gold Hill, around Lena Basin, and on the south side of East Fork Basin. A few are present farther down Bear Creek, in La Junta Basin, and in upper Bridal Veil Basin. One occurs in the south end of East Basin, and another extends from the lower part of the creek draining Blue Lake, across Bridal Veil Creek, the lower parts of Jackass and Silver Lake Basins, to the edge of the canyon of the San Miguel River southeast of Telluride. A few small pluglike intrusions crop out in the ridges southwest of the Gold King Basin and in the southeast corner of East Fork Basin.

Cross and Purington (1899) referred to two large areas of "granite porphyry" east of Ophir as "a porphyry body, cut in two by Howard Fork, which is in some respects analogous to a laccolith, although somewhat irregular in its relations to the inclosing sedimentaries." The southern body, off the south edge of the present map, may be as shown by Cross and Purington (1899); at a few points along Howard Fork coarse-grained quartz-feldspar porphyry was seen and was called quartz monzonite porphyry during fieldwork. The body shown on the north side of the valley, however, if present at all, is much smaller than as shown by Cross and Purington (1899), and is a different rock type than that south of the Howard Fork. Some of the scattered outcrops of quartz-feldspar porphyry on the map may be part of a single, very irregular body extending from a little west of the gulch on which the Carbonero mine is located eastward to the outcrop where the Hattie mine is located in Chapman Gulch. The author believes, however, that these exposures of quartz-feldspar porphyry are parts of several pluglike intrusions similar to the one just east of Spring Gulch and the one on the main ridge east and northeast of the Highline mine, but outcrops are too poor to prove the relations.

Several similar, somewhat smaller, quartz-feldspar porphyry bodies occur east and west of Chapman Gulch, and three small ones lie in the southeast corner of East Fork Basin. Although there is some variation in the composition of the different plugs, it is believed that they all approach an acid quartz monzonite in composition. Most of them are greatly altered.

The two largest masses of intrusive rock in the valley of Howard Fork are mainly dioritic in composition. The Ophir Needles body, extending from near Ophir Loop, north and east to within about a thousand feet of the Badger tunnel, is part of a larger mass that extends south of the Howard Fork and west of the Lake Fork of the San Miguel River (Cross and Purington, 1899). This rock is described, and a chemical analysis of it is given by Cross and Purington (1899, p. 6). According to them the diorite mass has a number of variations that show transitional contacts. Although a detailed study was not made of the Ophir Needles mass, sharp contacts were seen between the finer grained diorite and somewhat coarser grained monzonite. The diorite contains mainly labradorite, augite, and a little hypersthene. The monzonite, however, contains considerable orthoclase with the laboradorite or andesine, and somewhat less augite, some biotite, and no hypersthene. In some places the monzonite is fairly even grained, with the grains averaging about 1 mm in length; in some places it has a seriate texture with the larger grains close to 5 mm long; in other places it is porphyritic, having phenocrysts 1 to 6 mm long and groundmass crystals averaging half a millimeter in length. The color of both the diorite and the monzonite ranges from dark to light gray, the coarser-grained types being lighter in color.

Several small bodies of diorite crop out in Ophir Pass. Possibly they are small protrusions above a considerably larger intrusion underlying Ophir Pass and the area to the north. The presence of such an intrusion is suggested because all the rocks between Ophir Pass and the eastward-trending fault, about 1,400 feet south of Lookout Peak, contain considerable epidote, which is a common contact metamorphic mineral in this region.

Three small plugs are exposed north of the Ophir Needles intrusion, in the ridge southwest of the Gold King Basin, and on the south side of the next small cirque southwest of this basin. The more irregular-shaped body that crops out on the ridge southwest of the Gold King Basin is monzonite, containing considerable orthoclase in the groundmass and phenocrysts of labradorite and augite. This body connects with a small circular body about 400 feet to the east by a dikelike extension. Farther up the ridge, to the south, a small elliptical body of diorite cuts the monzonite; it consists mostly of labradorite and augite and a little hypersthene. The third body of this group is composed of monzonite and crops out on the southwestern side of the small basin southwest of the ridge. Judging from the metamorphism of the San Juan breccia surrounding this basin, the intrusion may underlie a good deal of the talus-filled basin. These three bodies lie within an area that is bounded in part by a circular fault and may thus be the upper part of a larger, compound, pipelike intrusion, similar perhaps to some of those described by Burbank (1941, p. 170–178, 246, 247).

There are many dikes in the South Telluride area, and they are especially numerous between the Ophir Needles diorite body and the Gold King Basin. Although they were called basic dikes in the field, they are mostly pyroxene andesite and latite. They range in width from less than 3 feet to about 40 feet, averaging about 10 feet. Some are fairly continuous for more than 2 miles, others appear only discontinuously along a single fracture, and still others are arranged in a distinctly en echelon pattern. There are many exceptions, but in general the northwestward-striking dikes are the oldest, followed in turn by the sparse westward-trending dikes and by the northward-trending dikes; the northeastward-trending dikes are the youngest. Most of the dikes appear to be older than the larger stocklike or plug-like intrusions, but a few do cut these intrusive bodies.

Many of the dikes are porphyritic and contain phenocrysts of labradorite, augite, or both. The pyroxene andesite dike rocks consist of labradorite with lesser and variable amounts of augite. The latite dike rocks usually contain phenocrysts of labradorite or pyroxene, but the groundmass contains a considerable amount of potash feldspar along with either andesine or labradorite, and may also contain a little biotite, hornblende, and quartz. Most of the dikes are greenish gray on fresh surfaces, and the pyroxene andesite is darker than the latite. Alteration usually lightens the color. Some dikes have lines of vesicles parallel with the edges; generally before weathering the vesicles contained calcite. As seen in thin section most of the dikes are flow banded with the feldspar laths arranged subparallel.

The dike rocks are commonly altered so thoroughly that only a guess can be made as to the original constituents. Sericite replaces the feldspars, chlorite replaces the mafic minerals and, in places, the plagioclase. Calcite is common throughout some of the dikes. Most of the quartz is probably secondary and formed during alteration. Some of the alteration may have been deuteric, but most of it is believed to have been hydrothermal. The dikes and adjacent rocks were strongly altered because of their location in and near fractures that were the principal channelways for solutions. A few dikes have frozen contacts and appear to be somewhat less altered. Like the altered country rock, the more intensely hydrothermally altered parts of the dikes weather brown from the oxidation of the pyrite, which was generally deposited during alteration.

In the area between the Ophir Needles diorite body and Gold King Basin, the oldest dike, an irregular intrusion of latite as much as 75 feet wide that strikes northwestward, now is considerably altered and contains much epidote and clinozoisite. Approximately six other dikes strike northwest, seven strike north, two about west, and five strike northeast. In general each dike differs a little from all others in color, grain size, character of phenocrysts, or in presence and amount of vesicles.

In the ridges from Gold King Basin to Gold Hill most of the dikes strike northwest or northeast. The northwestward striking dikes are the older, with the exception of the large dike along the northwestward striking Alta vein zone, which appears to be younger than the northeast dikes. A study of plate 16 shows other dikes in Lena Basin, East Fork Basin, in Bear Creek canyon as far north as the Champion mine, and in La Junta Basin. A thick (15 to 25 feet) dike with a distinctive porphyritic texture (phenocrysts of plagioclase as much as one-half an inch long) extends from a point north of Green Cone, across Bear Creek and into La Junta Basin. In La Junta Basin it twice occupies northward-striking fractures, then continues eastward under a large area covered by talus.

At the south end of Bridal Veil Basin, thin dikes, arranged en echelon along the south shore of Lewis Lake, extend northeastward from the lake. Another thin dike about 5 feet wide strikes east across Bridal Veil Creek a little way south of the Little Dorrit mine; it is extremely altered and so bleached in places that it resembles rhyolite. To the west it curves southwestward and apparently dies out after one en echelon-type offset. To the east, it is exposed in places along a fracture zone that crosses the south end of East Basin. The only other dike of any size in the eastern part of the area occurs discontinuously along the Millionaire fracture zone (pl. 17); after a change of strike this dike and the fracture zone continue north of the San Miguel River as the Alleghany vein. (See map, Burbank, 1941.)

Only a few breccia pipes of the type so common in the Red Mountain district (Burbank, 1941, p. 170–178) farther east, are exposed in the South Telluride area. All are on the north side of the east end of the valley of Howard Fork in the area of intensely altered rocks, where outcrops are few and poor. Because of the few exposures it is quite likely that more such pipes are present than were found; these pipes may be associated with the numerous small pipelike intrusions of quartz-feldspar porphyry. The breccia pipe along the next gulch east of the Carbonero mine is too poorly exposed to show whether it is associated with a porphyry pipe; the breccia is highly sericitized and has much disseminated pyrite in it.

The breccia pipe in Chapman Gulch, about a thousand feet northeast of the Calumet mine, apparently is quite similar to those described by Burbank (1941, p. 170–178). It has an oval-shaped outcrop of breccia about 500 feet in greatest dimension, whose center and eastern part is filled with quartz-feldspar porphyry. The generally angular or platy fragments of the breccia, ranging in size from less than a quarter of an inch up to about a foot and averaging about 3 inches, are replaced by much quartz and coarse-grained sericite, both also filling the interstices between the fragments. The weathered and leached rock is light yellowish-gray, with only a little brown stain from oxidized pyrite. The porphyry mass within the pipe is strongly altered and contains considerable disseminated coarse pyrite.

The third pipe seen in this area occurs rather low in the next gulch west of Chapman Gulch. Probably it represents a further stage in the silicification and sericitization processes seen in the Chapman Gulch pipe, as it consists almost solely of quartz and sericite, which are accomplished by pyrite and a little molybdenite.

Only two small "pebble" dikes were seen in the South Telluride area. Both were on the west side of Bridal Veil Creek, one west of the Royal mine, the other east of La Junta Peak. They occupy northward-trending fractures and are from 6 inches to 3 feet wide. They consist of 1- to 2-inch fragments of sandstone and shale, from pre-Tertiary formations (probably in part the Dolores formation) in a sandy matrix containing some clay material.

METAMORPHISM AROUND TERTIARY INTRUSIVE BODIES

The intrusion of the bodies of diorite and monzonite was accompanied by considerable contact metamorphism of the country rock. Metamorphosed pre-Tertiary rocks are especially well exposed on the west side of the Ophir Needles, northeast of Ophir Loop. Here the Brushy Basin member of the Morrison formation consists of alternating beds containing different proportions of biotite, epidote, other calc-silicate minerals, quartz, and magnetite. The rocks are hard, generally fine-grained hornfels, and range in color between dark green and various shades of gray. The main visible effect of the metamorphism has been, therefore, the reduction of the iron oxide, and the formation of calc-silicate minerals and biotite.

The lower sandstone of the Dakota sandstone was altered to a sandy quartzite with little color change. The upper part of this formation and the Mancos shale were changed to a succession of beds of quartzite and dark- to light-colored fine-grained hornfels, some containing calc-silicate minerals.

The Telluride formation was little changed by metamorphism, beyond a slight hardening and a change in color from reddish to gray.

The overlying tuff and breccia beds of the San Juan breccia were greatly changed; both the tuff and the breccia were recrystallized to such an extent that within 300 to 400 feet of the contact it is very difficult to distinguish them from the intrusive rock, especially on fresh surfaces; on weathered surfaces the bedding planes of the tuff, and the faint outlines of blocks in the breccia may show up. This similarity in appearance between the metamorphosed volcanic rocks and the intrusive rock is to be expected, of course, inasmuch as the pyroclastic rocks are made up principally of andesitic, and perhaps a little latitic, debris and have a very fine-grained matrix. Because of this similarity, it is very difficult to locate within a hundred feet the contact of the north side of the Ophir Needles body. Farther from the intrusions the breccia beds are lighter colored and distinctly greenish, because of the presence of considerable amounts of light-green epidote.

The groundmass of the flows of the Eureka, and presumably of the other flow rocks, has been recrystallized to a microgranular aggregate near the intrusive masses, and the flow-banded character visible in the glass or devitrified glass is lost. Near intrusions the phenocrysts of feldspar, which are normally clouded with sericite and other minerals, have been recrystallized into fresh feldspar. Secondary chlorite, which had replaced the mafic minerals in the unmetamorphosed rocks, was recrystallized to fine-grained pyroxene near the intrusions and to epidote farther away. Near Ophir Pass, the rocks between the upper part of the San Juan breccia and the top of the Burns latite contain considerable amounts of epidote, which apparently formed before the abundant silica and pyrite in this area was introduced.

Little change can be observed around the quartz-feldspar porphyry plugs because most of these intrusions are in the area of later intense hydrothermal alteration that has destroyed any observable changes.

Little change in the wall rocks could be detected along the mafic dikes beyond a slight hardening, probably caused by incipient recrystallization. Hardened breccia is commonly more resistant to erosion than the unaltered breccia or the dike rock, so that in places it stands out along the margins of a dike.

QUATERNARY DEPOSITS

A wide variety of unconsolidated material covers the bedrock in much of the mapped area. In addition to the widespread soil and vegetation, much talus and coarse rock-stream material, landslide debris, fanglomerate, alluvium, and a little glacial drift blanket large parts of the area. Because of the necessity of generalizing on the geologic map (pl. 16), these different types of surficial deposits are consolidated into two groups. The material shown as alluvium is mainly stream-laid material but includes some talus and glacial deposits; the talus includes all other types of unconsolidated cover, as well as some small local areas of alluvium.

LANDSLIDES

Landslides are numerous in the area mapped, as might be expected in a region where deep canyons have been cut by glaciation, and where weak formations are interbedded with strong ones. Most of the landslides have occurred where the conglomerate of the Telluride formation and the overlying volcanic rocks overlie either the weak Brushy Basin member of the Morrison formation, or the very weak Mancos shale.

The large Silver Mountain landslide, which in effect forms the west edge of the mapped area, probably is the largest single landslide mass in the country. It has been studied and described by Cross and Puprington (1899, fig. 10, and p. 11) and by Ernest Howe (1909, p. 17–21). According to Cross and Purington (p. 11),

The topography within this area is that most naturally characteristic of a surface made up of landslide blocks * * *. There are a great number of knolls, longitudinal ridges, or benches, the majority of which have steep outer slopes, with trenches, or depressions, often containing a stagnant pool, back of them, on the mountain side, and the drainage is extremely irregular * * *. While this area is large it exhibits relatively few exposures in which the attitude of the bedded formations there present can be clearly seen * * *. [In places] the tuffs strike somewhat west of north and dip * * * easterly * * *. [The upper edge of the slide] is not sharply indicated, except that above it are seen nearly continuous outcrops of the San Juan tuff in normal position and below it the confused landslide topography begins. On the west slope of Gold Hill, however, lateral ridges with a trench back of them, are found in several places near the cliffs of the San Juan. In some of these ridges the outcrops show the San Juan tuff dipping at various decided angles toward Gold Hill * * *. Rhyolitic debris [of the Potosi volcanic series] is scattered over the upper part of the slide area * * *. San Juan tuff and agglomerate forms most of the knolls and benches down to a level somewhat below 10,500 feet.

According to Ernest Howe (1909, p. 18) "It now seems probable that the Silver Mountain landslide * * * antedates in part the recent glaciation." Along the mountain front south of the Gold King Basin, however, several large masses of volcanic breccia have slumped since the area was glaciated. Some of these slides took place long enough ago so that they now are covered with soil and vegetation, whereas others are so recent that they are essentially free of vegetation. Bald Mountain and the ridge to the southeast that connects it with the main mountain front does not seem to have moved down, as the lowest exposed tuff beds of the San Juan breccia are at about the expected normal altitude.

Several somewhat smaller landslides occur along Bear Creek. Much of the upper part of the ridge east of the mouth of the canyon is covered by landslide material, from the altitude of the Wanakah formation up to the talus below the San Juan breccia. The Telluride formation is involved in the landslide where it is shown covered by talus.

A little farther south a landslide mass occupies most of the area (pl. 16) extending from the contact of the outcrop and talus 200 feet north of the Champion mine, 1,200 feet north to the Telluride and San Juan outcrops, and from the Dolores outcrop northwest of the Champion mine eastward to the point of talus north of the Weller mine. This mass has been little modified by erosion or vegetative cover, although from its lower edge a large amount of talus has gone down over the Dolores cliff. Its surface is very rough, and it contains some blocks of conglomerate hundreds of feet across. The position of the conglomerate and of a narrow basic dike in the mass northwest of the Champion mine shows that no great displacement is involved.

On the west side of Bear Creek a small landslide lies between the Contention mine and the Cutler outcrop to the east; part of it may have extended farther to the northeast almost down to the creek, but the area is now covered by talus and forest. The small flat below the Contention mine probably represents the upper part of the landslide mass. From a little way south of the Contention mine, south to the gulch north of the Canton mine, considerable landslide material lies between the cliff of the Telluride formation and the general altitude of the Cutler formation. Most of this material is covered by talus, soil, and vegetation. Large blocks of conglomerate, lack of outcrops, and the broken-up nature of the Mesozoic rocks are evidence of this landslide.

High on the east side of Gold Hill, southwest of the Nellie mine, a mass of San Juan breccia is broken up by slumping and grades downward into a large talus derived from it; its upper limit corresponds closely with a zone of altered rock along a north-northwestward-striking fracture.

TALUS AND ROCK STREAMS

Two types of unconsolidated deposits are widespread in the South Telluride area—talus and rock streams. They are prominent geologic features. They have an important bearing on any discussion of the geology and mineral deposits of the area as they cover much of the bedrock geology, and they restrict the location of mining operations, or make them difficult. Movement of talus may ruin or entirely wipe out trails, roads, or mining facilities.

The lower parts of many canyons and cirques are covered by deep layers of slide rock, and material falling from the stronger cliff-forming units buries many of the weaker layers in the section. The water-laid tuffs at the base of the San Juan breccia, the lower fissile part of the Burns latite flows (in some places almost the whole Burns latite), the gray latite flow and red latite flows and breccia of the Potosi volcanic series are commonly obscured by debris from overlying layers. The talus is particularly extensive on the north side of the valley of Howard Fork and in many places extends nearly to the top of the main ridge.

The talus has been forming since the glaciers receded. At the lower altitudes much of it is stabilized and covered with vegetation and some soil; in other places it is forming rather slowly, and so little movement is taking place that the lichen cover on the blocks is undisturbed. At higher altitudes, however, especially at or above timberline, the talus is being deposited rapidly, and consists of fresh material in relatively unstable equilibrium. In those places where the volcanic formations below the Potosi volcanic series form many cliffs, fragments both large and small can be heard falling intermittently all through the day; the largest numbers fall in the mornings, however, when the sun melts the ice that forms almost every night at high altitudes. The falling rocks generally bounce off the cliffs and land out on the talus, and the safest place to make traverses is therefore right at the base of the cliffs. The narrow chutes along faults, dikes, and altered zones through the cliffs deliver a great deal of material to the taluses.

The active taluses are surprisingly steep, especially in areas where much material from the San Juan breccia is available. Apparently a considerable amount of fine, claylike material is derived from the breccia and this acts as a binder for the coarser material; in addition, it is believed that much of this claylike material is almost permanently frozen. The result is that the angle of repose of many large taluses is between 38° and 41°, and the angle of repose of several fairly large areas is as great as 44° to 45°.

