Quicksilver Deposits of Steens Mountain and Pueblo Mountains Southeast Oregon

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QUICKSILVER DEPOSITS OF STEENS MOUNTAIN AND PUEBLO MOUNTAINS, SOUTHEAST OREGON

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ABSTRACT

The object of this survey was to examine the quicksilver deposits with the hope of locating large tonnages of low-grade ore.

The deposits occur in the south-central part of Harney County and are more than 100 miles from either Burns, Oreg., or Winnemucca, Nev., the nearest towns. The region is sparsely settled by stockmen; Fields, Denio, and Andrews are the only settlements.

The range consisting of Steens Mountain and Pueblo Mountains is a dissected fault block, 90 miles long in a north-south direction and as much as 25 miles wide, tilted gently to the west. Pre-Tertiary metamorphic and plutonic rocks occur at the southern end, but most of the block consists of Pliocene volcanic rocks. The major boundary faults on the east side of the range are concealed by alluvium. Minor northwestward-trending faults branch from them, their throws diminishing toward the crest of the range; other minor fractures occur near, and parallel to, the mountain front. The quicksilver lodes were formed in and along these subsidiary fractures.

The lodes occur in a more or less continuous belt just west of the eastern front of the range. They are steeply dipping and arranged in subparallel clusters, commonly standing out as resistant siliceous ribs against the softer kaolinized rocks that flank them. The lodes were formed in two hydrothermal stages, the first producing the reeflike masses of chalcedony and quartz with their halos of limonitic and calcitic clays and the second introducing silica and barite along with sulfides of iron, copper, and mercury. The second stage, the ore producer, was possible only where the siliceous lodes were fractured by movements later than the first period of alteration. The ore minerals occur in veins of chalcedony, clear quartz, and barite, or in open crush-breccias of reef rock. The veins seldom exceed 6 inches in thickness, and the breccia bodies measure only tens of feet. The primary ore minerals are chiefly mercurian tetrahedrite (schwatzite), chalcopyrite, and cinnabar, the latter being the only producer of mercury. In a host of secondary minerals an earthy mixture of cinnabar and "limonite" is of particular interest because it forms by weathering of schwatzite.

The primary ore minerals show a marked lateral variation. In the southern part of the district hematite, pyrite, and chalcopyrite, accompanied by a little schwatzite, are dominant. A few miles to the north schwatzite increases greatly in amount, chalcopyrite is abundant, and a little primary cinnabar is present.

From the central part of the district northward, primary cinnabar increases in relation to the other sulfides until, at the northern end of the district, it is the only ore mineral.

The total production of quicksilver, which has come chiefly from the Mogul and Alexander mines and the Steens Mountain prospect, has been only about 55 flasks. Judged from ore in sight, future production is not likely to be greater. There are no low-grade ore bodies of large tonnage, and high-grade ore is irregularly distributed. The region must remain one for the operator equipped with a small retort for the treatment of hand-picked ore.

INTRODUCTION

LOCATION

Steens Mountain and Pueblo Mountains extend for about 90 miles across Harney County in southeast Oregon, stretching from near the Oregon-Nevada line on the 42d parallel northward almost to the 43d parallel. (See fig. 4.) Quicksilver ores are unknown in the northern

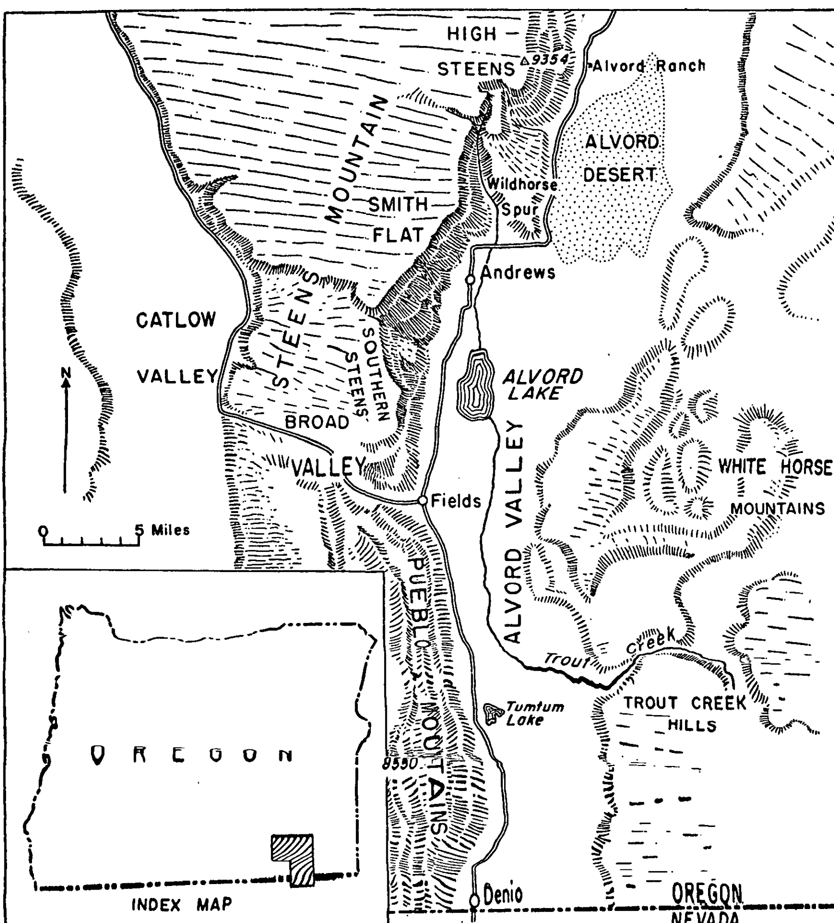

FIGURE 4.—Sketch map showing the main topographic features of the Steens-Pueblo region and the location of the area.

part, but many quicksilver occurrences have been prospected near the base of the range in the area extending from opposite Alvord Desert southward for 30 miles.

The region is settled by only a few hundred persons, mostly stockmen and sheepherders. Fields, Denio, and Andrews are the principal settlements. From Fields, near the center of the quicksilver belt, to Winnemucca, Nev., the distance by road is about 100 miles. From Fields to Burns, across the mountains by way of Frenchglen, the distance is 118 miles; along the east mountain base by way of Follyfarm, the distance is 134 miles. The roads are paved near these supply towns, but toward the quicksilver region they become poorer, and in winter they may be impassable. In dry weather, all the prospects can either be reached or closely approached by automobile.

SCOPE OF THE REPORT

The Steens-Pueblo area was given a preliminary examination by C. P. Ross in 1940 as a part of the Strategic Minerals Investigations program. In his report Ross (1942, p. 237) suggested that large low-grade deposits of quicksilver ore might be developed here, and this was one of the chief incentives for the investigation that led to the present report.

The field work paralleled Ross' preliminary work in most respects, adding only a more detailed study of the country rocks and a more inclusive examination of the ore deposits. A strip 40 miles long and 2 to 5 miles wide, following the lower flanks of the range, was mapped between July 7 and September 10, 1943; aerial photographs were used as a base. A mosaic of the photographs was then compiled by the radial line method, and township lines were added with the aid of plats issued by the General Land Office. Few section corners were located in the field, so the grid is only approximately correct. About 35 small mines and prospects were examined, several of which were mapped, and ores collected from them were studied in the office.

ACKNOWLEDGMENTS

For information concerning some of the prospects, acknowledgment is made to Andrew Shull, Ben O'Keeffe, and Robert Doan. In the microscopic study of some of the ores, valuable aid was rendered by Mr. C. D. Hulin, formerly at the University of California.

TOPOGRAPHY

Among the mountains that rise from the high plateau of southeast Oregon, Steens Mountain and Pueblo Mountains are unrivaled in size and grandeur. These two mountains are parts of the same tilted fault block, and they so nearly merge that they may be considered as one range. This fault block is about 90 miles long and 20 to 25 miles wide. The contrast between its opposite flanks is striking, for west of the crest long, gentle dip slopes lead to Catlow Valley, whereas on the other side, a tremendous scarp plunges to the flat floor of Alvord Valley. The crest, though sinuous in detail, forms a broad arc that is concave eastward.

The southern half of the range, shown in plate 8, consists of several fairly distinct topographic units. At the northern end rise the High Steens. Here the range reaches a culminating point of 9,354 feet, and its precipitous eastern scarp towers more than 5,000 feet above Alvord Desert. In this lofty part of the range, which remains snow-capped throughout most of the year, are large cirques and deep, U-shaped troughs, such as Wildhorse Canyon, which testify to former extensive glaciation.

Southward the High Steens drop sharply to an almost horizontal plateau, approximately 6,500 feet in altitude, known as Smith Flat or the Middle Steens. On three sides the plateau is bordered by bold cliffs, but opposite the village of Andrews the smooth crest formed by Smith Flat changes suddenly to the sinuous, serrated crest of the Southern Steens. In this part of the range several conspicuous peaks rise above the general level, notably Sharp Peak and Alvord Peak, the summit of the latter reaching an altitude of approximately 7,100 feet. South of Alvord Peak the crest swings westward, forming a wide re-entrant in the mountain front and falling to its lowest point in the saddle known as Broad Valley. Several northwestward-trending depressions cross the range in this area, and one of them provides an easy pass for the road between Fields and Frenchglen. Where the road crosses the divide the altitude is about 5,500 feet, or only 1,250 feet above Alvord Valley at Fields.

South of the Broad Valley re-entrant lie the Pueblo Mountains, which extend southward for more than 20 miles. For most of this distance their sinuous crest is between 6,500 and 7,500 feet in altitude, but near the Oregon-Nevada line it rises to more than 8,000 feet. The western slopes are gentle, but the eastern slopes are precipitous and extend onto a wide upland bench traversed by open valleys meandering between longitudinal cuestas. These cuestas, among which the Lady Comb is a conspicuous example, give to the higher slopes of the Pueblo Mountains scarp a terraced appearance. In striking contrast is the huge round-shouldered mass of Pueblo Mountain itself, which rises to an altitude of approximately 8,550 feet about 3 miles east of the Pueblo Mountains crest. Hardly less striking in contrast is the foothill belt extending northward from the high dome of Pueblo Mountain nearly to Fields. Within it the terraced lava slopes give place to broad, round-topped spurs that slope gently for 2 to 3 miles to the edge of Alvord Valley, and the open valleys of the upland bench are replaced by steep-walled gorges. The streams that descend from the higher part of the mountains lose much of their volume by infiltration as they cross this foothill belt, and the little water that is left disappears in the fans at the valley border. Most of the other perennial streams that drain Steens Mountain likewise disappear at the border of the range.

Alvord Valley, throughout most of its length, is 6 to 10 miles wide and between 4,000 and 4,200 feet in altitude. Wide alluvial fans, covered with greasewood and sagebrush, spread into the basin from either side. Alvord Lake, in the central part of the valley, is fed mainly by Trout Creek, which drains the White Horse Mountains to the east, and by Wildhorse Creek, which has its source in the snow fields of the High Steens. The alkaline water of the lake is never more than a few feet deep, although during exceptionally wet seasons it may overflow northward into the large playa of Alvord Desert. Tumtum Lake, northeast of Pueblo Mountain, usually retains a little water throughout the year. More detailed information on the water supply of the region may be obtained from a report by Waring (1909, pp. 70–78).

GEOLOGY

The dissected fault block of Steens Mountain and Pueblo Mountain consists of two principal rock assemblages. The older of these is exposed only in the southern part of the range and consists of metamorphic rocks and granitic igneous rocks. The younger, cropping out over the greater part of the range, is made up of Tertiary volcanic rocks showing a great variety of types. This volcanic assemblage is divided into four stratigraphic units, the older two siliceous and the younger two dominantly basaltic; the units aggregate a thickness of at least 8,000 feet. Overlying the lavas in the southeastern part of the Steens-Pueblo block is a thick layer of deformed alluvium that is distinctly older than the gravels of the present alluvial fans.

PRE-TERTIARY ROCKS

The pre-Tertiary rocks that underlie the mantle of younger lava and alluvium are exposed chiefly in the southeastern part of the Pueblo Mountains, but a smaller area of them is exposed near Horse Creek. No attempt was made to map these rocks in detail. Essentially, they consist of metasedimentary rocks, metavolcanic rocks, and plutonic igneous rocks of siliceous and intermediate composition. No new evidence concerning the age of these rocks was obtained in this study; presumably the metamorphic rocks are Paleozoic in age, and the plutonic rocks are Late Jurassic.

247731—53——2

The metamorphic rocks are dominantly metavolcanic rocks consisting of greenstone and chloritic and sericitic schists, locally accompanied by metasedimentary rocks. Greenstones are well-exposed along the northeast flank of Pueblo Mountains and may be seen in the gorge of Horse Creek and at the Blue Bull mine. At these localities they were originally basalts or andesites, locally very porphyritic; whether they were intrusive rocks or flows is unknown. Along Arizona Creek metavolcanic rocks are interbedded with argillite, quartzite, and thin beds of marble. Gray, lustrous sericite phyllite and chlorite schist are predominant along the east face of the Pueblo Mountains as far south as the Nevada line; they are especially well exposed in the canyon of Denio Creek.

The only plutonic igneous rocks examined in any detail are coarse-grained hornblende-biotite quartz diorite and quartz monzonite exposed along the South Fork of Willow Creek near the Cash prospects. Gigantic boulders of similar rock are very abundant in fanglomerate and conglomerate in the basal part of the Tertiary sequence on Cottonweed Creek.

TERTIARY VOLCANIC ROCKS

The scarp of Steens Mountain and Pueblo Mountains presents one of the most imposing displays of Tertiary volcanic rocks anywhere in the Pacific Northwest. The sequence, as first determined by Fuller (1931, pp. 43–130), is modified in this report as follows:

Terms used in this report	Terms used by Fuller	Description of unit
Steens basalt	Steens Mountain basalt.	Cliff-forming flows of olivine basalt with rare partings of tuff. On the High Steens the thickness exceeds 3,000 feet. Age, middle Pliocene.
Steens Mountain volcanic series.	Steens Mountain andesitic series.	Olivine and augite basalts, and amygdaloidal andesites rich in zeolites. Locally, thick sheets of dacite and rhyolite cap the basic lavas. Pyroclastic interbeds are rare and thin. Total thickness more than 3,000 feet in the Southern Steens and the Pueblo Mountains. Age, early Pliocene.
Pike Creek volcanic series.	Pike Creek volcanic series.	Rhyolitic and dacitic flows and tuffs. Thickness exceeds 1,500 feet. Age, early Pliocene.
Alvord Creek formation.	Alvord Creek beds	Acidic tuffs and tuffaceous sediments, clays, opaline cherts, and lenses of conglomerate. Exposed thickness, 500 feet; base concealed. Age, early Pliocene.

Although the rocks are all of Pliocene age, an unconformity separates each of the four major units. However, only the unconformity between the Pike Creek volcanic series and the Steens Mountain volcanic series marks an important break.

ALVORD CREEK FORMATION

The Alvord Creek formation is restricted in the mapped area to a narrow belt along the foot of the High Steens scarp bordering Pike and Little Alvord Creeks. It consists predominantly of well-stratified flat-lying white and pastel-tinted tuff, tuffaceous clay, and silt, with occasional interbeds of chert, opaline shale, and conglomerate, but near the mouth of Pike Creek it also includes a flow of rhyolite. The thickness of the formation cannot be determined in the mapped area as the base is not exposed, but at least 500 feet of beds are exposed beneath the unconformably overlying Pike Creek volcanic series. The age of the Alvord Creek formation has been determined on the basis of fossil leaves to be early Pliocene (Axelrod, 1944, pp. 241–248).

PIKE CREEK VOLCANIC SERIES

The Pike Creek volcanic series, as first described by Fuller (1931, pp. 57–74), consists of siliceous flows and tuffs that are exposed west of the Alvord Desert. In addition to these exposures at the type locality this unit is here considered to include siliceous volcanic rocks that crop out at four other isolated localities: west of Alvord Lake, on Red Hill, along Cottonwood Creek, and at Tumtum Point. As fossil evidence is lacking, the rocks at these four localities cannot be correlated directly with the series at the type locality; however, their lithologic similarity and stratigraphic position suggests that they were erupted during the same general period of rhyolitic and dacitic activity. Considering their stratigraphic position, Axelrod (Axelrod, 1944, p. 248) suggested that these rocks are early Pliocene.

The Pike Creek volcanic series is best exposed west of the Alvord Desert along the canyon of Pike Creek and in the canyons of Little Alvord, Toughey, and Indian Creeks. Fuller's detailed account of these rocks renders any further lengthy description unnecessary. Both the lavas and tuffs in this area, however, are so lenticular that the successions in adjacent canyons differ greatly. This lenticularity is due to the flows having been unusually viscous and to their having issued from a group of local vents alined generally parallel to the base of the scarp. Owing to the similarity among several of the flows, it is often difficult to make satisfactory correlations from one canyon to the next. However, the composite section from youngest to oldest may be summarized as follows:

Two biotite dacite flows: Pink-colored; the lower flow is 300 feet thick, and the upper flow is 500 feet thick. Over wide areas the banding stands at very high angles, suggesting an extensive vent under the divide separating Pike and Toughey Creeks and continuing southward toward Indian Creek.

Upper tuff: White and greenish siliceous tuff, as much as 40 feet thick on Pike Creek; coarser lapilli tuff as much as 80 feet thick on Indian Creek.

