STATE OF IDAHO
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BUREAU OF MINES AND GEOLOGY
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GEOLOGY AND ORE DEPOSITS
OF THE LAVA CREEK DISTRICT, IDAHO

by
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<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Purpose and scope of the investigation</td>
<td>1</td>
</tr>
<tr>
<td>Conditions affecting field work</td>
<td>2</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>2</td>
</tr>
<tr>
<td>Previous geologic work</td>
<td>3</td>
</tr>
<tr>
<td>Geography</td>
<td>4</td>
</tr>
<tr>
<td>Location and access</td>
<td>4</td>
</tr>
<tr>
<td>Topography</td>
<td>4</td>
</tr>
<tr>
<td>Relief</td>
<td>4</td>
</tr>
<tr>
<td>Drainage</td>
<td>5</td>
</tr>
<tr>
<td>Special topographic features</td>
<td>6</td>
</tr>
<tr>
<td>Climate and vegetation</td>
<td>7</td>
</tr>
<tr>
<td>Geology</td>
<td>8</td>
</tr>
<tr>
<td>General features</td>
<td>8</td>
</tr>
<tr>
<td>Sedimentary rocks</td>
<td>9</td>
</tr>
<tr>
<td>Mississippian series</td>
<td>9</td>
</tr>
<tr>
<td>Distribution and lithology</td>
<td>10</td>
</tr>
<tr>
<td>Age and correlation</td>
<td>10</td>
</tr>
<tr>
<td>Quaternary sediments</td>
<td>13</td>
</tr>
<tr>
<td>Igneous rocks</td>
<td>13</td>
</tr>
<tr>
<td>Extrusive rocks</td>
<td>14</td>
</tr>
<tr>
<td>Tertiary system</td>
<td>14</td>
</tr>
<tr>
<td>Distribution</td>
<td>14</td>
</tr>
<tr>
<td>General character</td>
<td>14</td>
</tr>
<tr>
<td>Augite andesite</td>
<td>15</td>
</tr>
<tr>
<td>Hypersthene andesite</td>
<td>15</td>
</tr>
<tr>
<td>Hornblende-andesite</td>
<td>16</td>
</tr>
<tr>
<td>Hornblende andesite</td>
<td>16</td>
</tr>
<tr>
<td>Andesite (?) tuff</td>
<td>17</td>
</tr>
<tr>
<td>Quartz latite</td>
<td>17</td>
</tr>
<tr>
<td>Latite-tuff</td>
<td>18</td>
</tr>
<tr>
<td>Rhyolite</td>
<td>19</td>
</tr>
<tr>
<td>Age of lava and tuff</td>
<td>19</td>
</tr>
<tr>
<td>Quaternary system</td>
<td>20</td>
</tr>
<tr>
<td>Basalt</td>
<td>20</td>
</tr>
<tr>
<td>Intrusive rocks</td>
<td>21</td>
</tr>
<tr>
<td>Tertiary system</td>
<td>21</td>
</tr>
<tr>
<td>Distribution and age</td>
<td>21</td>
</tr>
<tr>
<td>General character</td>
<td>22</td>
</tr>
<tr>
<td>Granite</td>
<td>22</td>
</tr>
<tr>
<td>Granite porphyry</td>
<td>24</td>
</tr>
<tr>
<td>Granite pegmatite</td>
<td>24</td>
</tr>
<tr>
<td>Syenite</td>
<td>25</td>
</tr>
<tr>
<td>Structure</td>
<td>25</td>
</tr>
<tr>
<td>General features</td>
<td>25</td>
</tr>
<tr>
<td>Mesozoic deformation</td>
<td>25</td>
</tr>
<tr>
<td>Tertiary deformation</td>
<td>26</td>
</tr>
<tr>
<td>Folding</td>
<td>26</td>
</tr>
<tr>
<td>Faulting</td>
<td>26</td>
</tr>
<tr>
<td>Metamorphism</td>
<td>27</td>
</tr>
<tr>
<td>Geologic history</td>
<td>28</td>
</tr>
<tr>
<td>Ore deposits</td>
<td>30</td>
</tr>
<tr>
<td>History and production</td>
<td>30</td>
</tr>
<tr>
<td>General character of deposits</td>
<td>31</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Mineralogy of the ores</td>
<td>32</td>
</tr>
<tr>
<td>FIGURE I</td>
<td>Index map showing the location of the Lava Creek district</td>
</tr>
<tr>
<td>PLATE I</td>
<td>A. View of the maturely dissected mountains drained by Lava Creek. The two volcanic vents perched high on the mountain sides are shown in the middle distance (dark-capped points). Blizzard and Boyle mountains to the left in the background.</td>
</tr>
<tr>
<td>B. South Vent, the high hill on the left from which the lava has tumbled into the valley of Lava Creek. Note the rough surface of the lava stream.</td>
<td></td>
</tr>
<tr>
<td>PLATE II</td>
<td>A. View of the exceedingly rough surface of the &quot;aa&quot; lava in the southern part of the Lava Creek district adjacent to the National Monument. This is one of the youngest basalt flows in the region.</td>
</tr>
<tr>
<td>B. This shows the characteristic outcrop of the Tertiary granite and its tendency to weather into spherical or rounded masses.</td>
<td></td>
</tr>
<tr>
<td>PLATE III</td>
<td>A. Blizzard Mountain, the highest point in the district from the edge of the Snake River Plain less than three miles away. The dark rocks on the left are quartizes and the light rock in the center running to the top of Blizzard Mountain the body of Tertiary granite.</td>
</tr>
<tr>
<td>B. Characteristic erosion of the Tertiary lava in the Champagne Creek drainage. Timber Mountain, the highest point on the left. The white areas in the middle distance are patches of hydrothermally altered andesite and exposures of bedded tuff.</td>
<td></td>
</tr>
<tr>
<td>PLATE IV</td>
<td>Geologic map of the Lava Creek district</td>
</tr>
</tbody>
</table>
THE GEOLOGY AND ORE DEPOSITS
OF THE LAVA CREEK DISTRICT, IDAHO

by

Alfred L. Anderson

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The Lava Creek district, one of the important silver producers in Idaho from 1864 to 1886, has had, however, a phenomenally short life. The oxidized and enriched ores near the surface were soon exhausted and primary base-metal sulphides, to which secondary ores gave way at slight depth, were not amendable to amalgamation, then the common metallurgical practice. Failure to recover silver values from the base metals probably was in part responsible for the rapid decline, but exhaustion of the enriched or bonanza ore was equally to blame. Succeeding years saw but little attention given these deposits, although several unsuccessful attempts were made to exploit them, and they were nearly forgotten. Development of modern metallurgical processes, however, has revived interest in these deposits and, particularly since 1926, attention has been directed toward possibilities of exploiting the base-metal sulphides, particularly those of lead and zinc which have added attractions of good silver values. Interest was especially strong in 1927 and 1928 and the following work was undertaken to determine the possibilities of these deposits as future lead and silver producers.

These deposits are somewhat unique among state mineral deposits in that lead and zinc sulphide mineralization belongs to the younger of two definitely established epochs of mineralization — namely, that associated with Tertiary volcanic rocks and hence much younger than the well-known lead and zinc deposits of the Coeur d'Alene mining district. Most of the Lava Creek deposits are in lavas of Miocene (?) age and are grouped near the borders of intrusive granitic rock that cuts the Miocene (?) flows. These deposits are also unlike deposits of a similar age described by Ross in Tertiary lavas in the Salmon River Mountains to the north, where the bodies are valuable for their precious-metal contents and have only small amounts of sulphides and selenides. The Lava Creek district is notable for the variety of mineralization ranging from tungsten to antimony and bismuth, in addition to lead, zinc, and a number of complex silver minerals. Perhaps few areas in Idaho have a greater list of minerals than is found within the relatively small confines of the Lava Creek district.

Aside from an interesting mineralization, the region has other features of unusual importance among which young intrusive granite has already been mentioned. This granite has alkaline affinities and was intruded near the axis of a broad anticline, developed in a thick series of extrusive rocks, mainly of andesitic and latitic composition. A thick series of older sedimentary beds of sandstones, shales, and limestones, carrying an upper Mississippian (Brazer) fauna, are present in the area. This series differs greatly in character and thickness from the equivalent formation to the east and to the south.

Further, the Lava Creek district adjoins and even includes the north end of the Craters of the Moon National Monument, the most unique volcanic region in the state.

CONDITIONS AFFECTING FIELD WORK

The writer began work in the Lava Creek district about July 20, 1928, remaining in the field until September 15th of the same year. The time was devoted to preparing a suitable base map upon which to place the geology, to geologic mapping, and to a study of the mineral deposits. As the time permitted in the district was too short to allow adequate studies of all phases of geology, only ore deposits received detailed treatment. Areal and structural geology were covered in reconnaissance.

No maps other than rather inaccurate township plates were available and it was necessary to prepare a suitable base before the geology could be started. Fortunately, three triangulation stations which had been accurately located by the U. S. Geological Survey fell within the area, and these, with one just outside of the district in the Craters of the Moon National Monument, were plotted on plane table and later flagged in the field. New stations were located and flagged from these four points by intersection and three-point methods, and from a number of established points the mapping was carried on by stadia and three-point location. Elevations of triangulation stations were determined by vertical angles from a known point within the Monument. To speed the work, elevations at other places were determined both by vertical angles and aneroid barometer. As the region is in a mature stage of dissection, progress was slow and it was necessary to change the contour interval to 500 feet in order to complete the studies on time.

Five geologic units were mapped: Upper Mississippian series, Miocene (?) lavas, Miocene (?) granite and granite porphyry, Quaternary basalt, and recent alluvium. No time was afforded for mapping individual members of the Tertiary extrusives nor the mosaic of faults that occur in their bordering the intrusive granite, nor was time available for detailed study of the older sedimentary rocks. It is to be regretted that the structure was not worked in detail and the sequence of flows determined in the Tertiary, but for these alone at least another summer's field work would be necessary.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the many courtesies extended by those interested in mining in the region. Particularly does he wish to express his appreciation to Mr. John L. Stone, in charge of development operations of the Federal Mining and Smelting Company at the Silver Bell property; to Mr. B. C. Williams of the St. Louis mine; to Mr. S. O. Nelson of the Hub mine; to Mr. M. H. Jacobs of the Edna mine; and to Mr. E. Dahl and Mr. M. M. Dahl of the Horn Silver mine. Valuable field assistance was rendered by Mr. Otto R. Brown, a student in the School of Mines at the University of Idaho, who accompanied the writer throughout the field season. Grateful acknowledgment is also made to Mr. Andrew H. Thomson of the University of Idaho for his reading and careful editing of the manuscript.
The only previous description of the mineralization and the mines of the district is incorporated in Professional Paper No. 97 of the U. S. Geological Survey entitled "Geology and Ore Deposits of the Mackay Region, Idaho," by Joseph B. Umpleby. In this, he describes briefly the Hub mine on Lava Creek and some of the properties on Champagne (Era) Creek and on Lead Belt Creek. He recognizes the Tertiary age of these deposits because of their occurrence in the Miocene (?) lavas and devotes considerable space to descriptions of mineralization, particularly as to the relation of sphalerite and wolframite in the St. Louis vein, and the occurrence of tungsten (hübnerite) on the top of Blizzard Mountain.

Other reports treat of the district incidentally, mainly in connection with lavas of the Craters of the Moon National Monument. These are listed in the bibliography which follows.

1. Anderson, A. L., Lava Creek Vents, Butte County, Idaho: Northwest Science, Vol. 3, pp. 13-18, 1929. Describes some lava vents which occur high in the flanks of the mountains in the district and from which lava has cascaded into the valley of Lava Creek and cut onto the Snake River Plain. Shows further that these are on an extension of the "Great Rift" along which the lavas of the Craters of the Moon National Monument have issued and that their position indicates the relation of the "Great Rift" to earlier structural lines developed in the older rocks in Mesozoic and Tertiary times.


The Lava Creek district has been extended to include three districts considered separately by Umpleby: The Lava Creek, the Era, and the Antelope. These are adjoining districts but inasmuch as no distinction is made between them locally, it seemed advisable to consider all as the Lava Creek district.

Location and approximate extent of the district is shown in the accompanying map. The district covers 108 square miles, including the whole of T. 2 N., R. 24 E., T. 3 N., R. 24 E., and the eastern halves of T. 2 N., R. 23 E., and T. 3 N., R. 23 E. The eastern boundary lies about 16 miles west of Arco, the county seat of Butte County and a station on the Mackay branch of the Oregon Short Line Railroad. The greater part of the district lies in Butte County, but part is in Blaine County.

Most properties, including those in the old Era district and the old Lava Creek district, lie within 25 miles of Arco, the shipping point for the ores. These properties are near the Idaho Central Highway, an improved state road which skirts the eastern border of the district along the edge of the Snake River Plain. This provides an excellent trucking road to the railway at Arco. The old Antelope district, which has some properties on Lead Belt Creek, is served by a poorly maintained road from Antelope Creek and has for its nearest shipping point the station of Darlington, near the mouth of Antelope Creek a few miles above Arco in Lost River Valley. Several unimproved roads extend well into the district, making all parts of it more or less readily accessible. The Lava Creek district may be reached twice weekly by stage from Arco and has as its local postoffice, Martin, near the mouth of Lava Creek.

The district may perhaps be located with reference to the Craters of the Moon National Monument, for it comprises the high mountainous area lying immediately to the north and northwest.

**TOPOGRAPHY**

**RELIEF**

The Lava Creek district lies at the south margin of the mountainous area covering such a large part of central and northern Idaho and overlooking the great Snake River plain. On clear days, mountain ranges south of the Snake River Plain and from 60 to more than 100 miles away may be seen from commanding points within the area. No established name has been given to this mountainous mass, although the high ridges rising immediately above the Snake River Plain at the Craters of the Moon National Monument have been designated as the White Knob Mountains, so named from the fringe of snow about their summits which generally lingers throughout the summer. The mountains lack the range-like aspect so characteristic of the Lost River and Lemhi mountains, and are more nearly like the dissected-plateau type which typifies the Salmon River Mountains nearly a hundred miles to the north. The district marks the terminus of the drainage divide between the Lost River and Wood River systems. About 30 miles to the northwest the same range is known as the Boulder Mountains, having as its greatest point Mount Hyndman, the highest peak in Idaho, 12,078 feet.
Fig. 1. Index map showing the location of the Lava Creek District.
Some of the outstanding elevations within the district have been given names. The highest of these is Blizzard Mountain with an elevation of approximately 9,370 feet, rising 3,370 feet above the Lava Plain less than three miles away. To the north of Blizzard Mountain, and separated from it by a relatively low saddle, is another high eminence, Boyle Mountain, with an elevation of approximately 9,150 feet. Another high ridge, to which no name has been given, lies still farther north across the valley of Dry Fork of Antelope Creek and is peculiarly surrounded by the valley except on the north. This ridge which has a very steep west slope rises slightly above 9,000 feet. The high ridge immediately north of the National Monument has an average elevation of 7,500 feet. The only other point named is Timber Mountain (also known as Timber Dome) in the extreme northeast part of the district. This is a rounded-top peak of approximately 8,350 feet and has been named from a curious patch of timber which may clothe the summit. The lowest part of the area is the Snake River lava plain embaying its eastern border. At the sinks of Champagne Creek near the margin of the Snake River lava, the elevation is slightly more than 5,500 feet.

The mountains have been maturely dissected or reduced entirely to slopes. The slopes are steep and some are even precipitous. The most remarkable character of the topography probably is the degree of dissection which has produced an unusually great number of ridges and gullies, a feature most noticeable to one engaged in preparation of a topographic map.

**DRAINAGE**

The district is surprisingly well watered for one of arid characteristics, although such drainage is not at all out of place with the degree of dissection. Flowing springs and streams are numerous in the mountains, many with large volumes of water. None of the streams live, however, to flow upon the Snake River Plain, but all disappear into the gravels at or before reaching the lava flows. The quantity of flowing water is no doubt a result of the character of the country rock, largely of more or less porous or broken Tertiary lava and tuff capable of storing great quantities of water during the winter or wet season and releasing it in nearly constant amounts for the remainder of the year.

Most of the drainage is directly to the Snake River Plain through Big Cottonwood Creek, Little Cottonwood Creek, Lava Creek, and Champagne Creek, named from west and south to east and north. Of these, Big Cottonwood Creek has the greatest volume, receiving a considerable part of its flow from melting snow on Blizzard Mountain. The creek disappears at the base of the mountain shortly before reaching the lava plain. Little Cottonwood Creek has sufficient flow to be piped and utilized at the camp in the Craters of the Moon National Monument. Lava Creek flows intermittently below and at the surface. Although draining a larger area than does Big Cottonwood Creek, its actual surface volume is less, probably because of a large subterranean flow beneath the lava which covers the floor in the lower valley. Lava Creek has two main branches, one which may be referred to as the North Fork and the other as the South Fork. The North Fork is the longer and rises high on Blizzard Mountain, draining to the east, although not in a direct line. This Fork is of more than ordinary importance because mineral deposits are grouped along it and the creek waters would be desirable for mining and milling purposes. Some lava vents lie high above the valley floor and from these basalt has cascaded into the valley and out upon the Snake River Plain. It is from these flows of lava in the valley that the stream and mining district take their name. Champagne Creek (earlier known as Era Creek) drains the northeast part, and also has important mineral de-
posite grouped along it running through what was formerly called the Etna mining district. The volume of water is not great and the stream often goes dry during late summer. For this reason, mining operations in this part of the district are handicapped.

The remainder of the drainage is to the Snake River Plain, but by a very roundabout course, starting from the district in a northerly direction. The Dry Fork of Antelope Creek probably is the largest stream or has the greatest valley. It rises in the northwest part of the area, following a peculiar course to the southeast for about four miles, then doubling back and flowing nearly due north for 10 or 12 miles into Antelope Creek. In doing so, it flows around, or nearly encloses, a high mountain ridge and barely escapes from passing over a low divide into Lava and Champagne creeks. Indeed, man has improved on nature and has diverted the waters by ditch over a low divide into a tributary of Champagne Creek to be used for irrigation in the lower valley. The upper course has considerable water, but below the point at which the stream has been diverted into the other system, the valley is dry or water appears only intermittently. Another tributary of Antelope Creek drains the northwest part of the district. This tributary is Lead Belt Creek and one branch of it rises very near the head of Dry Fork, separated from it only by a low saddle. Several properties lie along this stream. Lead Belt Creek carries a good supply of water except near its mouth. Antelope Creek flows northeast to join Big Lost River which eventually disappears into the sinks near Arco.

The west margin of the district is drained by tributaries of Fish Creek - Copper Creek and Iron Mine Creek - rising on the west side of Blizzard Mountain, the first flowing southwest and the second flowing northwest. Fish Creek drains south to disappear in the sinks near Carey before reaching Little Wood River.

SPECIAL TOPOGRAPHIC FEATURES

The district has several interesting physiographic features of which the line of craters and cinder cones and recent lava flows in the Craters of the Moon National Monument are the most outstanding. These have been described elsewhere (bibliography). Further are some interesting lava vents several miles back in the mountains on an extension of the "Great Rift" along which the features in the Monument are grouped. The largest of these vents forms a conspicuous reddish hill at a maximum elevation of 7,550 feet between the two main forks of Lava Creek. Lava has breached the lower side of the cinder cone which rises above the vent and has cascaded into Lava Creek Valley, 1,500 feet below, and out onto the Snake River Plain three and one-half miles to the east. In all, the lava descends nearly 1,900 feet and flows more than six miles. Where entering the main valley of Lava Creek, the flow is about 400 yards across, but becomes wider toward the mouth of the valley and flares widely where it spreads over the Plain. This lava orifice has been given the name of "South Vent." Its cone comprises largely black to reddish cinders and reddish scoria, built 120 feet above the fissure from which the lava issued. The lava actually breached the side of the cinder cone in two places on the north and east, the two streams uniting some distance lower on the mountain side surrounding an island of the older rock.

A second fissure, from which considerable lava has issued, lies about a mile to the northwest of "South Vent" and on the same fissure, separated from it by the North Fork of Lava Creek. This vent, "North Vent," is likewise conspicuous as a black and dark red cinder cone at an elevation of about 7,660 feet. It has been entirely surrounded by basalt from a separate
A. View of the maturely dissected mountains drained by Lava Creek. The two volcanic vents perched high on the mountain sides are shown in the middle distance (dark-capped points). Blizzard and Boyle mountains to the left in the background.

B. South Vent, the high hill on the left from which the lava has tumbled into the valley of Lava Creek. Note the rough surface of the lava stream.
inconspicuous crater lying about 360 yards to the west. This crater is nearly 80 feet in diameter with a rim several feet high. From it the lava has tumbled 960 feet into the valley below and then flowed northward into Dry Fork, occupying that valley for about one-half mile. In two places the lava nearly spilled into the Lava Creek drainage. In one of these places a tongue of basalt actually did pass over a low saddle into Lava Creek Valley and in so doing deflected the drainage.

Two other vents occur nearby along the same rift. One lies about 100 yards to the northeast of "North Vent." Its outlet, like that of the "North Vent," has a small crater 80 feet in diameter, depressed several feet below the outer rim. A small quantity of basalt issued from this vent, but none flowed down the valley side. A small spatter cone, lying between "North Vent" and "South Vent" in the valley floor of Lava Creek, has been built up by reddish lava clots to a height of about 30 feet and is roughly circular in outline. Some reddish cinders and scoria occur with larger fragments of ejected material, but much of the cone is composed of lava clots fallen on its side and of thin lava streams that have trickled over its surface. No crater rim is preserved at its top nor does lava extend from its base.

Another unusual feature is an open vertical fracture or fissure that extends across a limestone ridge, in direct line with the "South Vent" but trending N. 35° E. The fissure forms in part a gaping chasm, four to six feet wide, and of undetermined depth. This crack may be traced for several hundred yards, but lower on the ridge it has been filled with erosional debris. This great open crack may represent a fissure complimentary to the "Great Rift" and unfilled by lava.

Other features of interest are also present, particularly those of drainage. The singular course of Dry Fork of Antelope Creek needs explanation, for its remarkably straight upper course in direct line with an extension of the line of the "Great Rift" suggests structural control unverified in the field. Its change of direction northward is equally interesting, but cannot be explained by present surface topography. The low divide between Dry Fork and Champagne Creek may be explained by undercutting, for streams flowing southward to the Snake River Plain are cutting under head waters of streams which flow northward. This is true of Fish Creek as well, for its valley is much lower, even near its source, than the head of Antelope Creek a short distance away.