Rock streams, sometimes called rock glaciers, are abundant in the area. At least 62, combining all the types discussed below, have been counted in the area, and there undoubtedly are more, covered by vegetation and soil. These rock streams consist essentially of slide rock which has moved from its original place of deposition. A rock stream may be recognized by its front, which is debris derived from the rock stream itself, by the slope of the top of the mass, which is much less than the angle of rest for talus, by the concentric ridges and troughs on it, and by ridges parallel to the direction of movement.

Some of the rock streams are ridges of detritus, either parallel to, but somewhat higher than, the foot of a talus, or crescent-shaped masses near the foot of talus, with the outer upper edge higher than the talus slope on each side, and, generally, a slight depression in back of it. Other rock streams occur as long ridges going down gulches and cross flatter ground, standing somewhat above the talus on each side. Still other rock streams are a combination of several types;

good examples of composite rock streams are in the east side of Palmyra Basin, in Grays Basin, and in the northeast corner of East Fork Basin.

GLACIAL DEPOSITS

The area covered by this report was eroded by glaciers during Pleistocene time, and most of the material removed was deposited outside the area. The main terminal moraines must have been below the junction of the South Fork and the main stem of the San Miguel River (Atwood and Mather, 1932, pl. 3). Some glacially deposited material remains in the area, however, but it is spread rather thinly and is not obvious because much of it is covered by talus and vegetation. No attempt was made to study or map it.

Some lateral moraine probably lies along Bridal Veil and Bear Creeks, the Howard Fork, and the main stem of the San Miguel River. A few masses of moraine were noticed in Bridal Veil Basin; the largest is the mass in which the portal and first part of the adit of the Little Dorrit mine is located. The hummocky topography below Bridal Veil Falls probably is in part on moraine.

On the west side of the map area considerable amounts of morainal material lie in the lower parts of Prospect, Palmyra, and Gold King Basins, but it is not obvious because it lies on landslide topography and is largely concealed by a heavy vegetative cover. The three Alta Lakes probably are dammed by small terminal moraines. At least some of the ponds and undrained depressions southwest and west of the Gold King Basin are on morainal material.

ALLUVIUM

As mapped, alluvium includes stream deposits, alluvial fan deposits, mud flow deposits, and iron oxide deposits. Stream deposits are usually found only along the flatter parts of the stream courses. Considerable amounts are along the Howard Fork and the San Miguel River; some alluvium is also shown in the flatter parts of Jackass Basin and lower Bridal Veil Basin. Actually, of course, much more lies along most of the streams than is shown. The flatter parts of most of the basins contain some marshy ground; it is mapped as a part of talus or outcrops. Some alluvium also occurs along Turkey and Prospect Creeks.

In the valley of Howard Fork the alluvial fans, mapped as alluvium, are deposited both by stream flow and by mudflows that come down the gulches. The fan from Spring Gulch, on which the town of Ophir stands, is the largest and has pushed the Howard Fork over against the south side of the valley. Elsewhere, along Bear and Bridal Veil Creeks, and along the main stem of the San Miguel River, the alluvial fans have been mapped as a part of the talus.

Also included with alluvium are the deposits of iron oxide which occur north of Howard Fork between the mouths of Spring and Chapman Gulches. The largest occurs at Iron Springs, where several large terraces consisting mainly of iron oxide, with some clay and organic material, have been deposited by spring waters. Over a considerable area around the springs the coarse fanglomerate has been thoroughly cemented by the iron oxide. This large amount of iron oxide is probably derived by weathering of the pyrite disseminated through the large mass of hydrothermally altered rock that forms the whole mountainside to the north of the valley between Spring Gulch and a place east of Chapman Gulch.

SOIL AND VEGETATION

Much of the area is covered by soil and, at lower altitudes, by forest or brush, and above timberline, by grasses and annual vegetation. The soil over much of the country is immature and in many places consists mostly of frost-heaved rock plus creep material. Some better developed soil is found in the few flatter areas; such soils contain organic material in a few places where small patches of marsh occur. As mentioned before, much of the material marked as outcrop is partly covered by various thicknesses of immature soil.

GEOMORPHOLOGY

The present topography in the San Juan Mountains dates from Tertiary time, when a vast volcanic pile arose around the Silverton caldera. The youngest volcanic rocks in the area south of Telluride are a part of the Potosi volcanic series. According to Larsen and Cross (1956, p. 13) these rocks are overlain elsewhere in the San Juan Mountains by the Fisher quartz latite. Subsequent to the last volcanic activity a long period of erosion took place, and the San Juan peneplain of Atwood and Mather (1932, p. 21–26) was formed.

Only a few relic surfaces representing the San Juan peneplain are believed to be present in the South Telluride area. The largest one is a gently sloping area, rather deeply covered by soil, at altitudes between about 13,100 and 13,200 feet, between about 800 and 3,000 feet southwest of Bridal Peak. Other small areas of relatively gentle slope, such as that on La Junta Peak above about 13,200 feet, may be relics of the San Juan surface, but there are not many such remnants in this area. Somewhat lower and steeper upland surfaces may belong to the Florida cycle of erosion.

Consequent streams formed as the old-age surface was uplifted, and they flowed outward from the high volcanic center. In the South Telluride area these streams flowed westward and are represented now by the main stem and the Howard Fork of the San Miguel River.

Between the time when the San Juan peneplain was uplifted and the beginning of the last (Wisconsin?) glacial stage, several glacial stages and interglacial erosion cycles occurred, according to Atwood and Mather (1932, p. 27–31). In a summary, referring to the whole San Juan region they say (Atwood and Mather, 1932, p. 31)—

In general there seem to have been two main cycles of erosion subsequent to that in which the San Juan peneplain was developed. The earlier of these, the Florida cycle, progressed in general to the stage of late maturity before the cycle was ended by crustal movement. The second cycle, the Canyon cycle, is still in the stage of youth.

Normal stream erosion during Quaternary time has been interrupted at least thrice by glaciation. The first of these glacial stages, the Cerro, occurred during the Florida cycle. The second and third, the Durango and Wisconsin, both took place during the Canyon cycle of erosion.

Little evidence of any glaciation previous to the Wisconsin stage was seen south of Telluride, but the Florida cycle of erosion is evidenced by the "broad outer valley * * * [of the San Miguel] 8 to 15 miles wide and 1,000 to 2,000 feet deep" (Atwood and Mather, 1932, p. 51), and by the presence of many smooth, moderately sloping upland surfaces above the steep cliffs cut by glaciers. They generally are soil covered, and generally lie at intermediate altitudes as sloping benches between the peaks and ridges (which may be close to the altitudes of the San Juan peneplain, now largely removed) and the glacially cut cliffs around the cirques and canyons.

Probable remnants of the Florida erosion cycle are listed below according to approximate locations and altitudes.

North (11,800–12,300) and south (11,800–12,200) of Gold King Basin.

North (11,600–12,270) of Palmyra Basin out as far as, and probably including, Bald Mountain (a higher interval to the southeast, and lower one at the northwest end of the ridge).

From the broad pass (12,600) south of Gold Hill (12,738) northward to and beyond Green Cone (11,903) including the slopes down to about 11,000 at the north end.

The west side of the ridge on the west side of La Junta Basin (12,400 to 13,200).

La Junta Peak, between altitudes 12,600 and 13,200 and most of the upper, smoothly sloping parts of the ridge north to Ballard Mountain (12,804).

The more gently sloping areas of the upper parts of the ridges north of Silver Lake Basin, north and south of Jackass Basin, north and south of Grays Basin, and south of Mud Lake Basin.

By the begining of the Wisconsin stage of glaciation, the Canyon cycle of erosion (Atwood and Mather, 1932, p. 29), as well as the two previous glaciations, had left considerable relief in the South Telluride area; the total relief probably was approximately 4,000 feet, not greatly different from that at present.

The topography of the area between the San Miguel River and the Howard Fork shows considerable asymmetry with regard to the divide between the tributary streams respectively draining into the two main streams; the divide is in general about three times as far from the main stem as from the Howard Fork. It seems unlikely that this asymmetry can be related to the resistance to erosion of the bedrock, inasmuch as the largest mass of strongly altered, and apparently less resistant, rock in the whole area occurs between the Howard Fork and the divide to the north. Nor is it believed possible that the last glaciation could have done the amount of erosion necessary to produce so much asymmetry. Therefore, it is believed that most of the asymmetry of the drainage pattern was developed during the Cerro and Durango stages of glaciation. Presumably larger, and therefore more active, glaciers formed on northward-facing than on southward-facing slopes.

WISCONSIN GLACIATION

Wisconsin glaciers were important factors in the development of the present topography. Glaciation was intense and produced a fretted upland. The maximum extent of the ice is shown by Atwood and Mather (1932, pl. 3). The Bridal Veil glacier joined those coming down from the basins of Ingram, Marshall, and the other creeks north of the San Miguel River to form the large San Miguel glacier; farther down the canyon the Bear Creek glacier joined the main stream of ice. The Howard Fork glacier joined the one in the Lake Fork canyon, continued down the South Fork canyon, blended with the Bilk glacier (Atwood and Mather, 1932, pl. 3 and p. 72), and joined the San Miguel glacier; the terminus of the combined glacier was a short distance below the mouth of Deep Creek (to the northwest, off the map of this report).

Glaciation in the South Telluride area developed the features common to alpine glaciation, although these features are somewhat different from those developed in granitic or metamorphic terranes because of the influence of flat-lying lithologic units of differing resistance to erosion. The main upper basins of Bridal Veil Creek and the east fork of Bear Creek are compound cirques with several rock steps. Lena, La Junta, Silver Lake, Jackass, Grays, Mud Lake, and East Basins are tributary cirques, generally with several rock steps, which overhang the main canyons; all but Jackass, La Junta, and Grays Basins contain tarns. Most of the tarns are small, less than 7 acres in extent, but Blue Lake in East Basin is a large, deep body of water approximately 51 acres in extent when full. There are also numerous other ponds and marshes in the compound cirques, the largest of which is Lewis Lake. The level of many of the lakes and ponds in the Bridal Veil drainage area has been raised by dams. Many, but not all, of the upper parts of the rock steps in the cirques are the outcrops of the more resistant parts of the formations; the thinner, less resistant parts are covered by talus at the bottom of the rock steps.

The cirque of Deertrail Basin forms the head of a small hanging valley which falls directly into the canyon of the San Miguel River. West of the mouth of Bear Creek two incipient cirques cut the south wall of the canyon, their lips standing at about 9,800 feet. Along the west front of the mountains three small cirques form the upper part of Prospect Basin, and two larger cirques, Palmyra Basin and Gold King Basin, lie at the head of Turkey Creek and Gold Creek. Several tarns occupy these cirques. The three Alta lakes in Palmyra Basin lie in part on landslide material and are moraine-dammed features.

The part of the valley of Howard Fork within the mapped area has few typical cirques except for the large basin at the east end of the main valley, which contains Beaver Lake. The head of Staatsburg Basin is a fairly typical cirque; Spring Gulch is U-shaped and comes into the main valley nearly at grade. The rest of the gulches, however, have only a slight fanning out at their upper ends to show the results of glaciation. This is partly because the main canyon was filled with ice nearly up to the divide (Atwood and Mather, 1932, pl. 3) so that cirques formed on this south-facing slope probably only during the waning stages of glaciation, and partly because the weakly resistant character of the rock there has caused the over-steepened headwalls to slump down, forming extensive taluses.

All the main ridges above 13,000 feet are narrow jagged aretes and cols, and most of the peaks in the area are horns.

As the terminus of the main glacier fed by the tributary glaciers is outside the map area, little moraine is found in the area except for a little widespread material. The three glaciers in Gold King, Palmyra, and Prospect Basins did not join the main San Miguel glacier, however, and so deposited their moraines at the mouths of the respective basins; that is, on the upper edge of the Silver Mountain landslide.

POSTGLACIAL EVENTS

The several different geomorphic processes that have worked on the surface since the last glacial stage are: weathering, both physical and chemical; mass-wasting, including the formation of landslides, talus, rock streams, and mudflows, as well as talus-creep and soil creep; and the movement of material by running water, both sheetwash and streams. Some of the processes will be discussed briefly.

WEATHERING

Physical weathering consists principally of the alternate freezing and thawing of the water in fractures, which breaks up all exposed rocks. This process supplies abundant material for the taluses. The sound of much material coming down from the cliffs can be heard all summer long, as frost forms almost every night, and the process is therefore in operation all year long except during the coldest part of the winter when there is no thawing.

Normal chemical weathering, which is somewhat slowed up by the long period of cold weather, takes place everywhere, but more especially on the flatter surfaces. An accelerated type of chemical weathering takes place along the veins containing sulfides and over the masses of rock containing disseminated sulfides (mostly pyrite) that are present in certain areas. The acidic solutions formed by the oxidation of the sulfides, added to the other weathering agents, produces much deeper and more thorough alteration of the rocks. This is especially true north of Howard Fork where the effects of both physical and chemical weathering have been so intense that talus and soil cover extend almost to the top of the divide on the north side of the valley.

Mature soils are rare in the South Telluride area because of the relatively rapid movement of material. Soils approaching maturity may be found on a few flatter areas, such as the relics of the San Juan peneplain, and in the swampy areas in the basins. Elsewhere the soil is relatively immature.

MASS WASTING

In a region with so much relief, cliffs and steep slopes are so abundant that landslides are common, the formation of talus is continuous and widespread, many rock streams have formed from the talus, mudstreams flow almost every year, and the creep of talus and soil is active nearly everywhere as an important process in altering the topography.

LANDSLIDES

Landslides in the South Telluride area have been caused by oversteeping (generally resulting from glacial erosion) by the presence of weak shaly rocks underlying strong massive units, or, more commonly, by combinations of these two factors.

The large Silver Mountain landslide was formed when the South Fork of the San Miguel River had deepened its canyon sufficiently below the level of the thick black shale beds of the Mancos shale so that the weight of the overlying massive conglomerate (Telluride formation) and of the great thickness of volcanic rocks pushed out the shale to the west in successive great landslides. This happened first before the Wisconsin glacial stage, as parts of the landslide are overlain by moraine. According to Cross and Purington (1899, p. 10–11) and from evidence seen in the main Alta adit (eighth level) some movement is still going on.

All the landslides in lower Bear Creek canyon (p. 243) were caused by the oversteepening of the canyon by glacial erosion. Some are comparatively old, and may even be pre-Wisconsin in age, but the one north of the Champion mine (p. 244) is comparatively recent, and has been little affected by erosion since it formed. The landslide south of the Nellie mine is also mostly due to glacial oversteepening, as the rocks involved are all San Juan breccia, although hydrothermal alteration of the wall rocks along a weak vein may have helped by forming a line of weakness above the unstable mass of rock.

TALUS

The widespread taluses are the result mostly of physical weathering (freezing and thawing) of closely jointed flow rock and breccia. Enough claylike material is formed by chemical weathering for the matrix of the talus to be high in clay, and much of it is probably almost permanently frozen, especially where large deposits of talus stand with slopes as high as 45°. The formation of talus has been continuous since the end of the Wisconsin stage of glaciation. The large amount of talus available plus the presence of a frozen matrix in much of it is believed to have an important bearing on the origin of the rock streams.

ROCK STREAMS

Rock streams are abundant in the area, primarily because of the large amount of relief and the abundant talus. Most of the rock streams are found in cirques. Rock streams form when talus becomes unstable. Talus accumulates with maximum slopes ranging from 38° to 45°; this is possible because of the clay in the matrix, frozen at least in some places, and perhaps everywhere if rock streams are to form, and because the coarse material on the surface does not allow any but the largest blocks to roll far after falling from the cliffs. Possibly the matrix must be frozen for the slopes to stand at about 41° to 45°. Such high slopes of the talus result in unstable conditions which give rise to several different types of movement, and these different types of movement result in different types of rock streams. These are classified and discussed below:

1. Rock streams resulting from relatively slow creep.

   a. Creep of talus along a straight slope gives rise to a mass of material with a flatter slope out from the foot of the talus slope. This mass in places has a ridge of coarse material at its outer edge, which apparently could arise only from having large blocks roll across the snowbank that commonly covers the lower part of the slope until the middle of the summer; this ridge is found only on north-facing slopes, and this type of deposit resulting from solifluction plus rock falls across a snowbank is relatively rare. An example lies at the foot of the talus southeast of Lewis Lake.

b. Rock streams may be formed by slow creep of talus for a considerable distance down a gulch or depression. The creeping movement is probably helped considerably by alternate freezing and thawing. This material may show slight transverse concentric ridges and troughs at its lower end. Numerous examples occur in the upper parts of the gulches coming down the north side of the Howard Fork valley. When more water is present during formation, this type probably grades into regular mudflows, which deposit their load at the bottom of the gulch to form fanglomerate; several of them are present along the Howard Fork.

2. Rock streams resulting from relatively fast movement as a single event.

a. Slump of material that moves rapidly for a relatively short distance, pushing up a single concentric ridge above its toe, and leaving a depression in the talus slope behind it. The depression generally is more or less obscured, however, as the continually falling debris soon starts to fill it. This type of rock stream is believed to result from the melting of some of the ice in the matrix, with the result that at a certain time a considerable amount of material slumps down the slope. Good examples of these "single event" slides are two near the head of Jackass Basin, two in Lena Basin, and one at the head of La Junta Basin.

b. Slump of material that moves some distance with considerable momentum. This type usually involves more material than that in 2a, and may go considerable distances over relatively flat ground and even cross small gullies. This type of rock stream, like that in 2a, is probably caused by the melting of the ice in the matrix. One on the south side of Palmyra Basin is relatively long, narrow, and high with steep sides. It crossed at an angle the longitudinal ridges of an older compound rock stream that had come down from the southeast corner of the basin.

3. Compound rock streams. "Compound" rock streams generally form by a combination of periodic rapid movement interspersed with slow creep. Commonly such rock streams show the effects of repeated successive surges of the 2b type, plus perhaps some 2a and 1b types. Accumulation of talus must be rapid, with repeated overloading occurring to bring about this type. The 1b type of movement may be continuing slowly at present in these compound rock streams.

Ernest Howe (1909, p. 52–54) believed that all or at least most of the rock streams resulted from the breaking up of solid landslide masses as they tumbled down. One mass having such an origin is on the northwest side of Palmyra Basin. This mass lies north of the middle one of the three Alta Lakes; it has a doubly lobate steep front, a low angle of slope back of the front, a relatively small talus behind it, and the hillside back of it is a bare, treeless scar, standing out in strong contrast to the soil- and vegetation-covered slopes on each side of it. The landslide north of the Champion mine (see p. 244) is also somewhat broken up, but does not resemble a typical rock stream; it has no flat toe, the range in the size of the blocks is extreme, it starts in a scar in bedrock, and the movement is relatively slight, considering the size of the mass. The author believes, however, that all the other types of rock streams described above resulted from either slow or fast movement of steep taluses overloaded by the rapid deposition of material, and probably brought about in most types either by creep helped by alternate freezing and thawing (type 1) or by the melting of the frozen matrix (types 2 and 3). Howe (1909, p. 54) quotes Salisbury as suggesting that "some process analogous to solifluction" might account for "smaller rock streams."