Upper laminated rhyolite: A flow of platy pinkish rhyolite, 250 feet thick on Pike Creek and twice as thick near the supposed vent bordering Toughey Creek. Much of its top consists of dark obsidian. At the same horizon, adjoining Little Alvord Creek, is another flow of rhyolite as much as 400 feet thick; the flow spreads from a vent which is perfectly exposed where it cuts across the Alvord Creek beds near the canyon floor.

Middle tuff: Siliceous tuff and lapilli tuff, as much as 300 feet thick along Toughey and Pike Creeks. Includes a flow of rhyolite in the valley of Indian Creek.

Lower laminated rhyolite: A sheet of unusually platy rhyolite, as much as 200 feet thick, exposed along Pike and Toughey Creeks. The undulating flow bands stand at high angles over a broad area, suggesting the proximity of a vent.

Lower tuff: North of Pike Creek, siliceous tuffs as much as 200 feet thick. Locally cut by many sills of basalt.

The Pike Creek volcanic series is separated from the overlying andesitic-basaltic lavas in this region by an angular unconformity. Along the south side of Indian Creek the mafic flows overlap almost the entire succession of the siliceous volcanic rocks, as if they had accumulated against, and finally inundated, a high and precipitous slope.

Directly west of Alvord Lake the Steens Mountain scarp consists chiefly of massive and platy jointed flows of dacite containing plentiful phenocrysts of quartz and feldspar and occasional flakes of biotite in an aphanitic matrix. In some places only two flows can be distinguished; elsewhere at least four can be recognized. At the mouth of Bone Canyon and to the south they are underlain by acidic tuffs with one, and perhaps two, interbeds of dark basalt. Layers of greenish dacite tuff also separate some of the dacite flows, the thickest and most persistent tuff layer resting on the topmost lava. Locally, as on the Fisher claims, the upper two dacite flows are separated by a thin stratum of muddy lapilli tuff. This area of dacite is bounded on three side by faults; on the fourth, or west, side the siliceous lavas are overlain, apparently conformably, by a sheet of dark basalt that marks the base of the Steens Mountain volcanic series.

Two miles north of Fields siliceous lavas are exposed on the steep, rocky eminence known as Red Hill. Most of the hill consists of flow-banded rhyolite, which contains abundant crystals of quartz and feldspar in a glassy, or devitrified glass, base. Along the south and east flanks of the hill the banding of the lava and the bedding of thin layers of pumiceous tuff conform to the slopes, and the rhyolites apparently are surface flows. Along the northeast flank of the hill the banding is usually much less distinct and dips either vertically or in various directions at high angles. This rhyolite is intimately associated with reddish-purple dacite, devoid of quartz phenocrysts but crowded with feldspar crystals as much as an inch in length. For the most part, the dacite lacks flow structures, but locally it seems to grade indefinitely into the banded rhyolite. The presumption is that this part of Red Hill marks the composite filling of a vent. Along the southwest side of Red Hill a fault separates the siliceous lavas from the younger andesite and basalt; along the opposite side the sinuous contact is unconformable.

Siliceous volcanic rocks are also exposed in a belt 2 miles long adjoining the mouth of Cottonwood Creek. Here they are composed mainly of rhyolitic clays, silts, and sands. In the northernmost exposures of this inlier many of the tuffaceous sediments are characterized by delicate cross bedding, ripple marks, and rain pits, indicative of shallow lacustrine deposition. Interbedded with these sediments are layers of nearly pure glass dust and layers of rhyolitic lapilli tuff containing pieces of red and black basalt, some of which are as large as a clenched fist. Farther south beds of white and cream-colored tuff alternate with thick beds of soft clay, thinner layers of papery siliceous shale, occasional bands of opaline chert, and a few lenses of coarse tuff breccia crowded with large blocks of green rhyolite. Here also are flows of white and jade-green porphyritic and flow-banded rhyolite, which in part appears to have undergone intense autobrecciation where it flowed into water or over wet lake sediments.

A belt of alluvium 2 miles wide separates the siliceous volcanic rocks near the mouth of Cottonwood Creek from the nearest exposures of the Steens Mountain volcanic series. Doubtless, however, the buried contact is one of marked unconformity, for the strike of the younger series is uniformly a few degrees west of north, whereas that of the rhyolitic rocks is variable and over large areas is perpendicular to the strike of the younger lavas.

The rocky bluff called Tumtum Point, projecting into Alvord Valley between Tumtum Lake and Denio, is composed chiefly of reddish rhyolite with strong fluidal banding of variable attitude. Rhyolitic breccia and pumiceous tuff rich in andesite and basalt lapilli are locally interbedded with the massive rhyolite. In a small gully just west of the bluff is an ascending succession of red amygdaloidal andesite, clay, tuffaceous clay, white rhyolitic pumice, and, finally, buff and pastel-tinted tuffaceous clay with an interbedded flow of green autobrecciated rhyolite. The attitudes of all these beds are so variable and generally so different from those of the younger Steens Mountain volcanic andesite and basalt exposed 4 miles to the west that a pronounced unconformity is postulated to exist between the two series.

STEENS MOUNTAIN VOLCANIC SERIES

A long period of quiescence and erosion followed the eruption of the rhyolitic and dacitic lavas just described. Subsequently, andesitic and basaltic lavas were poured out in such tremendous quantity that locally they accumulated in thicknesses of more than 3,000 feet. This great pile of lavas, with rare interbeds of sedimentary and pyroclastic rocks in the lower part, comprises the Steens mountain volcanic series, According to Axelrod's correlation (1944, p. 248) of the overlying Steens basalt, the Steens mountain volcanic series must have been erupted during the late part of the early Pliocene.

The lavas of the Steens mountain volcanic series are extremely varied both in composition and in texture. Andesites and basalts predominate, but without microscopic study it is so difficult to distinguish between them that their relative proportions remain unknown. Most of these mafic flows are 10 to 25 feet thick; a few are as much as 200 feet thick. Hornblende andesites are exceptional throughout the series, whereas olivine basalts recur at many horizons. One olivine basalt flow is traceable for more than 6 miles, forming the prominent cuesta known as the Lady Comb; many thinner and shorter flows of similar character occur stratigraphically above and below it. In the upper part of the series, especially in the northern part of the region, are abundant olivine basalt flows characterized by conspicuous clusters of large feldspar phenocrysts. Some basalts and andesites are typified by large phenocrysts of augite in a dark semiglassy matrix; others have a coarse, diabasic texture. At intervals throughout the series, but particularly at lower horizons, for example in and near the belt of quicksilver prospects, the lavas are abnormally rich in amygdules. In some flows, the amygdules consist of quartz, opal, chalcedony, or chlorite(?); in others, calcite is the principal filling; most amygdules, however, are composed of an unusual suite of zeolites, many of which exhibit well-formed crystals. Included among these fillings are natrolite, pectolite, stilbite, analcite, and chabazite. The flows commonly exhibit bands of aphanitic, vesicular and amygdaloidal rock that alternate with highly porphyritic bands; generally the tops of the flows are scoriaceous and thoroughly reddened by oxidation. Many of the earlier lavas are also typified by stellate groups of slender feldspar phenocrysts, such as those on the Lucky Strike and Mogul claims. Around the headwaters of Bone Creek, blocky, clinkery, and autobrecciated dark basalts are widespread; around the mouth of Wildhorse Canyon, vesicular dark augite-olivine basalts predominate. In the valley of Little Alvord Creek, the topmost rhyolite tuffs of the Pike Creek series are overlain by a sheet of hornblende andesite. Southward, this sheet is traceable as far as Pike Creek; in the opposite direction, beyond the area shown on the map, it may be followed for at least 5 miles, reaching a thickness of at least 900 feet on the walls of Alvord Creek. To this imposing mass of columnar lava, Fuller gave the name "the great flow." The vent from which it was extruded is well-exposed on the northern side of Little Alvord Creek, almost directly above the vent of the underlying flow of rhyolite.

Toward the close of this period of andesitic and basaltic eruptions, a flow of pale-gray to purple vitrophyric dacite was erupted from a vent under Alvord Peak. The flow has a pumiceous crust, bearing drusy hematite and cristobalite. An outlier of this flow, as much as 400 feet thick, forms Sharp Peak, on the crest of the range. West of Alvord Peak is a younger flow of glassy, porphyritic rhyolite, as much as 150 feet thick, marked by strong fluidal banding.

Though pyroclastic and sedimentary rocks are relatively rare in the Steens Mountain volcanic series, they are represented by a variety of rocks. Most of these occur in the southern half of the mapped area, particularly in the vicinity of Cottonwood and Willow Creeks. Just north of Cottonwood Creek, near the base of the series, is a thick lens of conglomerate containing many large boulders of plutonic and metamorphic rocks. It is noteworthy that part of the overlying basalt flow exhibits a pillow structure. Bands of shale and biotite-rich arkose occur near the conglomerate, and a few feet above these are lenses of pebbly arkose, tuffaceous sandstone, and opaline chert. On the north side of Willow Creek thin bands of papery carbonaceous shale and water-sorted tuffs separate some of the oldest flows, and a few hundred feet above these are thin lenses of fresh-water limestone, calcareous sandstone, and conglomerate. Other occurrences within the mapped area are restricted to scattered thin layers of tuff and tuffaceous sandstone, a 20-foot layer of welded rhyolite(?) tuff on the northwest flank of Pueblo Mountain, and a flow of volcanic mudflow breccia southwest of Andrews. It is obvious from the foregoing that the Steens Mountain volcanic series merits more detailed examination.

STEENS BASALT

The varied assemblage of lavas of the Steens Mountain volcanic series is overlain by an imposing succession of flows notable for their uniformity and wide extent. These flows were products of fissure eruptions on a grand scale. They form the great precipices of the High Steens and Wildhorse Canyon and the cliffs that limit Smith Flat. Typically, they are composed of light- to dark-gray coarsely crystalline and porous olivine basalt marked by an abundance of large phenocrysts of labradorite. Usually the tops of the flows are scoriaceous and their bottoms commonly exhibit pipe amygdules. According to Fuller (1931, p. 102), the individual sheets range from less than 1 foot to 70 feet in thickness. On the High Steens their aggregate thickness exceeds 3,000 feet; on Smith Flat their maximum thickness is about 800 feet. The southward extent of these flows is uncertain, but they probably reappear along the crest of the southern part of the Pueblo Mountains. Eastward they are known to cover a vast area in south-central Oregon.

The age of the Steens basalt was believed by Axelrod (1944, p. 248) to be middle Pliocene, because this unit underlies the late middle Pliocene Thousand Creek beds of Merriam in the southern part of the Pueblo Mountains. In the High Steens a distinct unconformity separates the cliff-forming flows of the Steens basalt from the underlying andesites, but below Smith Flat the two series are either conformable or their divergence of dip is so slight as to be imperceptible.

RHYOLITIC INTRUSIVES

On the forks of Horse Creek the Steens Mountain volcanic series are cut by two elongate volcanic necks, each approximately three-quarters of a mile in maximum dimension. Where unaltered they consist of aphanitic rhyolite lightly stippled with small phenocrysts of quartz and feldspar and occasional flakes of biotite. Where flow banding is present, it is either vertical or steeply inclined and variable in strike. Over large areas the lava is massive and devoid of apparent flow structures; locally it is intensely autobrecciated, and toward the margins of the northern volcanic neck lithophysal varieties are common. In both necks the effects of hydrothermal alteration are pronounced; indeed, fully nine-tenths of the southern neck has been completely replaced by a mass of dense sugary quartz. Irregular joints in the quartz mass are heavily coated with limonite that resulted from the hydration of specular hematite.

BASALTIC AND DIABASIC INTRUSIVES

The mafic intrusives of the area are tabular bodies; most are dikes, but a few sills were found in the northern part. No mafic dikes were seen among the pre-Tertiary rocks on Pueblo Mountain, but scores cut the Tertiary lavas on the scarp of Steens Mountain and Pueblo Mountains; some are traceable as conspicuous broken walls for distances of 3 to 4 miles. Most of the dikes trend parallel to the mountain front; a few, however, diverge at high angles. Several of the larger ones, such as the arcuate dike west of Fields, are offset by many small faults. Most of the dikes are vertical, but a few dip eastward toward Alvord Valley. Their thickness is generally between 3 and 30 feet, but locally a few are 100 feet across. Some of the dikes on the High Steens are of multiple character.

No sills were identified with certainty in the southern part of the area, though they might easily have been overlooked. In the northern part, however, several intrude the Alvord Creek formation at the mouth of Pike Creek. On Indian Creek a thick, bulbous sill occurs within a flow of platy rhyolite; it, and the southwestward-trending dike that may be followed at intervals from Indian Creek across the mouth of Wildhorse Canyon, shows a coarse diabasic texture. On the west side of Wildhorse Canyon, the diabasic intrusion is offset at its intersection with a younger dike of aphanitic black basalt. Some of the dikes on the High Steens, and one on the cliffs bordering Smith Flat, are clearly feeders to surface flows of Steens basalt.

West of the crest of Steens Mountain and Pueblo Mountains, on the "back slopes" of the range, dikes are extremely rare, and east of the crest they are concentrated mainly on the lower flanks of the scarp. This distribution suggests that the present boundary between the mountains and the Alvord Valley coincides with an old zone of tensional release.

TERTIARY AND QUATERNARY ROCKS

Alluvium.—A belt of old alluvial deposits as much as 3 miles in width extends 15 miles along the mountain base from Red Hill to Tumtum Point. In the vicinity of Red Hill the maximum thickness of these deposits is only 200 feet, but southward it increases to about 800 feet in the valley of Cottonwood Creek. Except in a few places, the beds are easily distinguished from the younger deposits of Recent alluvium, for they are much more deeply eroded, are in general more indurated, and are considerably deformed. They are composed mainly of coarse, subangular detritus in a matrix of poorly sorted sand. Locally, they consist of a chaotic assemblage of large boulders; elsewhere, they contain lenses of stratified sand and silt, clays being notably scarce. The detritus in the northern part of the belt is made up almost exclusively of andesite and basalt most of which has apparently been derived from the Steens Mountain volcanic series. Nearer the bedrocks of Pueblo Mountain the content of plutonic and metamorphic debris tends to increase, although in some places, for example near Tuntum Point, fully 90 percent of the boulders consist of green rhyolites derived from the siliceous Pike Creek volcanic series.

Fine stratification is not lacking, but most of the deposits either are unstratified or show bedding only on a major scale. There is little doubt, therefore, that the materials were laid down rapidly by torrential streams discharging from the mountains onto alluvial fans. Presumably deposition occurred on fans inclined toward the east, but now the beds dip generally westward back toward their source.

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Evidence concerning the age of the older alluvium is indefinite. Ross (1942, p. 237) suggests that the beds are Pliocene, partly on the basis of a cameloid bone which he found among them; however, some of the beds may be early Pleistocene. Only this much is clear: the alluvium is younger than the youngest lavas of the region and was involved with them in some of the earlier uplifts that affected the region.

STRUCTURE

Essentially, Steens Mountain and Pueblo Mountains are parts of an enormous fault block tilted to the west. As Russell (1884, pp. 438–445) first suggested, and later workers have agreed, they appear to represent the western flank of a broad arch the keystone of which was downdropped to form the great trough of Alvord Valley.

In accordance with this simplified interpretation, the prevailing dips in the range are to the west at low to moderate angles. In general the westward dip of the younger lavas diminishes from south to north, and their strike swings in a broad, flat crescent, approximately parallel to the mountain base. Thus, in the Pueblo Mountains most of the flows strike N. 10° to 20° W. and dip westward at angles ranging from 10° to 20°. Along the western flank of Pueblo Mountain itself, where the uplift was greatest, the dip of the lavas that lap on to the bedrocks increases locally to 27°. Farther north, in the Southern Steens, the strike gradually changes until it is approximately north; the westward dips generally range from 5° to 10°. Still farther north, in the Middle and High Steens, the strike is northeast and the dip is 5° or less.

The older alluvium in the southern part of the range, although locally horizontal, dips westward at slightly lower angles than the adjoining lavas. In some places, however, as on Cottonwood Creek, the formation dips as much as 35°. Near the contact with the lavas of the Steens Mountain volcanic series, the strike differs considerably from that of the volcanic rocks.

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Prior to the widespread tilting of Steens Mountain and Pueblo Mountains and before the eruption of the andesites and basalts of the Steens Mountain volcanic series, the older lavas—the Pike Creek volcanic series and their supposed equivalent—had apparently already been deformed. The evidence for this is particularly clear in the southern part of the range, on Tumtum Point and at the mouth of Cottonwood Creek, where the attitudes of these older volcanic rocks are extremely variable and locally very different from those of the younger deposits nearby. (See pl. 9.) In the northern part of the range, however, this early formation was relatively slight, so that the angular discordance between the rocks of the Pike Creek volcanic series and the succeeding flows is hardly perceptible. Still farther north, in the Harney Basin, Park (Piper, Robinson, and Park, 1939, pp. 53–58) has noted that the older siliceous extrusive rocks are more disturbed than the younger lavas. These, in brief, are the dominant attitudes within the range.