CLIMATE AND VEGETATION

The region is arid and is covered characteristically with sage brush. Nevertheless, the abundance of springs and running water testifies to considerable precipitation, although the porous character of the country rock does not make it readily available for tree growth. The upper slopes are well covered with grass, and the district is a favorite for summer pasturage of sheep and cattle. Small patches of pine and fir grow in favored places high on the mountain slopes in the gullies where snow lingers latest in the spring. These places are scattered and the amount of timber almost negligible, little of it being found below 8,000 feet. One small mill was operating in 1928 on a tributary of Dry Fork and was furnishing mine timbers and some rough lumber. An adequate supply of mine timbers is a pressing problem. The character of the altered country rock near mineralized zones is such that tunnels will not remain open unless strongly timbered, especially when water filters in through the tunnel reducing the rock to a soft clay-like material. As most of the properties are at relatively low elevations, timbers must be trucked for several miles.
Because of the altitude, snowfall is considerable. Snow flurries may be expected every month of the year, save possibly July and August, but little snow remains on the ground in the autumn until November and most of it is gone from the lower slopes before April or May. Thunder showers are common in the summer months and rainfall, aided by irrigation, is sufficient to support several ranches on the flats near some of the stream mouths.

GEOLoGY

GENERAL FEATURES

Nearly half the Lava Creek district is underlain by sedimentary rocks comprising sandstones, shales, and limestones of upper Mississippian age. The remainder is underlain by a thick series of Tertiary volcanic rocks, comprising both flows and tuffs of andesitic, latitic, and rhyolitic character, and of intrusive granite and porphyry. The Tertiary extrusives filled great valleys carved in older sedimentary rocks, probably long after the major orogenic disturbance of the late Mesozoic which complexly folded and faulted the older series. The lavas and associated tuffs have not only filled the old valleys, but apparently covered the entire region. Subsequent erosion has removed much of the blanket, but the old lava-filled valleys remain. This period of volcanism occurred supposedly in Miocene time and probably continued into the Pliocene. It was apparently terminated by mild diastrophism at the close of the Miocene or in Pliocene when the lava was gently arched and intruded by stocks and dikes of alkaline granite and granite porphyry. Later rocks are represented by flows of basalt of Quaternary age. These are probably not more than a few thousand years old and some of them, as in the Monument, likely were poured out less than a thousand years ago. Recent alluvium is present in some stream valleys and at the margin of the Snake River Plain where basalt flows have obstructed the natural drainage.

Folding and faulting have so complicated the relationships of the sedimentary and extrusive rocks that measurement of reliable sections was not possible in the time available. Cuttore, especially igneous, are generally scarce, for alteration by mineralizing solutions has been so widespread that the rocks rapidly decay under weathering and are beneath considerable burden - a marked contrast with neighboring areas where all rocks give good exposures.

SEDIMENTARY ROCKS

Sedimentary rocks, comprising a large part of the mountainous country west, north, and east of the Lava Creek district, range in age from Cambrian (?) to Pennsylvanian, but only Mississippian sedimentary rocks have been identified in the Lava Creek area. Not far to the west, beds of Pennsylvanian age are widespread and a thick conglomerate at the mouth of Iron Mine Creek may mark the base of this younger series. Possibly masses of Pennsylvanian rock have been in faulted with Mississippian beds, but very detailed study and mapping would be required to recognize them. No older rocks are known in the immediately surrounding area, but as the region has not been satisfactorily studied, they may be present.

Although some tuff beds in the Tertiary volcanics are stratified and in part were deposited in water, they have not been differentiated from the flows and will be considered later with extrusive rocks. Younger sediments are recent stream deposits.
MISSISSIPPIAN SERIES

Distribution and Lithology

Mississippian beds that have yielded extensive fossil collections at several places within the area are widely distributed and of great thickness. A complete section has not been found, and the fragmentary information collected during the reconnaissance does not warrant placing together even a tentative section. In general, the series consists of a thick formation of shales, sandstones, and limestones with minor, but considerable, amounts of quartzite and conglomerate. Neither the base nor the top of the section was found, although an immense conglomerate with pebbles and boulders up to six inches in diameter, and probably several hundred feet thick, outcrops along the west margin of the area mapped. This conglomerate may be traced readily along Fish Creek a short distance above the mouth of Copper Creek, and gives a good exposure at the mouth of Iron Mine Creek. This conglomerate overlies the Mississippian shales and sandstones, probably representing the base of the Pennsylvanian. The partial section of Mississippian rocks seems more than 3,000 feet thick and probably is more than 4,000 feet. The total thickness cannot be determined in the district, but likely is much greater for Umpleby has found more than 6,000 feet of upper Mississippian beds in the Mackay region.

The beds, from which fossils were collected probably are all of upper Mississippian age, with the lower Mississippian or Madison limestone, so widely distributed in the Rocky Mountain region, apparently absent. Umpleby also finds lower Mississippian beds missing in the Mackay vicinity.

Although limestones apparently form the lower part of the Mississippian series, it is not altogether certain as they were not found in contact with other sedimentary rock but capped by Tertiary lava. These are exposed in the lower course of Lead Belt Creek and topographically, at least, they are lower than the shales, limestones, and sandstones outcropping at the head of the stream. The main part of the series comprises black and gray shales, gray and buff sandstones and quartzites, bluish limestone, in turn overlain by several hundred feet of massive grayish limestone, abundantly fossiliferous. The formations are duplicated on the east and west sides of the district probably because of faulting concealed by the Tertiary lava extending northward from Champagne Creek into Dry Fork Valley.

Mississippian rocks also may be found in the northeast part forming most of Timber Mountain and the long smooth slope stretching southward to Champagne Creek. Several thousand feet of grayish sandstones, shales, quartzite, and conglomerate are exposed here with only the conglomerate showing massive outcrop. The remainder erodes to smooth slopes making satisfactory exposures difficult to find and hence identification must be from soil debris. The conglomerate forming the massive outcrop on the ridge north of the road which passes up Champagne Creek is about 100 feet thick and comprises pinkish and grayish pebbles and boulders from one-half to four inches in diameter. The conglomerate is traceable only for a short distance along the strike and clearly owes its position to faulting. It probably does not belong with Mississippian rocks, for a similar formation was not found elsewhere. Some

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2 Umpleby, J. B., Ibid., p. 27.
fossiliferous, carbonaceous, black shales occur well up in the series, over-
lain by quartzite. Some quartzites also form pronounced ledges near the top
of Timber Mountain. This series of shales, sandstones and quartzites, mainly
the first two, are overlain by massive grayish limestones on the top of Timber
Mountain and on its north slope. These limestones are thick to thin bedded,
some of them cherty with numerous bands and lenses of black chert, alternating
with thin beds of quartzite. Many limestone members are fossiliferous. In
all, this particular calcareous series probably is more than 800 feet thick,
with the top buried beneath Tertiary lava.

An even greater distribution of this series occurs on the west side of the
district, continuing along with probable Pennsylvanian beds to Fish Creek
where they again pass beneath Tertiary lava. The high ridge forming the divide
between Dry Fork and Fish Creek contains a good assemblage of Mississippian
rocks. A traverse from Dry Fork to the ridge top shows a series of black,
carbonaceous shales, gray shales, gray and buff sandstones, conglomerate with
pebbles less than two inches in diameter, and a bed of dense bluish limestone.
These alternating beds are generally thin, rarely exceeding 50 feet in thick-
ness. The entire sequence is repeated in reverse order near the top of the
ridge and again on the west side as the beds dip into both valleys from an
anticlinal axis lying some distance east and below the ridge crest. The lime-
stone member is without fossils, except crinoid stems. It is persistent and
despite poor outcrops may be traced the entire length of the ridge to Boyle
Mountain where its thickness increases to about 100 feet.

The same grouping of sandstone, shale, and quartzite appears or continues
south of Blizzard Mountain and is well exposed on the ridge between Cottonwood
Creek and Copper Creek, in spite of smooth slopes. The beds on the ridge west
of Dry Fork pass under the high ridge that lies to the east and enclosed by
Dry Fork Valley. About 2,000 feet of black and gray shales, gray sandstones,
gray limestones, and thin beds of quartzites lie above and form the steep,
smooth slope on the west side of the ridge. Some of the shales are calcareous.
The top of the ridge is capped by massive limestone beds similar to those on
the north side of Timber Mountain, except the limestones do not appear as thick.
The dip of the beds carries them to Dry Fork where the stream is on its north-
ward journey and then under the lavas near Champagne Creek. A particularly
massive bed of limestone at the top of the ridge, about 200 feet thick, is
abundantly fossiliferous. The same bed is exposed along Lava Creek near the
basalt vents. Good exposures of limestone also occur on the high rounded hill
lying on the east side of Dry Fork, between it and Champagne Creek. The lime-
stone is grayish and a good cliff maker, forming particularly steep slopes
where the hill borders Dry Fork. The beds are thick to thin bedded and hold
some shales as well as sandy members. Some of the limestone is cherty.

What appears to be the same assemblage occurs in the ridge exposure south-
west of Martin Post Office where beneath some thick-bedded, white, massive
quartzites, outcropping well up on the ridge beneath a covering of Tertiary
lava, are thin-bedded, sandy and shaley limestones, calcareous shales, and
some gray and black shales.

Age and Correlation

Fossils were collected from a number of localities in the district, both
from limestones and from some of the black shales. A few beds are highly
fossiliferous, but unfortunately the fossil horizons are rather widely sep-
arated. The collections were identified by Mr. George H. Gerty of the United
States Geological Survey, who submits the following report: 
"The collections are numbered from 1 to 10, but as Lot 9 is missing, only nine are considered here. In geologic age, I am disposed to think that all belong in the upper Mississippian (Brazer) though with various degrees of confidence. In the present series, one lot at least is indeterminable (Lot 1). Several are clearly Mississippian and the rest are probably of that age, though on evidence more or less tenuous. The lots more confidently assigned to the Brazer (upper Mississippian) are Lot 2, Lot 4, Lot 7, Lot 8, and Lot 10. Though I believe that this assignment will be justified when we have a better understanding of the upper Mississippian faunas as a whole, I would not place the assignments, of these lots as beyond future revision. The other assignments, of course, are correspondingly more tentative. A useful check might be had if the stratigraphic relations of these lots to one another have been determined."

Lot 1: From the blue limestone bed near the crest of the high ridge between Dry Fork and Fish Creek. Indeterminable.

Crinoid stems.

Lot 2: A collection from the limestone on the north end of the ridge that lies between Dry Fork and Champagne Creek, Sec. 9, T. 3 N., R. 24 E. The beds consist mainly of thin to thick-bedded limestones, sparingly fossiliferous. Assigned to the Brazer with some confidence.

Pentremites n. sp.

Lot 3: One and one-half miles south on same ridge as Lot 2 in Sec. 22, T. 3 N., R. 24 E., and in same series of limestones. Only a few imperfect specimens found.

Productus ovatus var. latior?

Lot 4: On the southwest slope of Timber Mountain in Sec. 11, T. 3 N., R. 24 E. This collection of fossils from some highly fossiliferous, thin-bedded, black shales which weather grayish and lie beneath massive quartzites. Confidently assigned to the Brazer.

Obriculoides sp.
Productella hirsutiformis
doeth. sp.
Loichrzychus carboniferum var. polypleurum
Spirifer martiniformis?

Lot 5: From the fossiliferous limestones on the northeast side of Timber Mountain overlying the thick series of shales, sandstones, quartzites, etc., in which Lot 4 were collected. Mainly grayish limestone, alternating with thin quartzite members. Apparently corresponds stratigraphically to member on Dry Fork ridge from which the fossils of Lot 6 were collected and which have been assigned to the Brazer.

Charvetes radiana?
Campophyllum aff. terebratum
Triplophyllum sp.
Syringopora sp.
Perimella sp.
Polyphora ovat. sp.

Hustedia multicostata
Productus ovatus var. minor
Productus semireticulatus var.
Girtyella? sp.
Spirifer Brazeriannus
Spirifer Pellensis
Lot 6: From the limestones that have been exposed in the valley of Lead Belt Creek beneath a Tertiary lava covering. These may be the lowest part of the section exposed, but whether these belong lower than the upper Mississippian is not determinable. Sec. 3, T. 3 N., R. 23 E.

- Wewokella? sp.
- Triphyllum sp.
- Chaetetes radians
- Productus ovatus
- Diaphrampus elegans?
- Spiriferina spinoa?

- Sulcatipina sp.
- Articulipent sp.
- Levidentalium sp.
- Bellerophon sp.
- Pleurotomaria sp.
- Griffithides sp.

Lot 7: A collection from the black shales near the east base of the ridge between Dry Fork and Fish Creek, probably in Sec. 36, T. 3 N., R. 23 E. Assigned with some confidence to the Brazer and probably the stratigraphic equivalent of the black shales from which the collection of Lot 4 was made.

- Leiorhynchus carboniferum var. polypleurum

Lot 8: Collection from high ridge within the curve of Dry Fork in Sec. 17, T. 3 N., R. 24 E. The fossils were collected on the south side of a steep gulch at an elevation of about 8,000 feet. A massive bed of limestone about 200 feet thick, very fossiliferous, outcropping along slope of ridge above 1,000 feet of thin-bedded limestones, and some shales, only sparingly fossiliferous. Probably the stratigraphic equivalent of the limestone from which Lot 5 was collected north of Timber Mountain. This lot assigned with some confidence to the Brazer.

- Triphyllum sp.
- Cythathonia? sp.
- Syringopora surcularia
- Penestella sp.
- Pinnatopora sp.
- Rhombopora sp.
- Cystodictya sp.
- Productus semireticulata
- Productus Brasieranus

- Productus parvus
- Productus parviformis
- Leiorhynchus carboniferum
- Leiorhynchus carboniferum var. polypleurum
- Spirifer sp.
- Spiriferella? sp.
- Cleiothyridina sublamellosa
- Paraparchites sp.

Lot 10: Collection made from massive outcrops of limestone in valley of North Fork of Lava Creek in Sec. 8, T. 2 N., R. 24 E. Apparently the same limestone from which Lot 6 was collected and 5 miles distant. Assigned with considerable assurance to the Brazer.

- Syringopora surcularia
- Amplexus sp.
- Triphyllum sp.
- Stenopora aff. ramosa
- Penestella sev. sp.
- Rhombopora sp.
- Productus ovatus

- Productus aff. Burlingtonensis
- Productus aff. Gallatinensis
- Pustula gracilis
- Spirifer Pollensis?
- Spirifer neglecta
- Cleiothyridina sublamellosa
Lithology and the great thickness of the upper Mississippian of the Lava Creek district are its most striking features compared with sections in nearby areas. The lithology of the series in the Lava Creek district differs markedly from that near Mackay where the upper Mississippian (Brazer) is represented by a monotonous succession of thick-bedded and thin-bedded limestones, with variations in the color of widely separated beds as the principal present basis of correlation. Comparing this great succession of limestone beds with the marked thickness of shales and sandstones, and of lesser thicknesses of quartzes and limestones, all of the same age in the Lava Creek district, the contrast is startling and significant of the great sedimentation change occurring in a relatively short distance. When both districts are compared with neighboring sections, the differences, especially in thickness, are again striking. In northern Utah, the upper Mississippian is represented by the Brazer, consisting of 800 to 1,400 feet of massive to thin-bedded, light gray, siliceous limestone, including some sandstone beds, and resting on highly fossiliferous Madison limestone of about equal thickness. In southeast Idaho, the upper Mississippian again is represented by the Brazer, comprising 1,130 feet of massive, gray, light to dark limestone, locally with a shale bed about 15 feet thick and resting upon 1000 feet of Madison limestone. The Brazer in the Lava Creek district thus has added interest because of its dissimilarity, both in lithology and thickness, from equivalent formations in nearby regions.

QUATERNARY SEDIMENTS

The only Quaternary sediments are recent stream deposits. The district appears to have escaped Pleistocene glaciation, although several small glaciers may have clustered about Blizzard Mountain without leaving clearly recognizable deposits. Alluvium is present in nearly all stream valleys, but abundant only in a few wider ones, such as the Dry Fork of Antelope Creek and along the lower course of Champagne Creek where damming by the Snake River basalt has caused wide alluvial flats and aggraded valley floors. Similar gravel flats are found at the mouths of other valleys opening onto the Snake River Plain.

IGNeous ROCKS

Igneous rocks in the Lava Creek district are confined wholly to the Tertiary and Quaternary systems. The Tertiary volcanics are of particular importance inasmuch as they contain most of the mineral deposits of the district. Intrusive granite, especially, is important as it has undoubtedly been the source of the mineral-bearing solutions. Neither the lava flows or the intrusive granite have received adequate description, for existence of a granite younger than the Idaho batholith (late Mesozoic) only recently has been recognized. Quaternary rocks consist of Snake River basalt which, in the Lava Creek district, must be classed as recent.

EXTRUSIVE ROCKS

Tertiary System

Distribution

Tertiary volcanic rocks are widely distributed in the region. More than 1,000 square miles of the Salmon River Mountains are underlain by lava and associated clastic beds generally assigned to the Tertiary, and Ross\(^1\) intimates that the whole range probably was once covered by lava and that nearly all of Idaho, from the Snake River Plain to about 45° 10' north latitude and large parts beyond, was likewise mantled by such rocks. Erosion has stripped off much of this mantle, but vast areas still remain, especially in the former great valleys filled with flows and associated tuffs. Tertiary lavas are also widely distributed in the region about Lava Creek, covering hundreds of square miles.

Nearly half of the Lava Creek district is underlain by such rocks continuous with a broad belt to the north, particularly in the broad basin of upper Antelope Creek. This constitutes the largest belt of such rock in the Lost River area. From Copper Basin, the broad belt leads northward across the summit toward Chilly, another extends south, and a third passes over the divide and expands widely in the upper Antelope Creek basin. This part of the area connects with the Snake River Plain, one belt meeting the Plain north of Timber Mountain, another on the south and including the Tertiary rocks in the Lava Creek district, and a third crossing Antelope divide into Fish Creek and along its west side to the plain near Carey.

The distribution in the Lava Creek district may be seen from the geologic map. Most of the area that lies between Big Cottonwood Creek, Blizzard Mountain, and Antelope Creek on the west, and the lower part of Champagne Creek and Timber Mountain on the east, is underlain by these rocks. The belt narrows very perceptibly near the old town of Era, two miles northwest of south Champagne Creek, but flares widely to the south and especially to the north where it partially encircles Timber Mountain. It also encircles the high ridge within the great bend of Dry Fork, appearing again in the Lead Belt drainage to the northwest.

Total thickness of the section is unknown. The beds have been so disturbed by faulting in the Lava Creek district as a result of later intrusion, and outcrops are so unsatisfactory, that an accurate or complete section could not be obtained in the time available. The rocks occupy the lowest part of the area as well as outcrop near the summit of Blizzard Mountain, the highest point, giving a vertical range of nearly 4,000 feet. How much of the section has been eroded is impossible to estimate, at least until the section has been worked out in nearby areas. One of these areas probably lies immediately to the north of the district where the beds have been gently arched. The tilted and truncated, but otherwise undisturbed, members would afford excellent exposures for study. When mile after mile of tilted beds are crossed, it becomes apparent that the Tertiary section must be much more than a mile thick and perhaps several miles.

General Character

The Tertiary lavas are mainly intermediate in composition but include minor beds of rhyolite. Perhaps the most common types of rocks in the series are andesites and latites and their related tuffs. The complete series may be

listed as augite andesite, hypersthene andesite, hornblende-augite, andesite, hornblende-andesite, quartz latite, and rhyolite, as well as andesite-tuff and latite-tuff. The stratigraphic succession was not definitely established, the andesites likely occur near the base of the series and the rhyolites near the top.

Augite Andesite: Augite andesite is rather widely distributed between the lower part of Lava Creek and Champagne Creek and about the St. Louis, Ella, and Hornsilver mines to the north limit of the district. The number of flows are undetermined and likewise their thickness, although one, at least, measures about 50 feet. Augite andesite is the country rock in part, for much of the mineralization along Champagne Creek. It is usually found in the lower parts of the valleys beneath a capping of hornblende andesite or rhyolite.

The augite andesite is generally a dark gray to black, porphyritic rock with a variable proportion of glassy, plagioclase phenocrysts and black, augite crystals, measuring from one-eighth to more than one-half inch long, embedded in a dense aphanitic ground mass. The rock weathers brown to brownish red except in the mineralized areas where it is entirely bleached, often resembling a spotted or dirty white or gray sand. It may then be confused with altered rhyolite. The glassy, plagioclase phenocrysts are most noticeable and usually comprise about a third of the rock. The augite occurs in tabular black crystals less noticeable than the feldspar because the ground mass has essentially the same color. Near the Ella mine the augite forms laths three-quarters of an inch long, weathered out at the surface, giving the rock a peculiar vesicular appearance.

The porphyritic character is very apparent under the microscope for the colorless or faintly greenish diopside (augite) and the andesine phenocrysts are embedded in a fine ground mass composed of minute laths of a more acid plagioclase, diopside, and glass, beside several minor accessories. The ground mass is hyalopilitic to pilitaxitic, that is felted or andesitic, consisting of innumerable small feldspar-laths, simple or once twinned, with or without, a residuum of glassy matter. Some show a pronounced fluidal texture. The feldspar phenocrysts usually are basic andesines, zoned, and show albite and often carlsbad twinning. In some, the andesine shows corrosion and is rounded, but generally crystals have well formed outlines. The plagioclase in the ground mass is invariably more acid and ranges in composition from oligoclase to acid andesine. The diopside is usually, but not always, altered more or less completely to chlorite and calcite, and often has heavy mantles of magnetite. In some, the pyroxene is so altered that cleavage is recognizable only by the lines of magnetite. Diopside also appears as tiny microlites in the ground mass, usually with numerous tiny cubes of magnetite and minute hematite grains. Hypersthene occurs as a minor accessory in some specimens as phenocrysts. Biotite also is an accessory, particularly in rocks showing more acid tendencies and approaching latite in composition. Hornblende occurs in some as a minor accessory, but is usually altered with separation of magnetite. Alterations of these minerals have been great near mineral deposits, such rocks showing considerable silicification, and development of minute flakes of white mica (sericite ?), chlorite, zoisite, calcite, and pyrite.

Hypersthene Andesite: Hypersthene andesite occurs in the same general region as the augite andesite between Lava Creek and the north boundary of the district, but is also widespread in the Lead Belt drainage. Its stratigraphic relation to the augite andesite is undetermined, but likely some specimens came from the same flows as the augite andesite.