STRUCTURE

The geologic structures in the mapped area are the result of two periods of diastrophism. The earlier period may correspond in time to the Laramide revolution, for it involved tilting and faulting that followed deposition of the Mancos shale of Cretaceous age and preceded the erosion that took place before the deposition of the Telluride formation of Oligocene(?) age. Most of the later deformation probably took place in late Tertiary time, as most of it occurred after the emplacement of the last intrusives that cut the Potosi volcanic series of middle or late Tertiary age (Burbank, 1930, p. 192), but before the development of the San Juan peneplain in late Pliocene time (Atwood and Mather, 1932, p. 25). However, some of the faulting of this period of deformation occurred before all of the intrusives had been emplaced, as some dikes followed fractures on which there had been previous movement. During this later period of diastrophism some blocks were tilted toward the east and many faults cut the area.

Some of the faults in the South Telluride area appear to be related to the formation of the Silverton caldera, to the east, whereas others are apparently related to the stresses involved during the formation of the intrusive centers in the valley of Howard Fork.

OLDER DEFORMATION

The rocks older than the Telluride formation had been tilted to the northwest before the erosion surface beneath the conglomerate was formed. Thus, the Telluride formation rests on part of the Dolores formation at Bridal Veil Falls and south of the Silver Chief mine on Bear Creek, whereas it rests on rocks of Morrison age near the mouth of Bear Creek. The progressive overlap of the Telluride formation across the truncated edges of the older formations is exposed along Bear Creek, and in the canyon of the San Miguel River east of Telluride. The dip of the Mesozoic rocks now ranges between 5° and 10° NW., but must have been slightly greater when the Telluride formation was deposited, as this formation, as well as the rest of the Tertiary section, has been tilted eastward about 5°.

West of Ophir Needles, the Telluride formation rests on the Mancos shale, but in the east end of the valley it rests on part of the Dolores formation, according to Cross and Purington (1899, Historical geology sheet). Marble of Pony Express(?) age dips 20° NW. at the Crown Point mine, but the dips of the Mesozoic beds must decrease farther east; otherwise rocks below the Dolores formation should be at the surface.

Only two faults were observed on which movement took place before Telluride time, but there are probably others. One fault is exposed south of the San Miguel River about 2,400 feet S. 35° W. from the Smuggler Union mill. It strikes N. 50° E. and dips 75° NW. The first period of movement was of a reverse nature, the northwest side moving updip 40 feet relative to the southeast side. In late Teritiary time the fault was reactivated and the northwest side moved down about 5 feet relatively. As a result the base of the Telluride formation is thrown relatively downward 5 feet on the northwest side, whereas the Mesozoic formations are thrown relatively downward 35 feet on the southeast side of the fault.

A second fault about 700 feet north-northeast of the Contention mine strikes about N. 50° W., dips 60° SW., and cuts rocks of the Wanakah and Morrison formations. This may be the same fault as the one that cuts the Cutler formation in La Junta Creek just east of Bear Creek. To the southeast, the Telluride formation at the lip of La Junta Basin is not cut by a fault, so this fault may well be one with only pre-Telluride movement.

YOUNGER DEFORMATION

Tertiary diastrophism resulted in a slight eastward tilting, toward the caldera, and the formation of a great number of fractures. The exact amount of eastward tilt is difficult to determine, because the surfaces on which most of the stratigraphic units were laid down are uneven, because the individual flows and breccia beds are of uneven thickness and probably had at least a slight initial dip westward, and because there are many small faults, which make true dip determinations over any great distance almost impossible. Dips to the east of as much as 10° were observed, and probably average about 5°.

The area of the report was cut by a great number of faults during this diastrophism. The displacement on most of them is less than 50 feet, is between 50 and 100 feet for some, and more than 100 feet for only a few. In general the fault pattern in the eastern half of the area is strongly influenced by the structural pattern of the Silverton caldera to the east. Faults radial to the caldera trend westward across at least the eastern half of the area and faults concentric to the caldera trend northeastward in the northeastern part of the area, and turn to a more north-northeastward trend in the central part of the area. Some north- and northwestward-trending faults are also present.

The faults of the southwestern and southern parts of the area appear to be influenced by the intrusive centers in the valley of Howard Fork. They trend mostly northwestward and northeastward, and generally have only small displacements. A few faults also trend northward. A large compound graben, which brings the Potosi volcanic series down between masses of San Juan breccia, lies along the west side, from Gold King Basin northward into the valley of Prospect Creek. Most of the drainage area of Bear Creek is cut partly by faults from the caldera and partly by faults from the Howard Fork intrusive center. The rocks at the east end of the valley of Howard Fork are involved in a series of horsts and grabens formed between westward- and west-northwestward-trending faults, which suggests a zone of disturbance lying between the group of quartz-feldspar porphyry plugs in the east end of the valley and the Silverton caldera.

Many of the faults are intruded by dikes, most of the faults have at least some hydrothermal alteration along them, and all the ore deposits of any importance lie along them. As the fault systems can be divided into different sets in different parts of the South Telluride area, the area will be subdivided into sections for the purpose of discussing the structure. Some sections have rather indefinite boundaries, but their approximate location is shown on plate 17.

The eastern section includes the whole drainage area of Bridal Veil Creek, most of Deertrail and La Junta Basins, and the upper half of East Fork Basin. The western boundary of this section is rather indefinite, being a broad zone of faulting, which is called the Boundary Zone on plate 17.

The western section includes most of the drainage area of Bear Creek, except that part in the eastern section, and extends west to the limit of mapping (see pl. 17).

The southwestern section includes the area from the southwestern side of Prospect Basin south to the Ophir Needles intrusion and the top of the Telluride formation, west of the Spring Gulch zone (north of Howard Fork) and west of the Suffolk slump (pl. 17).

The southern section includes the north side of the valley of Howard Fork from Ophir Loop to Ophir Pass, except that part north of the

Ophir Needles intrusion and the Telluride formation west of the Suffolk slump.

The structures of these areas will be described in general according to age, from oldest to youngest, although in many places the relative ages of intersecting structures were not determined. Many fractures along which altered rock or vein matter is present may or may not be faults. The definite determination of a fracture as a fault depends upon observing the offset of some recognizable unit, such as a stratigraphic unit, a dike or another fracture. Where no offset was found, the assumption has been made that any fracture that is reasonably continuous or that contains gouge, hydrothermally altered rock, or vein matter, has had at least some movement along it, and is, therefore, a fault.

EASTERN SECTION

In the eastern section fractures of the oldest set strike northwestward, dip at high angles to the southwest and have relatively little displacement. In several places fractures of this set are offset by faults belonging to other sets, thus providing evidence of relative ages. Fractures trending westward or a little north of west are younger than the northwestward-trending set, but they are cut by northward- and northeastward-trending faults. Fractures of this westward-trending set are the principal loci for the economically important veins. Dips on these fractures are steep. None of these fractures is itself continuous for more than a few thousand feet, but there is a tendency for these short segments to cluster in a group, and the resulting zone may be a mile or more long. Numerous northward-trending fractures are present in the eastern section, and a few show relative northward movement on the east side. The youngest structures in this section are the northeastward-trending faults. Almost all show relative downward movement of the southeast side.

The faults of the Boundary zone (pl. 17) are discussed separately as they are probably controlled by a major fracture in the pre-Tertiary rocks, and are not directly related to the structure of the Silverton caldera as most of the other sets of faults previously mentioned.

The northwestward-trending faults are relatively short and discontinuous except for the Millionaire zone (pl. 17). They strike between N. 30° W. and N. 60° W., and dip southwest between 52° and 82°. Relative downward movement is on the southwest side, from 10 to 35 feet. The Cliff fault (pl. 17), is downthrown 35 feet, the largest throw observed on such faults. The Millionaire zone is continuous across the eastern section, from Blue Lake through the cliffs south of the San Miguel River. The fault is somewhat irregular in course, and the dips to the southwest range from 60° to 80°. Where it cuts the Telluride formation at the mouth of Deertrail Basin it displaces the rocks 30 feet downward on the southwest side. A somewhat altered dike is present discontinuously along it, and large amounts of mineralized rock are present in some places. This fault is believed to be one of the oldest in the section, both because of the presence of dike material along it, and because of its relations with other faults. In the workings at altitude 12,175 on the Dividend vein (pl. 18), the westward-striking Dividend vein cuts the dike on the Millionaire fault but is itself offset by renewed movement on this fault. North of the San Miguel River the fault continues northward, with a dike and the Alleghany vein along it (Burbank, 1941, map).

The westward-trending faults dip between 60° north or south and vertical. In general, the principal faults north of the latitude of Blue Lake dip north, those farther south dip to the south. The displacement is rarely as much as 40 feet, and is generally not more than half this amount.

The most continuous zone of westward-trending faults is the Champion-Dividend zone (pl. 17). Between the Boundary zone and Bridal Veil Creek this fault dips 60° to 80° N. and is downthrown as much as 20 feet on the north side. East of Bridal Veil Creek the dip changes through vertical to south, and the amount of downthrow on the south increases going east; at the base of the cliffs on the east side of Grays Basin the offset is 5 feet but at the top of the ridge it is 30 feet. The rest of the faults as far south as the latitude of the north end of Blue Lake, including the La Junta-Royal fault zone and Orient fault zone, are more discontinuous than the Champion-Dividend zone. Most of them, however, dip to the north.

South of the latitude of the north end of Blue Lake, the fractures striking approximately west are less abundant, and all apparently dip to the south instead of to the north. The most prominent and continuous of these are the three faults of the Little Dorrit fault zone; the middle one has a dike along part of its distance and has at least 40 feet of displacement. The most southward structure of this type is a zone of weak fracturing, trending about N. 80° E. on the south side of Lewis Lake.

These westward-trending fractures, although spaced more unevenly, are believed to be similar to the northwestward-trending faults in the Telluride-Sneffels area (Burbank, 1941, p. 215–227, and map) that radiate from the Silverton caldera. Most of these fractures in the South Telluride area however, are neither so continuous nor so regular in strike as those described by Burbank. Some of them can be grouped into zones that are fairly continuous across the eastern section and into the western section.

Many fractures trending north or a little west of north are the next youngest set. Many of them have some mineralized rock along them and, toward the south, some contain veins. Some are faults having both a horizontal and a vertical component of displacement, the east side being moved relatively north and downward. The more continuous of these faults are grouped in two zones, the North Bridal zone and the South Bridal zone (pl. 17). The Little Dorrit and Lewis mines both lie on the South Bridal zone. As observed, the amount of horizontal displacement on individual faults is not great, (7 feet north of the Royal mine, 12 feet north of, and 60 feet south of the Little Dorrit mine), but with many such fractures present, the cumulative relative displacement of the rocks on the east side of the zones to the north may be considerable. How this northward movement of the rocks on the east is related to the origin of the Silverton caldera is not known.

Northeastward-trending faults are the youngest in the eastern section. All are between the Wasatch zone and the east side of the section. The faults of this set trend between N. 30°–50° E., and dip to the southeast. All are downthrown on the southeast side, generally from 20 to 50 feet, but the Pulaski fault has about 150 feet of displacement in places. Toward the south these faults have a more southward trend.

These northeast faults line up with structures to the northeast, which Burbank has grouped (Burbank, 1941, p. 157–158) as the concentric system of the caldera; that is, they apparenly are fractures out in the shield area parallel to the edge of the caldera, on which there was some movement sympathetic to the dropped block within the caldera.

Some northeastward-trending fractures in the southern part of Bridal Veil Basin are believed to belong to a different set of fractures, with a different origin than that described above for the concentric faults. This set, of which the Lewis zone (pl. 17) is a member, generally has a more eastward trend than the concentric faults, shows up as broad zones of shearing rather than as definite fault planes, and is probably tied in with a broad northeastward-trending group of fractures coming into Bridal Vein Basin from the central part of the valley of Howard Fork.

The Boundary zone of faulting has in general an average trend of S. 40° W. from north of the San Miguel River (about 500 feet east of the Smuggler Union mill) to the Weller mine, and of about S. 20° W. from the Weller mine to the divide on the north side of Howard Fork. Although these trends are similar to those of northeastward-trending concentric faults, this zone of faulting is more complicated, appears to limit some of the west-northwest fissures in the western section, and it lines up approximately with the Wheel of Fortune vein of the Telluride-Sneffels area to the northeast (Burbank, 1941, map), which Burbank does not group with the concentric faults. Moreover, it is believed that this fault zone is relatively old, in contrast to the concentric faults which are the youngest set of faults, both because of the pre-Telluride movement on one of the faults along it and because of the presence of dikes along it. Burbank points out (1941, p. 213) that the Wheel of Fortune fissure has both andesitic and rhyolitic dikes along it, which would also indicate relatively early faulting.

The Boundary zone (pl. 17) is fairly simple from south of the San Miguel River to the west side of Deertrail Basin, consisting of one main fault, one split from it, and another fault, 500 to 700 feet southeast of the main fault. The general area around the Weller mine (from the Champion mine to Ballard Peak) shows a complicated structural pattern, apparently the result of the intersection of this northeast zone of faulting and the Champion-Dividend westward-trending one. Here, several northwestward-trending fractures are present in addition to the northeastward- and westward-trending fractures, both within the complicated area and trending to the southeast toward the La Junta mine as a group of faults. The main fault leaves the Weller area trending south, then turns about S. 30° W. across the lower La Junta Basin to the ridge on the west side of the basin; it shows as much as 50 feet of displacement downward on the east side. About 1,500 feet north of the Nellie-Wasatch zone the fault splits, turns south, and the amount of displacement decreases southward. Within La Junta Basin several splits from the main fault trend south across the basin. Southeast of the point where the main fault turns south, these southward-trending fractures become more prominent, and continue south-southwestward through the ridge on the west side of the basin; all show downward displacement on the east side. A dike along the easternmost through-going fault extends from upper La Junta Basin almost to the Highline mine on the south side of the Howard Fork divide. On the south side of East Fork Basin the zone of faulting enters an area having a complicated structural pattern where it is joined by the concentric faults coming southwest from La Junta Peak. It is intersected by the Bear Creek fault. The Boundary zone was not seen south of the Carbonero-Highline zone trending northeastward.

Possibly this whole Boundary zone of faulting overlies a fault or fault zone in the rocks underlying the Tertiary section, which was active in pre-Telluride time. The Wheel of Fortune vein to the northeast (Burbank, 1941, map) lies approximately along the same structural line. The broad zone of splitting fractures, having a roughly en echelon arrangement, may thus be a reflection in the Tertiary section of movement on a through-going fault in the pre-Tertiary rocks.

WESTERN SECTION

The western section has a few structures, trending northeastward and northward, more trending northwestward, and many trending west or west-northwestward. The age relations of the northeast and north and northwest fractures are confusing because of renewed movement along older fractures which had been filled with dikes, but most of these fractures appear to be older than the westward-trending fractures. One exception is the Bear Creek fault (pl. 17), which appears to be one of the youngest faults in the western section.

Of the few northeastward-trending fractures in the western section two have dikes along part of their extent, and of these only one, the Northeast Gold fault, has appreciable length and displacement on it. This fault has displacement as great as 30 feet downwards and 10 feet southwest on the northwest side. The other northeastward-trending fractures include a couple of faults seen cutting only the Mesozoic rocks along lower Bear Creek, and several relatively short ones with veins along them on the west side of the small flat where U.S.M.M. Delta is located. Although the Contention fault strikes about N. 75° E., this fracture probably belongs to the Champion-Dividend zone.

Three of the approximately northward-trending fractures occur in the south part of the western section; the only others in this section are a few fractures in and near the Champion mine, which may be minor northward branches of the boundary zone of faulting. Of the fractures in the south part of the section, the East Delta fault shows the greatest displacement, 100 feet downward on the east. The West Delta fault has only 18 to 20 feet of displacement downward on the east side; a dike lies along this fault discontinuously. The Lena fault trends across Lena Basin about N. 5° W. to the south end of Gold Hill, where it appears to die out; it has a dike most of the way along its extent, and shows only a small amount of displacement.

Three of the northwestward-trending fractures in the western section have dikes at least discontinuously along them, and four, of somewhat less extent, do not. The Green Cone fault has a dike along it, and shows only a small amount of displacement. The Fairview fault (pl. 17) shows 35 feet of displacement downward on the north side, and has a dike along it on the west side of the canyon; on the east side of the canyon it appears as only a relatively weak zone of fracturing, with no dike. The third fault with a dike along it in places is the San

Joaquin fault, which cuts the east end of the Spring Gulch diorite mass at its south end. It is a scissor fault, showing 15 feet downward displacement on the west side, west of Gold Hill, and 22 feet downward on the east side where it cuts into San Joaquin Ridge. The northwestward-trending fractures without dikes in them are generally of less extent. One northeast of the Contention mine has been mentioned already (p. 255). A northwestward-trending zone of fracturing cuts the Canton fault southeast of Green Cone, and several fractures with relatively little displacement are on Gold Hill and just east of it, trending parallel to the San Joaquin fault.

The westward- to west-northwestward-trending fractures are the most abundant type in the western section, as well as the most important economically, as almost all the known ore deposits lie along them. Most of them can be grouped into zones. From north to south these are: (1) the Champion zone, which is alined with the Dividend zone to the east; the Contention fault appears to lie in the same zone, although it has a strike of about N. 75° E.; (2) a group of zones from the Canton to the Silver Chief faults are alined with the zone from the La Junta to the Royal faults to the east; (3) the Nellie-Wasatch zone; (4) the Delta zone, which includes the westward-trending fractures between 1,400 feet north and about 1,000 feet south of U.S.M.M. Delta; it is alined with the Little Dorrit zone to the east; (5) a zone on the south side of Lena Basin, which does not appear to be alined with any zone to the east. Almost all the fractures in these zones are faults dipping to the north, with downward displacement on the north side of from a few feet to as much as 40 feet. The few exceptions are the western part of the Champion vein and the Savage zone of faults that show from 10 to 50 feet downward displacement on the southwest side; in the Savage mine itself, however, the dip is to the north. (See pl. 20*C*.)

The Bear Creek fault (pl. 17) appears to be the youngest fault in the western section, and everywhere shows downward displacement of from 115 to 200 feet on the west side. Its actual intersection with other faults was seen only in the Maryland mine (pl. 20*D*) where it cuts the Maryland vein 530 feet in from the upper portal.

The fault zone taken as the west boundary of the western section between Prospect Basin and the divide south of Lena Basin is a single fault (called the Spring Gulch zone on plate 17) where it crosses this divide, but to the north it splits into several faults, some having a northwestward trend and others a northeastward trend. Near the point where the fault is covered by talus on the south side of Lena Basin it splits, and on the northwest side of Lena Basin and on the south side of Prospect Basin a complicated fault pattern is evident.

Northward-trending fractures split off from the northwest faults, then trend northeast and disappear under the talus of Prospect Basin. Presumably they then turn again to the northwest down Prospect Basin, as none is seen in Gold Hill to the northeast.