Attention must now be directed to a discontinuous belt of reversed, or easterly, dips near the edge of the mountains, which coincides in part with the belt of quicksilver deposits. In this 12-mile stretch north of Pueblo Mountains most of the lavas protruding from beneath the older alluvium dip eastward toward Alvord Valley, and probably all the lavas underlying the alluvium also dip in this direction. The steepest easterly dip, 45°, was observed on Cottonwood Creek, and the widest exposure of the belt of anomalous dips, more than a mile, was seen close to Sesena Creek. Farther north, the belt crosses the Lucky Strike and Blue Boy claims and ends against Red Hill. Its northern continuation is represented by reverse dips occurring in small areas close to the edge of Alvord Valley immediately north of Red Hill, and again opposite Alvord Lake. Farther north, between Stone Creek and the mouth of Wildhorse Canyon, all the lavas along the mountain edge dip eastward. The change from normal to reversed attitudes throughout most of these foothill areas is so abrupt that faulting must be its principal cause, but where the transition is gradual, as for instance near Wildhorse Canyon, flexure without fracture may be the explanation. In other words, the foothill belt of reversed dips is essentially a subsidiary fault block that has slumped backward from the major mountain block toward the Alvord graben; where deformation is less pronounced, it appears to represent a boundary warp. The presence of basaltic dikes along parts of its western edge suggests that these movements were controlled by an older belt of tension.

BOUNDARY AND SUBSIDIARY FAULTS

These include the unmapped major faults defining the Steens-Pueblo block but lying concealed beneath the alluvium bordering the front of the ranges. Also included are the mappable subsidiary fractures which parallel the major faults and lie farther west along the flank of the range.

In general the trace of the mountain base as far north as Wildhorse Canyon is a broad crescent concave to the east. In detail, however, it consists of a series of zigzags believed to have resulted from displacement along intersecting boundary faults. For example, faults that trend almost at right angles to each other separate Tumtum Point from the valley, and farther north the changes in the trend of the mountain front, though much less abrupt, are conspicuous.

Owing to the cover of older and Recent alluvium, it is impossible to locate the main boundary faults with precision, nor can an accurate estimate be made of the displacements. Manifestly the throw reaches a maximum in the southern part of the range, and the following observations support the view that uplift began there long before it did to the north. The distance between the base and the crest of the range increases somewhat regularly from north to south. At the latitude of Wildhorse Canyon the crest has been eroded backward from the boundary fault for only 1½ miles; farther south at Tumtum Point, the crest has been eroded backward 6 to 7 miles. In the southern part of the scarp, moreover, the topography is mature and the broad subsequent valleys are in marked contrast to the youthful gullies that score the scarp to the north. The dips observed along the crest of the Pueblo Mountains, if projected eastward as far as the boundary fault, suggest a downthrow of 7,000 to 10,000 feet, plus the unknown thickness of Recent alluvium covering Alvord Valley. Opposite Alvord Peak, the corresponding throw is approximately 4,000 feet. Near Wildhorse Canyon, the amount of displacement indicated by the difference in height of Smith Flat on one side and the isolated plateau above Wildhorse Spur on the other is only about 100 feet, and this could probably be ascribed to either warping or faulting. In Wildhorse Canyon itself, however, the main boundary fault is replaced by two fractures enclosing a narrow sliver of cliff-forming Steens basalt near the canyon floor; the downthrow is approximately 600 feet. Higher up the canyon, and on the walls of the cirque containing Wildhorse Lake, there are no signs of displacement.

Approximately 4 miles east of Wildhorse Canyon a second major boundary fault, which probably originated at about the same time as those that border the Middle Steens, extends along the base of the High Steens. Opposite the culminating peak of the range, its throw exceeds 5,000 feet. Connecting the two major boundary faults is a subsidiary arcuate fracture that cuts across the tilted block known as Wildhorse Spur; it apparently joins the High Steens fault at, or near, the hot spring on the edge of the Alvord Desert, 1½ miles southeast of the Alexander mine. The downthrow, which is to the south, cannot be large, for the lavas that cap the high cliffs on the upthrown side are younger than those forming Wildhorse Spur.

West of each of the two major fractures and in general running parallel with them, is a series of subsidiary faults. With rare exceptions, the dip and downthrow of these are to the east. Along most subsidiary faults the displacements are measurable only in feet or tens of feet; along some, however, such as the fault crossing Cottonwood Creek, the downthrow is several hundred feet. Few subsidiary faults depart much from the vertical and most of these dip steeply eastward. Evidence indicating repeated movements along them is cited later in a discussion of the lodes.

In the northern part of the area the Alexander mine and adjacent prospects lie on one of these minor fractures. In the area to the south the subsidiary faults parallel to the edge of the mountains are associated with reversals of dip among the lavas. Between Wildhorse Canyon and the canyon of Stone Creek the rocks along the only subsidiary fault are unmineralized, but in the belt of reversed dips extending south of Red Hill the positions of countless mineralized fractures are clearly indicated by reefs of altered lava. Along most reefs there has been little displacement; they appear to mark tensional fissures either between blocks tilted oppositely or blocks tilted eastward at different angles.

Russell's opinion (1884, pl. 84) that a fault passes through the depression between the bedrocks of Pueblo Mountain and the lavas of the Pueblo Mountains scarp to the west, and Fuller's suggestion (1931, p. 29) of a graben there are not warranted. On the contrary, the depression is merely a wide subsequent valley cut in a continuous succession of westward-dipping flows.

TRANSVERSE FAULTS

Many faults cut diagonally across Steens Mountain and Pueblo Mountains, but only a few were plotted with sufficient accuracy to be included on the map (pl. 8). These range in trend between N. 30° W. and N. 60° W. The displacements along them are small by contrast with those along the major boundary fractures, for they reach a maximum of only a few hundred feet where they join the master faults near the mountain base. Toward the crest of the range their throw diminishes rapidly.

One of these transverse faults follows the south and west sides of Red Hill, bringing the early rhyolites partly against the lavas of the Steens Mountain volcanic series and partly against the older alluvium. Near the valley border its downthrow is to the west, but where it crosses the crest the downthrow is to the east.

Two other transverse faults, bordering a warped and tilted horst west of Alvord Lake, expose the older siliceous lavas under the Steens Mountain volcanic series. The northern of these two runs along Stone Canyon. Close to it the siliceous lavas, which farther south have a southwesterly dip, are strongly bent so that in places they dip northeastward toward the fault at 65°. The southern of the two faults forms the southwest boundary of the ridge on which the Fisher claims are located, and it has offset the siliceous lavas of the ridge several hundred feet upward in relation to the adjoining lavas of the Steens Mountain volcanic series. A short distance away from the valley border both faults have much smaller throw, and 2 miles away there is no indication of them. Some emphasis should be placed on this point, for, as the map indicates, the faults are convergent and if prolonged would come together at the southern edge of Smith Flat, precisely where Fuller has postulated another transverse fracture. Smith Flat is bounded on the north by a straight line of southward-facing cliffs, beyond which rise the High Steens. This scarp was not examined, but Fuller has shown that it also marks a transverse fracture along which the throw diminishes westward.

The lowest point on the entire range is Broad Valley, crossed by the Fields-Frenchglen road. The topographic forms and variable dips of the lavas in this area clearly indicate it contains a series of tilted blocks separated by northwestward-trending faults. Beyond the mapped area, along the western edge of the range overlooking Catlow Valley, the evidence of the relative displacement of these faults is especially clear. In this area the displacement is considerable; most of the faults, however, have diminishing throws as they continue eastward, so that near Alvord Valley only a few of the faults persist. Indeed, the only faults that continue into the mapped area are those marked by the conspicuous siliceous reefs crossing the Mogul, Blair, and O'Keeffe claims, and the vertical displacements along them are too small to be measured, though grooving and brecciation are evidence of some movement.

RECENT FAULTS

At several places along the base of the range there are clear signs of vertical fault movements in recent time. Some of the ends of the spurs that descend to the valley floor are distinctly faceted. A few of these facets were produced by wave action at a time when Alvord Valley was occupied by a large lake, but the majority are ascribed to faulting.

Unmapped fault scarps considerably modified by erosion cut the edge of the older alluvium south of Fields, a particularly good example being provided by the long, straight line of bluffs that crosses the mouth of Willow Creek. In the same area Davis (1920, pp. 760–768) pointed out, "open, graded valley floors now stand a hundred feet or more above the mountain base, and are sharply trenched by the streams that formerly graded them." In front of the tilted horst west of Alvord Lake, where the edge of the mountains is unusually steep, the sterams are even more deeply entrenched as the result of relatively recent uplift. Bone and Stone Creeks enter Alvord Valley through deep rocky defiles incised on a well-graded surface perched 500 to 600 feet above the plain. However, the movements by which these streams were rejuvenated were decidedly spasmodic. Near the mouth of Bone Canyon the rocky floor drops abruptly, and remnants of an old fan may be seen about 150 feet higher than the one now being formed. Moreover, the present fans of both streams are cut by numerous curving and branching scarplets. The displacement along these ranges from a few feet to more than 20 feet, but the aggregate displacement approximates 100 feet. These scarplets are the most youthful faults along the mountain front; they indicate an area of especial instability where two of the most marked transverse faults join the main boundary fault.

Farther north, near Andrews, gravel- and boulder-strewn pediments trenched by youthful gullies denote a long period of quiescence followed by several fairly recent uplifts.

Within the memory of the oldest inhabitants, few earthquakes have occurred in the region. About 25 years ago, however, shocks were felt in the vicinity of Bone Canyon, and the flow of springs was considerably affected. At the same time, the hot spring in Borax Lake, far out on the floor of Alvord Valley, suddenly showed exceptional activity. It may be, therefore, that these effects resulted from movement along the transverse fault on the south side of the horst opposite Alvord Lake, for that fault, if extended southeastward beneath the alluvium, would pass close to Borax Lake. On August 9 and 10, 1943, during the present examination, at least 12 shocks were felt at Fields and by Mr. Ben O'Keeffe on his ranch about 5 miles to the northwest; however, they were not felt in other parts of the region. Hence, it seems likely that these earthquakes were caused by movement along one of the transverse faults, perhaps the one marked by the siliceous reefs that parallel the Fields-Frenchglen road.

EPOCHS OF DEFORMATION AND MECHANICS OF FAULTING

The earliest recognizable disturbance of the Tertiary rocks occurred in early Pliocene time after the eruption of the Pike Creek volcanic series and before the outpouring of the lavas of the Steens Mountain volcanic series. Its effects were most pronounced in the southern part of the area. A second, but extremely gentle, tilting intervened before the flows of the Steens Mountain volcanic series were buried by the cliff-forming Steens basalt.

The elevation of the range began after the eruption of the Steens basalt, presumably some time during the late Pliocene. It started in the Pueblo Mountains, as indicated by the mature dissection of its scarp. That the range stood high prior to the deposition of the Pliocene and Pleistocene(?) older alluvium cannot be questioned, in view of the coarseness and great thickness of these deposits, possibly elevation continued during the accumulation of the older alluvium, but the evidence for this in inconclusive. A second pronounced uplift of the range then tilted the older alluvium westward, at the same time increasing the westerly dip of the underlying lavas. The fact that this tilt is most marked in the region to the south shows that once more uplift was greatest here. Presumably the main elevation of Steens Mountain also occurred at about the same time.

Smith's idea (1927, pp. 422–440) that the major fractures bordering Steens Mountain and Pueblo Mountains are thrust faults is based on inadequate evidence; Fuller and Waters (1929, pp. 204–239) have presented an adequate rebuttal of this hypothesis of compressive forces causing the mountain uplift. The mapping done for this report indicates that these are normal faults produced by tension and that the major boundary fractures and the transverse ones were developed contemporaneously in response to the same set of forces. Moreover, both the occurrence of volcanic necks close to the base of the High Steens scarp and the concentration of basaltic dikes near the mountain base imply that the boundary faults coincide with an old belt of tensional release.

The time of the initiation of the subsidiary faults parallel to the mountain base cannot be determined, but it seems probable that those in the Pueblo Mountains originated earlier than most of those along the base of Steens Mountain. Some of the faults in the Pueblo Mountains must have been in existence prior to the main tilting of the older alluvium, for these gravels rarely exhibit the reverse, eastward dips common among the adjacent lavas cut by the subsidiary fractures. Evidence for repeated movements along these subsidiary faults is included in the discussion of the silicified reefs. In summary, the record is one of recurrent movements along the same system of fractures, and apparently these have always been in the same stratigraphic direction along any given fault.

QUICKSILVER DEPOSITS

Exploration in the Steens-Pueblo region was first conducted for the gold and copper content of the ores occurring in the southern part of the district. Mercury, first noted about 1900, is contained not only in primary cinnabar but notably in mercurian tetrahedrite (schwatzite) and secondary cinnabar. The ore minerals occur in fissure veins and lodes, which are restricted to a northward-trending belt, 40 miles long though rarely more than half a mile wide, near the border of Alvord Valley (see pl. 8). On Pueblo Mountain the lodes occur in pre-Tertiary metamorphic rocks; elsewhere they are either in mafic lavas of the Steens Mountain volcanic series or in the underlying siliceous volcanic rocks of the Pike Creek volcanic series. All are believed to be of Pliocene age.

The yield from these lodes has been small. Production before 1941 amounted to less than 10 flasks, and under the stimulus of high prices during World War II the total production increased to only about 55 flasks, which came chiefly from the Mogul mine, the Steens Mountain prospect, and the Alexander mine.

MINERALOGY

ORE MINERALS

The primary ore minerals of the lodes are principally schwatzite, chalcopyrite, and cinnabar. Of these, only the cinnabar has proved to be of economic importance. Less abundant are hematite, pyrite, enargite, arsenopyrite, and galena (?). Prominent among the secondary minerals are chalcocite, covellite, malachite, azurite, chrysocolla, tenorite, cuprite, cinnabar, and various oxides of iron. Bornite, reported by Ross, was not identified in this study. As far as the authors know, metacinnabar, native mercury, stibnite, and marcasite have not been identified anywhere in the district.

Schwatzite, $(Cu,Hg,Zn,Fe)_{12}(Sb,As)_4S_{13}$, is present in all of the lodes except a few in the southern part of the range, and in many it is the only primary mercury-bearing mineral. In the Blue Bull and Rabbit Hole ores it is the dominant sulfide, where it occurs in anhedral grains and clots as much as several inches in diameter. On fresh surfaces it is medium gray in color and has the same irregular, somewhat granular appearance as ordinary tetrahedrite. In composition it closely approaches mercurian tennantite, as it contains a large amount of arsenic in place of antimony; locally the arsenic content is sufficient to make retorting difficult. An analysis of schwatzite from the Blue Bull mine given by Ross (1942, p. 241) shows 10.68 percent of mercury, 33.16 of copper, 11.03 of antimony, and 6.94 of arsenic. The mineral is partly replaced, particularly in the cores of the grains, by covellite and chalcocite. This, coupled with the fact that enargite (Cu_3AsS_4) is invariably concentrated in the cores, suggests that the schwatzite is zoned, its copper content diminishing outward as the content of mercury increases.

Cinnabar (HgS) occurs in two forms. Most of it in the southern part of the district is a bright red secondary earthy mixture associated with limonite. This secondary cinnabar is generally associated with schwatzite, from which it was derived. In contrast, the primary cinnabar has a granular crystalline habit by which it is readily distinguished from the secondary form. Though it is locally associated with schwatzite, its distribution bears no definite relation to that mineral.

The mode of occurrence of the primary cinnabar differs somewhat in various mines. The most widespread occurrence is in veinlets of pink "opalite" consisting mainly of chalcedony with some fine-grained quartz. In these veinlets the cinnabar occurs as minute particles dispersed in the siliceous gangue and accompanied by specks of chalcopyrite, pyrite, and schwatzite. Dustlike, or finely granular, cinnabar coats barite tablets in the Mogul mine and in some of the lodes north of Red Hill, particularly on the Fisher and Eldorado claims. In some parts of the open breccias of the Mogul mine it coats late drusy quartz, and in a few places it is partly covered by perfectly formed pseudomorphs of limonite after siderite or by films of botryoidal opal. Coarsely crystalline cinnabar showing good crystal forms is present at the Double Link claims, near Denio. Small quantities of cinnabar are disseminated as fine specks in altered lavas in and adjacent to many of the lodes. Locally these disseminations are concentrated on the walls of open fractures. At the Alexander mine, for instance, the high-grade material comes from films of cinnabar and wet brown clay (beidellite) coating breccia fragments; this cinnabar is possibly supergene. Along some cracks at the Steens Mountain prospect, thin veneers of limonite and chalcedony are covered with a thick layer of mammillary cinnabar locally overlain by drusy quartz and opal.

The primary ores show a lateral variation which, although irregular, is well-marked. With the exception of the Double Link claims, near Denio, the lodes south of Tumtum Point contain only coarse scaly hematite and a little pyrite. To the north, in the lodes of the Pueblo, Farnham, and Arizona claims, chalcopyrite and pyrite are predominant; hematite and pyrite are exceptional. In the Red King-O'Keeffe vein, the proportion of schwatzite, though irregular, increases notably, whereas on the parallel vein system passing through the Blue Bull and Rabbit Hole mines, nearly all the primary ore is schwatzite. From Sesena Creek northward to Alvord Lake the proportion of chalcopyrite to schwatzite is very erratic; in this stretch of the mineralized belt primary cinnabar becomes more plentiful, and at the Mogul mine it is the only primary sulfide. Finally, in the northernmost lodes, copper sulfides are entirely lacking, and except for traces of pyrite and arsenopyrite(?), cinnabar is the only sulfide.

GANGUE MINERALS

Within the lodes and their altered walls, many of the rocks have been so thoroughly changed that none of the original constituents or textures remain. The main products of the hydrothermal alteration are quartz, chalcedony, opal, calcite, dolomite, siderite, gypsum, barite, limonite, and various clay minerals.