-15-
The rock resembles augite andesite in all external appearances and can be identified only microscopically. In color, hypersthene andesite ranges from gray to nearly black to greenish gray, and, like augite andesite, is very porphyritic, generally composed of not less than 35% phenocrysts, but the pyroxene usually is not easily recognized in the hand specimen and generally is subordinate to the feldspar. The rock weathers brownish red.

Microscopically, the rock is much like augite andesite except that hypersthene has been largely substituted for the diopside. In some of the rocks classed as hypersthene andesite, however, the diopside is somewhat more abundant than the hypersthene, but this is not the usual case and often diopside is entirely wanting. The hypersthene is distinguished by its faint greenish and pinkish pleochroism and its generally opaque cross-section with truncating corners as contrasted with the regular octagon of diopside. Andesine phenocrysts are usually basic, zoned, some of them corroded, and twinned. Biotite and hornblende often occur as accessory minerals, both as phenocrysts and in the ground mass. The texture of the ground mass is andesitic, usually with some glass and comprising tiny laths of oligoclase or andesine, and tiny microlites of diopside, hypersthene, biotite with a dusting of magnetite and hematite grains. One rock near the St. Louis mine contained numerous phenocrysts of andesine, diopside, hypersthene, biotite, and magnetite in a cryptocrystalline ground mass of the same minerals, and possibly with a little orthoclase. In most of the rocks, apatite and occasionally zircon occur as accessories.

Hornblende-Augite Andesite: Hornblende-augite andesites occur in the same region as does augite andesite and may be phases of the same flows, although some occur separately. This type also prevails in the Lead Belt region. Hornblende-augite andesite is the country rock of the lower part of the Last Chance vein and perhaps for part of the St. Louis vein in the Champagne Creek district and apparently is somewhat lower stratigraphically than the augite andesite.

The hornblende-augite is similar to other andesites, ranging from brownish gray to grayish black in color and containing numerous scattered phenocrysts of glassy andesine, black pyroxene, and hornblende in a dense aphanitic ground mass. In specimens studied, the phenocrysts were less than one-quarter of an inch long. This type also weathers brownish.

The proportion of hornblende to diopside is variable and either may predominate. The hornblende is brown, although some has a faint greenish tinge. It occurs in well-shaped tabular crystals embedded along with generally corroded crystals of andesine and colorless crystals of diopside in a fine andesitic ground mass, usually showing faint fluidal structure. The ground mass is composed of tiny microlites of acid andesine or oligoclase, diopside, and more rarely hornblende, and residual glassy matter. The hornblende usually has heavy mantles or rims of magnetite and some smaller crystals are made opaque. The ground mass is well dusted with tiny cubes of magnetite and microscopic hematite flakes. A little titanite and apatite is accessory and one of the sections contained a very few rounded quartz grains. This latter rock closely approaches a dacite in composition.

Hornblende Andesite: Hornblende andesite cannot be distinguished from the other andesites except microscopically. It seems to be well distributed in the high ridge north of the St. Louis and Ella mines, where it may be a phase of the augite andesite flows. It also forms the base upon which "South Vent" rests near Lava Creek.
Its color ranges from grayish near "South Vent" to mottled dark gray and brown at the Reliance mine on Champagne Creek, and dark gray to black on the ridge north of the St. Louis. This rock is also porphyritic with the usual glassy phenocrysts and a sprinkling of black hornblende crystals. The phenocrysts are in general smaller than in the other types and less prominent.

The plagioclase phenocrysts range from acid to basic andesine, showing the usual zoning, corrosion, and albite and carlsbad twinning. These, along with brownish hornblende laths (usually with black rims of magnetite grains), are embedded in a fine andesitic matrix of minute oligoclase or acid andesine microlites, diopside microlites, and usually some glassy residue. The rocks are particularly high in their magnetite content due not only to alteration of the hornblende, but to a liberal scattering throughout the ground mass. One specimen contained considerable hematite. Another specimen contained a few crystals of diopside as phenocrysts. Another contained considerable quartz and would better be classed as dacite. This quartz was both in the glassy ground mass, as well as in scattered phenocrysts. Some flows are badly altered, particularly those near the basalt vent, and contained much secondary muscovite, zoisite, chlorite, epidote, and kaolin. Accessories include apatite and zircon.

Andesite (? Tuff: Beds of andesitic (?) tuff are widely distributed near the Champagne Creek mines and form parts of some vein walls. These occur between the andesitic flows and probably are composed of materials similar to the flows, although of entirely different appearance. These tuffs have been deposited in water apparently, as they show faint stratification and some hold rounded pebbles of other rock.

The tuff beds are light in color, usually grayish to buff and weather buff. The material is fairly coarse-grained, well cemented, and hard. Specimens collected near the mines show the tuffs composed of angular feldspar crystals and altered marlites, cemented, as well as replaced, by quartz, calcite, and chaledony. The tuffs have been extensively seritized and contain much chlorite. The rock is spotted with tiny magnetite grains largely altered to hematite. The tuffs appear to have been highly altered hydrothermally, making recognition of their original character difficult and in this case rather uncertain.

Quartz Latite: Quartz latite is especially widespread in the Lava Creek drainage and along with latite-tuff forms the wall rock of most of the ore deposits in that locality. A flow of latite was also found above andesites between Lava Creek and Champagne Creek and a small remnant on the north side of Champagne Creek. There are apparently several flows, each differing somewhat in general appearance. The flows evidently range from 20 to several hundred feet in thickness.

The latites usually may be readily distinguished from the andesites by their more glassy character and it is not uncommon to find considerable obsidian in some flows. They are also characterized by an abundance of biotite phenocrysts. The latite widely distributed on the ridge between the National Monument and Lava Creek has a dark grayish to nearly black color, showing a prominent flowage structure, usually by black glassy bands, and studded with scattered flakes and tablets of biotite, small glassy crystals of feldspar, and less commonly of pyroxene or hornblende. The latite occurring along the North Fork of Lava Creek differs somewhat from the above in that biotite is lacking, and that the rock has a grayish color with some greenish or lavender tints. This type is highly porphyritic and has an abundance of dull feldspar crystals and altered
crystals of hornblende or augite in a dense grayish base. The latite between Lava Creek and Champagne Creek is grayish with a pronounced pinkish or lavender cast, some nearly reddish. Glassy feldspar phenocrysts are numerous and accompanied by scattered crystals of hornblende and biotite, all embedded in a pinkish-gray matrix. The phenocrysts are usually less than one-fourth of an inch long.

The dark gray or grayish-black latites, in addition to numerous crystals of acid to basic andesine, contain lesser amounts of orthoclase, quartz, biotite, and diopside in a ground mass that is more glassy than in the typical andesites, but which also includes microlites of orthoclase and small grains of quartz, as well as minor amounts of biotite, diopside, and oligoclase. The andesine is twinned, usually zoned, corroded, and as a rule is more acid than that in the andesites. Orthoclase phenocrysts are less numerous than andesines but are much more abundant in the ground mass than the tiny oligoclase laths. The large orthoclase grains also usually show a zoning and are rounded. Only scattered, rounded grains of quartz occur as phenocrysts, in smaller grains than the others but usually are more abundant in the ground mass and probably constitute a goodly share of the glassy matrix. In some of the specimens the dark minerals have been resorbed and outlined by magnetite. Biotite is more abundant than diopside. In some of the specimens, pyroxene is lacking. Magnetite usually is an abundant accessory and occurs both in large and minute cubes scattered through the ground mass. In all these rocks the fluidal structure is particularly pronounced and the ground mass contains more glass than crystalline matter. Accessories include zircon and apatite.

The grayish and pinkish latites have much the same character as the grayish black latites except that some are without biotite and have mainly hornblende or diopside as their dark mineral. Some of these are near mineral-bearing veins and are so altered as to make identification difficult. Such rocks contain much secondary muscovite, and also contain chlorite and calcite as alteration products of the dark minerals. Secondary quartz or chloroedon is abundant in some. The pinkish or lavender tinted varieties owe their color to hematite dusted through the ground mass. The feldspars and their relations, as well as the character of the ground mass, are the same as described above.

Latite-Tuff: Quartz latite-tuff is particularly widespread in the southern part of the district, forming not only much of the country rock between the Craters of the Moon and Lava Creek but the wall rock of the veins of the Silver Bell and Hub mines as well. Excellent exposures may be found on the high ridge between the Monument and Lava Creek, along with grayish-black latite, and at the head of the east branch of Big Cottonwood Creek. Several beds of considerable thickness are present in the area.

The tuff apparently is not water-laid and might better be classed as tuff-agglomerate or tuff-breccia. It has a prevalingly greenish color and has numerous small inclusions, less than one-half inch, of purplish, grayish, and greenish andesite or latite in a greenish, grit-like matrix. It is a coarse-grained tuff intermediate between a normal tuff and an agglomerate. Some resembles a porphyritic lava in which numerous phenocrysts of altered feldspar are embedded in the fine-grained, greenish matrix.

The latitic character of the tuff is apparent in microscopic thin sections for much orthoclase and quartz can be recognized along with larger crystals of plagioclase (andesine). In some specimens, nearly half of the tuff is composed of broken and shattered crystals of andesine with lesser amounts of orthoclase and quartz in a glassy matrix, showing occasional microlites of the same minerals. In others, the feldspars and quartz are rounded and partially resorbed. A minutely crystalline matrix occurs in several specimens, but the
base usually is either made up of glassy material or is indeterminable. In
general, the tuff shows much alteration. The feldspars are seldom clear but
rather are represented by fine aggregates of secondary muscovite. The green-
fish color is due to the presence of abundant chlorite, developed from dark
minerals, probably biotite or hornblende. Epidote was also recognized in
some of the specimens. Magnetite is the chief accessory. The tuff has been
extensively altered near ore deposits and has much sericite (?), calcite,
chlorite, pyrite, and secondary quartz or chaledonic silica.

Rhyolite: Rhyolite is the least extensive of the Lava Creek flows. A small
remnant remains on the flank of the hill north of the mouth of Champagne Creek,
resting directly on Mississippian sandstones and shales. Patches of rhyolite
also occur on the hills lying between Lava Creek and Champagne Creek and a
little has been noted along Dry Fork. It is possible that the rhyolite was
poured out on the andesites, which it overlies, after a considerable erosional
interval, since some apparently rests in depressions or valleys in the ande-
site. In one outcrop, the flow is several hundred feet thick.

The rhyolite is characterized by a pronounced pinkish or lavander-pink
color. Some parts are highly vesicular with vesicles more than two inches in
diameter common. Other parts of the same flows are notably dense, or
minutely porous, and contain scattered crystals of glassy-like sanidine and
quartz or tridymite, more rarely oligoclase, in an aphanitic base showing a
pronounced fluidal structure, apparently largely glass. The upper part of
some pink rhyolite flows grades into black obsidian. No dark minerals were
recognized as phenocrysts in any specimens.

The microscope reveals only a scattering of phenocrysts, mainly clear
crystals of oligoclase, sanidine, and usually quartz. All are euhedral or
rounded and embedded in a glassy, ground mass. In one specimen, a few crystals
of diopside were noted. Although the ground masses are mainly glassy, streaks
of microcrystalline, quartz, and orthoclase alternating with glassy bands are
found, giving the rocks decided fluidal structures. Several of the rocks
further have microospherulitic structures and all show a tendency for such de-
velopment. Some druses are occupied by small grains of tridymite and others
by quartz and orthoclase. The glassy zones also contain occasional microlites
of orthoclase and small grains of quartz. A little magnetite is present and
the ground mass is dusted liberally with hematite to which the rock owes its
pinkish color.

Age of Lava and Tuffs

The lavas and tuffs are considered as Miocene by Umpleby\(^1\) because of their
relation to great erosion valleys developed after elevation of an Eocene
erosion surface and because a long period of degradation intervened between
their eruption and the extravasation of the Snake River basalt, commonly
accepted as chiefly Pliocene. Lake beds, contemporaneous with the lava series,
have been found in several places, and Miocene plant remains have been iden-
tified in Lemhi Valley in lake beds of the same geologic and physiographic
relations. Ross\(^2\) considers that available evidence, though inconclusive,
strongly suggests these rocks are Miocene. He also considers the possibility
that the lowest strata may be Oligocene, although it is improbable that any

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\(^1\) Umpleby, J. B., Op. cit., p. 35

are as old as Eocene. In southeast Idaho, Mansfield\(^1\) recognizes that the upper series of rhyolites are in part of Pliocene age.

**Quaternary System**

**Basalt:** In describing these rocks, the recent lavas in the Craters of the Moon National Monument will be omitted and only flows that cascaded down the mountain side from the Lava Creek vents will be considered. These flows are reasonably young, perhaps only a few thousand years old. Their surface has not been affected by weathering and has only a thin mantle of soil or is entirely barren. The cinder cones about the vents, although unconsolidated, have not been dissected or washed away by rain and melting snows. The lava is older than the very recent lava in the Monument which Stearns\(^2\) intimates was poured out more than 250 years ago and probably less than 1,000 years ago. But in the Monument, Stearns distinguished three main epochs of eruption, the earliest - "long before Egypt had a name" - producing a long line of cinder cones and thick jagged flows, consisting largely of broken blocks. Much of the lava and most of the cinder cones in the Monument belong to a younger second epoch, followed soon after by the youngest flows of the third epoch. The basalt from the Lava Creek vents is very similar to some of the older flows in the Monument and probably was poured out during the first period.

The lava, descending the steep slopes, formed veritable cascades, and on cooling left an excessively rough surface. The crust first formed was broken, the fragments being cemented together by still plastic lava to make up a coarse breccia. Many masses of the fragmental crust were carried far down the stream and out on the Snake River Plain. The rough surface of the lava is characteristically of the "aa" type and this character is preserved throughout the entire flow even onto the Plain where the movement was relatively slow and sluggish. The original rough, jagged surface was further broken by the settling of the crust after the lava had drained from beneath.

The surface of the basalt generally is glassy or scoriaceous, but this shell is relatively thin and a well defined crystallinity may be detected in broken fragments of the lava crust. The crystals, of minute size near the surface, become relatively coarse-grained a short distance inward and plagioclase crystals are recognizable. A few large crystals of glassy feldspar are scattered as phenocrysts in some of the rock. The basalt is generally vesicular, especially near the upper surface, the vesicles ranging from microscopic size to cavities several inches across. Most vesicles are either flattened or drawn out. In color, the basalt is a dark gray or grayish-black.

The basalt has a pronounced ophitic or diabasic texture with small crystals of augite and a dark glass filling the spaces between the acid labradorite laths. The labradorite is the most abundant constituent, though followed closely by augite and glass. Magnetite in minute cubes is an abundant accessory, comprising more than ten per cent of the rock. The rock is a normal, olivine-free basalt.

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A. View of the exceedingly rough surface of the "az" lava in the southern part of the Lava Creek district adjacent to the National Monument. This is one of the youngest of the basalt flows in the region.

B. This shows the characteristic outcrop of the Tertiary granite and its tendency to weather into spherical or rounded masses.
INTRUSIVE ROCKS

Tertiary System

Distribution and Age

Granitic rocks clearly younger than the Idaho batholith (late Jurassic) are known along the Middle Fork of the Salmon River and in and near the Wood River region in south-central Idaho. These younger rocks were first recognized by Ross presumably in 1925 or 1926, and since then similar bodies of rock have been brought to light elsewhere. Among these are the intrusive rocks in the Lava Creek district identified by the writer during the field work in 1928.

None of the intrusive bodies in the Lava Creek district is large, all being classed as stocks and dikes. The largest trends from Boyle Mountain southward across Blizzard Mountain and thence southeast to the edge of the basin near the Monument boundary, lying principally within the drainage of Big Cottonwood Creek, but with a part at the head of Lava Creek. This greatly elongated body is approximately six miles long, averaging better than one-half mile wide. It covers about four square miles. The second largest stock covers somewhat more than a square mile, mainly in the upper part of the east branch of Little Cottonwood Creek but with a tongue extending well down the Lava Creek side. Smaller stocks and dikes exist elsewhere, one of some size near the mouth of Little Cottonwood Creek, clearly an offshoot of the larger body. Others outcrop in the upper Lava Creek drainage and on the high ridge between Fish Creek and Dry Fork of Antelope Creek.

The age of these intrusives is obvious from their relationship to Tertiary lavas. The stock on Little Cottonwood Creek intrudes the latites and latite-tuffs, for not only may the irregular roof be seen in the canyon wall, but the lavas have been greatly metamorphosed at the contact and some distance therefrom. The stock on Big Cottonwood Creek has Mississippian beds on one side and Tertiary lavas on the other, but numerous apophyses of granite, cementing the shattered lavas about the margin of the stock, prove conclusively that the lavas were not laid down on the eroded surface of a granitic body. Metamorphism of the rocks about the body of granite gives the same conclusion. Some dikes occur in the lavas and others wholly in the older sediments, but all of them show a similarity of composition and texture which obviously relates and makes them the same age. The age is thus unquestionably younger than the lava series considered as Miocene. Ross finds similar relations to the north and definitely holds the granite to be younger than the lower part of the Tertiary volcanic strata and associated with orogenic movements taking place subsequent to formation of all Tertiary strata in the vicinity. He states further that any exact age of these Tertiary rocks has not been determined, but, on the basis of relations to plant-bearing beds farther east, it is believed that the upper part of the series near the Middle Fork is not older than middle Miocene, and that it is at least late Miocene and possibly Pliocene.

1Ross, C. F., Op. cit., p. 10
General Character

The intrusive bodies mainly have the composition of granite and granite porphyry showing very little variation except in texture. Differentiation has played but a minor role, and only the Little Cottonwood stock has borders in one place more basic than granite. Here a granodioritic and quartz monzonitic composition was recognized, and nearby some small pegmatite dikes. Several other bodies clearly related to the granite, but deficient in quartz, were found and are properly classed as syenites.

Perhaps the most notable feature of these stocks and dikes is their alkaline tendency markedly contrasted to the normal type of the Idaho batholith, although quite in keeping with the character of Tertiary granite described by Ross. The chief minerals are orthoclase and quartz (except in the syenites) with minor amounts of albite, biotite, hornblende, and diopside. In some places, the plagioclase is somewhat more basic than albite and has the composition of oligoclase or acid andesine, but the tendency has been toward the development of alkalic feldspars.

These rocks are also peculiar inasmuch as they lack the texture of a normal granite and are mainly porphyritic and granophyric. Drawing the line between granite and granite porphyry has been difficult in the case of the two largest bodies, with both normal and porphyritic textures represented. Nevertheless these two stocks will be described as granite, although their abnormality is noticeable even in the hand specimens. Some differences are noted about the border of the stocks, for generally along the periphery there is a zone from a few feet to a few hundred feet wide with a much finer grain than the main, coarsely crystalline part of the mass, although of essentially the same composition.

Another striking feature of these rocks is their highly altered character, an alteration not due to surficial weathering, for it is as pronounced in the freshest rocks as those collected near the surface, but which apparently is a result of deep-seated or hydrothermal action. The feldspars have been more or less changed to aggregates of white mica (sericite) and kaolin, in some so completely that even twinning lines of the plagioclase are scarcely recognizable. Further, the biotite and also the hornblende and diopside have been converted largely to chlorite and in many specimens could be identified only from the shape of the chlorite masses. These changes probably were induced in the rock soon after solidification when the gases and hot solutions, emanating from the molten portions below, soaked upward to replace the original minerals by those more stable under the new conditions. These solutions causing alteration of the granites probably in part are related to those from which the ore minerals were deposited.

Granite: The granite comprising the elongated stock on Big Cottonwood Creek shows some differences (largely textual) from the granite on Little Cottonwood Creek. The granite of the larger stock is notably pinkish and coarse-grained throughout. In some places the coarseness of grain persists to the very contact, but in others, particularly near Blizzard and Boyle mountains, the granite becomes fine-grained and more or less porphyritic near the border. The pinkish orthoclase can be recognized as the most abundant mineral, mixed with only a scattering of faint greenish acid plagioclase crystals and a sprinkling of altered biotite or hornblende. Quartz may also be noted, usually in much smaller grains than the other minerals and often as

a fine granular matrix with smaller grains of orthoclase.

A specimen of the coarse-grained granite from Blizzard Basin at the head of Lava Creek is more or less typical of the stock and is composed dominantly of pinkish orthoclase, a few scattered white chalky grains of plagioclase, quartz, and a sprinkling of biotite flakes. The granite is mainly hypsometric granular in texture with a few small patches of micropegmatite. The subordinate plagioclase has the composition of oligoclase. Quartz appears in surprising abundance, more so than indicated in the hand specimen. The orthoclase and plagioclase show the usual excessive alteration, the first mainly to kaolin and the second to white mica. Biotite has largely altered to chlorite and to lesser extent to epidote. The accessories include magnetite, apatite, and zircon.

A rock collected from the dump of the Paymaster mine probably is even more typical of the stock than that from the head of Lava Creek. In external appearance, it resembles the other, but has a slightly coarser grain, with the larger crystals of pinkish orthoclase associated with a finer matrix of orthoclase and quartz, giving the rock a peculiar porphyritic appearance. This rock has a liberal scattering of hornblende as well as a minor amount of biotite, both appearing greenish as a result of their nearly complete conversion to chlorite. In texture, this rock differs markedly inasmuch as it is nearly all granophytic. It has a minor amount of albite, but largely comprises orthoclase and quartz with micropegmatitic or granophytic relation. The accessories are the same and alteration has been equally as great. As most of the stock has a like appearance in the hand specimen, it no doubt has the prevailing composition and texture of granophyre as just described.

The fine-grained, pinkish phase near Blizzard Mountain is notably deficient in dark minerals (about five per cent biotite). This type is slightly porphyritic and contains scattered oligoclase laths of normal size. In some places orthoclase crystals are recognized in a much finer microcrystalline ground mass composed of quartz and orthoclase, with the quartz only slightly subordinated and both occurring in interlocking grains, with some subhedralism on the part of the orthoclase. Patches of granophyre also occur.

The granite making up the Little Cottonwood stock shows a greater range of composition and texture. Near the ridge top it locally has the composition of granodiorite, being represented by a dull, grayish rock of medium grain with only a faint pinkish tint. It is equigranular and has a normal hypsometric granular texture. It is composed dominantly of andesine and accompanied by smaller amounts of diopside (much altered to chlorite and epidote) and lesser amounts of quartz and orthoclase. The andesine forms good idiomorphic laths and is finely twinned. The orthoclase is highly altered, but strangely the plagioclase is nearly fresh. Nearby the rock is pinkish gray and highly porphyritic. The andesine occurs as phenocrysts (50 per cent) in a microcrystalline base of quartz and orthoclase with quartz only slightly subordinated. Much chlorite after diopside (?) is also present. Most of the upper end of the stock, however, has the composition and texture of granophyre. This is a pinkish, medium to fine-grained rock, with very few dark minerals. Fine graphic textures can be recognized even in the hand specimen, and in thin section the granophytic texture is outstanding. Orthoclase and quartz apparently are the only minerals beside the usual accessories. The feldspar shows marked alteration and the secondary products may serve to obscure any plagioclase present.