The faults in the western section are possibly related both to the Silverton caldera and to the two intrusive centers to the south (pl.17). Many of the fractures trending northeast, north, or northwest are filled with dike material similar to that at the intrusive centers, and the other fractures parallel to these presumably have similar origins. The zones of westward- to west-northwestward-trending fractures, however, are alined fairly well with the westward-trending zones of fractures in the eastern section, which are radial to the caldera; in detail, however, many of the individual fractures do not cross the Boundary zone. The Bear Creek fault is not obviously related to either center of structural influence.

SOUTHWESTERN SECTION

The overall picture of the southwestern section shows a few northeastward-trending fractures across most of the block, a complex of fractures between Gold King Basin and the Ophir Needles intrusion trending in several directions, a group of northwestward-trending fractures on and just south of peak 13470 on Silver Mountain, and a compound graben-type structure extending northward from southwest of Gold King Basin across the lower part of Palmyra Basin and down Prospect Creek an unknown distance under the Silver Mountain landslide mass. The south end of the graben is bounded by a circular fault.

The complex group of fractures north of the Ophir Needles intrusion, many filled with dikes, as well as the northeastward-trending fractures that extend across the southwestern section, appear to be structurally related to the Ophir Needles intrusion. The northwestward-trending fractures of peak 13470 on Silver Mountain, on the other hand, extend outward from the west end of the oval Spring Gulch intrusion and are probably structurally related to that mass; these are economically, the most important fractures in this section, as they contain important ore bodies. In general the age relations of the fractures in the southwestern section seem to be: The complex of fractures north of the Ophir Needles and the northeastward-trending fractures are the oldest. Then the graben was formed. The northwestward-trending fractures of peak 13470 on Silver Mountain are the youngest as they cut both the northwestward-trending fractures and the graben.

The older fractures of the complex north of the Ophir Needles and the northeast fractures of the whole southwestern section were filled with dike material, and in general show the age relations, from oldest to youngest of northwest, west, and north and northeast. Renewed movement on some of the older fractures after the intrusion of the dikes and the formation of newer faults give no definite relation of age in regard to direction. The dips are generally steep, in excess of 80° with many close to 90°, although a few are as low as 60°. The faults do not dip consistently in any one direction. The displacements are not great, although in many places they are indeterminate because only San Juan breccia is exposed on the surface. Apparent northward movement as much as 25 feet on the west side of some of the northward-trending faults occurred. Vertical displacement as much as 25 feet took place on other faults. One fault, which shows 160 feet of displacement down on the west side on the ridge south of Gold King Basin, is believed to be part of the graben.

The graben is a compound structure within which several blocks are separated by faults; the blocks are at altitudes much lower than in the rest of the area, and some are decidedly tilted. The structure is best exposed on the ridge on the north side of Palmyra Basin, which extends out to Bald Mountain, and the eastern part of it is also exposed in the ridge extending west-northwestward from Peak 13470 on Silver Mountain; what is probably the south end of the graben is exposed on the spur at the southwest edge of Gold King Basin, where a fault has 160 feet of displacement down on the west; just west of this fault a circular fault bounds an area that may be underlain by an igneous pipe of untrusive rock (see p. 238).

Along the ridge of the north side of Palmyra Basin, from a point 2,700 feet N. 66° E. from the portal of the St. Louis mine (4th level) toward Bald Mountain, the following structural units are exposed:

1. A graben of breccia and conglomerate of the Burns latite for 700 feet, dipping 15° to 30° west, and bounded on the west by a dike-filled southeastward-dipping fault.

2. A horst of San Juan breccia for about 1,100 feet, dipping about 40° northwest and divided by a southeastward-dipping fault into two blocks, the eastern one topped by flows of the Eureka rhyolite; the horst is bounded on the west by a northwestward-dipping fault having large downthrow on the northwest.

3. A graben of the Potosi volcanic series for approximately 2,300 feet, dipping northeast. A small patch of San Juan breccia, and flows and breccia of the Eureka rhyolite is faulted against the Potosi on the northeast side of the ridge. This graben is bounded on the west by

a fault, nowhere exposed, which must have a displacement in excess of 1,500 feet downward on the east side.

4. The rest of the distance to Bald Mountain is underlain by San Juan breccia. Low on the west side of Bald Mountain, the lower water-laid tuff beds of the San Juan breccia are exposed at approximately the normal altitude, suggesting that this complex graben is therefore not related to the formation of the Silver Mountain landslide.

The ridge on the south side of Palmyra Basin shows only the first narrow graben, consisting mostly of Eureka rhyolite topped by a small patch of Burns latite. The fault on the west side of this graben has a dike along it. A large mass of San Juan breccia is topped by some flows and breccia of the Eureka rhyolite in the horst to the west. For the rest of the distance westward to the portal of the Alta mine, the graben, if present, is covered by landslide material or moraine. Surface and underground exposures show that two of the northwestward-striking faults in the country east of the graben (the Hancock and Alta) continue westward across the fault bounding the main graben on the southeast side.

The northwestward-trending group of fractures of peak 13470 on Silver Mountain includes, from north to south, the Palmyra, St. Louis, Hancock, and Alta zones (pl. 22) which contain ore deposits that are among the most important economically in the south Telluride area. Five of the factures contain dikes. All of them dip 55°–90° NE., except one, which passes about 200 feet north of peak 13470 on Silver Mountain. They show downward displacement on the northeast side of from a few feet to as much as 50 feet. A few of the fractures were filled with dike material and had little later movement, whereas most of them apparently were reopened by movement several times. There is some splitting and branching of the fractures, and the Alta zone consists of a number of separate fractures, some having an en echelon arrangement. This group of northwest fractures converges toward the west end of the elongate Spring Gulch intrusion and may represent a zone of weakness that partly guided the emplacement of the intrusive mass; none of the dikes or fractures appear to cut this intrusion.

SOUTHERN SECTION

Exposures are poor throughout most of the southern section east of the Ophir Needles intrusion, except for a narrow strip near the divide on the north side of the valley and the west side of Lookout Peak and Ophir Pass. Available surface and underground exposures, however, indicate that the northeastward- and northward-trending faults of the southwestern section are in the northern part of this section; the Spring Gulch fault (pl. 17), cuts across the southern section;

in the central part of the section there is a broad northeastward-trending group of fractures that extend into the southern part of the eastern section, and also a few westward-trending fractures; east of Chapman Gulch a number of northwestward- and westward-trending faults form a group of horsts and grabens called the Lookout group on plate 17; they may represent a zone of weakness or sagging between the area of quartz feldspar plugs in the central and eastern part of the valley and the Silverton caldera, whose southwest edge is about 3 miles east of the Ophir Pass. Conversely, the group of horsts and grabens may be a reflection of the upward thrusting action of a possible diorite mass underlying Ophir Pass.

The fracture systems in the western part of this section, and many of those in the southwestern section, may be related to the fracturing that controlled the Ophir Needles intrusion; this intrusion (Cross and Purington, 1899) extends a considerable distance south and southwest of the area of this report. Likewise, the northeast zone of fractures may represent a zone of movement extending between this intrusion and the Silverton caldera to the northeast, the fracturing being probably more intense near the intrusion.

West of the Ophir Needles intrusion, only a few early-formed fractures are present in the narrow strip of metamorphosed Telluride formation and the underlying Mesozoic rocks. Most of them are filled with dike material and few have much hydrothermally altered rock along them. Only the edges of the intrusion were examined closely during mapping, but within it there are a few northeast fractures that line up with some in the southwestern section, and one dike-filled westward-trending fracture. East of the intrusion, few structures were mapped on the surface. Maps of the Crown Point and Santa Cruz mines and the Badger tunnel (pl. 21*D*, *G*, *J*) shows a few westward-, northward-, and northeastward-trending fractures.

The Spring Gulch fault is a single definite structure in the southern section, unlike the complicated fault zone northwest of Lena Basin. Just north of the Spring Gulch intrusion there has been 300 feet of displacement downward on the east side and about the same displacement near the mouth of the gulch where approximately the full thickness of the Telluride formation is faulted downward on the east.

Some fractures of the broad northeast zone are shown in the Badger tunnel, Gertrude, Carbonero, and Silver Tip mines (pl. 21*G*, *F*, *H*, *B*), in a few surface exposures northeast of the New Dominion mine (the Attica zone), and through and near the Highline mine (the Highline zone) (pl. 17). The northeast zone in the Calumet mine (pl. 21*C*) and those west of the peak (altitude 13,614 feet) may also belong to this northeast zone.

At the east end of the Howard Fork valley westward- and west-northwestward-trending faults cut the area between the south end of Bridal Veil Basin and Ophir Pass into seven structural blocks, some of which are horsts or grabens. The net effect of the faults is that the rocks on the north side of the whole zone are down about 200 feet relative to the rocks of Ophir Pass. A few northward- or north-westward-trending faults are also in this zone.

The Suffolk slump (pl. 17) is a block of peculiar structure that lies between the Suffolk mine and Staatsburg Basin. The block is bounded on the west and northwest by the fault 300 feet west of the Suffolk mine, a fault that trends northeastward irregularly until it meets the fault on the west side of Staatsburg Gulch, which bounds the block on the northeast. The south boundary of this roughly wedge shaped block is probably the outcrop of the Telluride formation. Within this area the breccia and flows dip in a southward direction from 20° to 50° and the rocks are cut by a large number of faults with relatively small displacement, which dip between 35° and 45° NNW., and have hydrothermally altered rock along them (fig. 25). The change from essentially horizontal layers outside the block to the southward-dipping layers within the block is abrupt, although

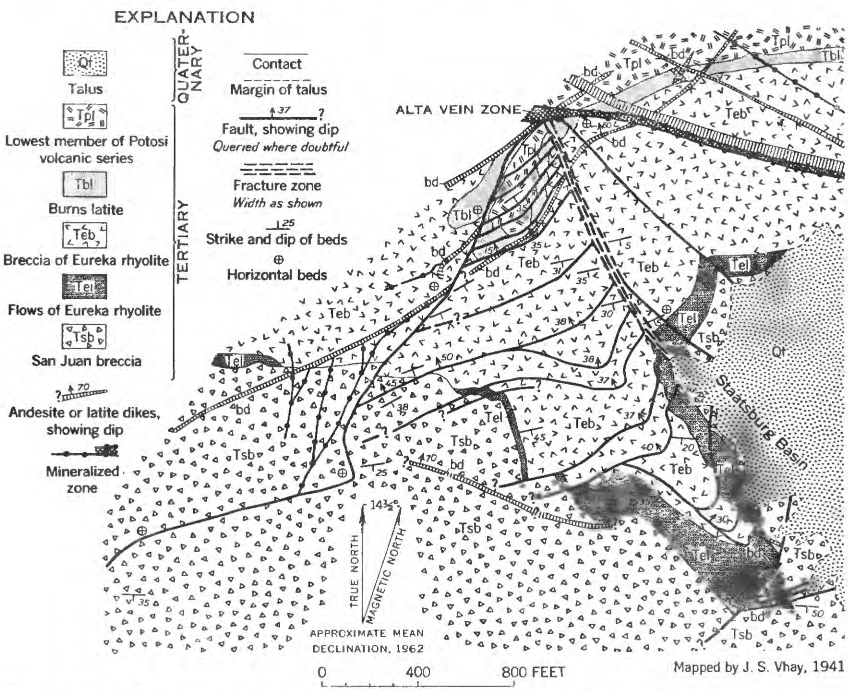

Figure 25.—Geologic map showing detail of structural complication in area between Suffolk mine and Staatsburg Basin.

the boundary fault can be seen only at its northwest end in Staatsburg Gulch, where it appears to be a relatively wide zone of closely spaced fractures. The layers just outside the block appear to be dragged down slightly, as they dip about 5° SE. near the fault zone. A distinctive porphyritic dike trending roughly east, about 100 feet south of the Suffolk mine, is offset approximately 100 feet south from its position in the undisturbed horizontal rocks to the west of the bounding fault.

Inasmuch as it does not seem possible that this block is a landslide, because of the presence of hydrothermally altered rock along the faults within it, the block may have moved on a synthetic fault which would crop out on the south side of the area just above the Telluride formation; the many small faults dipping north-northwest would then be antithetic faults (Burbank, 1941, fig. 3). No reason can be given, however, as to why this peculiar structure is located where it is. Unlike the situation which Burbank describes for the Red Mountain sag, the Telluride formation and the underlying metamorphosed Mesozoic section are hard, relatively resistant rocks.

ORE DEPOSITS

Early mining in the South Telluride area was for the gold and silver in the veins. Later, a few of the larger mines produced lead, copper, and, more recently, zinc, but even these could not have operated at a profit were it not for the gold or silver, or both, that accompanies the base metals. Considerable gold was produced from quartz veins that contained pyrite but no other minerals; a very few deposits of pyrite disseminated in intensely hydrothermally altered San Juan breccia were mined for gold. In most of the mines from which silver was produced veins that contained galena and tetrahedrite (or freibergite) with sphalerite and chalcopyrite, in places, were worked; gangue in these veins consisted of quartz plus siderite and ankerite, rhodochrosite, barite, or, more rarely, fluorite, or combinations of these minerals.

Most of the deposits of mineralized rock [2] in this area are veins that have filled open fractures along extensive zones of structural disturbance; these major zones are believed to be fractures that extend to great depth in the underlying rocks. Replacement deposits are less numerous but in some places have been mined. At a few places (such as the Gold King and Suffolk mines) many small veins cut the rock, and gold has been disseminated in the hydrothermally altered rock

[2] During this study of the geology, few samples were taken for assay, so that whether or not a particular "ore deposit" contained ore was not determined. For this reason, the term "mineralized rock" is used to describe the mineralized country rock, the vein filling, the gangue material, and the various combinations of ore minerals present.

around them; one bedded deposit (the Crown Point mine) has been formed in metamorphosed limestone of the Pony Express member of the Wanakah. The east half of the southern section contains a large area of widespread intensely hydrothermally altered rock accompanied by disseminated metallic minerals that form an extremely low-grade deposit of large size.

Few detailed studies of the mines in the immediate area under discussion have been published. C. W. Purington reported on the economic geology of the area (Purington, 1898; Cross and Purington, 1899). In these publications, Purington discusses the mineralogy of the areas and mentions a number of the mines as examples of different general economic features he describes. Unfortunately, only one mine map (of the Gold King and Suffolk mine workings) was included in the report and it shows no geology. Several short articles a few pages long describe special features at some of the properties, but they contain little detailed description of use in the present study.

In contrast to the meager descriptions of the mining properties in the mapped area, the mines to the north and east have been described in many publications. M. E. Hurst (1922) described the rock alteration along the Smuggler vein. E. S. Bastin (1923) discussed the relations of primary and secondary silver minerals in the Marshall and Savage Basins area, in the Red Mountain district to the east, and in the Rico district. W. S. Burbank (1930, 1933, 1935, 1940, 1941) has discussed the economic geology of several areas to the north, northeast and east, and V. C. Kelley (1946) has described the ore deposits and mines of an area on the north side of the Silverton caldera. Most of these reports have been useful during the preparation of this report.

HISTORY

An excellent summary of the history of mining in San Miguel County up to 1923 is given by Henderson (1926) in his "Mining in Colorado," to which the reader is referred for details. Henderson bases his report on the early days of mining in large part on Burchard (1881–1885) and Purington (1898). The following paragraphs are a brief summary of Henderson's report as it applies to this area.

The location of the first claim, the Smuggler, in 1875, stimulated the interest of prospectors in the area covered by the geologic map (pl. 16), and shallow mines were developed quickly during the next few years. By 1878 rich silver ore from around Ophir was being packed over Ophir Pass to the smelter at Silverton. In 1879 ore from the Gold King mine was being sent to an arrastre in the vicinity of Ophir. The Alta, Palmyra, Silver Chief, and Osceola ore deposits were discovered about 1877 and were developed rapidly. By 1881 a mill had been built in Gold King Basin below the Gold King mine. In the following year mines were being developed even at altitudes as high as the Lewis mine, about 12,500 feet, the Summit, and the Tip Top (the latter two on the ridge at the head of Gold King Basin, altitude 12,400 feet).

The region attained real importance as a source of ore after the Rio Grande Southern Railroad reached it in 1890. The railroad went past Ophir Loop and a branch went past Telluride up to the Smuggler Union Mill at Pandora. By 1898 most of the presently known deposits were producing ore. The use of electricity was widespread in the district and most of the mines of any size were connected by transmission lines to the power plant below Ophir Loop. Thereafter the mining has continued to the present with periodic ups and downs, controlled for the most part by metal prices. The mines operating on the argentiferous base-metal veins had considerable trouble in extracting the metals from the deeper unoxidized ore when it was first reached. Much experimenting was done on milling and recovery of the metals, but the problem was solved only by the advent of differential flotation, and mining once more became profitable. Some rather large operations, which produced rather large amounts of ore in the early days, now show little evidence of their former existence as the workings are inaccessible and the mills and other buildings have been torn down or destroyed by the elements, particularly by great snowslides.

The largest mines in the area that are still partly accessible are the Alta-St. Louis property, which was intensively mined from 1909 to 1924, and from 1936 until the mill burned in 1948 (p. 288–293), and the Carbonero mine, which has had several periods of activity, the latest being a project by the Defense Minerals Exploration Administration, which began June 2, 1952, and ended August 31, 1953. During the period 1938-42, and in 1947, at least some development was going on also at the following properties: the Dividend, Royal, Savage, Maryland, Silver Chief, Nellie, the western extension of the zone on which the Canton mine lies, and the Badger tunnel.

MINERALOGY

Little time has been given to a laboratory study of the minerals in the veins of this area, and consequently the discussion of the mineralogy is based in large part on field determinations and reference to previous publications (Purington, 1898; Bastin, 1923).

The following list is believed to include most of the important minerals in the veins and the hydrothermally altered country rock. Brief comments are given for some of them:

PRIMARY ORE MINERALS

Native gold.—Much of the gold mined in the area is not visible to the naked eye and occurs either as very small particles, or intimately intergrown with, or included in, pyrite and the other sulfide minerals. In places it is present as visible particles, especially in the quartz veins that consist of little else but quartz and gold. It may occur as small specks, as wires, more rarely as very thin leaves, as much as an inch across, or extremely rarely as large irregular masses.

Gold tellurides.—Although the name of the principal town of this area is Telluride, gold tellurides are extremely rare in the area. One specimen, given to the author by Mr. Isaac Partenan, appears to be calaverite, but no telluride was identified in any of the mines examined below the zone of oxidation, nor are any reported by Purington (1898) or Bastin (1923).

Argentite.—Both primary and secondary argentite has been reported from the general area by Bastin. None has been identified by the author, although the mineral no doubt occurs in some of the mines that produced much silver, especially those along the Howard Fork.

Silver sulfosalts.—Bastin reports proustite and pearceite as primary minerals in the general are, but none was recognized during this study.

Galena.—Galena is a common constituent in all the base-metal veins, and is also the most widely distributed base-metal mineral sparsely scattered in veins otherwise barren of the base-metal minerals. It may occur in base-metal veins as solid coarse-grained masses, as intergrowths with sphalerite, chalcopyrite, or tetrahedrite, or as isolated grains scattered through the vein; in places it may comprise nearly all of some of the bands in crustified ores.