Coarse-grained quartz is found only in the southernmost lodes on Pueblo Mountain, exclusive of the Double Link prospect. Elsewhere, most of the quartz is a very fine grained, dull-white variety of chalcedony, but a little of later origin occurs as well-formed crystals in drusy cavities. Chalcedony is by far the dominant silica mineral, and in most lodes it makes up almost all the gangue. It forms the bulk of the so-called "opalite" veins and the long stretches of massive jasperoid rocks of the resistant reefs. Any opal precipitated during the pre-ore stage of alteration has since been dehydrated; the present rare occurrences of fresh opal were formed either during or after the deposition of the ore as mammillary coatings on the side of cavities.

Various hydrous iron oxides are mainly responsible for the pastel tints typical of the highly kaolinized rocks and for the deep reddish-purple color of the mildly silicified lavas, such as those on the Lucky Strike and Mogul claims. A little limonite present within the lodes is a product of the alteration of chalcopyrite and schwatzite. As the ribs of limonite admixed with chalcedony are so prevalent within the strongly silicified reefs but are devoid of ore minerals, there is no doubt that the main period of limonitization preceded the formation of the sulfides.

Calcite is widespread in the altered wall rocks, but the principal carbonate in the veins is dolomite. On the Pueblo claims veins of dolomite range from a fraction of an inch to 6 inches in width; the northern end of the Red King-O'Keeffe vein near Sesena Creek is composed almost entirely of dolomite. Veins of coarsely crystalline ferruginous dolomite, locally mixed with botryoidal, cellular calcite, are plentiful on the Blue Boy claims; some, which are as much as 5 feet in width, cut the reefs of silica-limonite rock. Siderite, pseudomorphed by limonite, has been noted only at the Mogul mine, where it occurs as euhedral crystals coating cinnabar and barite. In none of these occurrences is the carbonate accompanied by ore minerals, and it is believed to be of later origin.

Gypsum was identified only at the Mogul mine, where it forms sporadic veinlets cutting kaolinized lavas; it is probably supergene in origin. Barite, on the other hand, is widespread, if not abundant, in most of the lodes between the Rabbit Hole and the Fisher claims. It is doubtless primary in origin. Some of it is finely granular and fills small gash fractures, but typically it appears as tabular crystals forming drusy coatings on the walls of cavities. Much of the cinnabar in the Mogul mine is present as a "frosting" on these perfectly formed tablets.

The clay minerals were not thoroughly studied. Kaolinite is probably the principal variety, particularly in the lavas containing pseudomorphs of clay after phenocrysts of plagioclase. Ross reports the occurrence of hydromicas and nontronite. At the Alexander mine fragments of fault breccia are coated with wet, waxy films of pale-brown beidellite admixed with cinnabar.

LODES

The character of the lodes is of considerable interest. The ore minerals occur either in late veins of opalite, clear quartz, and barite or as coatings on fragments of open crush breccia. Though the nature of these lodes is variable, they are for the most part steeply dipping silicified reefs in lavas or metamorphic rocks. The lodes at the southern and northern extremes of the district are rather irregular and diffuse, but those occurring in the central part are marked by prominent wall-like reefs. Most of these range from 5 to 15 feet in width; locally they increase to 80 feet. A few of the reefs are continuous for half a mile, but the continuity of most is broken every few tens or hundreds of feet by stretches of softer, more kaolinized rock that forms smooth slopes and saddles between the siliceous knobs and combs. Clusters of these shorter ribs commonly show a definite parallel pattern, as indicated on plate 8. In detail the lodes consist of anastamosing and intersecting bands of more silicified rock, dull-white to dark-brown according to the amount of limonite admixed with the fine-grained quartz and chalcedony, separated by lenses and stringers of less resistant kaolinized and carbonatized rock. Innumerable minor fractures traverse the reefs. Generally, they are parallel or almost so, but many curve and cross at high angles, and the striae on them pitch at random. The reef rocks are locally brecciated, and, commonly, angular fragments of lava occur in a matrix of dense quartz and chalcedony, which is itself brecciated.

Most of the northwestward-trending reefs are vertical or dip at angles exceeding 70°, though locally they may dip to the west or east at angles as low as 45°. The same holds true for the reefs parallel to the valley border (see pl. 8); the rule there is that the easternmost reefs dip eastward at the lowest angles, and westward dips are rare except among the westernmost reefs. Where reefs intersect, their surface trends are not affected.

The lodes are distributed unevenly through an almost continuous belt in which only three major gaps occur. The northernmost gap is 12 miles long, extending from Indian Creek southward to Bone Creek opposite Alvord Lake. A second gap, 4½ miles long, extends from the Lucky Strike claims southward to Sesena Creek, but perhaps this is only an apparent break, for lodes may be present there under a cover of older alluvium. A gap of 6 miles occurs between the southernmost lodes on Pueblo Mountain and the small Double Link prospects, which might be considered to lie on the southern end of the belt.

The lodes are localized by the fault pattern near the western border of the mountain block, for all but a few occur along the subsidiary fractures parallel to the master faults along which the Steens-Pueblo block rose. Some lodes follow the northwestward-trending transverse fractures in the foothills near Fields and west of Alvord Lake. Essentially, the controlling fractures either represent tensional fissures along the crests of anticlinal warps parallel to the valley border, or they define the limits of silver blocks tilted at different angles toward the Alvord graben. The vertical displacements along them appear to be small.

ORIGIN

Hydrothermal solutions, rising along the subsidiary marginal fractures and the transverse faults, produced extensive alteration of the adjacent rocks. Silicification was common and resulted in the resistant wall-like reefs. Where kaolinization, limonitization, and carbonatization were the only processes of alteration, low-lying belts of pastel-tinted clays denote the trends of the feeding fractures. Broad zones of slightly altered lavas near the main lodes were also formed during this period. During these early stages of hydrothermal activity, before the introduction of ore minerals, repeated movements occurred along many of the faults. In the cracks and breccia bodies formed by these movements, additional silica, along with barite and iron, copper, and mercurian sulfides, was deposited. Even during the deposition of the ore minerals, however, movements occurred locally, and in some places they have continued at intervals to the present.

Because of the marked lateral variation of the ores, no regional paragenesis of the ore minerals could be determined. In some of the ores with the best representation of ore minerals, as those from the Blue Bull mine and the Red King prospects, microscopic study shows that chalcopyrite followed pyrite; enargite and mercury-poor tetrahedrite began to crystallize prior to the termination of chalcopyrite deposition and continued thereafter. All the mercury-rich tetrahedrite appears to have been deposited later, and much of it replaces the chalcopyrite in irregular veinlets and blebs. The age relation of the primary cinnabar to the other primary sulfides could not be determined.

The weathering of schwatzite, giving rise to secondary cinnabar, is of particular interest. The schwatzite is most readily altered where it is accompanied by abundant chalcopyrite, which provides on oxidation the acids requisite to effect decomposition. Where chalcopyrite and pyrite are lacking, the schwatzite may be unaltered even at the surface. The secondary products include dull resinous patches of limonite, rare traces of cuprite and tenorite, malachite, azurite, chrysocolla, irresolvable mixtures of antimony and arsenic minerals, and secondary cinnabar. Because of the low solubility of cinnabar, except in chloride waters and alkaline sulfide solutions, it is not surprising that in this instance most of the secondary cinnabar is deposited near the parent schwatzite as red earthy coatings mixed with limonite and peppered with specks of relic schwatzite. In many places the fresh schwatzite grades to porous brownish-black limonite riddled with blebs and veinlets of cinnabar, malachite, azurite and chysocolla. This association is conspicuously displayed in the upper oxidized part of the vein in the Blue Bull mine, although the ore a few feet down the shaft contains virtually unaltered schwatzite. However, the secondary cinnabar is not everywhere deposited on the parent sulfide. In an alteration zone in the lower part of the Blue Bull vein it is spread laterally along feather fractures for distances of 3 to 4 feet. At the Red King prospect ovoid pods of chalcopyrite-schwatzite ore show irregular cracks lined with earthy cinnabar and secondary copper minerals, but some cinnabar is contained in fractures in the surrounding siliceous gangue for a distance of several feet out from the pods. Indeed, if the cinnabar found along shears cutting the soft kaolinized lavas on the footwall side of the Red King reef is also secondary, the migration is measurable in tens of feet. The means of transport of the secondary cinnabar is not apparent. No chlorine-bearing minerals were recognized in these lodes, although Ross (1942, pp. 254, 257) reports the presence of 0.07 percent of mercuric chloride in a sample from the Blue Bull mine, and a smaller quantity from the Mogul mine. Mercury could posibly have been transported by chloride waters and the sulfide precipitated by reaction with chalcopyrite. Transport by alkaline solutions seems highly improbable, but mechanical transfer of the friable, earthy cinnabar by groundwaters may have taken place.

Only the broadest generalizations can be made concerning the origin of the lateral variations of the Steens-Pueblo ores. In part, especially at the southern end of the belt, these lateral variations may merely express the degree to which the lodes have been eroded, the ore becoming relatively richer in chalcopyrite and hematite (copper and iron) with depth. The presence of coarse-grained quartz as gangue in the hematite-rich lodes, in contrast with the usual gangue of fine-grained quartz, opal, and chalcedony elsewhere, lends some support to this contention. Obviously, however, this cannot be the prime cause of variation, nor can it be ascribed chiefly to original lateral variations in the nature of the mineralizing solutions. It is to be noted that the southernmost of the lodes, the Double Link, contains cinnabar and schwatzite along with secondary copper minerals in fine-grained quartz and chalcedony. The main cause for zoning seems to be found in the age of the various fractures with respect to the changing content of the ore-bearing fluids. On this hypothesis, lodes rich in schwatzite with respect to chalcopyrite are in general younger than those poor in schwatzite, and lodes in which primary cinnabar is the dominant or only sulfide are regarded as those most recently formed. In other words, as time went on and new fractures were opened the ratio of mercury to copper and iron appears to have increased.

SIZE AND GRADE

Despite the great length and width of the belt of fracturing and hydrothermal alteration and the presence of innumerable siliceous reefs, no large bodies of ore have yet been found in the region. The most common occurrence of ore is in the so-called opalite veins, where the gangue consists chiefly of chalcedony, clear quartz, and barite. Few of these veins exceed 6 inches in width, and none are traceable continuously for more than a few tens of yards. Moreover, the distribution of ore minerals within them is extremely spotty, and in many the ratio of schwatzite and cinnabar to chalcopyrite varies greatly, so that the abundance of sulfides is not a good indication of quicksilver values.

Assay values from the various lodes emphasize the spotty occurrence of ore. Pods of high-grade chalcopyrite-schwatzite ore, yielding as much as 120 pounds of quicksilver per ton, occur at the Red King prospect, but the average amount of mercury recovered from a ton of this ore is only about one flask (76½ pounds). Ore rich in iron and copper sulfides reappears along the same zone of lodes to the north, on the O'Keeffe claims, but there the quicksilver content decreases to about 2 pounds per ton. At the Blue Bull mine, where schwatzite and cinnabar are the most abundant ore minerals, the vein is 5 to 6 inches thick and averages 5 pounds of quicksilver per ton. As much as 57 pounds of quicksilver per ton is reported from the Eldorado claims, but the average tenor of the veins is no more than 2 or 3 pounds per ton. Even the most promising veins on the O'Keeffe Mercury claims average only 3½ pounds per ton. Similarly erratic values were noted at the Steens Mountain prospect. The veins that cut Pueblo Mountain are far too poor in both schwatzite and cinnabar to merit development for mercury.

Perhaps the most promising ore bodies are the open breccia ores at the Mogul and Alexander mines, though even these appear to be mostly mined out. The Mogul pocket has yielded 28 flasks of quicksilver, and about 24 remain; the Alexander pocket has yielded 8 or 9 flasks, and about as many remain. The average tenor of the ore approximates 7 or 8 pounds of quicksilver per ton. No indications of similar ore bodies were seen elsewhere in the district.

OUTLOOK FOR FUTURE DEVELOPMENT

The reefs are well-exposed over long distances, and erosion has bared them to considerable depth, yet none of the surface indications hold promise of important reserves. Admittedly, exploration thus far has been almost wholly by shallow pits and trenches, the deepest working extending no more than 160 feet below the surface. Development, however, has been sufficient, where the showings are most favorable, to indicate that large deposits of high-grade ore are not likely to be discovered. Likewise, though a little cinnabar is disseminated in the soft kaolinized rocks bordering some of the reefs, supplies of low-grade ore adequate to justify large-scale operations are definitely not in sight and cannot be expected.

There seem to be only three general possibilties for future development. Perhaps the best of these is to prospect for breccia pockets like those found in the Mogul and Alexander mines; these are likely to occur where late movement has taken place on curving reefs. The cinnabar-opalite veins are a good possibility for the local operator equipped with a small retort and satisfied to exploit small bodies of high-grade ore for his wages. Likewise, the high-grade schwatzite-chalcopyrite ores of the Red King prospect and vicinity are good potential producers for the small-scale operator. However, the retorting difficulty caused by arsenic in these ores discourages development, and even if this metallurgical problem can be overcome by mixing quicklime with the ore, the veins are not likely to supply significant amounts of quicksilver.

MINES AND PROSPECTS

The various quicksilver properties, beginning with those at the southern end of the region and going northward, are described in the following paragraphs.

DOUBLE LINK CLAIMS

The seven Double Link claims, near Denio, owned by J. B. Fine and B. T. Fical of Frenchglen, are about a mile north of the Oregon-Nevada line in sec. 13, T. 41 S., R. 34 E. These claims, which have been operated only during short intervals since their location in July 1940, are the only known quicksilver prospects on the western flank of Pueblo Mountain. A road from Denio village gives easy access to the property.

The belt of mineralization, an inconspicuous zone of silicified and limonitized lavas flanked by kaolinized rocks, cuts westward-dipping flows of amygdaloidal porphyritic andesite or basalt (or both) near the base of the Tertiary volcanic sequence. The mineralized belt, which has been explored by several shallow adits and open-cuts, is traceable in a northwesterly direction for nearly half a mile, ending within 250 feet of the pre-Tertiary bedrocks.

Near the northern end of the belt, on the west bank of Denio Creek, a 43-foot adit has been driven along a brecciated zone of silicified lavas cemented and veined by opal and chalcedony. The adit exposes a vein, only a few inches thick, trending N. 30° W. and dipping 50°–60° E.; 10 feet from the end of the adit the vein disappears. A little cinnabar is visible as tinting in the opal-chalcedony matrix and as subhedral crystals coating joint surfaces in the adjoining lavas. Beyond the end of the vein the adit cuts soft kaolinized lavas apparently devoid of ore. On the surface the belt of hydrothermally altered rock dies out within less than 100 yards, indicating there is little likelihood of finding more ore in this direction.

About 100 yards in the opposite direction, on the east bank of Denio Creek, a 40-foot open trench, cut across the mineralized belt, exposes silicified lava containing thin veinlets of chalcedony and drusy quartz with some showings of cinnabar. An adjacent and parallel 30-foot open-cut, which continues into a 26-foot adit, exposes at its entrance a quartz-chalcedony vein 2 to 4 inches wide, trending N. 25° W. No cinnabar in place was detected, but samples on the dump show coatings of chrysocolla and malachite and a little schwatzite. The remainder of the open-cut and most of the adit are in soft kaolinized basalt, sheeted parallel to the original bedding. According to H. K. Lancaster, of the Oregon State Department of Geology and Mineral Industries, samples from this and the preceding cut range in mercury content from a trace to 8.6 pounds per ton, averaging about 1 pound.

Near the southeast end of the Double Link claims, a 35-foot shaft has been sunk in the silicified zone. At the collar and for 15 feet down the shaft, the zone is vertical and strikes N. 55° W.; below, it dips 65° E. Thin veinlets of chalcedony containing meager traces of cinnabar cut silicified lava lying above a footwall of kaolinized lava.

No production from any of these claims is recorded, nor is their profitable development anticipated.

FARNHAM AND PUEBLO GROUPS

On the east slope of Pueblo Mountain, in secs. 8 and 17, T. 40 S., R. 35 E., are two groups of claims. The northern, or Farnham, group consists of six claims—the Blue Bell, Yaqui, Waltham, Goldenwest, Balboa, and Anaconda—owned by E. D. Farnham of Winnemucca and worked intermittently between 1919 and 1939. The southern group, developed by the Pueblo Gold Mining Co. during part of the same period, adjoins the mill site at the end of the road from George Wilson's ranch; its limits were not ascertained.

All the prospects are in pre-Tertiary rocks, principally blastoporphyritic and fine-grained meta-andesites. All occur where these rocks were fractured, altered by hydrothermal solutions, and then refractured and cut by veins consisting of quartz, carbonates, and some primary sulfides. Secondary alteration of these primary sulfides has yielded a little earthy cinnabar. The content and attitude of the veins, as well as the character of the wall rock alteration, indicate that the deposition took place during the same general period of mineralization and under approximately the same conditions as the deposition of the ore in the siliceous reefs cutting the Tertiary lavas farther north.

FARNHAM GROUP

The principal working on the Farnham claims is an adit 780 feet long, now caved at its portal. It was driven from near the base of a hill to intersect one or more of the siliceous reefs exposed 200 to 300 feet higher up the slope. Examination of the rock in the dump suggests that the adit first passed through fine-grained meta-andesite containing veins of quartz, pyrite, and chalcopyrite; then it passed through soft purplish kaolinized meta-andesite; and finally, it cut a reef of silica-limonite rock. Specimens of the reef rocks contain malachite and chrysocolla accompanying pyrite, chalcopyrite, and a little schwatzite.