The main body of the Little Cottonwood stock differs, however, from the
above and may be described as a peculiar porphyritic rock with pale greenish or white albite phenocrysts and chloritic hornblende in a finely crystalline, pinkish or grayish base in which tiny grains of quartz may be readily recognized. Albite is in greater abundance than usual, forming tabular crystals many times larger than the crystals of the fine-grained matrix, rich in quartz and accompanied by only slightly more orthoclase. Magnetite, apatite, and zircon occur as accessories. Feldspars and hornblende alterations have also been extensive.

Two small bodies of porphyritic granite also occur at the mouth of Little Cottonwood Creek to either side of the sink. These probably are continuous with the larger bodies at depth. The one on the north side is grayish and has a sprinkling of biotite. It is porphyritic with phenocrysts of oligoclase and occasionally orthoclase in a fine microcrystalline cement of orthoclase, quartz, and a little oligoclase. This type approaches a quartz-monzonite in composition. The body on the south side of the sink is porphyritic and pinkish, similar to the fine-grained phase of Blizzard Mountain granite. It has scattered crystals of basic oligoclase and altered biotite in a microcrystalline ground mass of short, stubby orthoclase crystals, in turn cemented by micropegmatite, giving an impression of three generations of crystals. Quartz is present in abundance.

Granite Porphyry: Dikes outcropping in the upper Lava Creek drainage and on the high divide between Dry Fork and Fish Creek have a notably uniform composition and texture and may be classed strictly as granite porphyries (quartz porphyry). Large, rounded, and embayed phenocrysts of quartz, ranging up to one-half inch in diameter and set in a dense grayish cryptocrystalline matrix or cement, are the most distinguishing features in these. The quartz is accompanied by variable but subordinate amounts of albite or oligoclase and less commonly orthoclase, all of equal or slightly greater size and of about the same color as the grayish base. Plates of altered biotite and crystals of altered hornblende may be recognized also in some of the rocks.

In thin section, the porphyritic character is more striking as the large rounded and partially resorbed grains of quartz and tabular crystals of albite or oligoclase, and more rarely orthoclase, are in a finely crystalline base of orthoclase and quartz. The feldspars are greatly altered and clouded by sericite and kaolin, making some nearly opaque. The biotite and hornblende show extensive alteration to chlorite. Both occur as scattered phenocrysts but in some smaller crystals are also in the ground mass. The accessories include minor amounts of magnetite, titanite, apatite, and zircon.

Granite Pegmatite: Several small pegmatite lenses were noted in the granite body on Little Cottonwood Creek near the top of the divide, an apparently rare occurrence in the district. These lenticular masses are several yards long and usually about one to two feet wide with well-defined walls. In general appearance, they are similar to the coarse-grained, pinkish granite except that their crystals are larger. One specimen from a coarse-grained, somewhat porphyritic rock contains feldspar crystals an inch long embedded in a granular matrix similar to a coarse-grained granite. Large crystals of quartz may be noted and constitute at least one-fourth of the rock. Graphic or pegmatitic textures are prominent. The thin section shows a few albite laths, wholly enclosed by graphic or granophyric orthoclase and quartz. The dark minerals have entirely altered to chlorite and hematite. Another specimen resembles coarse-grained granite and is without graphic texture. Orthoclase, which appears to be the only feldspar, is almost completely altered, although carlsbad twinning may be recognized. The quartz is relatively abundant.

- 24 -
Biotite, mostly now chlorite, is the only dark mineral except scattered grains of magnetite. Accessories are apatite and zircon.

Syenite: Several of the smaller intrusives have the composition of syenite. These are clearly off-shoots of the larger granite bodies, differing only in a notable lack of quartz. One dike outcrops a short distance above the Golden Chariot veins. It is a pinkish, fine-grained rock with scattered hornblende crystals, some gray feldspars and a much greater amount of pinkish feldspar. The rock is slightly porphyritic and has small phenocrysts of brownish hornblende (berkevite(?)) and scattered albite laths in a microcrystalline base of orthoclase with a little accessory albite, biotite, and quartz. The quartz content is approximately five per cent and the rock may be classed as a quartz syenite. Intense alteration is shown with kaolin, sericite, and solisite abundant. The accessories again are apatite, magnetite, and zircon.

A small stock, a dike, and a sill of syenite of somewhat different appearance outcrop near the top of Boyle Mountain. The sill is in limestone. The rock is pale green to bluish gray, slightly porphyritic and has a few scattered albite phenocrysts and hornblende (altered to epidote) in a microcrystalline ground mass of short tabular orthoclase crystals and a little interstitial quartz, about two per cent. Because of the decided alkaline nature of these rocks, perhaps they are really quartz-nordmarkites rather than true syenites.

STRUCTURE

GENERAL FEATURES

Only the broader structural relations have been determined in the Lava Creek district, for the time allotted was far too short to unravel the complexity of minor folds and faults which have such a close relation to ore deposits. Effort was made to map faults in the Tertiary rocks, in particular, but before many had been studied it was necessary to leave the field. Because of the incompleteness of the work, it was thought unwise to show any on the geologic map. In the broader relations, however, the structure is fairly simple and involves folding, on a broad scale, complicated by faulting.

Two major periods of deformation are clearly recorded in the structural relations of these rocks. The period of most vigorous deformation was that which compressed the Mississippian beds and forced them into great folds and perhaps faulted them, probably as a consequence of the great Cordilleran Revolution near the close of the Mesozoic era. The second diastrophic period was less intensive, throwing the Miocene (?) lava into a gentle fold and breaking it by numerous normal faults. Igneous intrusion accompanied this younger period of deformation and probably was responsible for most of the faults which occur about the bodies of granite in the mineralized areas.

MESOZOIC DEFORMATION

The most notable feature of Mesozoic deformation is a great asymmetrical fold which trends northwestward and appears on the high ridge between Dry Fork and Fish Creek where the Tertiary lava has been stripped away by erosion. The axis of the anticline parallels and lies about a mile to the east of the crest of the ridge passing under the lava on Lead Belt Creek on the north and the lava east of the south branch of Dry Fork on the south. West of the anticlinal axis the beds dip moderately to the southwest at angles ranging from 20 to 30 degrees, becoming steeper near Fish Creek. The east side of the fold is much steeper than on the west and along upper Dry Fork ranges from 50 to 55
A. Blizzard Mountain, the highest point in the district, from the edge of the Snake River Plain less than three miles away. The dark rocks on the left are quartzites and the light rock in the center running to the top of Blizzard Mountain is the body of Tertiary granite.

B. Characteristic erosion of the Tertiary lava in the Champagne Creek drainage. Timber Mountain, the high point on the left. The white areas in the middle distance are patches of hydrothermally altered andesite and exposures of bedded tuff.
degrees. But on the high ridge, enclosed by Dry Fork, the dip flattens to 20 degrees and on the lower east slope is tilted the other direction because of a minor fold. The general easterly dip is maintained to the lavas within Champagne Creek drainage, but a probable major fault here has interrupted the continuity and caused the series to be duplicated on the east side. The trend of the beds has been changed somewhat on the east side of the fault, a result of many other breaks of undetermined displacement. These have caused the bed to strike northwest at a much wider angle, although the same general trend and easterly dip is resumed along the west side of Timber Mountain. The nature of the faulting is not wholly determined but the larger faults apparently trend northward nearly parallel to the strike of the beds, with those of lesser magnitude striking northeast. The magnitude of these was not determined exactly but probably amounts to from a few dozen feet to many hundreds of feet. Much faulting of minor magnitude is shown on the ridge west of Big Cottonwood Creek, but displacements have been insufficient to destroy the general westerly tilt and the northwesterly trend of the sedimentary formation.

TERTIARY DEFORMATION

The Tertiary deformation is more important than earlier diastrophism so far as economic features of the district are concerned. Intrusion of granitic stocks and dikes near the axis or center of a broad gentle anticline or dome in the Tertiary lava and shattering of the rock possibly by the force of the intrusion is the most striking feature resulting from these movements.

Folding

The Tertiary lava no where is horizontal, but is tilted at angles varying from eight to 35 degrees. Some of the greater dips represent tilted fault segments, but the rocks as a whole form a great fold or anticline, more or less dome-shaped, the crest of which is about a mile and one-half east of Blizzard Mountain. The axis of the anticlinal dome trends west of north nearly parallel to the folds involving the Mississippian beds, but with the axis more than a mile east of the older anticline axis. The axis of the younger dome may be followed from the edge of the line of craters at the Monument to Dry Fork with the Lava Creek vents on or very near the axis, and then again continued in the lavas east of Lead Belt Creek far beyond the mapping limits. East of the axis the flows and tuff beds dip eastward at a moderate angle averaging between 10 and 20 degrees, this structure being maintained far to the north and east of Timber Mountain to the Snake River Plain. On the west, the beds have a more gentle tilt, this westward dip having been observed far beyond the head of Fish Creek. Apparently the anticline plunges gently to the north and south from near Blizzard Mountain, for partial closure is seen in the lava when dips and strikes are plotted. Intrusions of granitic rock apparently have been near the crest of the anticline or dome and may have played a very important role in shaping the structure.

Faulting

Most faulting in the Tertiary lava and perhaps in the older sediments is either along or near the axis of the broad anticline or not far from masses of granitic rock showing at the surface or inferred to exist at depth. The faulting is mainly normal and due not so much to collapse of roof as to upward pressure that might be exerted by a rising granitic magma. The fault pattern is of the mosaic type generally found about igneous bodies, so completely described at Tonopah and the Bull Frog districts in Nevada. Many faults trend northeast with angles ranging from N. 30° E. to N. 60° E. Some strike north-
west nearly parallel to the older structural lines, while others have apparently no definite trend, intersecting or stopping against each other in a most confusing manner. The displacement of these is undetermined, but apparently is not great, most of these a few dozen feet to perhaps several hundred feet. Faults encountered underground have a steep dip.

The faulting is pronounced in the mineralized area on Champagne Creek, in the Lava Creek mineralized area and in the region between. Most faults are difficult to recognize on the surface because of poor rock exposures, a result of intense and widespread hydrothermal alteration that has softened and made the rocks particularly susceptible to weathering and reduction to smooth slopes. The faulting in the Champagne Creek was not worked out in detail, but the mineralized fissures have a general northward trend, varying usually less than 20 degrees on either side. Most fissures examined dip steeply to the west. This special locus of mineralization suggests the presence of an underlying granitic stock that shattered the rocks during its intrusion and not yet exposed by erosion. The relations along Lava Creek are similar except that the intrusive rocks are exposed at the surface and most of the mineralized fissures trend nearly east or west, at right angles to those on Champagne Creek. A northerly trending set is also developed, but is apparently less prone to mineralization. The fissures dip either north, south, east, or west at a steep angle. In the region between Lava Creek and Champagne Creek, which has escaped mineralization, the faults are more easily recognized forming a regular mosaic pattern.

Grouping of faults near the granitic masses and their scarceness in the lavas outside the district suggests that intrusions have been mainly responsible for local shattering. Some of the faults, especially the normal faults of considerable magnitude, approximately paralleling the general trend line of the folds, may be more related to the folding or uplift than to intrusion. One such fault cuts through the fault mosaic a short distance west of Champagne Creek. The pink granite lies not far from the axis of the broad anticline which so involves all Tertiary strata of the region as to indicate that its intrusion and the folding are genetically related. Most of the intrusive masses are elongated in the direction of the axis of the fold, but a few smaller ones cut across the anticline at right angles.

Little faulting, so pronounced in the lava, appears in the granite and for this reason the faulting was mainly completed before or during the magma intrusion. As volcanism in the area probably persisted into the Pliocene epoch, the associated earth movements likewise continued into that epoch and even later. As evidence of revived earth movement recently is the "Great Rift" in the National Monument along which interesting volcanic vents are located and which extends into the district at least as far as the Lava Creek vents. The "Great Rift", really a great crack in the earth's crust, is in direct alignment with the anticlinal axis of the Tertiary fold.

METAMORPHISM

One of the conspicuous features associated with granitic intrusions is the degree of contact metamorphism shown in the sedimentary rock and especially Tertiary lava. About the larger stocks are wide zones of altered rock, some extending dozens of feet from the contact, showing a similarity to both the fine-grained marginal granite and to the Tertiary lava. Such zones were noted in particular on both sides of the stock on Little Cottonwood Creek and near the top of Blizzard Mountain where a boundary between granite and lava was difficult to determine. In general, the lava has been altered to a dense, fine-grained, grayish to greenish rock without recognizable minerals. Some are
When the rocks are examined microscopically, the contact metamorphism becomes evident. In specimens collected, as much as a hundred feet from the known contact on the east and west sides of Little Cottonwood stock, the lava or tuff has been almost wholly replaced by small to large grains of diopside and albite as well as by minor amounts of biotite, orthoclase, zoisite, apatite, zircon, magnetite, and spinel. Only faint outlines of the original rock texture and the phenocrysts remain. In one rock, not as highly metamorphosed as the others, the hornblende and biotite, and especially the plagioclase, show extensive replacement by epidote and zoisite. The rock has a distinct greenish color in the outcrop.

Metamorphism of the sedimentary rocks has not been as pronounced, but in the limestone that is in contact with the syenite dikes and sill on Boyle Mountain, the metamorphic zone extends into the limestone for several feet and as a result of which actinolite, phlogopite, muscovite, magnetite, diopside, plagioclase, epidote, orthoclase, apatite, zoisite, zircon, grossularite, spinel, and rutile has been formed.

GEOLOGIC HISTORY

Great thicknesses of sandstones, shales, and limestones of upper Mississippian age records the earliest history of the Lava Creek area, but the geologic study of nearby rocks goes back to a much earlier time.

Possibly, for a long period during Algonkian time, the region was submerged under a sea in which a great thickness of sediments accumulated. These sediments were consolidated, folded, intruded by small igneous masses, and metamorphosed apparently before the dawn of the Paleozoic era. The sediments are now found to the north of the Lava Creek district near Mount Hyndman and in the north end of the Lemhi Range where subsequent geologic events have left their effects, until now they are highly metamorphosed and greatly disturbed. Southeastward, the region probably was land during much of the Algonkian period, but whether the Lava Creek district was above the shallow epicontinental sea may never be entirely known.

With the beginning of Paleozoic time, another era of prolonged sedimentation started during which thousands of feet of beds were laid down. These seas advancing first from the north and then from the southwest covered most of southeastern Idaho and possibly part of the site of the Salmon River Mountains, although the old shore-line apparently lies near the eastern and southern border of these mountains. Sea withdrawals and new encroachments are numerous within and between each period of the Paleozoic. The record in the Cambrian epoch is not so clear in the region north of the Snake River Plain, but to the south is represented by conglomerate, limestone, and shale more than 6,000 feet thick. Sands were deposited in early Ordovician, but ceased abruptly halfway through the period, with thick layers of magnesian limestone and dolomite accumulating throughout the remainder and again during early Devonian. Near the western margin of the sea, however, the deposits continued distinctly sandy and clayey throughout the Ordovician. Later, in the Devonian, calcareous clay beds were spread upon the ocean floor and soon covered with limestone and dolomite. Sedimentation conditions varied greatly in the Mississippian epoch. Near the site of Mackay, more than 6,000 feet of limestone beds were deposited. These, however, thinned to the east and changed character greatly to the south and west, for in the Lava Creek district probably an equal thickness of sandstones, shales, and limestones were laid down. Apparently the Lava Creek region was nearer the old shore line than the Mackay region and the country to the east and received sediments of coarser, more siliceous and argillaceous
character from a land mass existing to the west. The change in near-shore sedimentation is noticeable even within the district, for the limestone is thicker and the shale and sandstone beds apparently thinner near the east boundary than the west. Conditions of sedimentation remained practically unchanged through the Pennsylvanian epoch, more than 8,000 feet of sands, gravels, clays, and limestones accumulating in the Wood River region to the west. During the Permian, great phosphate beds were deposited many miles to the southeast, and thousands of feet of lava flows and pyroclastic deposits accumulated in the west. No record of either, however, is to be found in the Lava Creek district or immediate vicinity.

Extensive orogenic movements came during late Mesozoic and occasioned uplift and broad-scale folding and faulting. The folds were developed along northwest axes under compressive forces so intense that many were overturned and broken by overthrusting. About this time, probably during and following the dynamic activity, came intrusion of the Idaho batholith to the north. Most Idaho ore deposits generally are believed to have been formed at this time and to be genetically related to the batholithic intrusion.

So far as the record is legible, erosion was the dominant feature at the end of the Mesozoic and during early Tertiary. Possibly mountains formed by Mesozoic diastrophism had been worn down to low and gentle relief by the beginning of Tertiary time, but if so the land was subsequently elevated and by middle Miocene had been carved by broad, deep valleys. Then volcanism broke out on a grand scale and the valleys were flooded far below present drainage lines by andesitic and rhyolitic lavas. Thousands of feet of these lavas and their associated pyroclastics were piled upon the surface, eventually covering the entire landscape.

Diastrophism also was associated with the Miocene (?) igneous activity, but less violently than that of Mesozoic. The region was elevated and the lava thrown into gentle folds and broken by numerous normal faults. This diastrophism was accompanied by intrusion, with granite and its associated dikes forced upward until they penetrated the lower Miocene (?) extrusive series. This is the period in which the Lava Creek district are deposits were formed. Volcanism in the general region probably persisted into the Pliocene epoch, the associated earth movements likewise continuing into that epoch and even later.

Following the late Miocene diastrophism came uninterrupted erosion that stripped away most of the extrusive rock covering and by late Tertiary time had reduced the region to rather low relief. Warping perhaps was again active, this time on a vast regional scale which further depressed the great Snake River Valley and elevated the land to the north. As a result, active erosion was again inaugurated and continued to the present, but not without some oscillation of the earth's crust that has made physiographic history from the Pliocene epoch to the present an eventful one, although not wholly understood. During this time the Lava Creek district was carved into its present relief.

The last of the Tertiary and Quaternary periods were not without igneous activity, for many vents poured out vast floods of basalt on the surface and built up the Snake River Plain and encroached upon the flanks of the mountains to the north, then undergoing dissection. Some lava was added to that on the Plain from vents perched high on the mountain side in the Lava Creek district, but such flows apparently have contributed little toward formation of the vast lava field. Extrusions of basalt probably began in the Pliocene and have continued to the present time. The Lava Creek district has the distinction of having partially within its borders the youngest flows on the Plain, regarded
by some as having been poured out less than a thousand years ago.

ORE DEPOSITS

HISTORY AND PRODUCTION

Mining activity in the Lava Creek district began in 1883 with discovery of silver ores in the outcrop of the Ella vein near the head of Champagne (Era) Creek. No particular attention was drawn to the district, however, until the following year when rich surface ores of the Hornsilver mine were found directly across the valley from the Ella. Production started within a year and during 1886 several thousand dollars worth of ore were marketed, after being hauled by wagon across the Snake River Plain to Blackfoot and thence by narrow gauge railroad to Salt Lake, Utah. The richness of the ore caused a large influx of prospectors and shortly several more discoveries were made, among these the Reliance, Last Chance, Polyx, and St. Louis on Champagne Creek, and the Hub on Lava Creek.

The Hornsilver mine, originally located by Frank Martin, was sold in 1885 for a consideration reported to be $55,000. Work was begun on a 20-stamp mill, completed in August 1886 and operated first in October of the same year. This mill continued to operate until August 1887, treating the ores of five or six mines in addition to that of the Hornsilver. When the rich, oxidized silver ores were exhausted and base-metal sulphides encountered, the mill was made useless. During the short time the mill was in operation, it is estimated that $200,000 was produced from oxidized silver ores and of this amount $250,000 from the Hornsilver alone. The Hornsilver was revived in 1893, but the mill operated but a few months as the unoxidized ore was not amendable to amalgamation. During the early period of operation, a roll mill of 10 tons capacity was also erected and treated ores from several of the mines.

The district's rise was rapid owing to many discoveries of rich silver-bearing veins at about the same time, and its decline was equally rapid, due to general impoverishment at a very shallow depth. During this active period the hills swarmed with prospectors and the former town of Era was a thriving settlement that boasted two stage lines, three stores, several lodging houses, and many more saloons. In the territorial election of 1886, more than 100 votes were cast. Failure of the mines caused the town to be abandoned and the site is now marked only by cellars and building foundations, and even these difficult to recognise. The stamp mill, a mile or more below the former thriving settlement, has long been dismantled and only the foundation marks its site. It is reported that 600 claims were recorded at one time.

The Hub mine, discovered and worked about the same time as the Hornsilver, is the largest on Lava Creek and had an estimated production of $30,000. About half of this amount came from ores hauled to the Nicholus smelter during the few years following 1886, and the remainder from scattered shipments in later years.

The Lead Belt region was actively prospected at the same time, but as there were no railroads within a hundred miles little work other than exploratory was done until later. Consequently, not until 1906 were the deposits extensively developed, and the first production made in 1908 when several shipments of silver-lead ore were marketed. In 1910 more work was done and three carloads of ore were reported to have been shipped. Principal production was not until 1913 when 21 cars of 50 tons, each averaging 10 per cent lead and 16 ounces of silver to the ton, were shipped from the mines. As these properties are still so far from railroad, even completion of the Mackay branch
of the Oregon Short Line has not made exploitation particularly successful.

After the collapse of the early mining activity, the region as a whole has been relatively inactive and practically forgotten. True, attempts have been made from time to time to revive some properties but with little or no capital. Assessment work has been done on some of the properties for year after year, but a more popular method of holding the prospects has been to refilfe on them annually. Many properties have fallen into disrepair and are no longer accessible underground, others have had only sufficient work done to keep them partially open. A few have yielded a small production from time to time.

Not until several years after the World War did the district receive any special attention and then not for silver but for the possibility of utilizing base-metal sulphides as ores of lead and zinc. Early in the present decade, the old Last Chance and Hornsilver mines were acquired by the Dahle brothers and organized as the Horn Silver Consolidated Mines Company, work being started on a long crosscut to intersect the veins at depth. Several thousand feet of tunnels and drifts have been driven and at the time of the writer's visit in 1928 the Last Chance vein was being explored, the crosscut not as yet having reached the old Hornsilver vein. Awakened interest revived other properties. Among these was the St. Louis from which several shipments of ore were subsequently made, some as late as 1926. A new producer entered the list early in 1928 when the Silver Bell on lava Creek sent a car-load of ore to the smelter with returns over $50 per ton.