Sphalerite.—Sphalerite is present in many base-metal veins either as the iron-rich variety, marmatite, ("black jack"), or as the more pure dark greenish-yellow variety, ("rosin zinc"). It may be present as fairly coarse crystals, which in some places show free crystal faces in vugs, or as finer intergrowths in the other base-metal minerals. Sphalerite apparently is less common than galena throughout the region, but in places was abundant enough to have caused trouble in the days when the miners were penalized heavily for any zinc in the concentrate that they shipped to the smelters. Evidence for this remains in the form of sphalerite-rich parts of veins that have been left as pillars in the mines, and large amounts of sphalerite left in some dumps, where apparently it was discarded after being handpicked from the ore.

Chalcopyrite.—Chalcopyrite is fairly common in the base-metal ores, and usually is intergrown with pyrite or the other base-metal minerals, although it occasionally occurs as small masses scattered through the quartz, or more rarely, as crystals showing free faces in vugs.

Gray copper.—Bastin (1923) reports both argentiferous tennantite and argentiferous tetrahedrite in the general area, and Purington (1898) reports freibergite in the Terrible mine and San Juan mine, near Ophir Loop. A gray copper mineral believed to be tetrahedrite was identified during this study on the Lewis mine dump, in the Alta and Crown Point mines, and in some of the veins in the southwestern part of Bridal Veil Basin; it is believed, moreover, that some probably is in most of the base-metal veins, and much of it probably contains some silver.

Molybdenite.—A little molybdenite is present in the deposits of the valley of Howard Fork, either as scattered large flakes in coarse quartz, such as in the quartz-sericite pipe west of Chapman Gulch, or as very fine particles smeared on joint faces, as in the Silver Tip mine.

Hubnerite.—A little fine-grained hubnerite was identified in the Silver Tip mine, and more may be present in similar deposits, associated with molybdenite.

Pyrite.—Although pyrite itself can hardly be called an ore mineral, it carries gold or is closely associated with gold in so many places that it is described here. Like quartz, pyrite is found in almost all the veins that fill fractures, and it is widely disseminated through the country rock along the walls of some of these fractures. In many places it can be found as discrete crystals in the country rock that otherwise shows little effect of hydrothermal alteration. It is common in the zones of more intense hydrothermal alteration close to the fractures or the faults, which may or may not be filled with vein or dike material. The pyrite may be in masses, or as discrete grains or as crystals in vugs. The pyrite was deposited in several generations; it may be found out in the country rock, or the outside of crustified veins, intergrown with the base metals, or as late-formed crystals lining open vugs. According to local belief, the fine-grained pyrite is more likely to be accompanied by gold than the coarse-grained pyrite, but this remains to be proved.

GANGUE MINERALS

Quartz.—Quartz is the most common vein mineral in the area south of Telluride. It fills fractures or parts of fractures of all different orientations and makes up part of every type of vein, excepting a few calcite veins. Quartz was introduced at several times during mineralization, and it varies widely in appearance. The deposition of most of the different types is separated by fracturing and reopening of the vein. The chief habits of quartz are listed below. approximately in the order in which they formed:

a. Fine-grained quartz replacing the country rock.

b. Fine-grained waxy or chalcedonic quartz representing silicification of gouge or country rock close to a fracture.

c. Massive, clear or milky quartz in veins (the "bull quartz" of the miners).

d. Finer grained sugary quartz in veins.

e. Crystals of quartz, (as large as half an inch long) usually clear, in comb structure.

f. Large crystals of quartz (as much as 6 inches long), clear, milky or amethystine, in vugs.

g. Very fine crystals (drusy quartz) lining cavities and covering the two previous types.

h. Very fine grained quartz, perhaps in part chalcedonic, variously described in the field as onion quartz, cauliflower quartz or botryoidal quartz, in vugs.

More careful study of the different types of habit of the quartz and much assaying would be necessary in order to identify the types of quartz with which gold is associated, either free or in pyrite. In general, however, gold appears to be associated more commonly with the sugary quartz, the fine crystals in comb structure and the drusy type of quartz.

Carbonates.—Siderite or ankerite forms irregular masses in many veins containing the base metals; generally it was recognized only underground in the accessible mines, but is believed to be almost always always present in the veins containing significant amounts of galena, sphalerite, chalcopyrite, or tetrahedrite. The siderite or ankerite was deposited at an early stage in these veins. Hereafter in the report this early formed carbonate will be called ankerite although in places it may be siderite.

Some rhodochrosite was seen underground, and in all probability it is more common than it appears to be from surface exposures. This is true especially in the veins in and close to the Ophir Needles intrusion where a large amount of black manganese oxide is in the weathered zone of those veins.

Calcite is present as a late-formed mineral in a few veins, either as solid masses or as crystals lining vugs; a few veins consist only of calcite bordered by slightly altered wall rock. The mineral is common in the altered wall rock along other types of veins, mostly in a zone outside the sericitized zone that occurs close to the veins.

Barite.—Barite is present in some of the veins, usually intergrown with the base-metal minerals. It is associated in places with quartz and fluorite in the "Millionaire"-type veins, and in places appears to have been leached out by hydrothermal solutions, leaving cavities shaped like barite crystals; some of these cavities are lined with drusy quartz.

Fluorite.—Although generally sparse, fluorite is present in a few veins. It is most abundant in the veins around the lower end of Bridal Veil canyon. The fluorite generally is fairly coarse grained and light green. In places it has been leached out and the resulting cavities are lined with later formed fine-grained quartz.

Gypsum.—Gypsum is present in the Carbonero and Panama veins of the Carbonero mine. It is probably also present in other mines on the north side of the valley of Howard Fork, but was not identified. With quartz it makes up the sparse gangue accompanying the base-metal sulfides of the Panama vein, and is associated with quartz, some rhodochrosite, and calcite in the gangue of the Carbonero vein.

Sericite.—Sericite, with quartz and pyrite, is abundant in the hydrothermally altered country rock along almost all the veins. Hurst (1922, p. 681–685) gives an excellent description of this material as he found it in the wallrocks of the Smuggler vein. It is widespread in the large area of altered rocks on the flanks of the valley of Howard Fork. There, also, coarse sericite and quartz almost completely replace the breccia in breccia pipes. One such pipe, in the gulch west of Chapman Gulch, was so completely replaced that it was labeled a quartz-sericite pipe.

Clay minerals.—A pure white or light greenish-gray claylike material is present in the veins in places, which suggests that it is a primary mineral rather than the result of weathering; this mineral is probably dickite (Ross and Kerr, 1931), but no attempt has been made to identify it in the laboratory. Fairly massive light-brown to nearly white material from the strongly altered area on the north side of the valley of Howard Fork was identified as allophane by C. S. Ross of the U.S. Geological Survey (written communication).

Kaolinite is common in the altered country rock along the veins at the surface and is believed to result from the weathering of the feldspars in the rock, probably intensified by the sulfuric acid resulting from the oxidation of the ever-present pyrite.

Adularia.—Scattered small well-developed crystals of adularia occur along some narrow gold-bearing fractures. More careful microscopic work might prove it to be more abundant than it appears to be from a superficial examination.

Secondary sulfides and sulfosalts.—In this region of great relief, erosion is so rapid that there is little chance for the formation of any appreciable amount of secondary sulfides and sulfosalts (Bastin, 1923, p. 95). Aside from a little bornite(?), chalcocite, and covellite, no secondary sulfides or sulfosalts were recognized during this study. Bastin (1923) found that some proustite and some argentite in the silver-bearing veins are secondary.

OXIDIZED ORE MINERALS

Native silver.—Bastin (1923) reports that wire silver occurs with argentite. It undoubtedly occurs within a narrow range of the surface in the veins rich in silver. None was seen during this study.

Copper bloom.—Green and blue copper minerals (probably mostly malachite and azurite) are present in the oxidized parts of veins carrying copper.

Cerussite and anglesite.—Cerussite and anglesite are probably common in the oxidized zone of the veins that contain lead but were recognized in only a few outcrops of veins.

PARAGENESIS

The paragenetic sequence of minerals in the veins as outlined below is based predominately on field observation with only a minor amount of microscopic study. Much more detailed work will be necessary to work out specific mineralogic relationships, particularly between the various sulfides.

The age relationships of the different forms of quartz were determined on the basis of field observations, and the sequence of deposition of the other gangue minerals and the ore minerals correlated roughly in this general outline. The following sequence of events was deduced during the fieldwork for one of the barren(?) veins north of the Weller mine.

1. Formation of a fracture
2. Silicification and pyritization of the country rock
3. Fracturing
4. Deposition of large quartz crystals and pyrite
5. Fracturing
6. Deposition of fine vuggy comb quartz
7. Deposition of calcite and "onion" quartz in the vugs

This sequence of events, with local variation, applies generally to the whole South Telluride area. The so-called bull quartz and the fine waxy quartz formed during intense silicification were deposited before the fracturing under 3. In the base-metal veins sugary quartz, chalcopyrite, sphalerite, galena and tetrahedrite probably were formed at stage 4, accompanied locally by barite, ankerite, rhodochrosite, fluorite, or gypsum. Gold appears to have been deposited with the fine comb quartz of stage 6, but some may have been deposited earlier or later.

STRUCTURE OF ORE DEPOSITS

The individual veins occupy faults and fractures that constitute parts of more extensive structural zones. Only the larger of these structural zones have had mines developed along them. The Champion-Dividend zone (pl. 17) is exposed for about 15,000 feet and continues east-southeastward on Burbank's map (1941) for at least 3,000 feet more. Some of the zones that strike northeast across the eastern section and swing south as they approach the Howard Fork valley have a length of more than 20,000 feet, although they are not continuous over this length. They are known to continue a considerable distance northeast of the mapped area. The zones that extend across Bear Creek in a westward direction are exposed for as much as 8,000 feet, as are some of the northwest zones in the southwestern section. The longer zones of fracturing probably continue down into the pre-Tertiary rocks.

The individual veins are not nearly as long as the major structural zones in which they occur. The Alta-St. Louis mine (the only large mine studied in detail) develops veins as much as 2,000 feet long; shorter veins, not exceeding a few hundred feet, occur throughout the area. The shorter veins generally have been little developed by mining, except where they constitute a closely related group of veins arranged in echelon. (See below.)

Ore shoots in the Alta-St. Louis mine have been stoped continuously in one place for as much as 1,500 feet, but most of the ore shoots on veins in the area are much shorter. The individual ore shoots in the Nellie mine, for instance, are only a few tens of feet long.

Many veins are arranged in echelon in the parallel fractures of structural zones; the echelon arrangement may take place either along the strike or down the dip. This feature is best illustrated underground on the map of the Nellie mine (pl. 20*J*). There, echelon vein segments are spaced only 3 to 4 feet apart, so that the miners, in drifting, would break across from one fracture to the next, after leaving an ore shoot. At the Fairview mine, on the other hand, on the surface it can be seen that as one vein dies out westward, another, 10 to 20 feet north, increases in width, reaches a maximum width of between 2 and 3 feet, then dies out. In some places a few weak altered cross fractures join the successive veins together, in other places a narrow stringer of quartz bends over to a northwest strike and joins the next vein to the north. The fact that this feature was apparently not appreciated during development of the mine is shown by the highest level of the mine (pl. 20*H*), where one fracture was followed a long distance, and no crosscutting done to explore the parallel fractures. This echelon arrangement of the veins (and ore shoots as well) is probably quite common, although perhaps not everywhere so pronounced as at the above-mentioned two mines. The Nellie-Wasatch zone also shows a large-scale echelon offset to the south updip, across the high ridge between Bear Creek and La Junta Basin. (See pl. 16.)

Ore has been mined in the area from as low as the Canton mine, altitude 9,580 feet, in the Cutler formation, to as high as an altitude of 12,900 feet in the breccia member of the Eureka rhyolite of Palmyra Basin. In upper Bridal Veil Basin, mines at altitudes above 12,500 feet in flows of the Burns latite have yielded ore, and in the basin of Blue Lake ore has been stoped from the Potosi volcanic series at about the same altitude.

Neither the altitude at which a vein is found nor the chemical character of the wall rock is a factor in determining whether a vein contains sufficient valuable metals to be minable. The two important facts in forming minable veins are believed to be the fracturing characteristics of the wall rocks and the time of fracturing; fracturing took place several times in the area, and when fractured ground was available to solutions containing valuable metals, metalliferous veins were formed.

The formation of the veins and the ore shoots within them was strongly influenced by the type of fracturing that took place in the different lithologic units in the area, and by the changes of dip of the fractures. The most favorable units, on the whole, were those of intermediate strength and relatively coarse grain. Units having these characteristics are the San Juan breccia, the breccia members of the Eureka rhyolite, and the Burns latite, the conglomerate of the Telluride formation, and the conglomerate and sandstone of the Cutler formation. The San Juan breccia contains the most ore in the South Telluride area both because of its favorable characteristics under deformation and because it is the thickest of any unit. The Entrada sandstone might have been relatively favorable, but it is so thin and lies between such unfavorable units (the Dolores and Wanakah formations) that there are no known ore bodies in it.

Relatively weak units were unfavorable because fractures did not stand open long enough for veins to form in them. The Dolores, Wanakah and Morrison formations are of this category. The Pony Express limestone member of the Wanakah might be considered an exception. The few veins seen cutting this unit, however, do not change appreciably in width, nor are bedded deposits found in it as happens in the Ouray district (Burbank, 1940, p. 211), except for the Crown Point mine (pl. 21*I*); there a replacement deposit has formed in the metamorphosed Pony Express limestone member.

The stronger units form only narrow fractures when deformed and therefore contain only narrow veins, if any. The flows of the Eureka rhyolite and of the Burns latite are therefore relatively unfavorable, both as to fracturing characteristics and thickness.

The members of the Potosi volcanic series are in general relatively unfavorable host rocks, although a few small mines have produced ore from the lowest member in East Basin and in Bridal Veil Basin. The reason seems to be that faults and fractures that extend up into this formation split into broad zones of fracturing, and the hydrothermal solutions rising into these ramifying channelways caused widespread alteration rather than definite veins. Only rarely were vein minerals deposited in any of the narrow fractures, and where this happened the minerals were usually limited to quartz crystals and minor amounts of pyrite. This splitting of fractures in the formation may have taken place because of nearness to the surface and the resulting light load rather than because of the relative strength of the formation. The widespread areas of alteration, which include silicification and the formation of disseminated pyrite and clay, have formed extremely large deposits, probably much too low grade for mining in the foreseeable future.

The formation of ore shoots is controlled mainly by two factors. First, openings are widest in the steeper segments of normal faults of variable dip. Although there is little actual information available about the plunge of ore shoots in the area, it appears that where the change of dip plunges along a vein, the resulting ore shoots on the more steeply dipping part of the vein plunge similarly. Secondly, the fractures must be open at the time when solutions containing metals are available to traverse them. For this reason, fractures that have been reopened many times are more liable to have ore shoots along them than those which opened only a few times. In places, the earlier formed base-metal deposits have been enriched by being reopened at a time when gold-bearing solutions were available. This was seen at one place on the fifth level of the Alta vein, where a later-formed quartz vein containing gold cuts through an earlier quartz-ankerite vein bearing galena, chalcopyrite, and tetrahedrite. The same thing undoubtedly has occurred at many other places.

TYPES OF ORE DEPOSITS

Most of the ore produced in the South Telluride area has come from veins that fit the old definition of "true fissure veins"; that is, the material in the veins has been deposited in large part in openings along fractures. Successive movements along these fractures have resulted in repeated reopening, and therefore deposition of the vein minerals in successive stages was common, and the veins generally are crustified or banded. Hydrothermal alteration has affected the walls of all the veins of any importance, but only rarely was any gold or other metal of value deposited in this altered rock. Intense hydrothermal alteration of the rocks is widespread along the north side of the valley of Howard Fork and is present in a few other places. Solutions that produced the alteration also appear to have deposited disseminated ore minerals in the country rock; but this type of mineral deposit has been mined only rarely.

Mineralizing solutions were apparently available over a considerable period of time and must have changed their composition considerably from time to time. Therefore, the kind and amount of mineral deposited in any fracture depended on when the fractures were open. Fault zones of almost any bearing may contain one or more of the different types of deposits listed below. The same zone may also have different types in it at different places along its extent. The longer fault zones opened up more often and therefore had a better chance of having worthwhile ore deposits formed along them.

The different types of deposits of mineralized rock in the South Telluride area are as follows:

Barren veins:
- Calcite only
- Quartz, with or without calcite
- Quartz and pyrite
- Quartz, barite, with or without fluorite, with or without pyrite

Gold-bearing veins:
- Quartz
- Quartz and pyrite
- Quartz, barite, sparse pyrite, and galena, with or without fluorite

Base-metal veins:
- A gangue in most places made up of quartz, ankerite, barite, with or without rhodochrosite, fluorite, gypsum or calcite. Pyrite almost everywhere. The valuable metals are contained in chalcopyrite, tetrahedrite, galena, sphalerite; one or more of them may be absent. Silver almost always present, gold abundant enough in places to be recoverable.
- Rhodochrosite and galena, generally rich in silver.
- Replacement deposits consisting of relatively large volumes of intensely hydrothermally altered rock made up of sericite, quartz, clay, and disseminated pyrite; may contain disseminated gold and many small veinlets carrying quartz and gold; other valuable metals may be disseminated in the rock in small amounts.

AREAL DISTRIBUTION OF VEINS

In general the veins north of the latitude of the outlet of Blue Lake have been mined mostly for gold. Many of them contain gold, quartz, and pyrite, a few contain only gold and quartz, and a few contain sparsely distributed base-metal minerals besides. Most of them occupy the westward-trending fault zones, but a few occur in fractures of other directions. Deposits in the southern parts of the Bridal Veil and Bear Creek drainage areas and in the southwestern section in general have been mined for both gold and silver but contain considerable amounts of base-metal minerals as well. The relatively small area from the Gold King mine to the Telluride formation south of the Suffolk mine has produced principally gold from both veins and disseminations in altered country rock. Most of the deposits in the Howard Fork valley have yielded silver, lead, and copper from base-metal veins; the area just north and east of the Ophir Needles intrusion has a somewhat special type of deposit containing silver in galena-rhodochrosite veins. Quartz and quartz-pyrite veins are so widespread that they will not be specifically mentioned, but they should not necessarily be ignored in prospecting.

For convenience of description, the area will be divided into the same sections as were described in the chapter on "Structure."

EASTERN SECTION

Most of the ore deposits of the north half of the eastern section lie in the westward-trending structural zones and are valuable principally for gold. Some contain also sparse amounts of galena and chalcopyrite. A few of northeast and northwest trend have also been developed.

A special type of deposit containing fluorite in addition to the usual vein minerals occurs in the northern end of the eastern section. Included in this type are the Millionaire vein zone, the westward-trending veins just south of the Mayflower mine, a vein 900 to 1,000 feet north of this one, and a few others of northwest trend. These veins contain fluorite and quartz of two or three ages. The Millionaire vein zone shows the usual paragenetic relations (p. 275) but in addition, after stage 6, (deposition of fine comb quartz on margins of vugs, followed by deposition of a clay mineral and pyrite) there was a period of minor fracturing, followed by the leaching out of some fluorite and barite, then deposition of fine-grained drusy quartz. According to Purington (1898) the mine on the northeast side of Deertrail Basin, at an altitude of 11,434 feet (pl. 16) produced gold in the early days. It is not known at what stage the gold was deposited, but it may have been at stage 6 (p. 275) or, less likely, at stage 4. The fact that only one successful mine was developed along the Millionaire fault suggests that not much gold came into it.