The lowest of the reefs on the hillside above the adit has been explored by a 12-foot open-cut. Locally the silica-limonite rock therein is brecciated and veined with dense quartz carrying pyrite and copper sulfides with rare specks of cinnabar. The veins follow undulating shear planes that trend N. 20° W. and dip 45°–60° E., in accordance with most of the easternmost reefs in the region to the north.

A parallel reef, which crops out as a wall higher up the slope, dips 60°–75° E. Parts of it are highly silicified and limonitized; other parts are more kaolinized and carbonatized. Some of the altered rock was originally meta-andesite, but most of it was a papery quartz-feldspar schist. A 37-foot adit driven into the reef nears its northern end shows two inch-wide veinlets of chalcedony dipping 30° W. No ore was observed in place, but on the surface above the adit the reef rocks contain malachite, chrysocolla, a little azurite, and occasional grains of chalcopyrite and schwatzite. A second adit 25 feet long, near the southern end of the reef, exposes a 2-foot band of similar low-grade siliceous ore. Other short adits still higher up the slope explore a third reef containing brecciated and mineralized quartz veins a few inches wide.

"A few hundred pounds" of quicksilver are said to have been obtained on the Farnham ground as a byproduct of gold mining; however, the ore is much too poor and in veins too narrow and discontinuous to warrant development for quicksilver alone.

PUEBLO GROUP

Three shallow shafts, several trenches, and two adits on the hillside west of the abandoned gold mill are believed to lie within the Pueblo claims. A 260-foot adit close to the mill is caved 30 feet from the portal and the dump reveals no ore. One shaft is inaccessible; the others are timbered to the bottom. Near the lowermost shaft, a 60-foot tunnel exposes sheared and altered metavolcanic rocks. These rocks are cut by a vein as much as 18 inches wide, which strikes N. 10° E. and dips 70° E. It consists of fractured quartz and coarse-grained dolomite containing thin ribbons and lenses of pyrite, chalcopyrite, and scaly hematite. Locally, the primary ore, the supergene chalcocite developed from the chalcopyrite, and the gangue are cut by post-sulfide fractures which are in places filled with malachite and chrysocolla. Neither schwatzite nor cinnabar were seen in place, though samples from the dump include a little of each. Similar low-grade ore occurs in dumps from adjacent trenches, but the source is no longer visible.

No quicksilver production from any of the Pueblo workings is recorded. The low content of schwatzite in the ore, together with the thinness and shortness of the veins, rules out the possibility of much future production.

APACHE CLAIMS

The two Apache claims, owned by Dewey Moore and Paul Cramer, are on the north bank of Arizona Creek about 1½ miles west of the mountain front. They lie along a curving vein traceable for 825 feet across the metamorphic bedrocks. The strike of the vein swings from N. 55° W. at the northwest end to N. 80° W. at the opposite end; the 80-degree dip ranges from SW. to NE. The width ranges from 3 inches to 2 feet, average about 8 inches. Primary schwatzite, pyrite, and chalcopyrite are disseminated through a gangue of chalcedony and quartz; secondary cinnabar, copper minerals, and limonite occur in cracks and vugs in those parts of the vein shattered by postsulfide movement. Although the cinnabar is widespread, the quantity in any one place is extremely small. Further exploration, which along the strike is hampered by a heavy cover of talus, seems to be unwarranted by the present showings.

ARIZONA CLAIMS

In sec. 6, T. 40 S., R. 35 E., near the north bank of Arizona Creek, several shallow pits and a caved adit explore the pre-Tertiary bedrocks a short distance from their contact with the overlying Tertiary lavas. The Arizona No. 1 claim was located by A. W. Van Riper, A. R. Wood, and William Grobe in November 1934, though it is reported that much of the work on this ground was done at an earlier date. The Arizona No. 2 claim adjoins No. 1 on the west and was located in September 1942 by James Haltzsclaw, D. L. Tulles, C. M. Doan, and M. M. Doan.

The scarcity of exposures in this area makes it impossible to determine details of the structure, but most of the pits occur in a belt trending N. 60°–70° W. approximately parallel to the silicified reefs bordering Cottonwood Creek to the northwest. None of the shear zones exposed in the pits are traceable for more than a few feet, and even in adjacent pits the direction of jointing and schistosity is diverse. The bedrocks here are dense metavolcanic rocks, chiefly epidotized and chloritized andesite porphyries, accompanied by some argillite, quartzite, and sericite schist. Most of them are silicified; locally they exhibit irregular shatter zones and are veined with quartz, chalcedony, calcite, and siderite.

The ore is confined to thin patchy coatings of malachite, chrysocolla, azurite, and manganese oxides on fractures in the shatter zones. Rare occurrences of pyrite and chalcopyrite are known, but neither schwatzite nor cinnabar was observed. Some quicksilver minerals are said to have been found during the search for gold, but the quantity must have been trivial and the prospect for further discovery may be dismissed.

On the south bank of Arizona Creek crags of rusty-weathering feldspathic quartzite suggest a southward continuation of the zone of alteration, but they appear to be devoid of copper sulfides, secondary copper minerals, and cinnabar.

COTTONWOOD AND WILLOW CREEKS AREA, INCLUDING CASH CLAIMS

A belt of parallel discontinuous reefs of silica-limonite rock bordered by kaolinized lava extends for 7 miles northward from the place where the bedrocks of Pueblo Mountain disappear under the Tertiary lavas. The only noteworthy workings in the southern half of the belt are those on the Cash claims, but from the Blue Bull mine northward, many small prospects have been developed along it. For the sake of completeness, however, the entire 3-mile stretch will be described as a unit even though it is only locally mineralized.

Near the southern end of the belt, just north of Cottonwood Creek, a fault with downthrow to the east of several hundred feet brings the westward-dipping conglomerates at the base of the Tertiary sequence against eastward-dipping lavas (see pl. 8). Near the creek the fault is bordered by a zone of intense hydrothermal alteration approximately a quarter of a mile wide, in which the exact nature of the original rocks can no longer be determined. West of the fault were probably metavolcanic rocks of the pre-Tertiary basement; east of the fault must have been Tertiary lavas. The zone appears to be devoid of sulfides, despite the unusual extent of altered rock and the occurrence of reefs, as much as 80 feet in width, composed almost entirely of dense quartz.

This barren belt of alteration continues northward across the South Fork of Willow Creek, following close to the base of the Tertiary beds, as far as the Cash claims lying near the eastern edge of sec. 25, T. 39 S., R. 34 E. The claims, which were located in June 1941, by Ora Doan and Melvin Doan of Fields, are on a prominent reef that dips east 25°–40°, cutting sandstones, tuffaceous sediments, and interbedded flows that dip westward at approximately 20°. On claim No. 1, an adit 130 feet long has been driven N. 70° W. from the hanging-wall side of the reef, in part following a slickensided fault plane that dips 30° N. Except in the last 20 feet, the adit passes through soft, kaolinized, limonitized, and carbonatized andesite, apparently devoid of ore minerals. In its last 20 feet, the adit cuts silicified black shale and tuffaceous sandstone showing films of malachite and azurite on a few fractures. No chalcedony veins cut the altered rocks, nor are there any distinct zones of brecciation like these commonly containing ore elsewhere. A short distance to the south, by the discovery claim monument, a pit on the reef shows azurite, malachite, and chrysocolla on secondary fractures which dip almost at right angles to the reef itself. A few grains of pyrite and chalcopyrite occur in seams of chalcedony, but schwatzite and cinnabar are apparently absent.

Between the Cash claims and the North Fork of Willow Creek the belt of hydrothermally altered rock is largely obscured by slides. On the north side of that stream, however, it is well-exposed over a width of about a quarter of a mile. The nature of the original rocks here is indistinguishable; presumably most were sandstones and shales with interbeds of basic lava, but possibly along the eastern side they were pre-Tertiary porphyritic rocks like those at the Blue Bull mine. Though most of the alteration has yielded kaolin, carbonates, and limonite, locally it has resulted in the formation of short siliceous reefs that dip east 30°–40°. Some of these have been explored by shallow pits, but no ore was seen anywhere on the reefs.

In brief, the entire 3-mile stretch between Cottonwood Creek and the Blue Bull mine, though intensely altered and cut by numerous short siliceous reefs, appears to be virtually barren.

BLUE BULL MINE

In sec. 24, T. 39 S., R. 34 E., between Horse Creek and the North Fork of Willow Creek, is a group of six claims owned by Ora Doan, M. M. Doan, and D. E. Wheeler of Fields. The main workings, known as the Blue Bull mine, are near the divide between the two creeks; they include several shallow pits and trenches and a shaft 45 feet deep. All are in pre-Tertiary bedrocks, principally massive meta-andesite porphyry.

About 100 feet northwest of the Blue Bull mine, these bedrocks are intruded by a large body of porphyritic rhyolite, probably a volcanic neck of Tertiary age. Most of this intrusion is intensely silicified; at its southern end it is almost entirely replaced by fine-grained quartz. This secondary quartz is apparently devoid of sulfides but contains traces of specular hematite, which forms rusty coatings where it is altered. A few yards west of the mine the bedrocks are overlapped by flows of fresh basalt.

The main shear zone north of the mine swings around the eastern edge of the rhyolitic intrusion, the shear planes dipping steeply to the east. Locally, ribs of silica-limonite rock mark its course; elsewhere its path is indicated by clayey soil derived from hydrothermally altered lavas.

The inclined shaft of the Blue Bull mine trends N. 70° E. and follows shears which dip 55° to 65° E. At the 20-foot level a drift 40 feet long extends N. 10° E. along the vein. The wall rock is andesite porphyry and fine-grained andesite largely replaced by silica, limonite, kaolin, and carbonates. The thickness of the principal vein generally ranges from 3 to 8 inches, but where parallel shears that dip at angles of less than 35° intersect it the thickness locally increases to 15 inches. Moreover, much of the secondary cinnabar has migrated away from the vein, along the flat shears; in places this outward migration is as much as 4 feet from the intersection of the vein and the shears.

Six feet below the collar of the shaft the main vein forks upward into two branches, which range from a fraction of an inch to 3 inches in thickness. Some primary schwatzite occurs in these branches, but most of the ore in the mine consists of secondary cinnabar, malachite, azurite, and chrysocolla in a fractured matrix of opal and chalcedony. One sample from this oxidized zone contained 0.56 percent quicksilver and 3.89 percent copper; another, collected by Ross, contained 0.99 percent quicksilver and 0.07 percent mercuric chloride. Below the fork most of the principal vein consists of schwatzite accompanied by only a little cinnabar in a brecciated matrix of opal and chalcedony; chalcopyrite and secondary copper minerals are virtually absent. Along short stretches of the vein, the fine-grained opal-chalcedony gangue grades into less siliceous and more vuggy blocky kaolinized rock in which the schwatzite has been largely replaced by secondary cinnabar; such parts of the vein contain decidedly less quicksilver than the more siliceous parts. The average quicksilver content of eight assayed samples from various parts of the mine approximates 7 pounds per ton, but the average tenor of the vein is less than 5 pounds per ton. The average width of the veins is 5 to 6 inches.

The main vein pinches out 10 feet from the end of the drift, and on the surface there are no indications to guide further exploration. At the bottom of the shaft the vein, although of average thickness, is strongly brecciated and virtually barren.

No quicksilver is known to have been recovered from the ore owing to trouble caused by the presence of arsenic in the schwatzite. The present showings do not seem to warrant further development.

RABBIT HOLE GROUP AND SPRING CREEK CLAIM

The six claims of the Rabbit Hole group are located in sec. 12, T. 39 S., R. 34 E. and are owned by Ora Doan, C. M. Doan, and D. E. Wheeler of Fields. A detailed map of the property is included in U. S. Geological Survey Bulletin 931–J, plate 44. Development consists of a 63-foot shaft, a 25-foot adit, and several small pits and trenches. A 3-tube inclined retort was on the property when it was examined in 1943.

On these claims the andesitic and basaltic lavas, which elsewhere dip westward, are considerably deformed and locally dip eastward at moderate angles (see pl. 8). Whether these reversals of dip indicate nearly parallel folds or, more likely, tilted fault blocks, is uncertain owing to scarcity of exposures. The disturbed rocks are cut by many conspicuous wall-like reefs in which the lavas are extensively altered. On plate 8 the reefs are indicated as continuous lines; actually they consist of resistant nodes, rich in silica and limonite, linked by less-resistant lavas containing kaolin and carbonates. Most of the reefs trend northwest to north and dip eastward at angles of more than 60°. In local bulges the reefs have a width of 12 feet, but for most of their length it is 6 to 10 feet.

Except in a few places the reef rocks are barren of ore. The ore that is present is virtually confined to the more siliceous parts, in which it occurs in narrow zones of brecciated fine-grained quartz and chalcedony cut by veinlets of opal-chalcedony or clear drusy quartz. The reefs mark zones of repeated displacement. The initial fissures localized the early hydrothermal alteration; subsequently, the more brittle parts of the reefs were fractured, providing openings for the deposition of sulfides with silica minerals and a little barite; finally, this mixture itself was locally brecciated, and strings of cinnabar and secondary copper minerals were deposited in veinlets in both the sulfides and the gangue.

The Rabbit Hole inclined shaft, sunk at the junction of two siliceous reefs, plunges eastward at an angle of 56°. It follows an indefinite, vertical zone of silicification 4 to 24 inches wide. At the collar the main shear planes strike N. 50° W. and dip east 60°–70°; these are cut by planes that dip at low angles both to the east and west and by vertical fractures that vary greatly in strike. The pitch of striae on the fractures is likewise variable. At the 48-foot level, a drift has been driven N. 40°–50° W. for 30 feet along a second vertical zone of silicification. Other vertical shears in the drift strike N. 30°–35° W., and the back is formed by two shears dipping in opposite directions at angles of approximately 20°. Where these flat shears intersect the vertical ones the zone of silicification widens to about 4 feet.

No ore remains in sight. Examination of the dump material suggests that the best ore occurred in rock composed of angular fragments of altered andesite in a matrix of opalite. Small patches of cinnabar with malachite, azurite, and chrysocolla are disseminated along cracks in the opalite. Many samples consist solely of schwatzite and chalcedony; in others the schwatzite is coated with bright red earthy cinnabar. The cores of the schwatzite grains, in which are included scattered specks of enargite, are largely replaced by supergene chalcocite and covellite. Chalcopyrite is virtually absent.

During 1940, about a flask of quicksilver was retorted from 3 to 4 tons of selected ore. Since the silicified parts of the reefs pinch out a short distance from the shaft, the prospects for more ore are poor.

Between the Rabbit Hole mine and the Blue Bull mine 2 miles to the south, the older alluvium is bordered by a wide belt of pastel-colored clays derived from intensely kaolinized lavas. Locally the clays are cut by short inconspicuous veinlets of silicified lava showing traces of secondary copper minerals and by veinlets of chalcedony and cellular calcite. The thinness of these veinlets, their very low content of ore minerals, and their scattered occurrence discourage development.

Adjoining the Rabbit Hole claims on the north is the Spring Creek claim, located on July 1, 1939, by J. D. McDade of Fields. A few shallow pits explore siliceous reefs that parallel those of the Rabbit Hole group. In the pit by the claim monument altered lavas contain a small amount of azurite and malachite and minute traces of cinnabar, schwatzite, and chalcopyrite. The ore minerals are confined either to cracks in chalcedony or to coatings on the drusy quartz and are too limited to warrant any further development.

RED KING, O'KEEFFE, AND ADJACENT CLAIMS

The Red King-O'Keeffe vein system extends between Sesena and Horse Creeks along the western edge of a mineralized belt about a mile wide. Although it is marked by a few conspicuous reefs, it is one of the most persistent vein systems in the region. It can be traced with a few gaps from north of Sesena Creek at least as far as the Blue Bull mine, where it may coalesce with some of the eastern veins. A few weakly mineralized zones lie west of the Red King-O'Keeffe vein in the area between Sesena and Spring Creeks, but as they are so inconsequential, the Red King-O'Keeffe vein has been regarded as the western limit of the disturbed and mineralized volcanic rocks. Throughout most of its course the lavas west of the vein dip westward, and those east of the vein dip eastward. The presumption is that the vein follows the edge of a tilted fault block.

RED KING CLAIMS

These claims are shown on plate 44 of U. S. Geological Survey Bull. 931–J. The Red King group consists of four claims located April 6, 1939, by Glenn Stephenson, George Stephenson, Andrew Schull, and Bert Roark. Development includes two pits on the reef itself, and, to the east, an adit 100 feet long and a shaft 17 feet deep.

In the northern pit, which is 10 feet deep, brecciated lavas are cut by a 4-foot zone of strongly sheared silicified lava. The shear planes strike along the reef N. 20° W. and dip 50° W. Within this silicified zone are indistinct veinlets of milky quartz that enclose lenticular bodies of high-grade ore as much as 18 inches in length and 12 inches in width. The core of each lens consists of variable proportions of schwatzite and chalcopyrite partly altered to chalcocite and limonite. One core, approximately half of which consisted of schwatzite, assayed 6.08 percent of quicksilver and 23.75 percent copper. Enclosing the cores of the lenses are thin cellular shells of dense quartz and chalcedony from which the primary sulfides have been almost entirely leached, leaving abundant limonite, azurite, malachite, and some cinnabar. Cinnabar has also spread along cracks cutting the less silicified margins of the reef, and it extends along fractures into the kaolinized wall rocks. At the intersections of some of these fractures, the cinnabar forms pockets a few inches wide.

The southern pit on the reef is 15 feet deep. The silicified rocks, though strongly brecciated, have been largely leached of primary sulfides. Although secondary cinnabar and copper minerals spread along cracks throughout a zone about 10 feet in width, the content of quicksilver is much lower than in the ore from the northern pit.