The rich shipment from the Silver Bell attracted the Federal Mining and Smelting Company who early in the summer of 1928 acquired control of the property and began an intensive prospecting campaign. Development continued until January 31, 1929, when further exploration was abandoned because disclosures were of such size as to be unattractive to large-scale operation. The entrance of the Federal Company greatly stimulated activities in the district with prospecting and development reaching a high stage during 1928. What effect their withdrawal will have yet remains to be seen.

In all, the district has produced slightly less than half a million dollars, most of it from the rich bonanza silver ore in the early days. More than half of this amount came from one mine, the old Hornsilver.

**GENERAL CHARACTER OF DEPOSITS**

Deposits of the Lava Creek district belong to that group which has been shown to be of late Tertiary age and in or closely related to lava and tuff. In most places, Idaho and elsewhere, Tertiary lodes are valuable, principally for their precious-metal content, and have merely accessory base metals, if present at all. Such typical occurrences have been described by Ross in the Salmon River Mountains of Idaho where the lodes, valuable for gold and silver, contain predominantly cryptocrystalline quartz with metallic minerals seldom visible except as bands of black, extremely fine particles including selenides, pyrite, galena, chalcopyrite, and other sulphides. To find base metals in deposits of this age in commercial amounts is exceptional, although several occurrences are known. In the Lava Creek district, the ores are base metals, including mainly argentiferous galena associated with zinc sulphides and whose oxidation has yielded rich surficial silver ores. The deposits are, therefore, unique and of more than ordinary interest.

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The lodes in general occur as fissure veins or brecciated zones in which replacement of highly altered walls or wall fragments has been the dominant process. Fissure filling has played a part also in some of the lodes, but in a subordinate role to replacement. Ore has mainly formed in some by deposition along fractures, but the same lode generally has ample evidence of replacement in other parts and it is difficult to classify any as either distinctly fissure fillings or replacements. Only a very few are characterized by open clefths and drusy quartz, and as such are partial fillings in brecciated volcanic rock. Some occur in limestone as fissure fillings. In most of the others the veins are tight with the ore in clean seams or lenses, or disseminated in the wall, particularly lodes in the volcanic rocks and especially those containing argentiferous galena and zinc sulphides.

Classifying the deposits according to the chief metal content is difficult to make, for the deposits range from high-grade silver lodes to zinc veins and lead, with the exception of one deposit that contains only antimony, another that contains only tungsten, and one that only has a little copper. The Hub mine has silver as its chief value, occurring mainly as polybasite with minor amounts of argentiferous galena. This deposit is valuable mainly for its silver content and should be classed as a silver deposit. The St. Louis vein has also high values in silver, but contains considerable galena and zinc sulphides, as well as a bismuth mineral which might be valuable as a by-product. Silver occurs both in argentiferous galena and in the bismuth mineral, especially the latter. Again this deposit is essentially a silver one. In all the deposits worked in the early days, silver alone was sought, but as enriched silver ores at the surface are no longer present, it is difficult to classify many from their primary ores. Many are low-grade lead-zinc deposits with important amounts of silver, some are essentially silver-lead deposits, and several are essentially zinc deposits with lead as a by-product. In all of them, galena is silver-bearing and apparently furnished the silver for most of the rich surface ores. As the galena varies in subordinate to important amounts in most of the lodes, any classification that might be made purely as zinc or silver is complicated.

Additional interesting features of these deposits are occurrences of two forms of zinc sulphide - wurtzite and sphalerite - and of two forms of iron disulphide - marcasite and pyrite. Wurtzite is the hexagonal form of zinc sulphide and sphalerite the isometric form, the two being deposited under different chemical and physical conditions. Marcasite and pyrite, also of the same composition, and likewise differing in crystallization, are deposited under certain conditions analogous to the zinc sulphides. To find these intimately associated in the same deposits as primary minerals is most extraordinary.

MINERALOGY OF THE ORES

The district has an unusually long and interesting list of minerals with several comparatively rare and several with extraordinary associations of which the two zinc and iron sulphides have been mentioned. These minerals will be enumerated and brief notes will be given of their occurrence. For convenience, they will be treated under several headings as primary metallic minerals, gangue minerals, and secondary minerals or products of alteration, each listed in order of value of metal or other distinctive features. It has been necessary in this treatment to include some sulphides, really gangue minerals, with primary metallic minerals and reserve for the gangue minerals those of non-metallic character.
Galena: - Galena, lead sulphide (PbS), is the most valuable as well as the most widespread of the ores in the district. In some of the deposits it is the chief sulphide, but in others it is associated with zinc sulphides and pyrite as well as with minor amounts of other minerals. The galena is argentiferous and undoubtedly furnished most of the secondary silver ore that occurred near or at the surface of many veins. Some of its silver content is due to minutely enclosed grains of tetrahedrite but apparently in most of it the silver must be in solid solution as argentiferous galena. In general, the galena carries more than one ounce of silver to the unit of lead. The galena is usually coarse, cubical, and forms lenses, nodular masses or seams, but some of it occurs as disseminated grains in the wall rock. In the Paymaster mine, much of it is fine-grained and intimately associated with pyrite, pyrrhotite, and sphalerite, resembling some fine-grained ore of the Coeur d'Alene district.

Sphalerite: - The isomeric form of zinc sulphide, sphalerite (ZnS), is abundant in most of the ores and in the Paymaster and Last Chance surpasses galena. A great color variety is shown in several deposits, ranging from metallic steel-gray to grayish black, pale brown, yellow, green to brownish, and bright red. Lighter colored occurrences have pronounced resinous lustres, but the steel-gray and black are metallic in appearance, recognized from the galena only by close observation and by the brownish streak. The peculiar metallic type is found only along Lava Creek and in deposits near the two Cottonwood creeks, usually with the black and dark brownish-red variety. This unusual type when examined microscopically usually is filled with tiny chalcopyrite grains arranged in definite rows or lines as though it formed from an unmixing of a solid solution from the sphalerite in which it was dissolved. Sphalerite in deposits along Champagne Creek are of usual light color and almost free from chalcopyrite inclusions. In this district, yellow and pale brown varieties are most common, although merged with darker shades, and intimately associated with wurtzite undistinguishable from the isometric form, except microscopically. A small amount of the reddish variety is found in the Last Chance vein. Sphalerite in the Paymaster occurs in coarse crystals as well as being intimately associated with galena in fine-grained ore. In other deposits, it occurs as masses or lenses, or is disseminated in rounded grains in the wall rock, developed by replacement.

Wurtzite: - Wurtzite (ZnS), the hexagonal form of zinc sulphide, apparently is confined to Champagne Creek deposits where it has the same pale to reddish-brown color as the sphalerite. It seems abundant in the ores and even may surpass the sphalerite. It usually is intergrown with sphalerite in the same grains or masses suggesting that the two were formed essentially at the same time and before the galena was deposited. In the St. Louis, wurtzite and sphalerite occur together in the vein as well as in disseminated grains in the altered wall rock. Some wurtzite has a distinct hexagonal outline, but more commonly occurs in concentric shells or with semiform structure. It is best recognized in thin section by its pronounced anisotropism. Wurtzite also seems abundant in the Last Chance vein and was recognized in some of the others

Aukinite: - This comparatively rare mineral, aukinite, a sulphide of copper, lead, and bismuth (Cu₃S₂Pb₄Sb₂Bi₅S₄), is rather generously distributed through the St. Louis vein, was recognized in assorted ore at the Reliance, and again in very minor amounts in the last Chance ore. It is unusual, however, in that it carries high silver values. The mineral has a blackish lead-gray color and gives the same stagmatism. In the St. Louis vein, it occurs in microscopic crystal to compact, massive seams and lenses several inches wide and may be recognized
easily in the hand specimen. It usually occurs in tabular or acicular, orthorhombic crystals showing pronounced anisotropism with reflected polarised light. The individual crystals usually are small, those in the Galena ore specimens showing largest sizes. In the St. Louis ore, the mineral is intimately associated with an undetermined pale yellowish mineral occurring as minute inclusions within the other. It usually is associated with chalcopyrite, about contemporaneous, although the chalcopyrite in places shows minor replacement and is in part younger. The alkinitite also shows replacement of galena as well as cement fractures in wurtzite and sphalerite. For the most part, it occurs in scattered crystals or grains in the matrix of a carbonate gangue. The mineral gives a strong bismuth reaction with a potassium iodide-sulphur mixture before the bismuth and also gives good qualitative reactions for lead, silver, and copper. An approximate quantitative analysis was made of the impure material and when deduction was made for chalcopyrite, dolomite, and insoluble gave for the remainder about 30 per cent lead, 7 per cent copper, 33 per cent bismuth, 10 per cent silver, and 20 per cent sulphur. This apparently does not correspond to any described mineral, but if the silver is assumed to be isomeric with the lead, it gives a formula which closely approximates alkinitite. It may be a new species but until a more dependable analysis is made, it is best referred to as alkinitite. The high sulphur value may be due to other metallic sulphides not detected in the analysis, as the analysis failed by more than 12 per cent to total a hundred. The bismuth mineral is thus a valuable source of silver and may be regarded as a silver ore. Some impure ore gave values of 800 ounces in silver alone.

**Polybasite:** - The silver sulphantimonide, polybasite \(9\text{Ag}_2\text{S}\cdot\text{Sb}_2\text{S}_3\), occurs in variable amounts in the ore at the Hub mine and is abundant locally. It occurs in the richer ore as flakes or films in fractures in the quartz and rhodochrosite, and usually is associated with a young generation of chalcopyrite. It also occurs disseminated in small, variable amounts with other minerals, showing replacements of pyrite and other sulphides. The polybasite is iron-black and its streak usually black and only occasionally reddish. It does not show red by internal light from reflected polarized light. This mineral probably is the chief silver mineral at the Hub, but was not identified elsewhere.

**Stibnite:** - The sulphide of antimony, stibnite \(\text{Sb}_2\text{S}_3\), occurs as the only recognized sulphide in a single deposit on Java Creek as a filling in brecciated, silicified limestone in coarse, columnar or bladed forms, from one-half to one and one-half inches long. These also form radiating groups of crystals as well as a porous network. The crystals are striated or furrowed vertically.

**Hübnerite:** - The manganese tungstate, Hübnerite \(\text{Mn}_2\text{WO}_4\), occurs in platy aggregates or as occasional black crystals and bladed masses with drusy quartz, heavily stained with manganese oxides, in a deposit near the top of Blizzard Mountain. The crystals usually are long, bladed, black in color, and with a reddish-brown streak.

**Chalcopyrite:** - Chalcopyrite \(\text{Cu}_2\text{FeS}_3\), is nowhere abundant in the district, but invariably is present in minor amounts in most of the ores. In a vein at the Golden Cariot, it occurs alone associated with specularite and drusy quartz. It usually occurs as scattered grains or masses crystallizing later than the other sulphides, and also more peculiarly as minute grains or blebs arranged along dodecahedral cleavage lines in the sphalerite. Some sphalerite literally is filled with the copper mineral. It apparently occurs in several stages of deposition for at the Hub it is noted not only as inclusions in the sphalerite but also as younger generation with polybasite. In the St. Louis vein, it occurs in ramifying veinlets in shattered wurtzite and sphalerite.
along with calcite and shows replacement of other sulphides. It accompanies aikinite.

**Tetrahedrite (Gray Copper):** The copper sulphantimonide, tetrahedrite (4Cu₃S·8Sb₂S₃), occurs sparingly in some lead ores. It usually forms minute grains in the galena and is recognized only microscopically. The mineral is most abundant in the Ella ores and in others occurs as scattered grains or is entirely wanting. It probably is one of the minor silver ores.

**Argentite (Silver Glance):** The silver sulphide, argentite (Ag₂S), is reported to have been abundant as a secondary mineral in the enriched ores, but is generally lacking in primary ores. Some argentite, possibly primary, was recognized in the Edna, occurring as occasional grayish masses showing particular affinity for the galena and replaces the galena from the outer margin or periphery. Some argentite also was noted in the ores at the Diamond prospect.

**Proustite:** Light ruby silver, the silver sulpharsenite, proustite (3Ag₂S·2As₂S₅), is reported by Umpleby to be present in the Hub ore as minute crystals embedded in gangue and intergrown with pyrite, and also as narrow veinlets cutting across the sulphide ore. He also reports proustite in the ore at the Ella, probably as a secondary mineral. Proustite was not identified in any of the ores studied by the writer. Some of the polybasite at the Hub mine has a reddish streak but microchemical and optical tests showed this to be polybasite and not proustite.

**Stephanite:** Another silver sulphantimonide, stephanite (5Ag₂S·8Sb₂S₃), has been reported in the Hub by Umpleby with its occurrence the same as for the associated proustite. Stephanite has the same color and streak as polybasite, but was not recognized in any ore examined by the writer. All suspicious specimens were given positive optical and microchemical tests for polybasite.

**Gold:** Gold occurs in minor amounts in some of the deposits as detected by assays, but generally is unimportant as an ore, strangely so because Tertiary deposits usually are valuable for gold and silver alone. The Hub reports as much as $8 in gold associated with quartz and rhodochrosite. The Martin lode contains the highest gold values, some ore carrying three-quarters of an ounce per ton.

**Pyrite:** Pyrite (FeS₂) is the most common sulphide of iron and is incidentally the most widespread and usually the most abundant sulphide, though of no commercial value. It is associated with all deposits and occurs not only in the vein with the other sulphides but is distributed abundantly through the wall rock, commonly for dozens of feet from the veins. Crystal sizes range from nearly microscopic to an inch or more. One-fourth inch ones are most common. The crystals generally are cubes, mostly striated, but many pyritohedrons may also be recognized. In the Last Chance vein, pyrite apparently is associated with marcasite and occurs in reniform and globular masses, after showing a radiating structure.

**Marcasite:** The orthorhombic form of iron sulphide, marcasite (FeS₂), was noted only in Champagne Creek ores associated with the more abundant isometric pyrite. It was noted in particular in the deposits in the Last Chance, Mernsilver, and St. Louis veins, occurring as globular and reniform masses identical to the pyrite, but recognized by its anisotrophia with reflected polarized light. Marcasite obviously is a primary mineral of these deposits and occurs far below the zone of surface alteration. It is interesting to note that the marcasite occurs in the same deposits as wurtzite.
Pyrrhotite: The magnetic sulphide of iron, pyrrhotite \((\text{Fe}_3\text{S}_8)\), is intimately associated with pyrite, sphalerite, and galena at the Paymaster mine on Big Cottonwood Creek, especially in fine-grained ore. It occurs as minute grains and granular masses, best recognized microscopically although locally perhaps abundant. Some occurs as minute grains or blebs along crystallographic partings in the sphalerite, analogous to the chloropyrite. Pyrrhotite also was recognized in the ore at the Diamond prospect. Its presence in the ore is significant as indicative of high temperatures at which the minerals were deposited.

Arsenopyrite (mispickel): The iron sulpharsenide, arsenopyrite \((\text{FeAsS})\), was identified in one specimen of Paymaster ore occurring as scattered crystals associated with pyrite, pyrrhotite, sphalerite, and galena. It also occurs more abundantly in the Hub vein where it forms well shaped tabular crystals in a rhodochoresite gangue.

**GANGUE MINERALS**

Quartz: Quartz \((\text{SiO}_2)\) is by far the most abundant gangue mineral in the vein and lodes and is exceeded only in a few by calcite. Most characteristically it occurs as the cryptocrystalline variety and occasionally as chalcedony, mainly as a replacement of intensely altered wall rock. In general, a notable lack of crustification and banding such as is common in most Tertiary veins is shown. The quartz usually was the first mineral to be deposited and has been replaced or cemented by the sulphides. The quartz also occurs in a younger generation in veinlets cutting the earlier quartz and sulphides. In several deposits, the quartz is of the phenocryalline variety and is coarse in texture and in crystals which point into the veinlets toward a well-defined median plane with drusy surface. Drusy quartz crystals are particularly prominent in the tungsten on Blizzard Mountain and in the copper vein of the Golden Chariot group. In the latter the crystals are as long as one and one-half inches and in part are purplish colored or amethystine. Usually the interior or base of the crystals is colored, the exteriors being colorless or milky. The Golden Chariot vein also contains a minor amount of pseudomorphous or hackley (lamellar) quartz, forming a delicate cellular network of thin, straight, intersecting laminae. The meshes consist of a narrow median line adhered on both sides by quartz, projecting as minute crystals on the surface of the laminae. Such hackly, pseudomorphs probably are after calcite.

Calcite: Calcium carbonate, calcite \((\text{CaCO}_3)\), occurs in most veins, usually in subordinate amounts, and as one of the last deposited minerals, often in veinlets cutting the quartz and sulphides. It is, however, the chief gangue mineral in the Lead Belt district where it exhibits large rhombohedral crystals part older than the sulphides and part younger. Some has a pinkish tinge and is slightly manganiferous, probably the variety known as manganocalcite, and occurs locally with rhodochoresite.

Rhodochoresite: Manganese carbonate, rhodochoresite \((\text{MnCO}_3)\), is an important gangue mineral at the Hub mine as well as some veins on Lead Belt Creek. It is characterized by its pinkish color and rhombohedral cleavage, and on oxidation yields abundant black manganese oxide \((\text{spilocmelane})\).

Barite (heavy spar): Barium sulphate, barite \((\text{BaSO}_4)\), was found in a single vein encountered in the long crosscut to the last Chance vein on Champagne Creek. It forms large crystals associated with iron sulphides and arsenopyrite. Umpleby reports barite in another vein near the old Hornsilver, no longer accessible.

- 36 -
Dolomite: - Calcium-magnesium carbonate, dolomite (CaCO₃-MgCO₃), was recognized in the St. Louis vein in small veinslets in the shattered sulphides, and more or less contemporaneous with the mikanite and chalcopyrite, though outlasting the sulphides. It builds good rhombohedral crystals in the open clefts and is accompanied by calcite.

Specularite: - The specularite variety of hematite (Fe₂O₃) is an abundant gangue mineral in the Golden Chariot vein accompanied by drusy quartz and chalcopyrite. It occurs in black scales and plates, beginning its crystallization shortly after that of quartz, but ceasing before much quartz had been deposited. The scales range up to one-fourth inch in diameter. In some clefts, the thin laminae or plates project outward with the quartz crystals, but generally iron oxide forms the base for the quartz crystals.

Sericite: - Sericite, a variety of muscovite (hydrous silicate of potash and alumina) cannot be regarded as a true gangue mineral, but is produced through hydrothermal alteration of wall rock enclosing veins in this district. It is important to the miner and prospector as it shows localities which have been courses of mineralizing solutions. Sericite occurs in minute scales and flakes, often so exceedingly small that even a high powered microscope fails to resolve individual particles. It occurs as a replacement of wall rock minerals, usually the feldspars and is often accompanied by deposition of secondary silica and disseminated crystals of pyrite. Sericite is widespread in the district and extends many feet from the veins, with gradually diminishing intensity, in a broad halo surrounding the center of ore-deposition and hydrothermal activity. This type of alteration (usually shown at the surface by lava bleaching) is accomplished by hot alkaline waters and such waters in most cases have deposited metalliferous ores.

Leverrierite: - Leverrierite, a hydrous aluminum silicate, known also as gouge-clay or beldellite, was recognized underground in the Last Chance and at the Paymaster where it fills rock fractures as a soft, white, soapy mass resembling lard. When dry, the clay resembles hard soap. Its structure is laminated and platy, and when placed in water the material softens and cracks up gradually. Under the microscope, the material is transparent, colorless, and entirely crystalline with a finely foliated structure. It is birefringent with indices lower than kaolin or sericite. This mineral has excited considerable interest with those noting its occurrence.

Halloysite(?): - Halloysite, another clay mineral, was tentatively identified in wall rock of some deposits, probably a product of hydrothermal alteration. Feldspars have been replaced by a white clay substance, amorphous and isotropic under the microscope, and answering the description of halloysite. It is particularly abundant in some of the silicified lava where the quartz occurs as chaledony.

Chlorite: - Chlorite, the name given to a large number of species of hydrous silicates of ferrous and ferric iron, alumina, and magnesia, was noted as a gangue mineral in the Paymaster ore. It occurs in included fragments of the wall, in part intimately mixed with the sulphides and also in the quartzitic wall to which it gives a greenish color. Chlorite is also a product of hydrothermal action and in this case apparently has been replaced in part by the later sulphides.

Epidote: - Epidote is a silicate of lime, ferric iron, and alumina, noted in tiny yellowish green crystals in wall fragments of the talcite tuff in the Golden Chariot copper vein. It is secondary, developed as a result of hydrothermal action on the minerals in the tuff.
The secondary ores to date have been most profitable. Early work, however, stripped the veins of the rich oxidized silver ore and these no longer are important. There remains, however, a great number of secondary minerals that may be found in minor amounts in many outcrops. Some of these minerals are of interest.

Cerargyrite (hornsilver) - The chloride of silver, cerargyrite or hornsilver (AgCl), probably was the most valuable of early silver ores. Very little may be found in the district today. Its occurrence was very near or at the surface of the veins and generally did not extend more than 15 feet below.

Proustite - The proustite mentioned by Umpleby as occurring in Clammeage Creek ores might be secondary as it is associated with argentite and other secondary minerals.

Argentite - Argentite, also listed under the primary ores, was reported to have been abundant in rich surface ores as a secondary mineral. None is to be seen at present.

Native silver - Native silver also was reported to have been present in the bonanza ore. It is said to have occurred as wire and sheets in fractures in the lattite at the Hub mine.

Smithsonite - Carbonate of zinc, smithsonite (ZnCO₃), was recognized in some surface ores, particularly at the Silver Bell where it forms thin grayish crusts on the oxidized ores, associated with much limonite. Some occurs at the Paymaster and may be recognized in most outcrops. It has been reported also in the oxidized ores on Champagne Creek.

Anglesite - Lead sulphate, anglesite (PbSO₄), was recognized in many specimens as a replacement of galena. It commonly replaces the galena from along cleavage lines, often assuming grape-like structures. Some large crystals and masses were noted coating galena granules.

Cerussite - Cerussite (PbCO₃), the lead carbonate, is invariably present in the outcrops as a grayish mass associated with more or less anglesite. It usually coats or crusts nodular masses of residual galena.