Gold is in most of the westward-trending systems of veins south to the latitude of Blue Lake. These include the Champion-Dividend zone (pls. 17 and 18), the vein on which the Royal mine (pl. 19–*G*) is located, the one about 1,000 feet north of the Royal Mine (believed to be the Waterfall vein), and the one about 1,600 feet south of the Royal mine (on which the mine at altitude 11,575 feet is located);

some of these veins, such as the Royal vein, contain sparse base-metal minerals. The fault zone on which the vein of the Royal mine lies appears to continue westward to the La Junta mine (which produced a small amount of gold) on the east side of La Junta Basin, and to cross the basin to the west side, where it is coextensive with a group of west-northwestward-trending veins containing base-metal sulfides, quartz of four stages, and probably some gold. The vein about 1,600 feet south of the Royal mine extends westward to the east side of La Junta Peak, and the zone of fractures in which it lies continues across the north side of La Junta Peak, trending about N. 62° W. In the Orient mine, from which minor amounts of gold were also produced, apparently a vein in this zone was explored on the east side of La Junta Basin. Farther south, in the vicinity of the Little Dorrit and Lewis mines, there are fewer westward-trending veins, and those observed do not appear to be gold bearing.

The northeastward-trending veins generally contain only pyrite and one or two stages of quartz. These veins rarely contain gold. Although the shaft of the Mayflower mine goes down on one of them, it is believed that any gold produced probably came from the westward-trending vein about 200 feet south of the shaft, as this vein is part of a main fracture along which gold is known to occur elsewhere (Dividend zone, pl. 18). The small mine on the north side of Grays Basin (altitude 11,935, pl. 19*D*) has one stope from which gold was presumably produced. The northeastward-trending vein that passes under Mud Lake has galena and sphalerite in a quartz-carbonate-pyrite gangue where it crosses the ridge southeast of Mud Lake. The Wasatch fault (pl. 17) contains galena in a quartz vein at the head of Jackass Basin.

Most of the northward-trending fractures, many of which actually strike a little west of north, contain only quartz-pyrite veins. The mine on the west side of Bridal Veil Creek, between the creeks draining Jackass and Silver Lake Basins (altitude 10,883, pl. 18), does, however, contain some galena and chalcopyrite in a gangue consisting of quartz of two ages, pyrite, and ankerite.

The richer looking deposits in the southern part of the eastern section consist of base-metal veins on northward-trending fractures in the South Bridal zone (pl. 17) and, in Bridal Veil Basin itself, on northeastward-trending fractures of the Lewis zone. These base-metal veins contain chalcopyrite, tetrahedrite, galena, and sphalerite in a gangue that consists of quartz of at least two ages, some ankerite, and barite; they contain silver and probably some gold.

Southwest of the Millionaire fault two northward-trending veins contain base metals. One trends south from a point about 150 feet west of U.S.M.M. Pulaski, and in places contains base-metal sulfides in a gangue of silicified gouge and comb quartz. These two vein zones converge southward and apparently join into the single vein that is explored by the Little Dorrit mine. This mine is caved at the portal, but considerable base-metal material occurs on the dump. Farther south the Lewis mine is on the same vein zone; its large dumps also contain considerable base-metal minerals.

Several base-metal veins in Bridal Veil Basin, from the Little Dorrit mine south to Lewis Lake and across the full width of the basin, trend in general between N. 45° E. and N. 75° E., and contain chalcopyrite, tetrahedrite, galena, and sphalerite in places in a gangue consisting of quartz, pyrite, ankerite, and barite. This occurrence is rather unexpected, as the veins cut, and were mined in, the Burns latite and the lowest member of the Potosi volcanic series. Except for a few small mines on the southeast side of Blue Lake (perhaps an eastward extension of the same zone), this is the only place where base-metal minerals were seen as high in the rock column as the Potosi volcanic series, which in other places seems to be very unfavorable for the formation of veins that contain anything but quartz and pyrite. The presence of these base-metal veins in the Potosi volcanic series is, therefore, an indication of an area of particularly intense mineralization that may have important ore bodies in the much more favorable San Juan breccia buried below (p. 277). There is the possibility that this group of veins lies in the broad zone of structural disturbance extending approximately from the Badger tunnel in the valley of Howard Fork almost to Blue Lake (p. 259, 266 and pls. 16 and 17).

WESTERN SECTION

In general the deposits in the western section like those of the eastern section, contain mostly gold in the northern half, but towards the south contain increasing amounts of base-metal minerals, so that around U.S.M.M. Delta, and farther south they are base metal veins containing considerable silver and gold. Most of the deposits to the north lie in the westward- to west-northwestward-trending structural zones, whereas around U.S.M.M. Delta some also are on both the northeast and northwest structures.

A relatively large area, where gold has been mined from veins having several different trends, lies along the Champion-Dividend fault zone (pl. 17) where it intersects the south-southwestward-trending boundary zone. This area will be referred to hereafter as the Weller area, after a mine within it. Quartz veins within this Weller area are present in several groups of fractures; these include veins trending between N. 50° W. and N. 65° W., veins trending between N. 10° W.

and N. 25° W., and at least one vein about N. 20° E. The veins generally contain quartz of three or four ages and some pyrite; many must have contained moderate amounts of gold, to judge by the large amount of digging done on them. Besides the Weller and Champion mines there are many opencuts and small adits. The mine at the north edge of the area (altitude 11,690 feet) has been stoped to the surface for a considerable distance along a vein that strikes N. 20° E. A small mine on the east side of Ballard Mountain is shown as *A*, plate 19. The mine, 700 feet S. 40° E. of the Weller mine, has a fair-sized dump. The Weller mine itself must have been important for the production of gold at one time, as a tram line went down N. 32° W. to Bear Creek, and this tram apparently had considerable use. According to Purington (1898), the quartz veins in this area contain gold and very little pyrite. He further states that the Champion mine was worked only in the conglomerate (Telluride formation) where the fissured zone is a fault breccia in which a solid vein of quartz contains little else than gold.

The Contention mine (altitude 10,375, pl. 16) west of Bear Creek lies on line with the Champion-Dividend zone, but the vein strikes about N. 75° E., at an angle to the zone. The mine is completely caved and inaccessible, but according to Purington (1898), the vein was worked in the conglomerate (Telluride), where the fissured zone is marked by a fault breccia filed with quartz containing gold and very little pyrite. Where the vein was observed during this study at a higher altitude in the San Juan breccia, it shows silicified and pyritized rock, fractured, and filled with comb quartz and a little pyrite.

Farther south along Bear Creek are the Canton, Maryland, Silver Chief, and Fairview mines (pl. 20*B*, *D*, *I*, *H*). These develop some of the veins on the west to N. 70° W. group of faults (pl. 17). All the veins have approximately similar mineralogy; the wall rock is somewhat silicified, two or three generations of quartz make up the vein and contain some pyrite and, in places, gold. The Canton mine (pl. 20*B*) has been stoped on three levels and produced much profitable ore. The Maryland (pl. 20*D*) and Fairview (pl. 20*H*) mines have had somewhat less production. Other gold producers along Bear Creek mentioned by Purington (1898) but not definitely located during this study are the Northern Ohio and Elizabeth mines.

On the east side of the canyon, in the great cliffs on the west side of the ridge between La Junta Basin and Bear Creek, are a number of veins trending about N. 50° W. on the average. Only some have mines along them, but they are basically similar and any of them could contain undiscovered gold-bearing ore shoots. The Savage mine (pl. 20*C*), from which a small amount of high-grade gold ore was produced, is on a vein near the north end of this group of veins, at altitude 11,709 feet, in La Junta Basin.

The vein in the Silver Chief mine has somewhat different mineralogy. Chalcopyrite and galena occur in a gangue consisting of pyrite and two stages of quartz; Purington (1898) reports the presence also of sphalerite, mispickel (arsenopyrite?), calcite, and sericite. He further describes the vein in this mine as being as much as 9 feet wide, as showing crustification and ribbon structure along the sides (probably due to reopening), and as being essentially silver-bearing. This vein apparently is alined with the vein in the Fairview mine on the west side of the canyon and with another quartz-pyrite vein on the east side. Another vein in the Cutler formation, S. 67° E. from the portal of the Canton (the Northern Ohio?), also shows chalcopyrite, galena, and sphalerite on the dump of the adit in the Culter formation, although up in the Telluride formation and the San Juan breccia only quartz and pyrite were seen in the vein.

The next productive fault zone to the south is that on which the Wasatch and Nellie mines are located (pl. 20*J*, *K*). It is a pronounced echelon zone that extends from the west side of La Junta Basin across the north end of Gold Hill. West from the ridge on the west side of La Junta Basin it is offset to the north twice at distances of about 200 and 300 feet, and on the slope of Gold Hill it is offset to the south somewhat; conversely underground observations show that along strike to the west this structure is offset repeatedly 2 to 4 feet to the north in the Nellie mine, and perhaps also in the Wasatch mine. The veins on the offsetting fractures consist of two and three stages of quartz, with pyrite and, in places, gold. In the Nellie mine, intense hydrothermal alteration has converted the country rock along the veins to a soft clayey material that may carry some gold.

Farther south a large, irregular shaped area is characterized by the presence of considerable amounts of base metals in the veins. This area, hereafter called the Delta area, can be considered as surrounding U.S.M.M. Delta between the Lena fault and the Boundary zone. A western extension of this area is the west slope of Gold Hill. Within this general area several veins contain at least some of the base-metal minerals, such as galena, sphalerite, chalcopyrite and, in places, tetrahedrite, in a gangue more complex than that of the gold-bearing veins to the north. Barite, ankerite, in places much pyrite, and some rhodochrosite (as indicated by heavy manganese oxides) are present in addition to the quartz, which generally is of three or four ages. Some of these veins must contain considerable amounts of silver, or gold, or both metals, judging by the number of small abandoned mines with fair-sized dumps. None of the mines were accessible except the one east of U.S.M.M. Delta (pl. 20*L*), marked altitude 11,640 feet on plate 16. This mine is on the most continuous vein in the Delta area; the vein extends from the west side of Wasatch Mountain a little south of west to Prospect Basin.

Other veins with westward and northeastward trend are common, and there are a few with northwestward trend, and at least two with northward trend. One of these, on the Lena fault (pl. 17), contains sulfides in a quartz-barite gangue in the flows at the top of the Burns latite. Within the Delta area is also an area of extremely altered rock where a number of rather closely spaced fractures in several different directions occur; this area is in a narrow canyon along the East Fork of Bear Creek, about 1,000 feet north of the mine at altitude 11,640 feet. This area contains rocks that are replaced by sericite, clay, and pyrite, and has a number of quartz veins of different trends.

SOUTHWESTERN SECTION

Base-metal veins in the southwestern section occur on northwestward- and northeastward-trending faults. In the southern part of the section there are a group of galena-rhodochrosite veins containing a considerable amount of silver near the Ophir Needles intrusion, and one northward-trending vein zone associated with a mass of hydrothermally altered rock from which gold has been produced.

A group of veins trending between N. 30° E. and N. 60° E., and an intersecting group trending between N. 45° W. and N. 70° W., contain at least one, and generally several or all, of the base-metal minerals, chalcopyrite, galena, sphalerite and tetrahedrite, in the usual type of complex gangue found with the base-metal minerals; rhodochrosite may be more abundant here than farther north or east. In places, these veins are high in silver, especially those reportedly high in galena and tetrahedrite (freibergite?), and have also been enriched by later-formed gold-quartz veins introduced approximately along the same fractures. Near the surface supergene enrichment in silver must have taken place by the formation of sulfosalts, argentite, and native silver, and in gold by the oxidation and leaching out of base-metal minerals and pyrite; this is indicated by the large production of gold and silver in the early days from many small mines in the shallow oxidized zone. The property of the Alta Mines, Inc., which is the largest in the area and most recently operated, is described in somewhat more detail on pages 288–293.

In the area from approximately 1,500 feet east and west of the north end of the Ophir Needles northeast to the cliffs southwest of the lake in Gold King Basin are a number of veins of diverse trend (mostly north and north-northeast, but some east) which contain an exceptional amount of rhodochrosite, judging from the large amounts of manganese oxide in the outcrops; the rhodochrosite is accompanied by some barite, quartz, and pyrite. Most of the veins presumably contain some base-metal minerals and silver. No large mines occur in this area, but again many small, near-surface mines, now inaccessible, are present. Extending across the notch northeast of Ophir Needles is an area of iron-stained intensely altered rock containing considerable amounts of clay and manganese oxide in the outcrop.

A special situation exists in the general area from the Gold King mine south past the Suffolk mine and down into the Telluride formation south of the Suffolk mine. Little could be observed during this study, and what follows is based almost entirely on Purington's description (1898). In this area there are many small quartz veins of diverse strike that are not shown on the map (pl. 16). The country rock between all these veins is much altered and considerable pyrite has been introduced. The quartz veins themselves and the altered country rock contain appreciable amounts of gold, probably in or accompanying the pyrite. This situation exists as far south as the conglomerate of the Telluride formation. (See notes for Gold Crown on p. 298). Both the quartz veins and the altered pyritized country rock in this area have therefore been stoped. Old stopes caved to the surface can be seen along the Gold King vein north of the Suffolk portal shown on the map (pl. 16). Originally a number of separate small mines were worked in this area. (See notes for Globe, Gold Crown, and Suffolk on p. 297, 298, 302.) Later they were combined into a single property, worked mostly through the Suffolk portal (altitude 11, 321, pl. 16). The ore was sent by aerial tramline to a mill near Ophir.

SOUTHERN SECTION

Aside from a few northward-trending quartz veins and the disseminated gold ore around the Suffolk mine, already described, most of the veins on the north side of the valley of Howard Fork trend either within 10° of N. 65° E., or approximately east. All these veins contain one, though generally more than one, of the base-metal minerals, galena, sphalerite, chalcopyrite, and tetrahedrite, in a gangue of pyrite, quartz of several ages, and in places barite, ankerite, rhodochrosite, or gypsum. Most of them also contain considerable amounts of silver and some gold. Some of the near-surface (secondarily enriched?) ore shoots mined in the early days must have been exceptionally rich in silver, as the ore was sent by pack train over Ophir Pass to smelters at Silverton. The Crown Point mine workings (pl. 21*J*) were in a replacement deposit in metamorphosed limestone of the Pony Express member that contained silver-rich tetrahedrite, galena, and chalcopyrite. A few deposits contain some molybdenite and a little hubnerite. Near and east of Chapman Gulch only quartz-pyrite veins containing a little gold are present. A large area of intensely hydrothermally altered rock containing very low amounts of base-metal minerals extends from Spring Gulch to Chapman Gulch. All the accessible workings of the mines on the north side of the Howard Fork valley are shown on plate 21, with notes regarding the local geology.

The group of veins trending within 10° of N. 65° E. lies in the broad zone of structural disturbance that extends from the Badger tunnel to Blue Lake, and presumably farther northeast. (See 259, 266.) The following veins belong to this group and most contain base-metal minerals: the vein 570 feet from breast of the Badger tunnel (pl. 21*G*); two or three veins explored by the Osceloa and Gertrude workings (pl. 21 *A*, *F*); two veins about 2,200 feet N. 50° E. of the New Dominion portal (pl. 16); three veins explored by the Carbonero mine (pl. 21*H*), on one of which the Highline mine also lies; the veins explored by the workings in the Silver Tip mine (pl. 21*B*); the vein about 1,000 feet N. 35° E. from the Illinois tunnel as well as a number of veins within that adit (pl. 21*I*); and the vein explored by the Calumet mine (pl. 21*C*). Perhaps also the several faults and altered zones that lie across the main ridge northwest of the unnamed peak (altitude 13,614 feet) north-northwest of Lookout Peak are a part of such a broad zone.

The Carbonero mine (pl. 21*H*) has probably had the largest production of any mine on the north side of the valley of Howard Fork. According to data supplied by W. B. Meek (written communication), from 1907 to 1941 the mine produced a total of 101,662 tons of ore containing an average of 0.024 ounce gold, 8.7 ounce silver, 6.99 percent lead, 4.7 percent zinc, and 0.16 percent copper. The vein farthest north, the Carbonero vein, strikes between N. 50° E. and N. 85° E., averaging N. 75° E.; the average dip is 80° N. This vein is as much as 36 inches wide, averaging 12 inches, and consists of one to four stringers of sulfides in gangue or altered country rock. The sulfides, in the order of decreasing abundance, are pyrite, galena, sphalerite and chalcopyrite; the nonmetallic minerals are gypsum, quartz, calcite, and, rarely, rhodochrosite. The next vein south, the Panama, has an average strike of about N. 55° E., and a steep dip to either the northwest or southeast. The Panama vein is considerably narrower than the Carbonero, being only 1 to 6 inches wide but consists of almost solid sulfides, (sphalerite, galena, pyrite, and chalcopyrite, in order of abundance) with a sparse gangue of quartz and gypsum. Not much can be seen of the third vein in the Carbonero mine, that at the portal, but a fault breccia cemented by limonite and containing some quartz and galena was noted.

So far as observed the eastward-trending veins show about the same mineral content as the northeastward-trending veins. Mines in which ore was produced from veins of this direction are the Osceola (pl. 21*A*), the Santa Cruz (pl. 21*D*), and the New Dominion (pl. 21*K*); other mines, now inaccessible, probably worked similar veins. Some can be seen also on the maps of the Silver Tip mine (pl. 21*B*), the Badger tunnel (pl. 21*G*), and the Crown Point mine (pl. 21*J*).

Several small veins containing quartz, pyrite, clay, scarce base-metal minerals, and some gold are exposed along Chapman Gulch and east as far as Lookout Peak. They trend in general west and northwest. The gold content of these veins was sufficient so that considerable stoping, some extending to the surface, was done.

Molybdenite in small quantities can be seen at several places in the Howard Fork valley. It generally is associated closely with the quartz-feldspar porphyry intrusions. A little is in small veinlets in the New Dominion mine (pl. 21*K*); in the lower level of the Silver Tip (or Yellowjacket mine) (pl. 21*B*) it occurs as a thin coating on joint faces for about 400 feet along the crosscut. Some rather coarsely crystalline but rare masses occur in the breccia pipe replaced by quartz and sericite in the gulch west of Chapman Gulch. A little hubnerite occurs with the molybdenite in places.

From a short distance west of Spring Gulch to the east side of Chapman Gulch, hydrothermal alteration has effected all the rocks—sedimentary, extrusive, and intrusive. In many places the alteration is so intense that it is impossible to differentiate any of the formations below the Potosi volcanic series. Possibly there are some extremely large sized, low-grade deposits where hydrothermal alteration was especially intense. Extensive sampling would be necessary, however, to delimit them and to determine the grade.

ALTA MINES, INC.