An adit 100 feet long, now caved 50 feet from the portal, was driven westward through the kaolinized lavas bordering the reef to its footwall, at which point a rapid inflow of water caused the work to be abandoned. Of four samples taken from its walls, two showed no "colors" on panning, whereas the others showed a fair to moderate amount of cinnabar.

A short distance south of the adit is a caved shaft, once 17 feet deep. According to Andrew Shull, the footwall clay here contained an average of 20 pounds of quicksilver per ton over an area of about 25 square feet; however, one sample collected from the walls of the pit at a depth of 10 feet assayed less than 1 pound per ton. Although it is reported that "colors" can be panned from any of the clay within 400 feet of the footwall side of the reef, most of the secondary cinnabar lies close to the reef at fracture intersections. South of these workings the reef may be discontinuously traced to the Blue Bull mine. Some of the more favorable parts have been prospected by pits and, in one place, by a 285-foot adit. Throughout this part of the reef cinnabar is so scarce that further exploration seems unwarranted.

Finally, reference may be made to workings along a narrow mineralized zone approximately parallel to, and 300 yeards east of, the O'Keeffe claims near Sesena Creek. Except near Sesena Creek no siliceous reef marks the course of the mineralized zone; it is readily traceable, however, by light-colored clayey soil rich in limonite and by many shallow pits. Approximately 300 yards south of Sesena Creek, a 50-foot adit cuts a vein that trends N. 70°–80° W. and dips 30°–40° S. The vein consists of siliceous stringers and lenses, a few inches to 2 feet wide, containing a little pyrite and chalcopyrite but no visible schwatzite; only traces of cinnabar were observed. The remainder of the adit passes through barren altered andesite.

O'KEEFFE CLAIMS

The O'Keeffe claims include the north part of the vein near Sesena Creek. Near their northern end a shallow pit reveals a strongly sheared silicified zone trending northwest and dipping 65° E. in soft kaolinized lava. Within the silicified zone is exposed a lens of quicksilver-copper ore with a maximum width of 3 feet. Though it pinches out toward the surface, its downward extent is unknown. The ore consists mainly of chalocopyrite largely replaced by chalcocite and limonite, a little schwatzite, malachite, and azurite in a gangue of quartz and dolomite. A single assay of the ore showed 0.11 percent quicksilver and 22.32 percent copper.

OTHER CLAIMS

Approximately 300 yards south of this pit several shallow trenches and a tunnel 50 feet long cut the vein and expose ore similar to that just described. According to Ben O'Keeffe, a sample from the tunnel assayed 0.015 ounce per ton of gold, 2.2 ounces per ton of silver, and 19.59 percent of copper. No assay for quicksilver was made, but from the visible content of schwatzite the amount must be very small. A short distance farther south, where the vein crosses an unnamed gully about halfway between Sesena and Spring Creeks, a caved pit has reportedly yielded ore assaying 0.12 ounce per ton of gold, 4.92 ounces per ton of silver, and 14.4 percent of copper. Between these scattered prospect pits the course of the vein is marked only by occasional outcrops of jaspery silica-limonite rock practically devoid of ore minerals.

HARMONY, SURPRISE, AND AJAX CLAIMS

A wide belt of altered ground containing numerous siliceous reefs lies east of the Red King-O'Keeffe vein and north of the Rabbit Hole mine, in secs. 1, 2 and 12, T. 39 S., R. 34 E. Included in it are the seven claims of the Harmony group, located in March 1941, by C. M. Doan and Margaret Doan. The claims, on which are included many shallow pits and trenches, lie north and south of Sesena Creek for a total distance of about a mile. Adjoining these on the south are two claims belonging to the Surprise group, located in August 1940, by W. B. Stewart. During August and September of that year a small pit and a 30-foot adit were dug, but no subsequent work has been done. West of the Surprise claims, and adjoining the Harmony group on the south, are five claims belonging to the Ajax group, located in April 1937, by M. M. Doan. They include, in addition to a few small cuts, an adit 80 feet long on the Ajax No. 5 claim. As far as could be learned, no work has been done on this property in recent years.

Throughout the area covered by these three groups dark vesicular olivine basalts with interflows of amygdaloidal and porphyritic andesite dip eastward at low angles. Locally, the lavas are intruded by dikes of basalt. The hydrothermally altered rocks are identical with those already described in other areas. In this area, however, the reefs of "silica-limonite rock" are not only closely spaced, especially south of Sesena Creek, but they show a greater diversity of trend and dip than anywhere else in the Steens-Pueblo region. The dominant trend is between N. 20° W. and N. 40° W., as elsewhere, but many reefs bordering Sesena Creek are oriented in a direction at right angles to this, and the courses of others are sinuous. Although the easternmost reefs, as usual, dip eastward and most of the others approach the vertical, many reefs dip at low angles in various directions. The reason for this complexity is not apparent.

The only ore minerals occur in thin veinlets of opalite, which, except for a few in the soft kaolinized lavas, are restricted to the siliceous reefs. One of the best showings is in a 10-foot pit near the north-center post of Harmony No. 3, on the south bank of Sesena

Creek. Here small fragments of silicified lava occur in a matrix of opal, chalcedony, and clear quartz sparsely stippled with grains of chalcopyrite and schwatzite. Locally, the matrix is cut by veinlets of chalcedony, limonite, and dolomite, and some of the cracks are coated with malachite, azurite, and chrysocolla accompanied by a few specks of cinnabar. Other small patches of secondary copper minerals are visible in some of the cuts on the Harmony claims; primary sulfides are rare ,and invariably chalcopyrite is much in excess of schwatzite. Cinnabar is virtually absent.

An adit on the Surprise No. 1 claim runs parallel to, and 15 feet east of, a prominent eastward-dipping reef. It passes entirely through old rubbly talus, some fragments of which are veneered with a little secondary cinnabar. An adit on Ajax No. 5 was driven N. 35° E. for 80 feet, apparently in an effort to intersect a siliceous reef in which some malachite and azurite may be seen, but the adit nowhere passes out of the adjoining kaolinized lavas. Both the walls and the material on the dump are practically devoid of cinnabar.

In brief, none of the claims of these three groups has produced any quicksilver, and despite the unusual abundance of reefs and the widespread alteration, no mineable ore has been found.

MOGUL MINE

The five claims of the Mogul group, owned principally by members of the Doan family, are immediately north of the Fields-Frenchglen road, in sec. 26, T. 37 S., R. 32¾ E. Until the end of 1940 this property had been developed by only a few shallow trenches and pits. Early in 1941 an inclined shaft was sunk, intersecting one of the main reefs at a depth of 110 feet and penetrating an ore body. The property was then leased to Roy Elliot of 918 Hobart Bldg., San Francisco. An inclined raise, driven up the footwall of the reef to the surface, served as haulageway and manway. From October 1941, to January 1942, a crew of 6 to 12 men recovered 19 flasks of quicksilver. Scarcity of ore in sight, in addition to trouble from a faulty retort, resulted in the abandonment of the Elliot lease early in 1942. During February and March of that year, Cecil M. Doan and Robert Doan recovered 9 additional flasks of quicksilver, but critical failure of the retort forced them to abandon operation.

Most of the lavas exposed on the Mogul claims are andesites characterized by conspicuous stellate clusters of plagioclase phenocrysts; accompanying these are flows of amygdaloidal andesite and fine-grained black basalt. Outcrops are too scattered to permit drawing satisfactory contacts between these lavas. Presumably a fault zone coincides approximately with the boundary between the Mogul and Lucky Strike claims, for on the Mogul ground the dip of the lavas is to the southwest at low angles, but on the Lucky Strike ground the dip is in the opposite direction.

The distribution and attitudes of the Mogul reefs are shown on the map (pl. 10). Generally, the reefs are vertical, but in places the western reefs dip steeply to the west, while parts of the eastern reefs dip steeply eastward. The width of most reefs is between 10 and 20 feet. At several points they have been explored by minor workings, but these reveal only very small amounts of chalcopyrite and schwatzite and occasional patches of secondary copper minerals.

The only major development on the property is at the northwest end of one of the eastern reefs. The reef, which strikes N. 35° W. and dips 50°–60° E., is exposed over a length of 320 feet. The reef rock is porphyritic andesite, sheared, silicified, kaolinized, and limonitized to a varying degree through a thickness of 25 to 30 feet. As shown in the plan and section, figure 5, both the reef and the fractures within it maintain approximately the same attitudes for at least 180 feet down the dip. On the 120-foot level, however, there is some deviation from this general parallelism; here two of the stronger fractures converge and may possibly cross. In addition, the main hanging-wall fracture flattens over the stope on the 120-foot level. Beneath the flatter part of this fracture, where the two converging fractures appear to cross, is a pocket of open fault breccia. This, the principal ore body of the mine, is about 30 feet long, 15 feet wide, and 20 feet high. To the north and south of the breccia pocket, the principal hanging-wall and footwall fractures carry good ore for only a short distance. Above the pocket, for 40 feet, small corkscrew stopes follow strings of mineralized breccia; below, two rootlike shoots of breccia continue downward for 25 and 55 feet, respectively. On the 180-foot level ore is virtually confined to a zone 3 feet wide along the hanging-wall fracture zone. The other fractures on this level are small, discontinuous, and almost devoid of cinnabar.

The Mogul ore differs markedly, in mode of occurrence, from all other ores in the southern part of the Steens-Pueblo area. In most of the southern area cinnabar occurs chiefly in well-defined veins of opalite generally associated with copper sulfides. Traces of this "normal" type of ore do occur on an adjacent reef 900 feet southwest of the Mogul mine, but in the mine itself copper sulfides and opalite veins are entirely lacking. Instead, the ore is contained in a loose open breccia composed of angular fragments of porphyritic andesite completely altered to a chalky-white mixture of kaolin and chalcedony. The fragments vary in size from blocks several feet across to fine powder. Some cinnabar is present within the porous fragments, but a far greater amount occurs as minute crystals and earthy films coating veinlets and crusts of drusy barite. Prior to the cinnabar

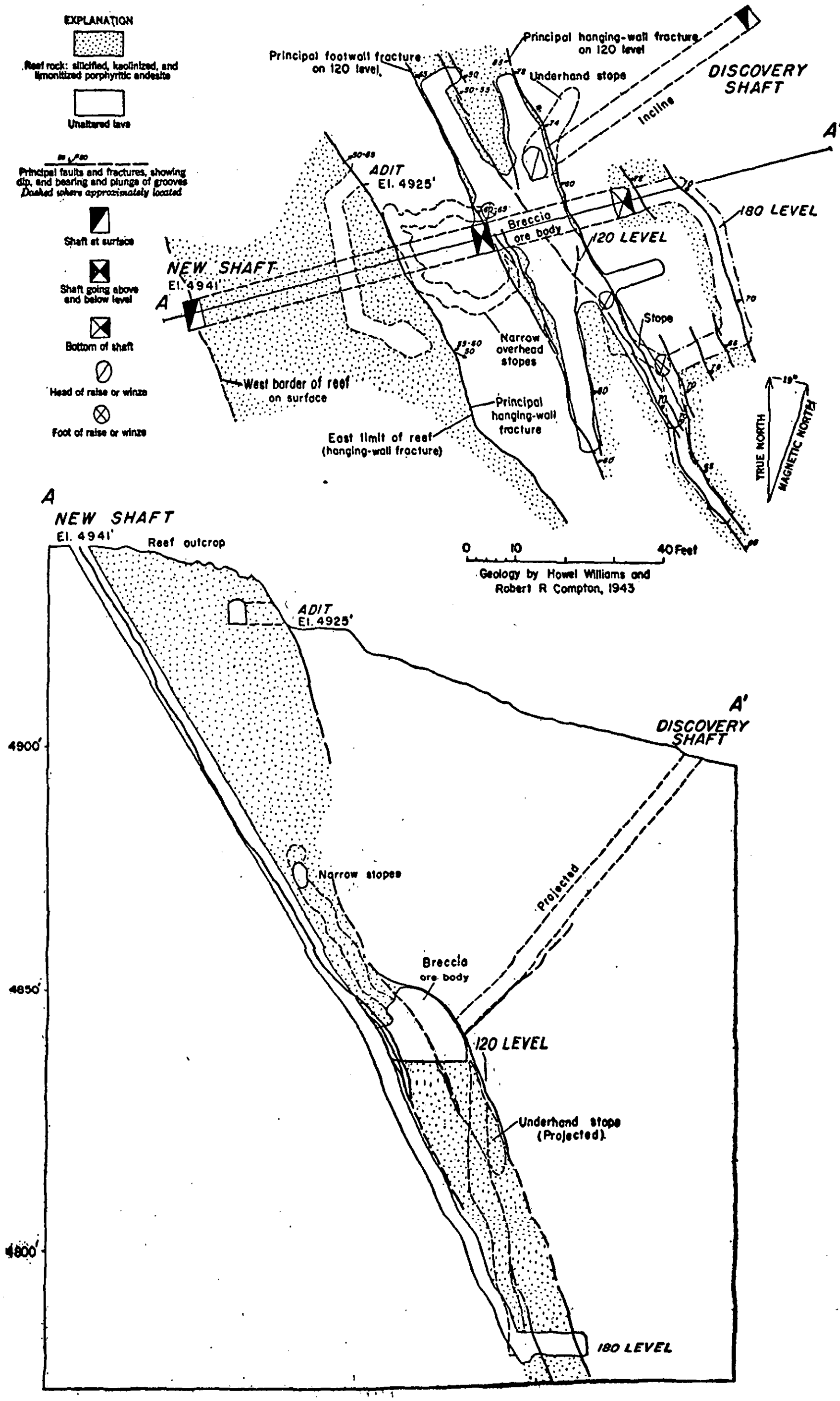

FIGURE 5.—Geologic map and cross section of the Mogul mine, sec. 26, T. 37 S., R. 32¾ E., near Fields, Harney County, Oreg.

deposition the barite was coated locally with euhedral quartz and with limonite, part of which pseudomorphs siderite.

When the mine was examined in 1943, the reserve of ore was estimated to be about 300 tons. Assays indicate it contains a little more than 6 pounds of quicksilver per ton; full recovery from the 300 tons of ore would yield 24 flasks of quicksilver. Similar pockets of good-grade ore may well be enclosed by fractures elsewhere in this and in the adjoining reefs, but, unfortunately, there seem to be no surface indications to serve as guides for systematic exploration.

O'KEEFFE MERCURY AND BLAIR CLAIMS

Northwest of the Mogul mine are six claims known as the Connor Blair group and owned by Rube Blair of Andrews. The accompany-

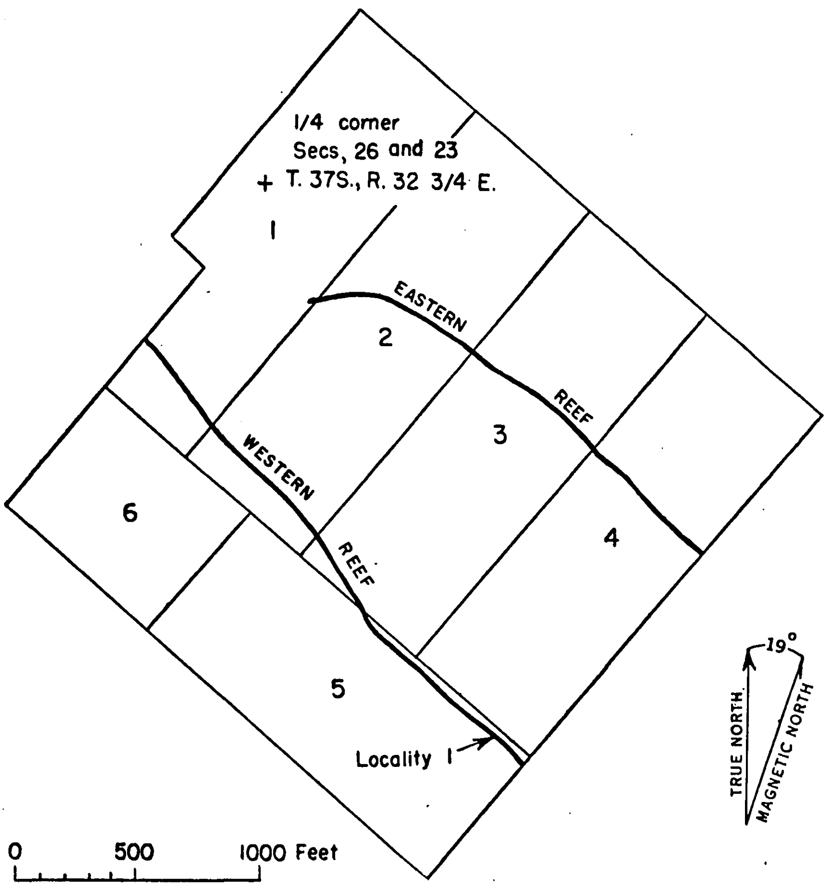

FIGURE 6.—Sketch map of the Connor Blair claims.

ing sketch (fig. 6), supplied by the Oregon State Department of Geology and Mineral Industries, shows the relations of these claims to the "silica-limonite reefs" that cross them. The only development consists of several pits and trenches and two short adits on the western reef; no work has been done on the seemingly barren eastern reef. Both reefs are alined with lodes on the Mogul ground, where the more silicified parts crop out as detached knobs instead of as dikelike walls.