Pyromorphite - Lead chlor-phosphate, pyromorphite (2PbO.3P₂O₅.2PbCl₂), was recognized in surface ore at the Pandora on Boyle Mountain. It forms small greenish crystals in open spaces, coating the vein filling.

Malachite - The greenish copper carbonate, malachite (2CuCO₃·Cu(OH)₂), was noted in minor amounts in most outcrops. It occurs either as greenish crusts or stains on the lead ore as a result of the oxidation of chalcopyrite associated with the galena. At the copper vein of the Golden Charlot, it also occurs as aggregates of thin, acicular crystals or needles, coating the quartz crystals or filling fractures in the rock.

Azurite - The basic copper carbonate, azurite (2CuCO₃·Cu(OH)₂), was noted in some oxidized ore at the Silver Bell where it forms deep, bluish crusts and slender fiber aggregates along with malachite.

Chrysocolla - Chrysocolla (CuSiO₃·2H₂O), the hydrous silicate of copper, occurs in the surface ores of some veins as opal-like bluish and bluish green crusts or filling seams. Some are nearly black from impurities. It seems most abundant at the Pandora, associated with malachite.
Covellite: - The cupric sulphide, covellite (CuS), was recognized at the Silver Bell where it replaces galena, and at the Golden Chariot where a little replaces chalcopyrite.

Chalcocite: - Cuprous sulphide, chalcocite (Cu₂S), occurs in outcrops of all deposits containing chalcopyrite, usually in minor amounts replacing chalcopyrite and associated with copper pitch ore.

Copper pitch ore: - Copper pitch ore is an impure hydrated copper silicate with variable amounts of iron, manganese, etc. It has a black color, is amorphous, and forms as an alteration product of chalcopyrite, usually with chalcocite. It is rather abundant in the oxidized minerals at the Pandora.

Chalcantinite: - Chalcantinite (CuS0₄.5H₂O), occurs in the walls and timbers in upper workings of the Last Chance Vein on Champagne Creek. The copper has been carried in solution from above and deposited as a sulphate.

Stibiconite: - Hydrated antimony oxide, stibiconite (Sb₂O₃·H₂O), was recognized in the antimony deposit as a white to grayish alteration product on stibnite, and some in fibrous or bladed pseudomorphs after stibnite.

Cervantite: - Antimony oxide, cervantite (Sb₂O₃·Sb₂O₅), occurs in some abundance in the antimony lode as yellowish coatings, passing into the dirty whitish coating mentioned under stibicosite. It also occurs in yellow to white acicular crystals.

Valentinite: - Another antimony oxide, valentinite (Sb₂O₃), occurs in appreciable amounts in partially oxidized stibnite as drusy coatings and crusts and in prehnitic crystals. The crystals are waxy in luster and olive green in color. These are scattered in patches throughout the oxidation products, some in bundles of crystals nearly half an inch long, often protruding into small vugs.

Tungstite: - Tungsten trioxide, tungstite (WO₃·H₂O), occurs in small amount in the tungsten deposit as a yellow, ochreous filling in small cavities in rusty quartz from which the Nboreite has been oxidized. The mineral is very finely crystalline, but earthy in appearance.

Psilomelane: - The hydrated manganese oxide, psilomelane [probably Na₄MnO₅], is an abundant secondary mineral at the tungsten vein, an alteration of manganese tungstate (H₂MnO₄). It coats the vein filling in fractures and on exposed surfaces, staining the vein and surrounding rock black. It also is abundant in the outcrop of the Hub vein and really constitutes manganese ore. The entire outcrop is stained black and contains much psilomelane with mamillary structure. It has developed as an alteration of rhodochrosite gangue. Psilomelane was noted in the surface ore at Lead Belt also.

Gypsum: - Calcium sulphate, gypsum (CaSO₄·2H₂O), is rather abundant in abandoned workings on Champagne Creek where it occurs as a thick coating on mine timbers and tunnel sides, as small crystals or as long fibers, associated somewhat with melanterite. The accumulation has been particularly marked at the St. Louis and the tunnels are clothed entirely in white, much like a white fuzz. Gypsum also occurs as a secondary mineral at the Golden Chariot forming crystals up to one-half inch thick crusty ore from a fault breccia. The gypsum is no doubt the result of action of sulphuric acid, generated by oxidation of iron sulphides on contact with calcite gangue.
Melanerite (copperas): The hydrous sulphate, melanerite \((\text{FeSO}_4 \cdot 7\text{H}_2\text{O})\), occurs in considerable abundance at the Last Chance and St. Louis mines where it forms a coating in unused tunnels. The melanerite has an especially astringent taste and has various shades of green passing into white.

Limonite: Hydrated iron oxide, limonite \((2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O})\), is a common alteration mineral and constitutes most iron capping and ochreous staining usually observable in the outcrop. It is an alteration product of nearly any mineral that contains iron and here particularly forms after pyrite and mercasite.

**SUCCESION OF MINERALS**

Primary minerals of this district are products of one general period of mineralization during which movement along the vein concurrent with mineral deposition occurred so that some veins were reopened and new minerals introduced. The different stages of mineralization have not been entirely worked out and little can be said of them. In nearly all veins the minerals were not deposited simultaneously, but show a rather definite sequence of crystallization, but with considerable overlapping in the succession of minerals deposited.

In most quartzs was the first mineral to be deposited, both as a vein filling and as a replacement of the wall. Invariably this early quartz has been minutely fractured and then pyrite introduced, assuming its own crystal form by replacement of the earlier mineral. Introduction of the pyrite was in most places followed by sphalerite, galena, and chalcopyrite. These younger sulphides in part have replaced the pyrite which may be seen as residual grains engulfed in the other sulphides. The pyrite in some was fractured and these cemented by the other sulphides, generally accompanied by replacement. In the Paymaster vein a little arsenopyrite crystallized shortly following pyrite and shows various stages of replacement by the younger sulphides. Pyrrhotite in the same vein developed later than the pyrite, cementing it, but is in turn cemented by sphalerite and galena against which it gives its characteristic crystal boundary. The sphalerite has some unusual features, invariably holding numerous inclusions of chalcopyrite while the larger crystals of chalcopyrite, not so included, are distinctly later and slightly younger than the galena usually enclosing the sphalerite crystals. This abnormality may perhaps be explained by the unmixing of a solid solution of chalcopyrite originally dissolved in sphalerite. Similar relations were noted in one place with pyrrhotite in sphalerite. The galena shows younger crystallization than does the sphalerite as it usually occurs between sphalerite crystals, and in one place in part replaces shattered sphalerite. Tetrahedrite is not sufficiently abundant to work out its relations except that it occurs in the galena and probably is nearly contemporaneous with it. These relations described above are true for the Lava Creek deposits (except possibly at the Hub) and hold generally for the deposits of the entire district. Later movement along the vein has fractured the ore and has introduced either quartz or calcite in most veins and in some places accompanied by additional sulphides. On Lava Creek, calcite generally was introduced in the second stage. Possibly the rhodochrosite at the Hub mine was deposited at this time.

In the St. Louis zone, second stage minerals evidently have deposited carbonates and the bismuth mineral, aikinite, and another generation of chalcopyrite, nearly contemporaneous with the bismuth. Carbonates outlasted the sulphides in this deposition. In the Hub mine, the carbonate (rhodochrosite) was fractured and polybasite, and apparently a younger chalcopyrite and arsenopyrite, introduced along these cracks. The second generation of chalcopyrite especially has been prone to replace the galena. Again carbonates have
outlasted the sulphide deposition. The Hub vein has been shattered so greatly during and since mineralization that deposition stages are obscure and not definitely determined.

Minerals in the Last Chance show the common sequence of pyrite and marcasite, sphalerite and wurtzite, and galena. This succession is brought out strikingly in the vein itself where iron sulphides have been coated by the zinc sulphides, the galena only partially filling the clefts remaining in the vein. In fact, in many places the galena fails even to enter the unfilled clefts in the zinc sulphides.

The relations in the veins on Lead Belt are different from those given above, for here the earliest mineral is calcite, minutely fractured and the fractures and cleavage lines enlarged by replacement with sphalerite and galena. These sulphides in turn are cut by younger calcite that fills ore fractures probably caused by renewed movement along the vein as mineralization was going on.

In the tungsten deposit, quartz was deposited first, continuing while the hübnerite crystallized and even later. Conditions are similar in the Golden Chariot copper vein where specularite and chalcopyrite crystallized shortly after the quartz started and ceased long before the quartz had finished. Several growths of quartz crystals in these deposits suggest that mineralizing solutions were pulsating in this action.

Relations of the barite in one of the veins at the Last Chance was not accurately determined, but probably is about contemporaneous with, though outlasting, the sulphides.

GEOLOGIC FEATURES OF THE DEPOSITS

GEOLOGIC DISTRIBUTION

Ore deposits are distributed throughout all types of rocks in the Lava Creek district except the young basalts and alluvium. Their distribution in no way is related to the character of the inclosing rock, but to certain structural features and special loci of mineralization. These happen mainly to be in the Tertiary lava but also extend into the nearby older rocks from which the lava has been stripped by erosion. By far the greater number of deposits are in Tertiary lava, andesites and bedded tuff along Champagne Creek, and latite and latite-tuffs along Lava Creek. A few deposits are in Tertiary granite and several occur in fissures along the granite contact with Mississippian rocks. Most of the Boyle Mountain and Lead Belt deposits are in older sedimentary rocks at the outskirts of the mineralized zone, trending along Cottonwood and Lava creeks.

STRUCTURAL RELATIONS

Major structural features of the region have been discussed elsewhere and it is necessary here only to show the relation of ore deposits to faulting and fissuring. The ore deposits are found in areas that have been most greatly faulted or broken, probably by orogenic forces attending folding of the Tertiary lava and also by the shattering of the rock with igneous intrusion. Most extensive shattering has been along Champagne Creek, and also along Lava Creek or the axis of the Tertiary fold with its intrusive dikes and stocks.

The most pronounced faults trend northwest in direction with the axis of the fold, and along northeast lines at nearly right angles. Mineralization, however, has been in minor fissures or zones of movement trending either north or west.
or at small angles with these two main directions. In the Champagne Creek region, mineralization is entirely in the northerly trending set of fissures and brecciated zones, departing not more than 25 degrees to either west or east and with but one exception not more than 20 degrees. The fissures dip more or less steeply, usually at angles of 40 degrees to 75 degrees to the west, and only one prospected dips east. On the other hand, deposits along Lava Creek distinctly favor the westerly-trending set, although a few occur in the other. These generally depart less than 30 degrees to either north or south of west and many less than 20 degrees. They dip steeply either north or south. The same tendency is shown in the deposits on Little Cottonwood Creek and on Boyle Mountain. Curiously, at the Silver Bell, the northerly-trending series is mineralized most completely, although the westerly set is more pronounced. In the Hub, both sets are represented, but the general trend of mineralization has been west. Several directions are also shown at the Edna and the northeast one carrying the most sulphides. On Lead Belt Creek, the fissures trend north and dip west. A few veins seem to follow major trend lines and strike either northwest or northeast, but in general only the smaller breaks in these directions show mineralization.

Why certain areas should favor mineralization in certain directions and not in others, and why such a relation is reversed in other areas is for future study. Development of gouge has played a role in some places, for the gouge zone at the Silver Bell is heavy along the westerly set and the fracture relatively clean along the other and better adapted for the passage of mineralizing solutions. Somewhat similar conditions exist at the Hub. The westerly set is scarcely noticeable along Champagne Creek probably explaining mineralization in the other set in that region. Perhaps the control has been the amount of movement in the two sets, variable from place to place, the nature and amount of movement determining the ease at which the mineralizing solutions could be permitted to travel free from gouge hindrance.

Many mineralized veins or lodes are along simple fissures in the rock, but an even greater number are in brecciated or crush zones, where movement has fractured the rock for as much as a dozen feet. The veins in limestone are mainly in fissures, but even here one is in a very extensive crush zone. Many lodes appear to represent a combination of the fissure and breccia type in that the footwall has a gouge seam, although the hanging wall is extensively shattered or brecciated. Either type or their combination has been favorable to mineralization, but the crush zone shows a greater tendency to dilute values with the admixture of country rock. In some places, the movement has been more or less taken up by overlapping fissures, but no zone of movement can properly be classed as a true shear zone. Intersection of fissures has been especially favorable to mineral localization apparently because it provides greater rock shattering and makes more open channels for the mineral-bearing solutions. Displacement in the zones of movement or along the mineralized fissures generally has not been great, only those of minor magnitude being favorable to ore deposition. The displacement usually ranges from a few to not more than a hundred feet, although the amount of movement generally is difficult or impossible to determine.

Most veins and lodes show post-mineral movement, usually a few inches along the plane of the vein, generally increasing the size of the gouge band along the footwall. Post-mineral movement, however, has not been great and nowhere has seriously offset the ore bodies. Evidently the greatest movement occurred prior to mineral deposition and had nearly ceased when the ore solutions appeared, although some movement occurred concurrent with deposition which permitted the fissures to reopen and introduce new minerals.
STRUCTURE OF VEIN FILLING

Most deposits are nearly tabular in form and follow fissures or brecciated zones in the country rock. In the sedimentary rocks, the veins are mainly fissure fillings or fillings in brecciated zones, but in the igneous the relations are somewhat different. In a few igneous deposits, the fissures have fairly distinct walls and the boundary between vein and wall is more or less pronounced, but in many the walls are indistinct and the vein matter occurs as a replacement of the wall and wall fragments.

The sulphides are distributed irregularly in many deposits in small seams or veinlets in the brecciated rock, enlarging the original fractures by replacement. Commonly, these seams or veinlets extend far into the wall rock. Another common type of filling is the occurrence, especially galena, in scattered nodules or lenses, or in small pockets in the fissure or vein breccia, usually accompanied by a minor system of stringers. In only a few deposits do the sulphides occur in compact seams or lenses more than several inches wide and more than a dozen feet long on either strike or dip. Such a filling occurs at the Edna where the sulphide seam is as much as two feet wide, but the shoot is characteristically lenticular, pinching and swelling in short distances. Disseminations of sulphides, particularly of lead and zinc, for several feet into the wall, are characteristic of some of the lodes. These sulphides occur in scattered small crystals and grains, bordering the mineralized fractures and have been deposited along with pyrite by replacement. Usually each vein shows two or more of the filling combinations described notably in veinlets, in nodules, and disseminated. Curiously, none shows banded structures and only those occurring as fillings in brecciated zones show crustification. In only one, the Paymaster, does the ore occur as more or less massive replacement of the wall rock, and this too has many stringers, but not without some enlargement of the original fractures by replacement.

DISTRIBUTION OF ORE IN DEPOSITS

Few fissures or brecciated zones are mineralized for any great length, but the ore locally occurs in small shoots, or as scattered occurrences along the lode. The width of the mineralized bands or lodes ranges from mere stringers, a fraction of an inch to several inches wide, to fillings or replacements in breccia zones several feet wide. In the Paymaster, the vein in one place enlarges to a dozen feet, but the occurrence is exceptional. Few of the veins are mineable for more than several hundred feet along the strike and most of them but a few dozen feet. A single vein may have several shoots. In general, mineralization is very erratic or irregular in distribution and in ore, and with but few exceptions may be said to be pocketty. Some of the shoots play out at depth as well as on the strike, but there is reason to believe that mineralization will appear again in other shoots at greater depth.

Ore distribution in the deposits is difficult to explain. Some shoots occur near the intersection of fractures, probably because of additional shattering of the rock and increased porosity which would serve to better control the passage of ore solutions. Other shoots are along those parts of the fissure that suffered the most shattering with consequent greater porosity, for no fissure is the same throughout, and in places may be tight and unfavorable as ore channels. In parts of some fissures, so much of the rock is reduced to gouge that solutions cannot enter, accounting for irregular mineralization of fissures. Some veins or fissures probably were reopened at the proper time to permit solutions to enter and deposit their mineral load, others were not. All these factors probably figure in localization of the ore shoots.
CHARACTER OF ORE

The ore solutions did not leave the same list of minerals or the same proportion of minerals in each of the veins or lodes, and for that reason classification of deposits according to the character of the ore or the most valuable metal is desirable. Some deposits are valuable mainly for the silver they contain, others for silver and lead, others for zinc, and one each for copper, antimony, and tungsten. All occur under similar structural relations, have essentially the same structure of vein filling, and other geological relations.

Silver Lodes

Three deposits may be classed as silver lodes, for the silver value outranks their worth for lead and zinc, although appreciable amounts of these other minerals are present. In these lodes, silver values occur principally in certain silver minerals and subordinately in argentiferous galena. In the Hub mine, the silver occurs principally as polybasite in an ore and gangue that includes nodules of galena, a little sphalerite, arsenopyrite, pyrite, chalcopyrite, quartz, rhodochrosite, and calcite. In some places, polybasite is easy to recognize in the ore, but more commonly it occurs in minute grains with the sulphides or the rhodochrosite-quartz gangue. The deposit occurs in a large brecciated zone in latite and latite-tuff as nodules and stringers. The mineable ore is several feet wide and extends for perhaps 150 feet. Some of it is particularly high-grade, averaging more than 100 ounces in silver to the ton, and the remainder is of milling grade. Limits of the ore shoot can be determined only by careful sampling and assay.

The St. Louis mine has rich silver ore associated with the bismuth mineral alkinite. Selected ore samples give values more than 1,000 ounces in silver to the ton. Some alkinite occurs in more or less massive bands or lenses in the vein and some is scattered in minor amounts with other sulphides. Considerable argentiferous galena also is present in stringers or bands, or disseminated in the wall, but furnishes only a small amount of the silver in the vein. Other sulphides present include pyrite and marcasite, sphalerite and wurtzite, and chalcopyrite in a gangue of quartz, dolomite and calcite. Zinc sulphides are relatively abundant but the value of either the zinc or lead is subordinate to that of silver associated with the alkinite. In places, the vein is a foot or more wide with the ore in stringers, lenses, and disseminated in the wall, in andesite and bedded tuff.

The Martin mine on Little Cottonwood Creek carries high values in silver as well as valuable amounts of gold. The silver evidently occurs in an undetermined mineral present as minute inclusions in the galena. Some assays several hundred ounces in silver. In addition to the galena is considerable pyrite and sphalerite, all in a peculiar tube-like shoot determined by intersection of many fractures. The ore occurs as seams in fractures and disseminated in the wall. Gold occurs in the more siliceous portions of the shoot and is present from a quarter to three quarters ounces to the ton. This lode is in granite.

The Reliance may be included in this type of deposit when its character is better known.

Silver-Lead Veins

Most of the Lava Creek deposits may be classed as silver-lead veins with the chief values in argentiferous galena, usually an ounce of silver to the unit.
of lead. Galena generally is associated with sphalerite, pyrite, and minor amounts of chalcopyrite in a quartz gneiss, locally calcite as along Lead Belt Creek. The veins in limestone are of this type as well as most of the veins and lodes in the fissures and brecciated zones in the lava. In general, the ore occurs in stringers, seams, nodules, and compact lenses in the fissures or breccias, and the shoots are of uncertain size and distribution. The Edna and Silver Bell mines on Lava Creek, and the mines on Lead Belt perhaps are the best examples of this type of deposit. Some Champagne Creek properties, such as the Ella, might be included in this group, but the character of their primary ores is not sufficiently well known. In some deposits, zinc is also an abundant as well as perhaps a valuable constituent of the ore, but probably it is not advisable to make an additional grouping of lead-zinc veins.

Zinc Veins

Two deposits may be classed as zinc veins, although both contain appreciable amounts of galena, slightly argentiferous. One of these is the Paymaster on Big Cottonwood Creek where the sulphides, including sphalerite, pyrite, pyrrhotite, arsenopyrite, galena, and chalcopyrite, have replaced the quartzitic wall of a fissure along the granite and quartzite contact. Some sphalerite is coarse-grained, but some is very fine and intimately associated with the other sulphides, notably pyrite and pyrrhotite. The mineralized shoot is more persistent than is common in other deposits.

The Last Chance vein on Champagne Creek has zinc sulphide with abundant iron sulphides. This ore, too, is accompanied by a little galena, but it is notably low in silver. The vein has an interesting structure and in part is a filling and in part a replacement in a narrow fissure zone in andesite. The iron sulphides, pyrite and marcasite, occur in reniform and semi-spherical masses and are covered or cemented by wurtzite and sphalerite, and last by galena. The old Hornsilver may also be similar to this deposit.

Copper Vein

Occurrence of a copper-bearing vein is of more scientific than commercial interest. In this vein, chalcopyrite occurs in small scattered grains and masses, associated with specularite and drusy quartz. The vein is characterized especially by open spaces and vugs into which project crystals of quartz, partially amethystine. Wall fragments also serve as a base for the quartz crystals which attain a length of over an inch. Some blades of specularite project into the vugs with the quartz, but most of it and the chalcopyrite are enclosed by the quartz which began its deposition before and outlasted the others. This vein is persistent, but mainly less than a foot wide. It is in latite, not far from granite on the Golden Chariot property.

Antimony Lode

Antimony deposition as stibnite in a brecciated zone in silicified limestone is of scientific interest. This deposit is along the North Fork of Lava Creek more than a mile north of the Hub mine. Curiously, no sulphide other than stibnite was deposited and this mineral forms a cement of the brecciated fragments of silicified country rock. Great brecciation has been noted over a zone as much as 50 feet wide. Unfortunately, stibnite does not occur throughout the entire zone, but in an essentially small shoot where the greatest amount of open space had been developed. Unusually good crystals of stibnite in radiating groups were formed in this deposit, some masses measuring more than a foot in diameter.

- 45 -
Tungsten Lode

Tungsten as hübnerite is found in a brecciated zone at the contact of granite and sediments near the top of Blizzard Mountain. Deposition mainly has been by filling along fragments of altered granite and quartzite in the crushed zone, principally by coarse-textured, drusy quartz in which the hübnerite occurs as scattered platy aggregates and isolated plates. The lode is as much as five feet wide.