The property of the Alta Mines, Inc., covers considerable ground in Palmyra Basin, Gold King Basin, the ridge between the two basins, and across the ridge at the head of Gold King Basin down into Staatsburg Gulch. The approximate boundary of this property is shown on figure 26, which also shows the levels of the Alta mine, the levels 2 and 4 of the St. Louis mine, the Jonnie drift which joins level 4 St. Louis with the level 5 of the Alta, and the new work from level 8 of the Alta over to the St. Louis ground. Levels 1 and 3 of the St. Louis mine, and the newer work on level 8 in both the Alta and St. Louis ground are not shown.

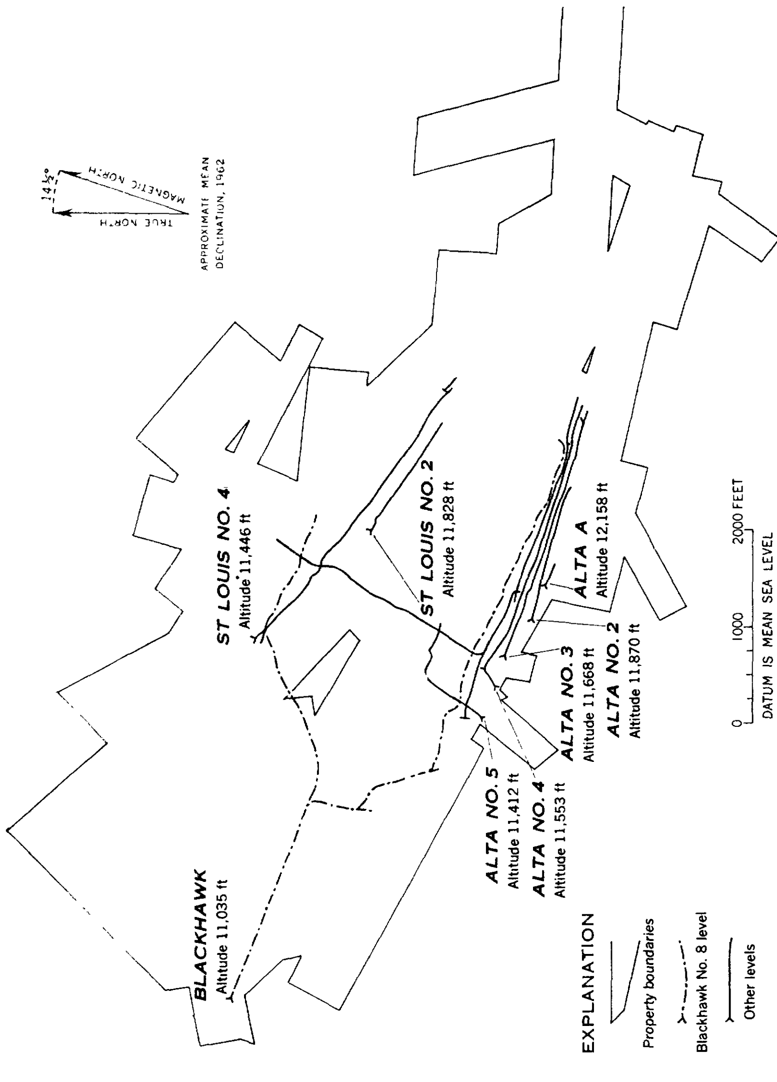

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FIGURE 26.—Map showing property boundaries and most of the mine workings (as of 1942) of the Alta Mines, Inc.

The following brief summary of the history of the property is based on what the author was told by John M. Wagner, a long-time resident of the region who was active in developing and consolidating this property.

The first claim of this group, the Alta, was staked in 1877. Development of the veins in the region was so rapid that by 1879 the Gold King Co. had built a 20-stamp mill, and two arrastres were operating near Ophir. By 1881 the Alta and Palmyra claims had been developed sufficiently to prove that ore in paying quantity and grade was present; a year later level 2 of the Alta had 700 feet of development on it. Development and production continued on several properties. By 1897 the San Juan Co. had consolidated many claims and built a 200-ton cyanide mill. This mill was unsuccessful and a change was made to stamps and gravity concentration. Operation continued until 1907, when the company was bankrupt, reportedly because of incompetent management. During this same period the 4-Metals Co. worked the Palmyra-St. Louis property, shipping ore to smelters. The company failed but later leasers were somewhat successful.

In 1908 John Wagner acquired the property of the Alta Mining Co., and during the next few years acquired adjoining claims. The mill was operated on Alta ores, and in 1910 the tramline to Ophir was built. In 1913 the Palmyra-St. Louis group was acquired, and the Jonnie drift was driven from the Alta level 5 to the Palmyra vein, the Palmyra vein was drifted on, and a raise driven to connect with the older Palmyra workings. Wagner reports that from 1909 to 1917 the gross production was worth $849,147, and the profit was $627,268.

In 1917 John Wagner and Clyde A. Heller organized the Belmont-Wagner Mining Co., which was active from 1917 to 1924. A large mill was built below the portal of the Blackhawk adit (altitude, 11,035 feet), and this adit was then driven in over 6,000 feet to form the Alta level 8. During the period 1917 to 1924 the Belmont-Wagner Co. mined and milled 126,430 tons of ore, but failed in 1924, because of inefficiency and high metal losses in the mill.

From 1924 to 1929, when the mill was destroyed by fire, John Wagner operated the property, doing development mostly and mining only enough ore to finance the operation.

About 1936 Alta Mines, Inc., took a lease and option on the property, and mined until after the war. In 1948 the mill and much of the surface plant was again destroyed by fire.

There are eight levels on the Alta vein. The ore in the highest five levels was mined out some time ago. Levels 6, 7 and 8 supplied most of the ore more recently. The ore in the Palmyra vein in the St. Louis mine has been mined out from the four upper levels for a distance of about 2,000 feet at the west end; the eastern extensions of these levels have not been developed. The company has extended a crosscut from level 8 of the Alta over to the Palmyra vein where it developed ore about 400 feet below the old 4th level.

The ore mined during the early years of World War II averaged about 0.10 ounce gold, 4.0 ounce silver, 1.4 percent lead, 0.15 percent copper, and some zinc. The concentrate as shipped average about 0.5 ounce gold, 32 ounce silver, 12.3 percent lead, 1.75 percent copper, and unstated amounts of zinc, for which the company received credit. The table following shows the production since 1901.

The developed part of this property (pl. 22) is entirely in the San Juan breccia. The lowest level is probably not more than 200 feet above the Telluride formation and much of the San Juan breccia in the lowest level consists of fine-grained waterlaid tuff. The volcanic rocks are cut by a number of andesitic dikes, veins and faults, most of which trend from N. 50° to 70° W., and from N. 30° to 45° E. Dips are generally from 60° to vertical.

The veins are, in general, composite and were formed in several stages separated by recurrent movements. The fractures tended to open up along or close to the earlier formed dikes, so that there are few dikes that do not have at least a little mineralized rock along them, and only a few veins that do not follow dikes. The earliest stage of mineralization resulted in the formation of sericite, the introduction of pyrite and calcite, and in places considerable silicification of the country rock. The second stage was preceded by the development of fissures on which there was relatively little movement, and resulted in the formation of discontinuous (en echelon) fissure veins containing galena, chalcopyrite, sphalerite, and tetrahedrite in a gangue of quartz, barite, and rhodochrosite. The next period of fracturing was accompanied by considerable movement which formed rather continuous breccia and clay gouge zones. They cut through and along the earlier fissure veins in some places and in places cut the barren country between them. This period of movement was followed by the formation of vuggy comb quartz veins containing gold. There has been some postmineralization movement along northeastward-trending faults. The veins in the higher levels are considerably oxidized and are richer in gold. The ore in the lower levels may have a higher percentage of zinc than that in the upper levels.

The ore shoots occur in the relatively steep parts of the veins and may occur on the hanging wall, within, or on the footwall of dikes. The structural control is not entirely understood, however, and more complete, accurate surveys of the mine will be necessary before the problem can be solved satisfactorily.

Mine production of gold, silver, copper, and lead from the Alta and St. Louis mines, 1901–57, in terms of recoverable metals

[Prepared by Division of Mineral Industries, U.S. Bureau of Mines. Published by permission of owner]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)
1901	709	151	41,866	—	—
1902	9,695	799	91,560	4,155	680,800
1903	9,058	57	28,173	—	252,888
1904	20,170	1,895	117,446	—	977,754
1905	(1)	2,322	153,669	15,727	1,317,745
1906	15,462	3,096	204,891	68,720	1,756,983
1907	19,990	1,542	115,638	790	418,604
1908	(2)	—	—	—	—
1909	13,200	899	45,379	33,280	340,314
1910	19,643	2,428	98,107	45,890	676,750
1911	25,428	2,843	73,798	35,347	442,137
1912	32,095	3,378	99,301	49,312	608,610
1913	27,000	4,233	94,500	46,648	574,032
1914	19,000	2,831	95,836	36,919	792,329
1915	9,636	1,111	19,909	8,094	149,447
1916	15,000	3,134	54,810	26,743	326,047
1917	14,036	1,656	43,755	23,452	265,673
1918	7,079	422	24,705	13,186	107,271
1919	27,338	1,602	100,557	45,234	354,969
1920	20,180	974	63,138	26,738	311,771
1921	20,215	810	82,089	40,162	387,595
1922	42,117	3,637	171,940	40,045	645,540
1923	23,698	1,573	117,668	45,772	435,895
1924	1,350	200	3,666	2,155	23,615
1925	2,700	167	7,919	3,000	43,000
1926	3,450	207	27,347	11,000	103,500
1927	846	79	9,182	6,263	37,310
1928	8,250	220	11,804	6,278	35,673
1929	23	10	1,617	761	6,480
1930	(2)	—	—	—	—
1931	14	11	14	—	—
1932	60	61	43	—	—
1933	30	28	16	—	—
1934	20	14	1,225	400	8,500
1935	15	57	459	200	2,200
1936	35	119	729	330	3,980
1937	12,000	524	26,351	23,100	113,030
1938	32,695	2,412	96,578	70,950	363,600
1939	40,403	5,909	66,869	116,350	310,540
1940	45,988	4,756	100,023	67,538	553,397
1941	40,498	2,546	115,330	76,500	928,960
1942	32,683	2,613	110,558	78,800	1,033,634
1943	17,964	1,199	40,676	32,214	471,789
1944	15,000	2,285	30,605	35,407	308,090
1945	40,372	3,589	35,525	90,032	413,932
1946	32,132	3,305	75,822	184,495	472,410
1947	26,079	1,947	24,475	85,812	262,313
1948	24,000	1,186	18,035	47,770	240,679
1949	(2)				
1950	(2)				
1951 [3]	52	67	902	1,770	12,000
1952	(2)				
1953	(2)				
1954	(2)				
1955 [3]	22	25	443	500	3,700
1956 [3]	1	32	29	—	700
1957 [3]	11	15	183	100	1,700

[1] Ore tonnage unknown. 3,862 tons concentrates.
[2] No production.
[3] Cleanup.

The Alta and Palmyra vein zones are the only ones on which development or mining has been done to any depth. The branching and en-echelon character of the Alta vein suggests the possibility of overlapping or parallel ore shoots, but few of the splits along the main zone have been followed for more than a few feet. At several places conspicuous clay-gouge zones branch off and these have rarely been investigated.

The St. Louis workings are entirely on the Palmyra vein; the St. Louis vein, which joins the Palmyra just west of the Como vein, has never been explored. The St. Louis vein apparently was not discovered underground because it is only a weak altered fracture where it joins the Palmyra and for about 200 feet east of the junction. Farther east on the southwest side of peak 13,470 on Silver Mountain the outcrop of the St. Louis looks even stronger than the Palmyra at the level 8 and there is the possibility of ore on the St. Louis vein which has never been mined. The Hancock vein was drifted on the Alta level 8 for only about 100 feet. There it consists of a fairly wide fractured and altered zone in which some quartz, barite, galena, and chalcopyrite occur. As even the best veins may show low-grade stretches for distances greater than 100 feet, it is felt that the Hancock has not been sufficiently tested at this level. On the surface it has a long, locally conspicuous outcrop, with as much as 6 feet of quartz, barite, and oxidized sulfides, though it does not follow a dike except at its east end. On level 5 it was stoped between the Bessie and the Little Sioux veins, but the workings are caved and could not be examined.

SUGGESTIONS FOR PROSPECTING

Although some small undiscovered high-grade ore shoots may remain near the surface in the South Telluride area, it is believed that large-scale, deep development will be necessary in order to obtain important production in the future. One major difficulty with deep development is the necessity of consolidating under one control an area large enough to justify the expenses involved in exploring at considerable depths. Many of the claims were staked three or four generations ago, with the result that the ownership of the ground is distributed among many heirs now living in widely scattered parts of the country.

ORE CONTROLS

The ore deposits in the area are controlled by fractures for the most part. The most favorable places for deposition of vein minerals were at sites where strong, persistent fault zones cut massive, fairly resistant rock units. The important, known hosts for ore deposits are the San Juan breccia, the Telluride formation, and the Cutler formation; the breccias of the Eureka rhyolite and of the Burns latite are of somewhat secondary importance, because they are not as thick. The Pony Express limestone member of the Wanakah formation may be a relatively favorable host rock because of its easily replaceable character. No great importance is attached to depth relations; the Cutler at the bottom of Bear Creek canyon apparently contained rich gold ore shoots in the Canton mine, and the mines at low altitudes in the valley of Howard Fork apparently had ore bodies as rich as those at higher altitudes. Mines at altitudes close to 12,500 feet on the southeast side of Gold King Basin and in Bridal Veil Basin produced rich ore in the early days.

Perhaps of some importance, so far as the western part of the area is concerned, is the observation made to the author by Isaac Partenan that few important ore deposits occur in the part of the Tertiary section that is underlain by the shaly upper part of the Morrison formation or the Mancos shale. This does not particularly affect the immediate area under discussion as most of the areas underlain by shaly units are covered by the Silver Mountain landslide mass; however, northwest of a general line between the Contention mine, the Champion mine, and the Smuggler-Union mill, no mines have been developed. This suggestion may be of even more importance for prospecting north of the San Miguel River.

PROMISING AREAS

In general the areas pointed out below as promising for prospecting are long-range possibilities, generally reachable only by long, expensive workings, so it is believed that considerable diamond drilling should be done as a first stage of exploration.

The Dividend and Royal gold-bearing zones are believed to be too spotty as far as rich ore shoots are concerned to justify the cost of a deep southward-trending crosscut at some depth at or below the altitude of the Telluride formation, unless the price of gold is advanced considerably. The long adit, 1,500 feet S. 25° W. from Bridal Veil Falls (altitude 10,818 feet on pl. 16 and pl. 18), might be used, however, to explore, at no great cost, the Dividend structure in the San Juan breccia west of Bridal Veil Creek.

The large area at the upper end of Bridal Veil Basin, between the Little Dorrit mine and the Lewis mine and from Bear Mountain on the west to Bridal Peak on the east would seem to be a favorable area for exploring for veins containing base metals, silver and gold, inasmuch as here base-metal minerals were observed up in the usually unfavorable Potosi volcanic series and in the underlying flows of the Burns latite. But to explore this area at depth, after some probing by diamond drilling, would require a long adit from some point such as at the lower end of Chapman Gulch, near the old road. Such an adit, however, could also aid in the exploration of the large alteration zone on the north side of the valley of Howard Fork, of the breccia pipes at depths, and of the west and west-northwest fracture zones south of Bridal Veil Basin.

The intersection on Ballard Mountain of the westward-trending Champion-Dividend zone with the south-southwestward-trending

Boundary zone (the Weller area) appears to be a good place to prospect for gold at depth. The many gold-bearing veins of diverse trends at the surface may coalesce into fewer veins at depth, but there is no apparent reason why these veins should not bear gold in at least the Cutler, Telluride and San Juan formations. An adit driven eastward from a point on the east side of Bear Creek near the mouth of La Junta Creek would reach the center of the favorable area in about 3,800 feet. Of course, under the present price of gold, such work probably is not attractive, but with a rise in the price of gold, justification could be made for such a project. Another project which would be much more attractive under a higher gold price would be a long, deep crosscut below the ridge between Bear Creek and La Junta Basin. Such a southward-trending crosscut would intersect about 10 possible gold-bearing veins between La Junta Creek and the Nellie-Wasatch zone. A southwestward-trending crosscut under the ridge on the west side of Bear Creek might also be suggested, but westward, more and more of this ridge is underlain by shale of the Morrison formation, and, therefore, the Telluride formation and the San Juan breccia there cannot be considered as being as favorable as on the east side of the creek. If the shale beds acted as a dam during mineralization, however, this would make the rocks underlying them even more favorable hosts for ore, providing that mineralizing solutions were available as far west as that.

The Delta area (p. 284) seems to be a favorable area to prospect for both base metals and silver and gold. As it will be expensive to put mine workings deep in this area, it probably should be tested carefully by deep diamond drilling before such workings are considered.

The general area around Silver Mountain probably has several favorable zones at depth in which base metals, gold, and silver are present. Among the better structural zones that have had production in the San Juan breccia and to some extent in the Eureka rhyolite are the Palmyra, Hancock-Arlington, and Alta veins of northwestward trend, and the Bessie, Little Sioux, Dixie-Crown Jewel, and Summit-Tiptop veins of northeastward trend (pl. 22). A 7,000- to 8,000-foot adit from some locations such as that of the Badger tunnel, at altitude 9,625 feet, driven north under peak 13470 on Silver Mountain, would not only give a chance for exploration of all these veins, but could also be used as a starting point for exploration at depth below the general Gold King-Suffolk area.

A deep exploration adit below the Carbonero-Highline area probably would not only intersect a number of argentiferous base-metal veins lying in the broad zone trending N. 65° E. but also would give the opportunity to obtain bulk samples of the intensely altered country rock in this area. However, such deep exploration as this, as well as most of the exploration recommended in this chapter, should be preceded by some deep diamond drilling in order to get some idea of the size and location of the deposits being sought.

EARLY DATA ON TELLURIDE AREA

The quotations below are from C. W. Purington's field notes (1896) and information from H. C. Burchard's Reports to the Director of the Mint (1881–85) regarding many mines in the southern part of the area. Much of Purington's information was never published, except in very generalized form in the 18th Annual Report of the U.S. Geological Survey (1898), and in Folio 57 of the Geologic Atlas (Cross and Purington, 1899), and it seems worthwhile to make his observations available, even at this late date. Many of the mines have not been located during the present study, and the approximate location of others, as far as can be estimated, is indicated in parentheses before the quotation.

Attica mine, Iron Springs district:

Probably the caved adit located about 2,000 feet N. 56° E. from lower portal of New Dominion mine. Purington, field notes, 1896.

Located on Silver Mountain about one mile ENE of the town at 10,500′—a mere prospect. 2 levels both cc. [crosscut?]. Lower strikes N 48 W 430′ long; upper 255′ E of it strikes N 27 W. Main vein strikes N 80 E dip 70° N seen only 4″ wide—white quartz and galena. Other small veins cut in c.c.

In the upper tunnel slickensides seen Str N 65 W dip SW 80° also groovings. No ore has been shipped from here but I am told on good authority that with its own mill this mine would pay. Its principal value is in gold, tho' a good bit of silver accompanies.