According to H. K. Lancaster of the Oregon State Department, a cut across the reef on Claim No. 4 (locality 1 on fig. 6), formerly showed an 8-inch mineralized zone, which included a ¼-inch seam of almost pure cinnabar, 3 inches of "opaline quartz" impregnated with cinnabar, and 4 or 5 inches of "diabase porphyry" (andesite) impregnated with cinnabar and azurite.

The main workings on the Blair claims are on the west side of two conspicuous knobs on the western reef in claim No. 2. An adit, driven 10 feet into the hanging-wall side, exposes slightly altered porphyritic andesite cut by slickensided fault planes. The rock shows little silicification, secondary veinlets of opal-chalcedony are lacking, and only traces of cinnabar "paint" occur along fractures. Forty feet to the northwest a second adit, driven into the hanging-wall side, penetrates the reef for a distance of 25 feet. The portal is in soft kaolinized lava that yields only a few colors when panned; the remainder of the tunnel is in fine-grained purplish porphyritic andesite, highly silicified and limonitized. One exposed shear zone is partly occupied by a lens, 8 inches in maximum width, consisting of brecciated lava in a matrix of opal-chalcedony. The lens is fractured and veined with clear quartz and drusy barite accompanied by a little schwatzite, cinnabar, malachite, and azurite. Most, if not all, of the ore reported to have come from this tunnel was obtained from this lens of opalite. Lancaster reports that a sample cut across a width of 2 feet assayed 14 pounds of quicksilver per ton; Ross states that a sample from a 4-inch band contained 0.47 percent quicksilver. Cinnabar also occurs in cracks cutting kaolinized lava adjacent to the opalite lens, but the quicksilver content is small.

Northwest of the Blair claims lies a group owned by Ben O'Keefe of Fields. These claims contain no conspicuous silicified reefs, though they are cut by at least two wide poorly exposed belts of altered lava paralleling the main reefs of the Blair and Mogul claims. Both belts have been explored by shallow cuts, and early in 1943 they were further exposed by stripping with a bulldozer. In the western belt, near the Frenchglen road, kaolinized andesites and basalts are cut by steeply dipping shear planes trending approximately N. 30° W. On some of these shears are strings of opalite, generally only a few inches wide but locally a foot across. These contain a little schwatzite and chalcopyrite with secondary cinnabar, chrysocolla, and other minerals. According to O'Keefe, the widest opalite string averaged 3½ pounds of quicksilver per ton; another sample from a fracture zone 18 inches wide assayed 2.1 pounds of quicksilver per ton.

The other shear zone on O'Keefe's claims follows the crest of the ridge 200 feet east of the widest opalite string. Several thin strings of opalite cut the kaolinized lavas, and although one assay from this eastern shear zone is reported by O'Keefe to have yielded 3.2 pounds of quicksilver per ton, the average tenor is lower than in the veins of the western zone.

It may be that the strong fractures represented by the siliceous reefs on the Blair and Mogul claims disperse into more widely scattered and smaller shears on the O'Keeffe ground where the pre-ore alteration was mainly kaolinization. In that event, the possibility of finding large veins of opalite is reduced.

LUCKY STRIKE CLAIMS

The claims of the Lucky Strike group (pl. 10) are near the southeast corner of T. 37 S., R. 32¾ E. They cover the eastern end of the broad northwestward-trending ridge on which the Mogul, Blair, and O'Keeffe claims are also located. According to Ross, part of the ground was originally staked in 1929 by Pete Cachenaut, Ora Doan, and Robert Doan, because of the discovery of gold in some of the lodes. In 1933 the ground was restaked by M. M. Doan and associates. The only development on the property consists of a few shallow pits and trenches.

The lower flanks of this ridge consist chiefly of dark basaltic flows, locally rich in veinlets of calcite. Near its western end, on claim No. 4, amygdaloidal andesite unusually rich in zeolites forms sporadic outcrops. The crest of the ridge, where hydrothermal alteration has been most intense, consists mainly of altered porphyritic andesite with feldspar crystals as much as 3 inches in length. All the flows dip eastward, in contrast to those on the Mogul ground which show the normal regional dip to the west.

On the Lucky Strike No. 3 claim the lavas are cut by a basalt dike, as much as 15 feet wide, which dips westward at very steep angles. It is traceable southwestward from the claims for more than 2 miles, forming an arcuate wall interrupted by several abrupt offsets. On claim No. 3, the dike shows a similar offset of nearly 100 feet where it crosses a siliceous reef. These displacements are primary features of the intrusion and are not to be ascribed to subsequent faulting. Though the intrusion preceded hydrothermal alteration of the adjacent lavas, the dike remains unaltered even close to its contacts with the siliceous reef, presumably on account of the fineness of its grain.

The principal zones of alteration on the Lucky Strike ground are indicated on plate 10. Most of them trend N. 50°–60° W.; a few trend N. 20°–30° W. Within these zones, which may either stand out as prominent ribs or have indefinite boundaries, the andesites are partly replaced by quartz, chalcedony, limonite, kaolin, and carbonates. For instance, within the broad, indefinitely bounded belt of altered ground forming the ridge crest on claims No. 1 and No. 5, part of the lava is altered mainly to limonite, and only locally is it sufficiently altered to obscure the original textures. In other places, where alteration has entirely obliterated the primary texture, ribs of dense quartz and chalcedony are traversed by branching bands of softer kaolinized lava.

Most of the siliceous reefs stand vertically; some dip steeply either to the north or south. Most of the countless small fractures that cut the reefs trend parallel, or nearly parallel, to the strike of the reefs, but a few cross at high angles. No systematic arrangement concerning the direction of pitch of striae on the reef walls could be detected.

Although the area of altered ground is extensive, the showings of cinnabar on the claims are extremely meager. A little "paint" coats fractures in slightly altered lava in a 15-foot pit at the western end of the westernmost reef on claim No. 4; in another pit on the same claim, a short distance east of the center, fair colors may be obtained by panning lava consisting of a soft cellular mass of limonite, kaolin, and carbonate. Small amounts of cinnabar may also be found on some of the fractures cutting the more silicified ribs. On the other hand, samples of silicified lava taken from a shallow pit on the main reef on claim No. 3, near its intersection with the basalt dike, yielded no cinnabar when panned. Samples of altered basalt veined with calcite, taken from an excavation on claim No. 3, and samples of limonitized and kaolinized rock from pits along the ridge crest on claims No. 1 and No. 5, likewise were barren. Indeed, all the purplish limonitized lavas that retain original textures must be considered virtually barren. No coatings of secondary copper minerals were observed, but their absence is not a certain indication of a lack of cinnabar, as shown by the ore of the Mogul mine.

BLUE BOY, CRIMSON ROSE, WHITE PICK, AND ADJACENT CLAIMS

A belt of prominent siliceous reefs extends northward from the Lucky Strike ground for almost a mile. At its southern end it approximates a third of a mile in width and includes two principal reefs. The eastern reef is included in the Blue Boy, Crimson Rose, and White Pick claims. Between these principal reefs are numerous minor ones separated by bands of less resistant kaolinized andesite and basalt. Northward the reefs converge into a single rib, on which the Globe and Spring claims are located. The reefs in the area occupy tension fractures along and near the crest of a warp, but the vertical displacement along them cannot be determined.

The Blue Boy claims were located on the southern end of the main eastern reef in January 1929, by Olive Doan, R. E. Doan, and C. Sturgeon. (See map, pl. 10). The main reef trends N. 15° W. and either stands vertically or dips steeply eastward. It consists of strongly sheared andesite almost entirely replaced by a lenticular network of quartz, chalcedony, and limonite veins that alternate with seams of more carbonatized and kaolinized rock. In places the reef includes veins several feet wide made up wholly of dense dull-white quartz, but no sulfides or coatings of secondary copper minerals were seen in any of the rocks. West of the reef the lavas are altered in patches to kaolin and carbonates tinted in pastel shades by hydrous iron oxides. Cutting these soft rocks and the adjoining reef are numerous calcareous veins ranging in width from a few inches to 5 feet and composed of coarse-grained ferroan dolomite, limonite, and botryoidal cellular calcite. All these calcareous veins trend approximately east and stand nearly vertical. In none were ore minerals observed.

The principal working on the Blue Boy claim is located west of the reef. It consists of an adit 100 feet long approached by an open-cut 15 feet in length. Except for a few thin veinlets of calcite, the adit passes entirely through massive slightly kaolinized andesite. No distinct planes of shearing or veins of opal-chalcedony are exposed, and only traces of cinnabar were detected by panning crushed samples.

A short distance to the north of the adit, a 40-foot shaft has been sunk in altered andesite containing thin veins of opal and drusy quartz. Films of malachite and a few specks of pyrite and schwatzite were noticed in dump specimens of the more silicified lava. Elsewhere on the Blue Boy ground, despite the unusually wide zone of hydrothermal alteration, no cinnabar was detected.

The main reef crossing the Blue Boy continues northward to the Crimson Rose and White Pick claims. Ross reports that the Crimson Rose claims were located by members of the Doan family; the White Pick was located on August 19, 1941, by Chris Purvis, W. D. Wheeler, M. M. Doan, and R. D. Doan. The claim limits were not ascertained.

Northward from the Blue Boy claims the main reef becomes even more conspicuous and finally attains a width of approximately 150 feet. Most of it is composed of extensively limonitized porphyritic andesite cut by sporadic stringers of more silicified rock. Near the White Pick claim post two small trenches in the reef expose thin, brecciated veins of quartz, chalcedony, and dolomite; a third trench in the reef a short distance to the north, where the reef reaches its highest point, is in similar rock. A small amount of pyrite, chalcopyrite, and schwatzite occurs in some of the chalcedony, accompanied by a little cinnabar "paint" and patches of malachite and azurite on cracks; the ore minerals, however, are much too scarce to warrant further development of these claims. Immediately west of, and below, the White Pick claim post, a 20-foot open-cut leads into an adit 60 feet long driven N. 85° E.; the adit is driven toward, but does not intersect, the footwall of the reef. Three representative samples from the adit wall failed to show colors when panned.

Except for a few very shallow pits, no work has been done on the main western reef. The bulk of it is made up of limonitized lava, although some barren silicified bands occur within it. In August 1941, Ora Doan, M. M. Doan, and R. D. Doan located the Globe and Springs claims near the northern end of the reef, where it ceases to form a thick, continuous rib and breaks into a chain of detached lenses isolated by soft clayey rock. No indications of ore were recognized here.

CLAIMS ON RED HILL

Near the eastern edge of Red Hill are many small pits and trenches, but none have produced any quicksilver and none show more than a very small amount of cinnabar.

Ben O'Keeffe of Fields holds two claims, located near the center of sec. 30, T. 37 S., R. 33 E., which are known as the Red Hill, or O'Keeffe No. 2, and the Red Hill No. 1. The former was located on March 1, 1941, the latter on February 25, 1942. On the eastern or Red Hill claim, directly overlooking the Fields-Andrews road, two parallel 8-foot trenches on the steep hillside expose brecciated and kaolinized rhyolite. It is cut by veinlets of chalcedony as much as 6 inches in width and by several shear planes of which the dominant ones trend N. 10° W. and dip 70° E. No cinnabar was observed in either trench, nor was any seen in a third cut 60 yards to the south. On the western or Red Hill No. 1 claim, a 15-foot trench extends N. 30° E. into massive, kaolinized, and weakly opalized glassy rhyolite seamed with limonite. The rock, which has neither been sheared nor hydrothermally altered, contains no ore minerals.

Above and to the west of these claims is the Dorose group, located by C. M. Doan and Louise Doan in February 1942. Several shallow pits near the claim monument expose kaolinized rhyolite, which contains thin irregular veinlets of opal-chalcedony showing a few specks of cinnabar. On Dorose No. 2, near the northeast corner of Red Hill, other small pits explore silicified dark-purple dacite containing barren veinlets of chalcedony. Finally, on the side of a gully about 800 feet west of O'Keeffe's Red Hill No. 1 claim, a short trench follows a shear zone striking N. 37° E. and dipping 80° E. In it a narrow lens of fractured and silicified rhyolite enclosed by kaolinized lava shows meager coatings of cinnabar and mammillary opal along cracks.

Though the large rhyolite-dacite mass of Red Hill represents a vent area, the quicksilver mineralization is not to be ascribed to emanations from a vent source. Mineralization is confined to the area just east of the mass and follows the same system of fractures that accounts for the belt of siliceous reefs among the younger lavas to the north and south. Compared with these younger lavas, the rhyolite-dacite possesses greater rigidity; hence the fractures and zones of mineralization within it are relatively small. For this reason, the outlook for ore on Red Hill must be considered unpromising.

FIELDS LODE, RED DOME, AND LUCKY STAR CLAIMS

A narrow belt of reefs extends northward from Red Hill for about three miles; it is near, and parallel to, the foot of the mountains. Included in it are the unproductive Fields Lode, Red Dome, and Lucky Star claims (see pl. 8).

On the southernmost or Fields Lode claim, located in June 1939, by Ike Kusisto, shallow pits have been sunk near the edge of a thick siliceous northwestward-trending reef. They expose kaolinized and limonitized porphyritic andesite but no chalcedony veins or visible ore minerals.

The Red Dome claim, located by Paul Holmes, Ora Doan, and Robert Doan, is a little farther north in sec. 18, T. 37 S., R. 33 E. The longest of the three reefs crossing the property strikes N. 10° W. along the center line of the claim. Two shallow pits on it expose a steeply dipping zone of sheared and kaolinized lava locally stained by secondary copper minerals and a little cinnabar. The other two reefs strike N. 60° W. across the southern part of the claim. A pit on one of them, near the south boundary of the claim, reveals a shear zone 10 inches wide, striking parallel to the reef and dipping 65° S. It carries veinlets of chalcedony accompanied by drusy barite. In places the chalcedony is stained with crysocolla and azurite, and in cavities a little powdery cinnabar that is admixed with limonite appears to be secondary after schwatzite. The sharp contact between the highly altered reef rock and the adjacent flows of fresh basalt suggests that the reef marks a fault with sizeable displacement.

North and northwest of the Red Dome are several claims belonging to the Lucky Star group, located in 1939 by Ike Kusisto and Andrew Shull. Claims No. 5 and 8, the only ones identified on the property, include at least six branching, irregular reefs with an average trend of about N. 10° W. A shallow pit in a silicified and carbonatized shear zone on No. 5 shows splashes of secondary copper minerals; occasional specks of sulfides, including a trace of cinnabar, are also present. Elsewhere on the property ore minerals are confined to meager showings in short veinlets of chalcedony.

ELDORADO GROUP

The three claims of this group are in the central part of sec. 7, T. 37 S., R. 33 E., approximately 5 miles north of Fields. They are owned by Ben O'Keeffe, Andrew Shull, and Warren McLean.

Two principal reefs cross the property. The northern one strikes north, forming on the crest of an elliptical hill a finlike ridge 700 feet long; near its midpoint a minor reef branches to the southeast. The main part of the other reef, which lies to the southwest, strikes N. 20° W., and near its southern end a branch forks to the south. In general, these resistant, siliceous reefs range from 15 to 20 feet in thickness. In the intervening ground the lavas are mainly altered to kaolin and carbonates.

Near the middle of the northern reef, close to the center line of claim No. 1, a 10-foot shaft exposes two cinnabar-bearing veins of chalcedony in sheared lava. Some cinnabar occurs on cracks, but most of it is dispersed as a finely divided "suspension," which imparts a rose color to the chalcedony matrix. Locally, it is accompanied by a little schwatzite and stains of chrysocolla. The veins are steep, parallel the reef, and have a thickness of 2 to 8 inches. South of the shaft they are joined by at least two other veins which have a lesser content of cinnabar. Near the southern end of the reef a 6-foot adit cuts a strongly silicified zone apparently devoid of ore minerals. On the subsidiary reef branching to the southeast, a small pit sunk about 100 feet from the fork shows a little cinnabar in chalcedony veinlets; elsewhere on this branch no ore minerals were observed.

The southern reef and its branch lie partly on claim No. 3 but mainly on No. 2. They are developed by two small pits that reveal small chalcedony veins containing a little schwatzite, secondary copper minerals, and cinnabar. Most of the other stringers on this reef appear to be barren.

No quicksilver has been produced from these claims. The owners report assays ranging from 3 to 57 pounds of quicksilver per ton, but the ore minerals are erratically distributed and the average tenor of even the most promising veins does not exceed a few pounds per ton.

FISHER AND SHEEPHERDER CLAIMS

The six claims of the Fisher group, owned by Ora Doan, C. M. Doan, Robert Doan, and M. M. Doan, are west of Alvord Lake in sec. 29, T. 36 S., R. 33 E. A branch from the Fields-Andrews road makes them easily accessible. During 1939 and 1940 several pits and trenches and an adit 40 feet long were dug, and much of the adjoining area was stripped with a bulldozer. Although one pit yielded 20 pounds of quicksilver from 1½ tons of selected ore, no further work has been done on the property.

The claims are near the northern end of a prominent ridge, which is part of a triangular tilted horst cut off on the east by the main boundary fault and on the other two sides by diverging subsidiary faults (pl. 8). The lower flanks of the ridge are composed of platy and massive flows of dacite with thin interbeds of tuff and andesitic lava. Capping the dacites is an extensive layer of greenish dacite tuff locally admixed with sediment and in turn overlain by dark andesites and basalts.

Most of the rocks on the ridge have been only moderately affected by hydrothermal solutions, but a zone of intense alteration, represented by a belt of conspicuous reefs, extends along the southwestern side of the ridge. The reefs dip 70°–80° SW and parallel the diagonal fault trending N. 25° W. Along fractures in this belt both the dacites and the overlying basalts have been converted into subparallel ribs of "silica-limonite rock" with an aggregate thickness that locally exceeds 150 feet; these ribs alternate with bands of kaolinized and carbonatized lava. Despite the unusual length and width of these reefs, they contain no visible ore minerals.