ALTERATION OF THE WALL ROCK

One of the most notable features of mineralization is intense and widespread alteration of the enclosing wall rock, especially about the lodes in Tertiary lava and granite. The rocks in general have been bleached light gray or white and impregnated with numerous cubes and pyrrhotedrons of pyrite ranging from microscopic sizes to three-quarters of an inch. Alteration usually extends for dozens of feet from the lodes, and where several mineralized fissures occur near to one another may cover hundreds of feet. The hydrothermal solutions from which the sulphides were deposited in the veins have attacked the minerals in the wall rock, especially the feldspars and ferromagnesians, replacing them by both sericite and quartz, and later pyrite. Sericitization in general extends for much greater distances from the lode than does either silification or pyritization. Near the mineralized lodes or fractures, the minerals and textures of the original rock have been entirely destroyed and replaced by quartz and sericite. But farther out, the outlines of the feldspars may be recognized from the selective replacement by sericite, and finally by minor flakes and shreds of sericite which fall entirely to obscure the original minerals. In some walls, flakes of sericite attain considerable size, but generally occur in fine-grained aggregates, outlining the original feldspars. Near most deposits, sericitization has been far more important in rock alteration than silification. Chlorite occurs in minor quantity in some of the wall rock, usually as an alteration of the original biotite, hornblende, or diopside. In some of the deposits, sulphides of lead and zinc as well as of iron have been introduced into the wall several feet from the mineralized seams and constitute the disseminated ore in some of the lodes. These disseminated grains also have been deposited in the wall by replacement, usually after silification.

Some what different alteration also is shown on Champagne Creek where rocks of several mineralized zones have been extensively silicified and replaced by chalcedony and a white, non-polarizing, clay-like mineral probably halloysite. This new type of rock is dense, flinty, nearly white to light buff, and weathers less readily than do the highly sericitized rocks.

Hydrothermal alteration is one of the unique features of the mineralization and may be accounted for by porosity of the volcanic rocks mainly induced by wide-spread shattering accompanying the movement along the lodes and fissures, and also by original pore space in the lavas. The presence of large amounts of sericite in most wall rock indicates addition of potash from the mineralizing solutions and suggests further that the solutions from which the sulphides were deposited were alkline in character. This has significant genetic bearing.

SUPERNEME ENRICHMENT

Surficial enrichment was responsible for the rich bonanza ore first mined in the district, but is no longer a factor. Apparently the enriched zone was shallow, for erosion has been rapid and has in many deposits kept slightli
ahead of enrichment. In most deposits, the early mining was within 15 feet of the surface, and in the Hornsilver the ores were not profitable below 65 feet. Evidently in the Last Chance and the St. Louis, enrichment from above did not extend lower than 50 feet as a maximum. Most lodes show only slight surface alteration. The most valuable of the enriched silver minerals was cerargyrite, but doubtless argentite, native silver, and possibly ruby silver were present in oxidized secondary ores. The secondary lead, zinc, and copper minerals are unimportant.

GENESIS OF THE DEPOSITS

RELATION TO FAULTING AND IGNEOUS ACTIVITY

An obvious relationship exists between mineralization and the main structural features of the area, for the ore deposits occur in rocks that have been extensively faulted and fractured and are not found in regions nearby where only slight disturbance has taken place. It is significant that the most extensive shattering has been near igneous intrusives, mainly about margins of the stocks, or as in the Champagne Creek region above such bodies presumably not yet exposed at the surface by erosion. Ore deposits are thus grouped about the centers of igneous activity, in fissures in the country rock nearby and less commonly in fissures in the granitic rock itself. This suggests intrusive rock as the source of the mineral-bearing solutions, a conception generally conceded by students of mineral deposits as applicable to most western United States ore bodies.

Mineralization came somewhat later than the intrusions, for several of the veins occur in the granitic rock and the walls have been extensively altered by hot alkaline solutions which carried in the sulphides. But the mineralization period was still within the period of igneous activity, although near its close, as most fissures and brecciated zones show movement concurrent with mineral deposition such as might occur as a result of readjustments within the magma at much greater depths. The character of mineralization, the sequence of deposition or the mineral paragenesis, and the ore textures all favor an igneous source for the ore-bearing solutions. This source is the pink granite and granite porphyry of late Miocene or of Pliocene age.

CONDITIONS OF ORE DEPOSITION

The Lava Creek deposits unquestionably were formed at much greater depths and at much higher temperatures than silver-gold lodes described by Ross in the Salmon River Mountains. Assuming the granite was intruded within 500 feet of the surface, though it likely did not extend within several thousand feet of the surface prior to peneplanation, at least 4,000 feet of cover have been removed from some veins and probably as much as 5,000 or 6,000 feet. These deposits obviously were formed at great depths and the temperatures probably were high, though variable from place to place.

Certain veins from the minerals found in them clearly were deposited at high temperatures, or under hypothermal conditions. Such deposits that are strictly hypothermal are the tungsten, the copper, and the zinc (Paymaster). Hübnerite is deposited only at high temperatures, likewise specularite and pyrrhotite, the diagnostic minerals of the copper and Paymaster lode respectively. All three deposits are near the granite, two at the contact and one a short distance therefrom.

Most of the silver-lead deposits were formed at more moderate temperatures. These include the Silver Bell, the Edna, the Lead Belt and others, properly
classified as mesothermal deposits. Possibly the Champagne Creek deposits belong in this group, but they show some characteristics indicating less intense conditions. Lead deposits tend to favor mesothermal conditions for commercial occurrence.

Several deposits probably were formed at relatively low temperatures, among these the antimony deposit, for stibnite usually occurs in either the upper part of the mesothermal type or in the epithermal, the type formed at shallow depths and lower temperatures (± 100°C). Polybasite likewise is more common in the epithermal type of deposit than in the mesothermal and in all probability the Hub lode belongs to this type.

Deposits near the igneous intrusives in general show higher temperature characteristics than those a distance therefrom, but there are some reversals, namely, the mesothermal deposits in the mesothermal belt; and a mesothermal lode on Little Cottonwood Creek in the granite itself. Perhaps if the ultimate source is considered and also the difference in time of mineralization, the zonal thermal distribution is not so inexact. The Champagne Creek deposits show generally lower temperature characteristics than those in Lava Creek and presumably are farther removed from the source of their ores. The absence of intrusive rocks along Champagne Creek tends to verify that assumption.

CHARACTER OF SOLUTIONS

Ascending ore-depositing solutions were mainly alkaline, and for the most part strongly alkaline, as suggested by extensive sericitization of the wall rock. The formation of sericite involves transference of potash from ore solutions into the wall and solutions which carry potash or alkali metals are necessarily alkaline. It is from such solutions that most Western ore bodies are believed to have been deposited. Probably all deposits along Lava and the Cottonwood creeks have been deposited from such heated alkaline solutions, but the minerals in the Champagne Creek region show some exceptional features suggesting the character of the depositing solutions were somewhat different.

The occurrence of wurtzite and marcasite in the ore along Champagne Creek is peculiarly significant inasmuch as both minerals are believed to be deposited only from acidic solutions and at lower temperatures in contrast with sphalerite or pyrite. The genesis of the zinc sulphides has been the subject of exhaustive synthetic study by Allen and Crenshaw who conclude that sphalerite crystallizes from alkaline solutions and at temperatures above 300°C from acidic solutions, but that wurtzite is formed only from acidic solutions. This latter conclusion is in accord with observations already recorded on occurrence of wurtzite and also for marcasite. Both are the products of ascending acidic solutions. However, as wurtzite and marcasite of the Champagne Creek deposits were formed with sphalerite and pyrite, and are unquestionably primary minerals the genesis of the deposits is somewhat exceptional. Little room is left to doubt otherwise, for the wurtzite is intimately associated with sphalerite and with galena and pyrite in places entirely surrounded by these minerals, or at distinct grains intergrow with them, locally as spherical masses traversed by veinlets of galena and elsewhere as parts of apparently continuous veins, other parts of which are sphalerite. This interrelationship occurs not only in the vein material proper, but with patches of ore minerals that unquestionably replace igneous wall rock, locally several inches from any veinlets. The sulphide minerals essentially are contemporaneous in origin, and obviously represent the

primary mineralisation which accompanied the introduction of large quantities
of potash into the wall rock and consequent extensive development of sericite.

Little can be said at this time of the character of the solutions from which
the wurtzite and sphalerite, as well as the marcasite and pyrite, were deposited,
other than that the solutions contained some alkali and that the only evidence
of acidity lies in the presence of barite, barium sulphate, in one vein en-
countered in the Last Chance tunnel. Possibly the solutions experienced a
change in alkalinity as deposition began and the temperature interval was such
that either or both types of zinc sulphide and iron sulphide could be deposited.
Until experimental work can be done, the problem must remain open.

ECONOMIC CONSIDERATIONS

In general, the history of mining in lodes in Tertiary volcanic rocks in
the United States does not encourage the idea that large and valuable base-
metal ore bodies will be found in such rocks. In the Lava Creek district, the
lodes are relatively small, the ore irregularly scattered with tendency to
occur in nodules, seams, lenses, or pockets along the fissure or brecciated
zone in shoots, generally not persistent on strike or dip. There are some ex-
ceptions and several lodes are persistently mineralized for considerable length.
In many lodes, the values are too widely scattered through the shattered country
rock and much diluted by admixture of country rock to be highly profitable.
Notwithstanding, several properties, particularly the larger lodes which carry
high silver values, several of the silver-lead veins, and perhaps the zinc
lodes, are worthy of careful development and if worked on a small scale might
yield profitable returns.

Few lodes have been explored to any great extent below the surface. The
greatest depth attained on any vein is at the Last Chance where a drift from
the long crosscut about 400 feet below the surface has disclosed the ore body
which shows little or no difference in size or character on that level than
higher. The St. Louis vein has been explored for 160 feet in the dip and in
that distance the lode pinches. There is, however, strong likelihood that it
will again strengthen with additional depth or that the ore will appear in
nearby fractures. The Hornsilver was prospected 285 feet below the surface
but nothing is known of the disclosures. Veins on Lava Creek and on Big
Cottonwood Creek have been examined only to slight depths. From the differ-
cences in the vertical distribution of the veins and lodes, it is apparent
that they may be mineralized for great lengths on the dip. Indeed, perhaps
hundreds of feet have been removed from some veins by erosion. Yet there is
great likelihood that the primary ores (the secondary ores are no longer of
consequence) may extend to great depths, much deeper probably than the limits
of profitable mining, and will show essentially no difference in character of
mineralization or size of the ore bodies.

The primary ores offer no special metallurgical problems. Driving of
tunnels and drifts is relatively inexpensive on most of the veins and lodes
as the intense hydrothermal alteration has greatly weakened and softened the
rocks. This softening is also a handicap, as most workings must be heavily
timbered if they are to remain open. Mine timbers are expensive, as the region
is largely void of forest growth.
Lava Creek district mines and prospects may be grouped in three geographic areas corresponding to the three fairly distinct centers of mineralization. These are Champagne Creek, the Lava Creek and Cottonwood Creek drainage, and Lead Belt Creek. There is some uncertainty in drawing the boundary between the Upper Lava Creek deposits, particularly near Boyle Mountain, and Lead Belt, as the two have much the same type of mineralization and really are a part of the same zone. The distinction is made merely for convenience in description.

DEPOSITS IN THE CHAMPAGNE CREEK REGION

The Champagne Creek deposits are valuable mainly for silver and for zinc, although galena is an important constituent in the ore. Most bodies are especially characterized by the presence of wurtzite and sphalerite as well as pyrite and marcasite, and some contain aikinite, a bismuth mineral here usually rich in silver. Only two properties are actively engaged in development, the Last Chance whose ores are mainly zinc and lead, and the St. Louis whose ore is mainly silver. All deposits are grouped closely, lying at elevations between 6,000 and 6,600 feet. All are easily accessible.

Last Chance Mine

The Last Chance mine, under operation of the Horn Silver Consolidated Mines Company and worked in conjunction with the Hornsilver mine, lies along Champagne Creek in Sec. 15, T. 3 N., R. 24 E. This mine was credited with an early small production included with that of the Hornsilver a short distance to the east. The older workings are extensive and comprise an upper tunnel 150 feet long from which the ore has been stopped to the surface, an intermediate tunnel 800 feet long and 150 feet below which connects by a raise with the upper tunnel. From the intermediate tunnel is a shaft about 180 feet deep. The last work done in the intermediate tunnel was about 1916, all later work having been on a long crosscut from the Creek to tap the veins at depth including the Hornsilver. Fortal elevation of the crosscut is about 6,075 feet with the outcrop near the crest of a steep ridge several hundred feet higher.

Several veins have been intersected in the long crosscut, but only the Last Chance is being developed now. These veins are wholly within porphyritic andesite and bedded tuff probably of both hornblende and augite varieties. As usual, the andesite is extensively altered, but probably contains less pyrite in the walls than about the veins on other nearby properties. The veins in general trend about N. 25° E. and dip about 70° west. The Last Chance vein becomes less steep with depth, but near the surface dips nearly vertically. Deposition apparently has been both by filling and by replacement in narrow brecciated zones in the andesite, the vein filling containing much altered country rock. Mineralization has been persistent in the Last Chance and is about as extensive on the lowest level as on the higher.

The filling of the Last Chance vein has been mainly by iron and zinc sulfides with minor amounts of galena and chalcopyrite. The iron sulfides include pyrite and marcasite, both of which occur in spherical or semi-spherical, radiating aggregates, reniform and mammillary masses, seldom if ever in their cubic or orthorhombic crystal forms. The iron sulfides usually show considerable shattering and they have been cemented, crusted, as well as in part replaced, by sphalerite and wurtzite. The wurtzite may be more abundant than the sphalerite. In external form, both are the same and occur as pale brownish to reddish brown, bright red, masses and grains intimately associated.

- 50 -
Much of the ore is porous or has many open clefts partially filled with the zinc sulphides. Some of the clefts have an inner coating of galena, crust of the zinc sulphides. Galena evidently was the last mineral to be deposited and was not sufficiently abundant to replace older minerals, including early quartz, or even fill all open spaces along the vein. Neither the zinc sulphides or galena contain much silver, and the ore may be considered essentially as zinc. Some nearly pure zinc sulphide, assayed for gold and silver, gave 3.6 ounces of silver per ton. Some pure galena was assayed also and gave 2.6 ounces of silver per ton. However, a little tetrahedrite was noted in some galena, but it apparently is not rich in silver. Aikinite was noted in some specimens collected on the dump, intimately associated with galena and pyrite and essentially contemporaneous with them. These specimens probably are not from the Last Chance vein, but the Spar vein which in general resembles the Last Chance, but contains barite as a late gangue mineral. This ore is reported to have good values in silver. Also near the Spar vein is to be found soft, soapy masses of leverrierite, filling fractures in the rock.

Ore textures of the veins are peculiar and difficult to describe and are unlike the textures of other deposits in the district. The mamillary or reniform character of the iron sulphides, the bright red color of some of the zinc sulphide, and indefiniteness of any vein banding are perhaps the most outstanding features.

The Spar vein is first cut in the long crosscut about 560 feet from the portal. This vein in general strikes about N. 226° E. and dips 70° W., and has been opened to the north by drifting for about 140 feet. It carries considerable mamillary pyrite and marcasite, barite, and chalcedony in a zone five to eight feet wide without definite walls. A little sphalerite and galena is noted, and probably aikinite, as the ore is reported to assay 125 ounces in silver and to carry four per cent copper. The minerals appear to cement fractures in a thoroughly silicified brecciated zone in the andesite. The occurrence of barite as a chief gangue mineral in this vein is of much interest as is the presence of leverrierite in the fractured rock. The vein probably is worthy of more intensive prospecting, especially to the north of the crosscut, for it apparently pinches to the south.

The Last Chance vein is encountered slightly more than 645 feet east of the Spar vein, but several mineralized zones are cut between in both altered turf and andesite. The first is about 122 feet from the Spar and contains a little galena in a broken shattered zone several feet wide which trends N. 226° E. and dips 70° W. Another mineralized zone carrying iron sulphides and apparently northerly trending was cut 245 feet from the Spar. A drift to the south disclosed nothing promising, but in the crosscut the broken zone is about eight feet wide and contains some iron sulphides and chalcedony. It is more than likely that the vein would show more promise to the north of the crosscut. Other mineralized seams are shown as well in the crosscut, but no others have been prospected.

A drift was first driven south of the crosscut on the Last Chance vein but the vein played out and work was transferred to the north, the drift being extended many feet while the writer was in the district. It continued to show increasing promise as the work progressed, all values in zinc and a little lead, but with low values in silver. The vein dips 80° W., not as steeply as in the upper tunnels. It is enclosed wholly in the silicified andesites, and is along a brecciated zone from two to seven feet wide without definite walls, for the ore shades into country rock. The vein filling breaks or shatters readily and includes many horses of country rock. Greatest mineralization evidently has been in the most highly shattered zones, such as where other fractures intersect the main fissure. The drift has been extended about 90 feet along the
vein while the writer was in the field and the face showed five feet or more of mineralized rock, most of it in iron sulphides and zinc sulphide but with some galena.

The Last Chance vein as explored in the intermediate tunnel about 200 feet above the crosscut has a similar character. The vein strikes N. 20° E. and dips vertically, showing the same list of minerals and the same relations as below. The tunnel is 600 feet long and, about 200 feet in, has a shaft extending to within 20 feet of the lower workings. A raise also connects with the upper tunnel. About 50 feet of the vein is explored and no ore has been mined from the level. Since abandoning, the tunnel has been covered with a coating of melaniterite and in places crusted with chalcanthite.

Much stoping has been done from the upper tunnel, 160 feet above the intermediate level. One stope is about 85 feet long on the strike of the vein and shows the workable shoot to have been from four to eight feet wide. The stope probably is over a hundred feet high. The ore is reported to have been horn-silver (cercarargyrite) with a little residual zinc sulphide and galena. It is 130 feet to the shaft in the upper tunnel where the first stope occurs and then the tunnel follows the vein for 500 feet more, all stope to the surface. The vein is well exposed at the surface and outcrops above the hillside wash. It is reddish, characteristic of oxidation of iron-bearing sulphides in the presence of galena.

The vein, explored for more than 350 feet on the dip, shows little or no change in its character of mineralization. If anything, the sulphides tend to increase. The vein may be expected to continue to greater depths probably with much the same character and size shown in the lowest level.

St. Louis Mine

The St. Louis mine is on a branch of Champagne Creek in Sec. 15, T. 3 N., R. 24 E., along a road to Dry Fork Valley. The elevation of the main tunnel is approximately 6,310 feet. The property consists of five unpatented claims and is developed by three principal tunnels, two from the east and one from the south, and an inclined shaft 160 feet deep. The tunnels consist of more than 1,500 feet work, most of it done during the early mining activity. All tunnels are now inaccessible except the main No. 3 tunnel, more than 800 feet long, principally on the vein. The shaft has been driven recently. Possibly $15,000 worth of ore has been shipped from the mine, largely in silver values, although local estimates have placed production as high as $75,000, including the ores shipped in more recent times.

The St. Louis vein is remarkably persistent, though mineralized sporadically, and may be traced probably for half a mile on the surface. It forms a rather inconspicuous cropping, although somewhat more resistant to erosion than the country rock nearby which escaped silicification. It shows slight reddish staining. The vein has a general trend of N. 59° E., but this varies from due north to as much as N. 15° E. Its dip also varies from 40° to 60° west. South of the shaft the vein has a hanging wall of intensely altered andesite with sericite, quartz, and pyrite extensively developed. Its footwall is a white, thin-bedded, water-laid tuff showing the same type of hydrothermal alteration. The tuff locally is folded, but has a rather persistent dip of 20° E. and a northerly strike. North of the shaft, the vein is wholly within the tuff, although porphyritic andesite is nearby.

The ore occurs in small irregular lenses and bunches from six to 15 inches wide, and in small stringers cementing the brecciated rock along the fault
The ore is made up almost entirely of argentiferous galena, sphalerite, wurtzite, pyrite and marcasite, and locally aikinite, in a quartz-dolomite gangue. Minor quantities of chalcopyrite and calcite occur also in the ore. Some ore is very rich in silver and selected assays have given more than a thousand ounces to the ton. The same analyses have given relatively low values in lead, copper, and zinc, usually less than 10 per cent for each. The silver is unquestionably the chief metal of the deposit. Some lead and zinc sulphides were assayed for the writer and gave less than 22 ounces in silver. Analysis made on some of the impure aikinite, so-called bismuth ore, however, gave more than 800 ounces in silver. Silver values, apparently then, lie with the bismuth mineral which occurs in minor quantity through most of the ore and abundant locally. At least, one large lense of nearly pure aikinite weighing several hundred pounds was mined and the writer has a specimen measuring nearly a foot across. The paragenesis of the minerals has been discussed elsewhere. The sphalerite and wurtzite, intimately associated in the same masses, in grains and locally in semi-spherical masses, are of pale brown to dark brown color. Some of the galena occurs in cubes. Two main stages of mineralization are apparent, the first which deposited pyrite, sphalerite, wurtzite, and galena in about the order given, and the second, aikinite, chalcopyrite, dolomite, and calcite. The carbonates outlasted the deposition of the other minerals.

South of the shaft the vein has been followed for 165 feet, but only about 70 feet of it has sulphides to any notable extent, the remainder with occasional grains of galena, pyrite, and zinc sulphides. Seventy feet south of the shaft the vein has about a foot of disseminated sulphides which continues to show improvement to the north, here and there containing lenses of galena measuring up to four inches wide. Much of the veins has been stoped to the surface. A drift 35 feet below the No. 3 level has been driven from the shaft about 48 feet to the south and opened a considerable body of lead-bismuth ore, very rich in silver. It is reported that the compact ore occurred in a bulge in the vein and to have measured two and one-half feet wide, 15 feet on the strike and 12 feet on the dip. This ore has been removed, but in the face many seams and stringers up to eight inches wide are scattered through a zone several feet wide. Some disseminated ore also occurs in the crush zone. The shoot apparently plays out with depth, for 30 feet below the No. 3 level in the shaft it becomes a mere stringer, the fissure continuing. However, mineralization is again noticeable in the bottom of the shaft and specimens show considerable aikinite. Possibly another shoot will open up below.

Mineralization extends a short distance north of the shaft and then ceases and even the fracture is barely noticeable in places. However, 140 feet to the north the fissure again is mineralized, mainly by galena and zinc sulphide. This shoot has been mined more than 200 feet and entirely stoped to the surface. Little work has been done below the No. 3 level. In this shoot, the ore occurred in scattered lenses and seems a few inches wide, in a zone of brecciated tuff measuring from six to 18 inches wide. A second mineralized fracture, called the Dry Silver vein, lies 15 feet to the east and gave several loads of rich ore at the surface. The unoxidized ore is mainly iron sulphide and aikinite.
Apparentiy, mineralization has been restricted to places showing the greatest amount of brecciation with the minimum amount of gouge. Mineral deposition is light wherever the walls are tight and unfractured, and also where the amount of gouge is great, for gouge prevents passage of mineralizing solutions. The sulphides mainly have been deposited in the brecciated zones, cementing and replacing fragments of wall rock and as disseminations in the wall. The shoots are relatively small and uncertain and pinch on both strike and dip. The oxidized zone is shallow and only primary ores remain. In places these are notably rich in silver. Mineralization may be expected to persist to considerable depths, probably not continuously but in scattered shoots or in parallel slips or fractures. Their occurrence would be impossible to forecast.