Badger, Iron Springs district:

Purington, field notes, 1896.

This is situated on the S. slope of Silver Mountain, ½ mile NW of the town of Ophir. It has been worked considerably but I think not a great deal of ore has been taken out. The workings consist of the Hathaway tunnel which is a cc and cuts the main vein at about 1000′; the upper tunnel 285′ vertically over which cuts the main vein at 300′—and about 1000′ of drifting on the vein. Tho' merely in the prospect stage, the mine is well opened, and the work is practically all of development character. The property is owned by Mr. ?. G. Hathaway of Denver, Colorado.

Country is of a mixed character. The lower tunnel starts in a diorite, which it penetrates for a distance of 100′; then hard silicified shale is encountered, the contact of which with the diorite dips to the S.E. The shale is the Gunnison of the Jura and has a very curious silicified and metamorphosed appearance. It is intensely hard. Much of it is of red and green jasper-like character. The red and green parts are in the form of elongated lenses.

Through the shale penetrate narrow dikes of the diorite which cut in several directions. The strike of the shale beds is N 60 E dip 10 SE. Some faulting of dikes one by another is seen. The dikes are slightly finer in grain than the mass of the diorite. I saw none more than 6″ in width. In the upper tunnel the country is the shale—but so fresh exposures of it are not seen. It gets into conglomeratic stuff at its N end. The fissuring in this mine is typical of the mountain-jointing here. In the lower tunnel sets of fissures strike N. 86 E, others strike N 60 W, one set of joints strikes N 45 W. Along the first of these three veins occur up to 3′ in width. 200′ in a vein strikes 85 E of N which is indeed the direction of the main or Badger vein. The veins are later than the dikes, as are all the fissures. A number of small veins have been found running in directions 15 W of N to N–S. It has not been found that any of these veins are so good here as the main E-W running vein. None of the veins seem earlier or later than others, but to have been filled at the same time. The dip of the veins is to the south. The ore is for the most part quartz gangue of finely crystalline character. The minerals are iron pyrite, and smaller amounts of zinc blende and galena associated with calcite. The ore body averages 4′ in width and has more the character of a single vein than is usual in these deposits. The gold is contained partly in the sulphurets, but is more than usually free. In the drift of the Badger it is said that the country rock is impregnated with auriferous pyrite to the extent of $8 per ton. Manganese oxide is very common in the vein and is said to be favorable to the occurrence of ore. Free gold occurs in thread form in the white vug-like quartz and has been seen in calcite. Silver values are almost nothing in the vein. From the undecomposed sulfides the gold may be mechanically panned and $17 a ton is the average yield. Small cross veins are crossed in the Hathaway tunnel which are found to carry $4 in free gold beside auriferous sulfides.

Crown Jewel, Lower San Miguel district:

See plate 22 of this report. Burchard (1883, p. 521).

The Crown Jewel has 150 feet of tunneling on a galena and gray copper ore vein, several tons of which have been shipped.

Burchard (1884, p. 424).

The Crown Jewel, on the Ophir side of the range, is an extension of the Palmyra, in Turkey Creek. The mineral of this claim is a fine-grained galena thickly impregnated with gray copper that averages 150 ounces silver and 30 per cent lead per ton. The mine is opened by drifts that aggregate 600 feet.

Globe, Iron Springs district:

Probably somewhere close to and east of the Suffolk mine. (Burchard, 1883, p. 523).

The gold veins of this district have been but little worked during the year, with the exception of the Globe mine, from which 5,000 pounds of ore were shipped to Denver.

Burchard (1884, p. 425).

Shipped in 1883

Tons ore	Oz Ag	$Au	Lbs Pb
7	------	910	------

Burchard (1885, p. 247).

The Globe, on Silver Mountain, has a tunnel of 125 feet, with a pay streak, while the Suffolk, near by, has a 100-foot drift, showing a decomposed vein from 4 to 12 feet wide, with some gangue matter.

Gold Crown, Iron Springs district:
Purington, field notes, 1896.

This is situated NNW of the town of Ophir at 10,600′—at the horizon of the San Miguel conglomerate. Worked by a CC 200′ long and drift on one vein 900′ and an opening on a cross vein. All on one level. The CC strikes N 3 E. The workings has just been started and 55 tons a day is being put through—a tram connects the mine with the Suffolk mill in the valley below. The country is in part San Miguel conglomerate and farther in the San Juan formation. These have a dip to the N—the rock is greatly decomposed throughout, tho' not picking ground. Very large pebbles even boulders occur in the San Miguel of quartzite, slate, and basic igneous rocks. Much brown iron-oxide staining is throughout the mine.

The main vein strikes 80° W. of North—another strikes 80 E of N and the third, called the Belcher vein strikes N 40 E dip 70W—the two E–W veins dip to the S steeply. The main vein dips N a part of its course. The main vein changes in appearance from the conglomerate to the andesitic breccia.

In the cg it is much brecciated, a rather crushed zone appearance, while in the breccia itself it is much more of the linked vein character, having a few large horses rather than many small fragments. This is due to a difference in mechanical consistency of the rocks and seems to affect the values for the worse. Whether any chemical effect is also responsible I don't know. It seems that the rocks having the chemical makeup of the andesite are in the San Juan the most favorable for the occurence of ore. 18″ ave. width. Decomposition is so far advanced that it is often difficult to distinguish any now metallic constituents. Gold was undoubtedly originally contained mostly in pyrite or at least accompanying, but the dissemination of this pyrite is puzzling. Whether it was contained in veins, or in the cement of the conglomerate is uncertain. It is said the ore milled when I visited the mine ran $5 to the ton. It seems to me that a considerable portion of the ore is merely the country rock which is throughly impregnated for short distances from the veins.

Gold Eagle, Iron Springs district:
Burchard (1885, p. 247).

The Gold Eagle is a new discovery. A drift of 125 feet has been run on the vein, showing 2 feet of pay ore, which is being taken out in large quantities and sacked for shipment.

Gold King, Lower San Miguel district:
Burchard (1883, p. 521).

The Gold King has a 4-foot pay streak, the ore from which averages by mill run $50 in gold per ton. Owned by Messrs. Brown and Warner.

Gold King extension, Lower San Miguel district:
See plate 22 of this report. (Burchard, 1883, p. 521).

The Gold King extension has 3 feet of gold ore and 50 feet of development.

Grand View, Iron Springs district:
Burchard (1884, p. 425).

Shipped in 1883

Tons ore	Oz Ag	Lbs Pb
8	3,600	2,400

Burchard (1885, p. 247).

is located on the summit of Silver Mountain, near Ophir, and is now producing from 4 to 5 tons of good ore per day, with a small force of men * * *. The upper drift of the Grand View is in 127 feet and the lower drift 85 feet, a portion of which has been run through slide rock.

Lookout, Iron Springs district:
Burchard (1883, p. 522).

The Lookout has a 60-foot shaft with a 60-foot drift from the bottom, both on vein; a cross-cut to reach the vein at 300 feet is nearly in. Two pay streaks are found on the Lookout, one of galena and one of chlorides. Lookout ore averages at mill 135 ounces per ton. Both Tip Top and Lookout are shipping ore.

Burchard (1884, p. 423, 425).

The Lookout is worked by a cross-cut tunnel that cuts the vein about 300 feet from the surface.

Lookout and Tip Top shipped in 1883

Tons ore	Oz Ag	Lbs Pb
160	9,600	160,000

Lookout Tunnel, Iron Springs district:
Purington, field notes, 1896

This is located N of the town—elevation of 600′ and the horizon of the San Miguel conglomerate at its lower edge. No vein has been found in it, but the entire mass of the cg which, by the way, is in a remarkably fresh condition, is impregated with iron pyrite and has a very siliceous cement, so much so that it seems highly probable that a secondary silicification has taken place, probably from infiltration of ore-bearing solutions. The great number of small veins which I know to penetrate this part of the district furnish abundant source for ore solutions which have worked through the permeable conglomerate, and mineralized the cement. This same conglomerate may be seen along the mountain side for 1000′ having a brown-stained appearance and doubtless mineralized for its whole length. This is the only locality where I have seen the San Miguel mineralized to such an extent, and I do not doubt that it is a auriferous, tho' whether in paying quantity or not as a whole I am not sure. As hereafter stated, I have seen in the Gold Crown mine ore which is practically nothing but the mineralized conglomerate. It has been stated to me that the conglomerate away from any workings sampled runs in gold as high as $8 a ton.

Minnie Myrtle, Lower San Miguel district:
Burchard (1883, p. 521).

The Minnie Myrtle has about 250 feet of development. The ore carries both gold and silver. The owners of these mines erected a 10-stamp mill with vanners in 1880, and are increasing the capacity by 10 stamps. Their mines are located high on the mountain, and the ore is taken to the mill by a Hallidie tram 2,600 feet in length.

Mohawk, Iron Springs district:
Burchard (1883, p. 523).

The big San Juan Mining Company commenced operations on the Mohawk mine in September. This mine is on Silver Mountain, near Ophir, some 2,000 or 2,500 feet higher than the town, and about 12,000 feet above sea-level. It is a true fissure carrying galena and oxidized lead ores with some gray copper and iron pyrites; also native silver in small quantities. The developments are 100 feet of shafts and 175 feet of drifts. The production, owing to the limited time the mine has been in operation, was small; the ore averaged 113 ounces of silver to the ton and 34 per cent of lead.

Burchard (1884, p. 425).

In 1883 shipped

Tons ore	Oz Ag	Lbs Pb
2	232	960

Burchard (1885, p. 247).

The Mohawk has a drift of 170 feet; shaft down 100 feet; drift from bottom of shaft 35 feet. Some ore has been shipped, which runs 153 ounces silver and 40 per cent lead.

Osceola, Iron Springs district:
Burchard (1882, p. 420).

In the vicinity of Ophir in Iron Springs district, 10 miles south of San Miguel, are a number of mines located on Silver and Yellow Mountains and on Wilson Creek. The ore is high grade, although the veins are narrow, the widest being that of the Osceola mine.

Burchard (1883, p. 523).

There are numerous gold-bearing lodes in the district, but they are chiefly in the hands of their discoverers, and have been but little developed, with the exception of the Osceola group, which shows a large amount of excellent gold quartz.

Palmyra, Lower San Miguel district:
Burchard (1883, p. 521).

The Palmyra has a 300-foot tunnel, ore gray copper and galena in iron spar gangue, vein 5 feet, ore streak 18 inches, average assay 300 to 900 ounces.

Parnell, Iron Springs district:
Burchard (1885, p. 247).

The Parnell is a late discovery on Silver Mountain, and has been opened only 6 feet in depth, from which about 10 tons of ore were taken.

Red Jacket, Iron Springs district:
Purington, field notes, 1896.

This is situated ½ mile directly W of the Gold Crown mine, and altho quite elaborate, is not greatly worked now. The intention is to work this extensively in the coming spring. The elevation is 10700′, and in common with the mines at this elevation, with deficient transportation, work usually has to be suspended in the winter time.

The country is here so far as exploited the San Miguel conglomerate and has the same decomposed appearance noticed in the Gold Crown.

The vein strikes 50 W of N and is faulted 500′ in, the NW part being thrown to the SW 50′. The veins are here indistinct, and have no well defined continuity but partake of the character of link veins; so little product has been made from this mine that one can hardly tell what the ore is worth. It is said to pay to work with the existing conditions, a tram wire way down to the mill at the town and a 50 stamp mill which may be put into requisition.

Santa Cruz, Iron Springs district:

Burchard (1884, p. 425).

Shipped in 1883

Tons ore	Oz Ag	$Au	Lbs Pb
35	2800	36	21,000

Purington, field notes, 1896.

Situated NW of the town of Ophir about 600′ NW of the upper tunnel opening of the Badger mine and 200′ farther up slope. It is not much more than a prospect—only about 700′ of work having been done. A vein 200′ in strikes 80 E of N–dip N. The vein carries iron and copper pyrites and galena and has yielded high silver values which is rather remarkable considering its situation. Here again a faulting of the fissures occurs as noted in the Suffolk. It is *not* a faulting of the veins. The Winnemucca vein crossed 30′ in the west drift of the Santa Cruz vein—strike 30 W of N–dip 80 SW. This faults the Santa Cruz vein 10′, the W part of it being shifted to the N. The evidence of any motion having taken place after the veins were formed is, it seems to me, scanty throughout the region.

The country is sandstone.

The ore carries $60 in silver and 1½ oz Au. In Nettie gulch the beds dip SW and in a little gulch just W of the Badger mine the cg is impregnated with iron pyrite said to run $2.50 per ton in gold.

Single Standard, Iron Springs district:

Purington, field notes, 1896.

This and other claims of L. L. Nunn on the S side of Silver Mountain are situated at about 12,000′ elevation directly N of the town of Ophir. The mine was worked most extensively in 1890, and produced then 1600 tons valued at $8 per ton.

The country is the andesite breccia and makes the rock for 300′ above this point, where it is overlain by the more massive andesite. It is here greatly decomposed, as is the rock generally on this mountain side, and on the north side so far as I have seen, altho' to a less extent on the north side than on the south. This decomposition is due for the most part to the large amount of iron pyrite which impregnates the rock.

The veins worked on appear to be several and strike in various ways, the main one seems to be N 80 E. Bunches of narrow veins of vug character cut the andesite and are in the characteristic zone or linked form which is so common through the country. The country is much impregnated along the sides, but they tell me that it carries only a trace in gold.

As seems likely from the appearance of the mine, the ore is 90% free milling and the value was gold. It was packed on burros and taken down to a 20 ton mill in the valley below. Other claims in this group are El Mundo, Bijou, Little Eva, Bonita.

As noted before, the permeation of all the rock on Silver Mountain by solutions which deposited iron sulphides must have been very extensive. The deep gulches worn out along this side are caused by zones more extensive than usual, or more thoroughly pyritiferous. One of these—¼ mile E of the Single Standard has a zone 50′ wide—strikes 20° W of N, dips 70° to the E.

Staatsburg, Iron Springs district:
Burchard (1884, p. 425).

Staatsburg is listed as a producer, but its output is not tabulated separately.

Suffolk, Iron Springs district:
Purington, field notes, 1896.

This located high on Silver Mt., the lowest working being at 11500′ and the upper workings going to the top of the divide nearly and connecting with the drifts of the Gold King mine on the north side of the divide. The workings consist of about 3000′ of drifting and much stoping. There are five levels on only three of which has extensive work been done. The country so far as I saw it is decomposed breccia, while the upper workings penetrate the andesite and have no different appearance from the lower rock so great is the pyritic staining.

The most interesting point illustrated by the Suffolk mine workings is the complexity of the fissuring. The Suffolk vein, so called, strikes N 30 W and this is crossed in the mine workings by two which are 100′ apart and are called the Globe and Globe Parallel. These strike N 12 E and in their N extent the ore is taken by fissures which strike N 15 W and N 30 W respectively. The Suffolk vein on the 2nd level 500′ in throws the Globe Parallel vein 8′—the S part to the W. The Globe and Globe Parallel veins dip to the W. The Yellow Girl which has practically same strike dips east. The result is that these 2 veins nearest each other practically come together in the lower level of the mine, but have not as yet been found to cross.

The Yellow Girl vein which has been one of the most productive in the mine is very narrow and is high grade.

The abrupt changes which occur on this hill-side in the directions of veins illustrate the fissure systems which prevail on it and which seem to be more evenly developed than in any other part of the Telluride district. The result of this non-prominence of one over another is that the veins are scattering and not so apt to be good, as one fissure will peter out and another take the ore off in a different direction. It is only when the veins are very numerous and the country is thoroughly impregnated that the ore is pay. There the choice of ore is not limited to the mere quartz but several feet on each side may be taken and put through the mill, so far as the impregnation extends.

The gold is doubtless originally contained in iron pyrite tho' I have specimens showing a considerable amount in the quartz apart from any decomposition stain.

The Yellow Girl ore runs $50–75 per ton. The larger veins run much lower even down to $5. By reference to the assessors ????? on p. 46 (this book) the product of the Suffolk-Gold Crown etc. may be had. These two and the Red Jacket are under the same management as that of Mr. Scoutt. This gentleman informs me that the gold runs 650–700 fine. Almost no silver accompanies. The ore is treated in a 40 stamp mill in the valley below to which the ore is conveyed in gravity bucket trams. The concentrates run very low, and tailings $1 per ton. The last seems surprisingly high in such low-grade ore; punched slot screens are used in the mill giving better satisfaction than anything else after many trials. The mill is operated by water, as is also the Carribeau mill. Abundance of water power in the valley.

Summit, Iron Springs district:

Probably southwest of Tiptop claim, see plate 22 of this report.

Burchard (1883, p. 522).

The Summit mine is situated on the divide between Iron Springs and Upper San Miguel districts, or on top of the range between Ophir and Turkey Creek Basins. The development consists of an upper tunnel of 350 feet; tunnel No. 2, 530 feet, the two connected by a winze. Both tunnels and winze are on the vein, which is a clearly-defined fissure, 5 feet between walls, and a shaft 40 feet from tunnel No. 2, also on the vein. Below these workings tunnel No. 3, a cross-cut, is in 135 feet. The ore, a sulphuret and galena, averages in large lots 150 ounces silver and a good percentage of lead. About 700 tons of ore have been shipped to Silverton, which averaged about 175 ounces of silver to the ton.

Burchard (1884, p. 422–423).

On Lookout Mountain the Summit mine has been continually shipping ore. A cross cut tunnel intersects the vein about 500 feet from the surface, where levels are run disclosing large bodies of ore. The other developments consists of two drifts. The upper drift is 390 feet, the lower one 610 feet long. Winzes connect these drifts. The vein is about 5 feet between walls, the pay streak about 2 feet.

Burchard (1884, p. 425).

In 1883 shipped

tons ore	Oz Ag	Lbs Pb
140	18,480	140, 000

Burchard (1885, p. 247).

produced some good ore.

Purington, field notes, 1896.

1894 output—$14,495.15

Tip Top, Iron Springs district:

Burchard (1883, p. 522).

The Tip Top and Lookout, adjoining the Summit, belong to the Duquesne Mining Company of Pittsburg, Pa. The Tip Top is worked through the upper tunnel of the Summit, having a 150 foot drift. The ore in quantity and quality bears a marked resemblance to the Summit ore.

Burchard (1884, p. 423).

[The Lookout and Tip Top] have been worked considerably, having kept a train of 75 jacks busy packing ore to the Ames smelter. The character of the ore is sulphurets and galena, averaging 150 ounces silver per ton and 28 percent lead.

Valley View, Iron Springs district:

Burchard (1885, p. 247).

The same parties [as Sulphurette] have a lease on the Valley View. Drift No. 1 is 110 feet; about 250 feet from this, No 2 is in 115 feet. The third level, being just commenced, is in only a short distance. No stoping has been done.

The pay streak averages from 6 to 8 inches, giving 244 ounces silver and 36 percent lead. Character of mineral, galena and sulphurets.

Windsor, Iron Springs district:
Burchard (1885, p. 247).

About 1000 feet below the Summit is the Windsor, which is being worked by a shaft down 55 feet, showing a strong vein 4 feet wide, producing galena and carbonized lead, running 200 ounces.

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