The reefs on the Fisher claims are small and inconspicuous in comparison with the more massive reefs on the ridge; nevertheless, they contain the only ore found in this area. The workings occur principally along and near two steeply dipping reefs that trend approximately north and cut the mafic flows overlying the dacites. Between the reefs most of the ground is also hydrothermally altered, and in places it is crossed by minor reefs that trend eastward (see fig. 7). The principal workings are numbered on figure 7 and are discussed in numerical order.

The 35-foot adit east of the main reefs (locality 1) has yielded no ore. For 8 feet from the portal the adit cuts altered basalt; beyond this it passes through silicified tuffaceous mudstone and silt which are intersected by shear zones as much as a foot in width and by bands of open, blocky fault breccia that dip to the northwest at high angles.

North of the adit a 20-foot open-cut (locality 2) traverses fine-grained siliceous reef rock of uncertain derivation. At its west end is a vertical zone, approximately a foot wide and trending eastward, rich in opal-chalcedony and drusy barite. No ore minerals were seen in place, but some of the material on the dump is coated with patches of malachite and azurite.

At locality 3 a short trench follows a shear zone trending N. 38° W. and dipping 70° W. It ends in a pit 9 feet deep, which exposes silicified lava cut by veins of chalcedony and barite. No ore is exposed in the pit, although a few samples on the dump contain a little cinnabar and secondary copper minerals.

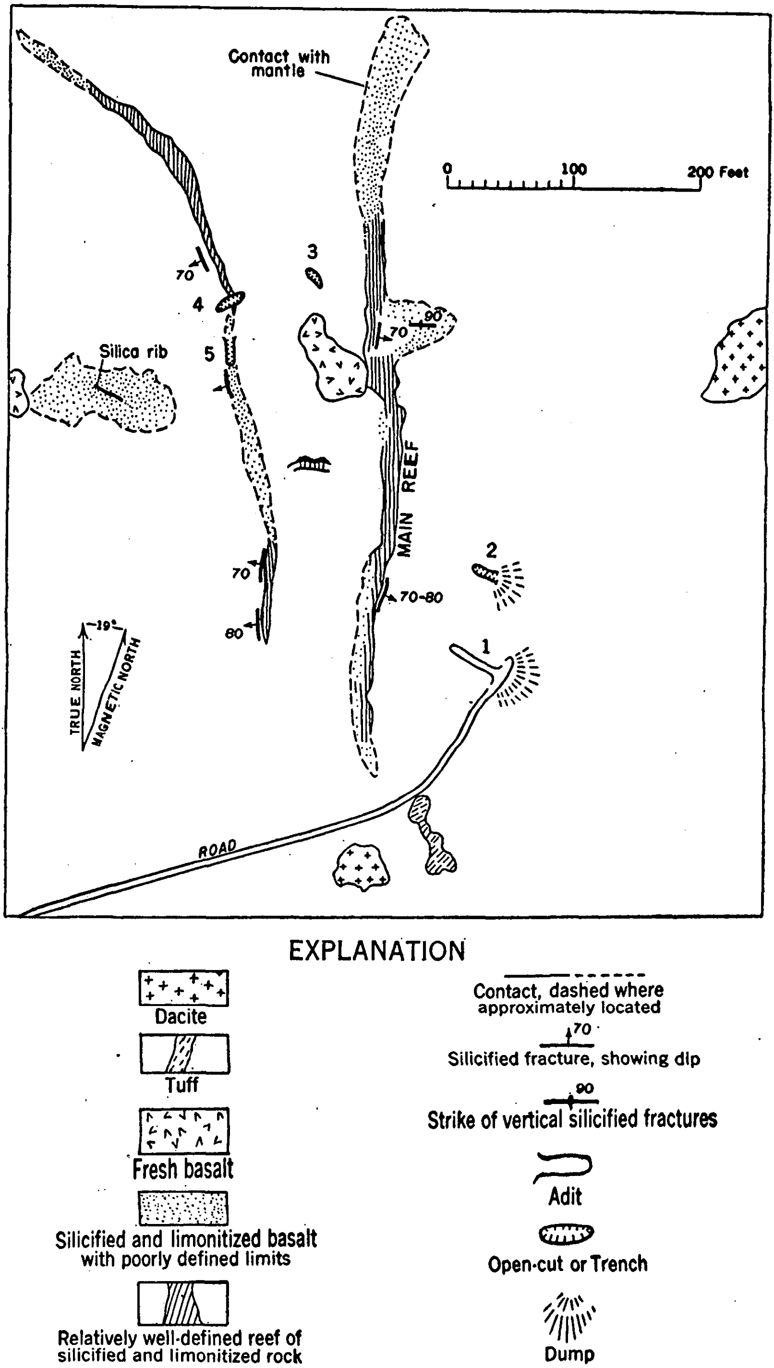

FIGURE 7.—Sketch map of the Fisher claims showing outcrops.

At locality 4 a 25-foot trench crosscuts the western reef, exposing a central more silicified part of the reef which is 9 feet wide. Most of this rib is unsheared and apparently devoid of ore, but along the footwall side, over a width of 10 to 22 inches, it is strongly brecciated and cut by opal-chalcedony veins that contain traces of cinnabar. The highly kaolinized porphyritic lavas that border the siliceous core of the reef fail to show colors when panned.

At locality 5 a second short trench has been cut in the same reef. Apparently this supplied the only retort ore recovered from the Fisher claims. Within a shatter zone, 3 to 5 feet wide, the reef rock is riddled with veinlets as much as 3 inches in width. These veinlets consist of a gangue composed of chalcedony, barite, and opal, which contains a little schwatzite, chalcopyrite, malachite, azurite, chrysocolla, and cinnabar. Where these veinlets are brecciated, the secondary minerals are thinly disseminated along cracks; some of the cinnabar has migrated along these cracks a short distance into the wall rocks. Further excavation along the reef might reveal other small bodies of ore in these veinlets, but as selected specimens of the ore averaged only about 14 pounds of quicksilver per ton, any large-scale development, either here or elsewhere on the property, is not warranted.

To the north, a few siliceous reefs can be traced at intervals for approximately half a mile to the Sheepherder claim, located in November 1941, by Warren McLean and Clay Fisher. The northernmost reef on this claim has been explored by an 8-foot pit, and, although meager showings of secondary copper minerals occur in opalite veinlets, neither schwatzite nor cinnabar was seen.

ALEXANDER AND ADJOINING CLAIMS

In the southwest corner of T. 34 S., R. 34 E., is a line of claims that extends approximately northeast across Indian Creek, roughly along a dike of basalt. Three claims, known as the Last Chance No. 1 and No. 2 and the Indian Chief, on the south side of the creek and the east side of the dike, are owned by Gus Stertman of Fields. Only a location pit has been dug on the Indian Chief claim, but on the Last Chance claims are two small open-cuts. Bordering these claims on the east are others located by Harry Alexander in July 1941; the only development here consists of two shallow trenches, 6 and 10 feet long. On the north side of the creek at about the same altitude are the Indian Creek claims, located in May 1941, by A. J. Shull; on these are three small prospect pits. Farther north is another group of claims owned by Harry Alexander; included in this are the Alexander mine, an inclined shaft 20 feet deep, a 30-foot open-cut, and smaller diggings.

From this group about eight flasks of quicksilver have been recovered during the past 2 years, but at the time of the present examination no work was in progress.

The area is underlain by nearly flat lying flows of rhyolite cut by a basalt dike and an irregular intrusive of similar rock. The northernmost prospect hole on Shull's claims is partly in the basalt dike, and a small hole farther down the slope is in the bulbous intrusion of basalt. Otherwise all the workings are in massive and platy rhyolite, which is probably the upper laminated rhyolite of Fuller's Pike Creek volcanic series. The Alexander mine is located near the top of the flow; the prospects to the south are at lower horizons. The alinement of these workings close to the basalt dike suggests a zone of fracture parallel to the dike. Since the basalt shows the same type of mineralization as the rhyolite and otherwise resembles some of the mafic dikes that cut flows of cliff-forming Steens basalt, the deposition of ore must have taken place after the eruption of the rhyolites and cannot be genetically related to the rhyolitic and dacitic vents in the vicinity. Furthermore, the dike and the belt of mineralization extend generally parallel to the main fault defining the western edge of Alvord Valley. Doubtless the cinnabar was deposited at about the same time as the schwatzite-cinnabar ores in the siliceous reefs in the southern part of the district.

The Alexander mine is developed by an inclined shaft, 30 feet long and 20 feet deep, which has an average trend of N. 25° E. The shaft follows a fault zone of opalized blocky breccia that cuts silicified and kaolinized rhyolite. The footwall of the fault zone ranges in strike from N. 12° E. to N. 35° E. and in dip from 70° to 80° E.; most of the hanging wall is vertical and trends N. 25° E. The hanging wall of the fault zone intersects two horizontal shears separated by about 2 feet of soft, kaolinized lava; on the footwall these horizontal shears are absent. The width of the ore-bearing breccia averages about 3 feet, but locally it reaches a maximum of 4 feet. No breccia is exposed at the foot of the shaft; at the end of an irregular drift extending along the fault from the base of the shaft the width of the mineralized breccia is only about 18 inches. Although some cinnabar is disseminated in the fragments of breccia, the best values come from the thin films of brown clay (beidellite) that coat the fragments and follow the horizontal shears cut by the hanging wall. Locally, the ore contains a little pyrite, but copper sulfides are absent. Although the ore lens apparently has been mined out, comparison of the production of quicksilver with the volume of ore removed indicates that the yield was approximately 8 pounds of quicksilver per ton.

A 30-foot open cut has been dug on the steep hillside to within 25 feet of the collar of the shaft. Here the breccia zone trends in the same direction as in the shaft but is offset 6 feet to the west. Between the shaft and the open-cut the shear planes limiting the breccia curve and converge, becoming tightly appressed. This curvature, together with the pitch of the striae, indicates a normal fault with a small strike-slip displacement, to the north, of the footwall side. Apparently the ore occurs in pockets of breccia at favorable bends in the fault. The width of the ore-bearing breccia at the end of the open-cut is approximately 5 feet at the floor and 2 feet at a height of 8 feet above the floor. Eight feet above the floor, but only on the west side of the cut, are two low-dipping shear planes separated by 3 feet of kaolinized rhyolite; above these, the breccia disappears.

Approximately 80 feet farther south on the vein, and 60 feet below, a 6-foot open-cut exposes 18 inches of blocky breccia containing a small amount of cinnabar.

Many slickensided fault surfaces, most of which trend approximately east, cut the rhyolite near the Alexander mine. None of them appear to be accompanied by mineralization. On the other hand, many ribs of strongly silicified rhyolite lie within 20° of north, approximately parallel to the Alexander vein. Though these have not been prospected, it is possible that some may contain lenses of ore-bearing breccia. Further excavation, particularly southward along the Alexander vein, may also reveal lenses similar to the one already removed from the shaft; however, it is unlikely that any of these will be large.

Very little cinnabar was seen in any of the prospects south of the Alexander mine. Of the three cuts on A. J. Shull's Indian Creek claims, the northernmost is 20 feet long and follows a northward-trending dike of basalt that is apparently an offshoot from the bulbous intrusion to the east. The dike averages 6 feet in width, and its dip ranges from 60° W. to vertical. Most of it is thoroughly kaolinized and limonitized, and in places it contains narrow irregular veinlets of opal-chalcedony with traces of cinnabar. Cinnabar "paint" also coats the silicified rhyolite at its contact with the dike, and a little was found in opal-chalcedony veins cutting the rhyolite. A short distance to the south two other cuts explore similar veins in the rhyolite, but their content of cinnabar is very small.

A small prospect hole on the steep slope below Shull's claims occurs within the bulbous intrusion of basalt where it is crossed by a narrow zone of clay containing seams of opal. No ore was observed here.

On the Last Chance claims, on the south wall of Indian Creek, two short cuts expose a zone of brecciated rhyolite trending N. 60°–65° W. and dipping steeply to the southwest. The rhyolite fragments are cemented by opal and chalcedony containing drusy quartz and calcite,

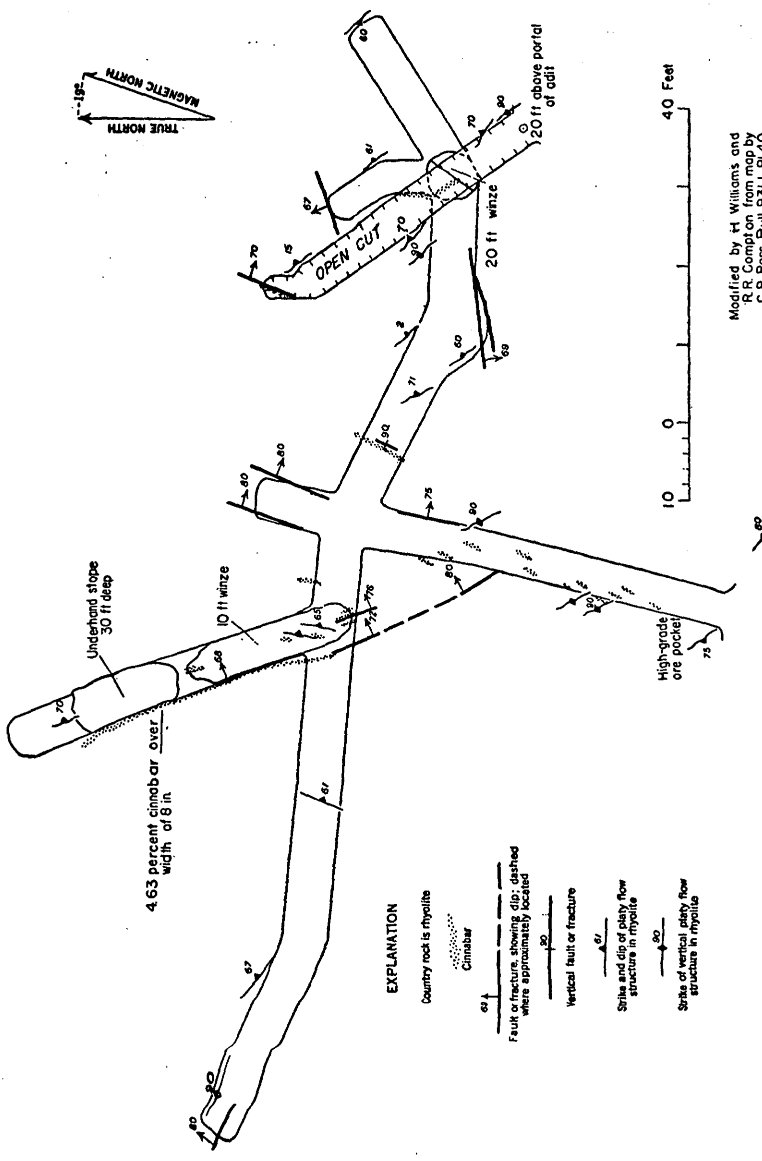

FIGURE 8.—Geologic map of the Steens Mountain prospect.

a little disseminated cinnabar, and traces of pyrite and arsenopyrite; a small amount of cinnabar also coats cracks in the breccia. On the adjacent Alexander prospects no ore minerals were observed.

STEENS MOUNTAIN PROSPECT

The Steens Mountain prospect, also known as the Stephenson and Bradley mine, includes six claims in the north and east parts of sec. 19, T. 34 S., R. 34. E., on the north side of Toughey Creek. They were located in October 1938, by Glenn Stephenson of Andrews and Efeard Bradley of Follyfarm. During 1939-40 these claims were worked by the Horse Heaven Mines Inc., but, after about 9 flasks of quicksilver had been produced, the option was allowed to expire. The total output is said to be about 15 flasks.

The principal development, consisting of an adit with 265 feet of underground workings (fig. 8), is located on claim No. 5. It was driven in a flow of laminated rhyolite immediately beneath its contact with a thick sheet of dacite. Though the upper surface of the rhyolite is essentially horizontal, the platy banding within the flow is steeply inclined and varies both in dip and strike. The banding bears no systematic relation to the ore distribution, which is controlled by a double set of short and disconnected steep fractures. One set trends approximately N. 20° E. and the other N. 20°–30° W. Some are occupied by veinlets of opal and chalcedony and by seams of clayey gouge bearing cinnabar. H. R. Lancaster of the Oregon State Department of Geology and Mineral Industries reports that near the portal several seams of high-grade ore were mined. They varied in width from 1 to 3 inches and contained 50 to 200 pounds of quicksilver per ton. Ross states that at least six flasks were obtained from about 1,800 pounds of this ore. A few additional flasks were obtained from seams in the underhand stope; from this ore Ross records an assay showing 4.63 percent quicksilver and 0.21 percent mercuric chloride. A few of the seams now exposed underground show cinnabar, but the quantity is small and the distribution is erratic; partly for this reason, work has been abandoned.

A small, but very rich, pocket of ore is said to have been found in the open-cut directly above the winze in the east drift; some cinnabar is still visible along a shear in the face of the cut. Specimens of high-grade ore, having thick coatings of earthy cinnabar partly covered by drusy quartz, may be seen on the adjacent dump. The shallow diggings on the other claims reveal little or no cinnabar.

Further development may uncover additional pockets of good ore on the property, but nothing suggests that they will be any larger than those already mined. Certainly there is no evidence of major fractures that might denote more persistent veins in the vicinity.

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