Reliance Mine

The Reliance group of four unpatented claims lies in a small gulch tributary to Champagne Creek less than half a mile north of the St. Louis mine at an elevation of about 6,500 feet. The property was opened soon after discovery of the old Horn Silver, although production was unreported until the World War. The workings were inaccessible at the time of visit, although work was being done to reopen them.

The enclosing formation is andesite showing the usual intense hydrothermal alteration accompanied by bleaching and the dissemination of pyrite. This alteration extends many feet from the vein and has made the country rocks along the vein particularly susceptible to weathering or decomposition. The vein as exposed in the upper tunnel strikes N. 20° W. and dips about 70° E. At the portal it is about two feet wide without definite walls, but is reported to average three to four feet wide. A small amount of ore remained at the portal and this shows sulphides as occurring in scattered grains, nodules, and lenses, and as irregular stringers in crushed andesite. The sulphides, galena, wurtzite, sphalerite, and pyrite, as well as marcasite, occur in the ore with quartz. These have been fractured and cemented by later calcite and dolomite, abundant locally. Bismuth ore, in every way similar to that at the St. Louis mine, was recognized in sacked ore. The aliknite is accompanied by nearly contemporaneous chalcopyrite although both are younger than the other sulphides.

Lower workings consist of a crosscut 300 feet long and a drift 40 feet long, unconnected with the upper workings. Determination of the length of the mineralized shoot or the merit of the property from the inaccessible tunnels or the surface exposures, was impossible.

Ella Mine

The Ella mine lies near the head of Champagne Creek at an elevation of about 6,400 feet in Sec. 11, T. 3 N., R. 24 E. The mine, one of the first discoveries in the district, is credited with a production of 10,000 tons. The last production was in 1907 and 1908 when a roll mill some distance below the mine was in operation. Since then only necessary assessment has been done. The development is said to comprise approximately 1,000 feet of work in one long tunnel and several shorter ones. Unfortunately, the tunnels were in such a dangerous condition in 1928 that the writer did not go underground.

The vein lies well within the lava series and has hornblende andesite for its wall rock. It may be traced 150 feet underground in the workings but the alignment of cuts on the surface suggests that the vein is several thousand feet long. Because of silicification of the country rock along its course, the vein rises somewhat above the more easily weathered andesites and bedded tuff. The vein trends N. 20° E. and dips apparently about 30° W. At the surface
where exposed in one cut, the vein is about two feet wide, but underground it is reported to be four feet wide. It lacks well defined walls and shades into silicified and sericitized andesite, containing the usual disseminated cubes of pyrite.

Ore minerals clearly have been deposited, for the most part, by replacement of the silicified wall. From specimens still remaining in the ore bin, the chief minerals appear to be galena and reddish sphalerite, associated with considerable pyrite in a quartz and calcite gangue with many fragments of wall rock. The vein filling is not altogether compact as some drusy quartz was found and some sulphides do not entirely fill fractures or vugs. Galena is more abundant than sphalerite and some occurs in solid seams up to one-half inch thick. It is heavily loaded with microscopic grains of tetrahedrite, with some chalcopyrite. The presence of minor amounts of argentite and proustite has been reported but these were not noted in ores examined by the writer. Cerargyrite probably has been the most valuable mineral in the vein, but little remains, although both cerussite and smithsonite still occur in the outcrop with galena. The workings do not extend more than 50 feet below the surface and the oxidized and enriched zone is much less. It is reported that the ore contains eight per cent lead, five to 10 per cent zinc, and 12 ounces of silver to the ton, but what little ore remains in the bin tends to indicate lower values. Some selected samples assayed .01 ounces in gold and 18.3 ounces in silver to the ton.

**Hornsilver Mine**

The Hornsilver mine, by far the largest producer in the district, lies near the head of Champagne Creek on the south side of the valley, mainly in Sec. 11, T. 3 N., R. 24 E., at approximately 6,500 feet. The mine was operated only three or four years following its discovery in 1885 and the 20-stamp mill three miles below the mine has long been dismantled. It is claimed locally that during its period of activity approximately $250,000 was derived from the rich silver ores, mainly cerargyrite in heavily iron-stained quartz. The workings long have been abandoned and were entirely inaccessible. The property is under bond and lease by the Horn Silver Consolidated Mines Company which plans to intersect the vein at depth from an extension of the long crosscut that has been driven to explore the Last Chance vein. The old development is said to comprise about 5,000 feet of work, including a 285-foot shaft from which extensive prospecting was done on the lower levels. Nearly all the ore came from within 65 feet of the surface.

The whole surface of the hill is a maze of pits, cuts, shafts, and portals of caved tunnels, all inaccessible. The vein strikes N. 50° E. and dips 75° W. It may be traced for several hundred yards on the surface by means of the silicified outcrop rising above the more easily eroded andesites, but apparently only 300 feet of it contained sufficient ore to be mined. The vein varies in width, but the average appears to be about four feet and as much as five feet in one cut. The filling is mainly cryptocrystalline quartz, that cements the brecciated andesite. A few scattered fragments of low grade primary ore was found after extended search, containing cryptocrystalline quartz with tiny scattered seams and occasional minute grains of galena and zinc sulphides. When examined with reflected polarized light, wurtzite is more abundant than sphalerite, both having a pale brownish color. Marcasite in spherical masses occurs with pyrite. The Hornsilver mineralization appears to be much like the Last Chance.
Oxide Lode

The Oxide lode, consisting of five unpatented claims, lies on the ridge separating the two forks of Champagne Creek a quarter of a mile east of the St. Louis mine in Sec. 15, T. 3 N., R. 24 E. Little could be learned of this property because the extensive workings are either caved or the portals have been padlocked. The underground working, judging from the size of the dump, must total more than 1,000 feet. There appears to have been no production.

The vein lying in the highly altered andesites and bedded tuffs strikes N. 200° W. and possibly dips 60° S.W. A new crosscut at an elevation of 6,250 feet is in 200 feet of altered andesite but has not reached the vein. A short distance above are some old tunnels which judging from the size of the dump must be at least 1,000 feet of work. These were in a dangerous state and were not fully explored. The vein where examined 70 feet from the portal is about two feet wide, but shades into the altered wall. Its only content is pyrite, also widely disseminated in the wall. The only material on the dump consists of silicified andesite and pyrite. A third tunnel at an elevation of 6,350 feet is recent work, but the portal has been closed with a door and padlocked. The tunnel probably is in 500 feet. A small pile of ore in the dump consists wholly of massive pyrite and possibly some marcasite in silicified andesite gangue. Pyritized tuff is also shown on the dump, indicating that tuff is encountered underground as well. Older workings occur 200 feet higher on the ridge, but these are caved. The vein is 20 feet wide in places underground, it is reported.

DEPOSITS IN THE LAVA CREEK AND COTTONWOOD CREEK DRAINAGE

Lava Creek and Cottonwood Creek deposits hold a variety of ores including silver at the Hub and Martin, silver-lead ore at the Silver Bell, Edna and several others, zinc at the Paymaster, copper in one of the veins at the Golden Chariot, antimony at the Antimony prospect, and tungsten at the Wolframite. These are rather widely distributed, compared to the close grouping of the deposits along Champagne Creek, and occur at elevations ranging from 6,000 to 9,300 feet. The important properties are within easy reach of the highway and have side roads to them. Some properties high on the flanks of the mountain are difficult to approach.

Hub Mine

The Hub mine lies along a tributary of the South Fork of Lava Creek about two and one-half miles east of Martin Post Office in parts of Sec. 8, 9, 16, 17, T. 2 N., R. 24 E., at an elevation between 6,200 and 6,600 feet. It is easily reached by road from Martin. The mine was worked soon after the discovery of the old Hornsilver and has been credited with a total production of at least $30,000 mostly in silver with some gold. About half came from ore hauled by wagon to Blackfoot and shipped from there to the smelters by train, and some from ore hauled as far as the old Nicholau smelter on Birch Creek. Much of this ore is reported to have carried 150 ounces in silver and $9 in gold to the ton. Most work done on the property was during the first two years following its discovery, but it has been worked from time to time since then and the early development extended. Some early workings are no longer accessible. Unfortunately, the Hub mine was the last one examined and time did not permit adequate study.

A series of veins or mineralized zones of complex structure have been disclosed on the property in tunnels and shafts. The general direction of movement has been to the west, but many of the breaks have occurred along northerly lines. All are within extensively altered latite or latite tuff whose character
is only recognized by examination of rock many feet from the lodes. The latite and tuff show extensive silicification near mineralized breaks completely destroying the volcanic textures. A gradation, however, may be detected outward to where the igneous textures and the original minerals are recognizable. Sericite is abundantly developed in the wall rock as well as pyrite. The movement preceding mineralization caused extensive brecciation of the rock through zones as much as a dozen feet wide and the ore was deposited in the zones of breccia. Considerable movement during mineral deposition is apparent and some continued later, displacing the ore bodies in some places. The ore occurs as stringers, lenses, and blebs in the zone of breccia and rarely is in veins with well-defined walls.

The chief value of the ore is in silver occurring mainly in the mineral, polybasite, associated with pyrite, arsenopyrite, sphalerite, galena, chalcopyrite, in a calcite-rhodochrosite-quartz gangue. Stephanite and proustite, both silver minerals, have also been reported. Of the gangue minerals, the rhodochrosite probably is the most abundant. There has been more than one stage of mineralization in the lodes, perhaps three in all, although the relations are so complex that interpretation is difficult. The first minerals deposited likely were quartz, pyrite, sphalerite, galena, and chalcopyrite in the order given, each showing signs of replacement of the preceding. Some carbonate may have been deposited toward the last, but most of the carbonate gangue came after a slight movement which fractured the sulphide ore. The carbonates, particularly rhodochrosite, were then slightly fractured by movement and the main second stage minerals introduced. Polybasite and chalcopyrite were then deposited, either in plates in the fractured rhodochrosite or quartz, or by replacement of the earlier sulphides, particularly galena. This stage was accompanied by deposition of arsenopyrite, mainly in the rhodochrosite. The final stage is represented by small veinslets of quartz and calcite which cut the earlier minerals. The most abundant sulphides of the deposit are pyrite, arsenopyrite, galena, and polybasite, all in stringers, lenses, or blebs in the brecciated zones. In places the galena has clearly replaced the brecciated material, but elsewhere it seems to have occupied open fractures. The silver minerals occur as minute crystals embedded in the gangue material and as narrow veinslets cutting across the sulphide ore.

The most recent work has been in a tunnel east and some distance below the place from which the first ore was removed. The tunnel portal has an elevation of about 6,300 feet and from it the crosscut was carried in a northerly direction for more than 700 feet until it encountered a mineralized fissure trending east or west and dipping 60° north. The tunnel was extended farther but disclosed only silicified latite. However, a drift turned to the west along the zone of movement disclosed a wide brecciated zone with slips joining the main zone at nearly every angle. The slips dip steeply to moderately north, others south, and some are nearly horizontal. The main zone, however, appears to dip steeply north and has latite tuff on the south and latite on the north, all highly silicified. The lode is about 10 feet wide and without definite walls, but contains stringer and nodules of carbonate gangue and minor amounts of sulphide scattered through the shattered rock. Probably not all is workable grade for the first 200 feet. In one place, the lode is intersected by a pre-mineral fissure which strikes N. 22° E. and dips 70° N.W. Stopping has been done on the next 50 feet and as good ore was disclosed in a shoot averaging about five feet wide and containing considerable polybasite and galena in rhodochrosite and quartz. The ore here is reported to run 200 ounces in silver. In the stopes the lode has a well-defined footwall, but the hanging is more or less indefinite. Some lenses or nodules of calcite and rhodochrosite are as much as eight inches in diameter, and the sulphide bands are as much as two
Widespread. The stoping ground is 115 feet long with 50 feet considered high grade. The shoot apparently stops on the west against a fissure trending N. 40° W. and dipping 60° S., along which there has been some post-mineral movement. From here the drifting has been carried to the northwest for 100 feet or more, crossing many stringers of calcite, rhodochrosite and quartz as well as occasional nodules of galena. Most small stringers trend to the west. In some zones the movement has been considerable and some gouge bands are as much as five feet wide. The country rock appears to have been extensively shattered for dozens of feet with the values scattered through a wide zone.

Other work has been conducted higher on the hill to the north. At the Liberty tunnel, at 6,400 feet, the vein is reached by a crosscut 500 feet long. It has been followed for 350 feet, but as its strike is N. 50° E. and dip 70° N.W., it may not be the one encountered in the lower tunnel. The lode shows the usual degree of brecciation over a zone 20 to 30 feet wide with much gouge in places. As this vein is near the surface, it shows considerable oxidation, the rhodochrosite altering to black psilomelane. Some quartz is reported to carry $19 in gold. Considerable zinc occurs in this part of the vein, mainly as smithsonite, but lead is rare. A small vein was encountered 200 feet from the portal and drifted on for 225 feet. This vein has a similar strike and dip, but less mineralization.

Both veins have been explored at the surface, the first by a shaft 125 feet deep whose collar stands at an elevation of 6,510 feet. The first vein trends N. 60° E. and dips about 75° N.W. The ore is oxidized and is reported to have contained hornsilver. Another shaft is on the second vein at 6,550 feet and parallels the one lower on the hill. The shaft is 40 feet deep and has two 30-foot drifts, each of which shows cerussite and anglesite, encrusting residual nodules of galena, as well as some copper minerals, wire silver, and zinc carbonate, in a vein four to five feet wide. The outcrop is composed mainly of psilomelane and the whole upper part of the vein might constitute manganese ore.

The oldest workings are 200 yards farther up the valley, including a tunnel several hundred feet long at an elevation of 6,450 feet and an inclined shaft on the vein. The early ore was taken from this work. The underground workings total more than a thousand feet, but as the shaft and stores are no longer accessible, little could be learned of the vein and mineral occurrence. This vein may be a different one from those explored in the other workings. All values were reported below the tunnel level.

A tunnel, the Mayflower, has been started near the road at an elevation of 6,200 feet to intersect all veins on the hill. It has intersected several small seams of vein material one to two inches wide which strike N. 60° E. and dip steeply northwest or vertically. These seams are reported to carry as much as an ounce and a half of gold. The face of the crosscut is still a long distance from the other veins.

The property seems to have a number of veins, each mineralized to various degrees and each worthy of exploration, if showing any signs of mineralization, and most do. Mineralization is apt to be very erratic and scattered in irregular shoots. As polybasite carries the chief values, the ore cannot be judged from the abundance of sulphides, for rarely does polybasite occur in recognizable masses nor is it always associated with other sulphides such as galena. Careful sampling and assaying is necessary therefore along the lodes throughout their length, especially where rhodochrosite is present. It may be that in some places the values are diluted in too much shattered country rock to be commercially profitable. Polybasite appears to be a primary.
hypogene mineral and may be expected to continue below the present working level. Gold is also an important element in the ore, but sphalerite or galena are of little consequence.

Martin Property

The Martin property on Little Cottonwood Creek in Sec. 22, T. 2 N., R. 24 E., was discovered and first worked about 1922. It has subsequently produced about 30 tons of ore, mostly since 1924. The small production has been due largely to difficulty in handling the flow of water from the creek as the lode lies in the creek channel and the water percolates into the incline making continuous pumping necessary. This has been impossible as a gas-driven pump in the tunnel soon filled the workings with exhaust fumes and the work was limited to several hours out of every twenty-four. This property may be reached by road and lies at an elevation of about 6,300 feet about one and one-half miles up the east branch of the creek. This lode shows some unusual features as the chief values are silver and gold, the silver averaging well over 100 ounces, and gold from one-quarter to three-quarters ounces to the ton. Unlike other lodes in the district, the mineralized shoot does not follow a single fissure but occurs at the intersection of a great many small slips or fissures, the ore body lying as an inclined pipe.

The pipe-shaped ore body is within the granite or more truly a granite porphyry stock, a short distance from the contact with the latite and latite-tuff. The granite shows intense hydrothermal alteration, and in the mineralized area and many feet therefrom, has been silicified and the feldspars also converted to sericite. The whole has been heavily impregnated with pyrite cubes and pyritohedrons, the tiny fractures also being filled with small seams of pyrite, sphalerite, and galena. Near the main ore shoot, the wall is also filled with sphalerite, the disseminated rounded granules ranging from pinhead size to one-quarter inch.

The property has about 300 feet of workings, including a 70-foot winze which follows the ore pipe. About 140 feet of the workings are on the lode, the remainder on the crosscut. Where the pipe is intersected, it strikes N. 70° W., but the trend soon changes to N. 82° W., showing considerable crookedness. The pipe in general plunges to the northwest, but it also shows variation, in places lying nearly flat and steepening to as much as 15 degrees. Its position is apparently determined by the intersection of a great many fractures or fissures, some with an inch or more of gauge. The fractures intersect at a rather narrow angle and in general trend from N. 70° W. to N. 70° E., and dip steeply either north or south. Most of the fractures, however, trend westerly. The fissures also show mineralization and hold narrow seams of sulphides, usually less than one inch thick, as well as certain disseminated sphalerite and galena in the walls. The most extensive deposition, however, has been in the more greatly shattered zone as determined by intersection of the system of fractures. The pipe is nearly the size of the tunnel, perhaps averaging four feet in diameter, and has a central core of massive sulphides usually a few inches in diameter and then an outer zone of silicified wall that has disseminated pyrite, sphalerite and galena, all considered ore.

Pyrite, sphalerite, and galena are the chief sulphides and in the most highly mineralized zone occur in about equal amount. In the wall, the disseminated sphalerite exceeds the galena. The sphalerite is both of the steel-gray metallic variety and reddish brown. Silver and gold are the most valuable constituents of the ore as the gold content ranges from 0.25 to 0.75 ounces, and the silver from 80 to as much as 315 ounces, these figures taken from smelter returns. Some very ordinary ore assayed for the writer carried 0.76
ounces in gold and 141.5 ounces in silver to the ton. Gold appears to occur
in the more siliceous portions of the pipe, possibly associated with pyrite,
while the silver appears in an undetermined mineral forming numerous tiny grains
and rod-shaped crystals in the galena, possibly one of the ruby silvers, as the
mineral is anisotropic. Chalcopyrite also is a minor mineral in the ore. In
some massive seams, the pyrite forms. the outer borders and the sphalerite and
galena the central core or seam. A few veins were seen in some parts of the
lode and in these young drusy quartz coats the sulphides. All the ore in the
deposit is primary. The distribution of ore values may be understood more
easily from assay returns. One shipment of 88 sacks in 1926 gave gold 0.245
ounces, silver 130.0 ounces, lead 12.4 per cent, copper 1.5 per cent, and zinc
7.4 per cent. A shipment of 12 sacks in 1925 gave gold 0.655 ounces, silver
170.0 ounces, lead 10.7 per cent, copper 1.5 per cent, zinc 11.8 per cent,
while 14 other sacks at the same time gave gold 0.66 ounces, silver 214.3
ounces, lead 10.1 per cent, copper 2 per cent, and zinc 9.2 per cent.

Several other veins occur on the property, but none has been considered
worthy of extensive prospecting. Some are small fractures mineralized like
those described above, in reality mere stringers. Others are of considerable
size, but show few signs of mineralization.

**Paymaster Mine**

The Paymaster mine is the only property described in this report which is
not in Butte County. It lies along one of the west tributaries of Big Cotton-
wood Creek in Blaine County about a mile southeast of the top of Blizzard
Mountain at an elevation of 8,900 to 7,100 feet. It may be reached by road
which near the mine is steep. So far as known, no ore has been shipped from
the mine although two large piles, perhaps of several cars each, are stored
at the portals of two main tunnels.

The development work is extensive and includes two long tunnels or drifts
along the vein and unimportant surface workings. The development has disclosed
a large body of zinc ore which carries some galena and a little silver values.

The vein is along a pronounced fissure very closely following the contact of
the granite stock and the quartzite, so much so that for most of the distance
the foot wall is granite and the hanging wall quartzite. Only in a few places
does the fissure cut apophyses of the granite and only in a few places is the
vein wholly in quartzite. For most of its course, the fissure has from two to
10 inches of gouge along the footwall, especially where the movement is in
granite, and mineralization is confined wholly to the hanging wall by replacement
of the quartzites and by filling fractures in the shattered wall. The
hanging wall of the vein is therefore indefinite as the ore shades into country
rock. The vein is particularly persistent and is mineralized for a great length.
The width of the ore body in the more highly mineralized parts is several feet,
usually the width of the tunnel, and in one place is as much as 15 feet, contain-
ing both massive bands and more or less disseminated ore. The strike of the
vein is N. 40° W. for part of its course, and N. 50° W. for the remainder,
although in some places it shows variation between the two. Its dip ranges
from 70° to 74° southwest. The granite as usual shows rather extensive hydro-
thermal alteration.

The chief mineralization has been in pyrite, sphalerite, and galena accompani-
ed by minor amounts of quartz, calcite, pyrrhotite, chalcopyrite, and arseno-
pyrite. Sphalerite is generally considered to be the main ore but it is
accompanied by galena, surely worthy of recovery. About half of the ore is
course-grained, composed of brownish-black to steel gray metallic crystals of
sphalerite in lenses or seams accompanied by considerable pyrite and a little galena. In thin sections made of this ore, the pyrite is seen to replace early vein quartz and is itself partially replaced by sphalerite after being more or less shattered. The sphalerite contains as usual numerous tiny inclusions of chalcopyrite and in some specimens rows of pyrrhotite inclusions. The galena is not abundant in this type of ore. Other minerals shown in the gangue are calcite, sericite, chlorite, and albite. As is common in the district, the sulphides show a slight shattering and cementation by a younger generation of quartz. Many stringers of this ore cut the altered quartzite wall and show distinct replacement of it. In the richer shoots, the sulphides are massive and in some places faintly banded. The remainder of the ore, however, is very fine-grained and composed of an intimate mixture of sphalerite, pyrite, pyrrhotite, galena, and gangue, as well as minor amounts of chalcopyrite and arsenopyrite, clearly products of a single stage of mineralization. Some massive ore when assayed yielded 12.2 ounces in silver. Certain zones are richer in some sulphides than others, giving the ore somewhat of a banded appearance. Usually the individual minerals are not easily recognized because of their small size and intimate association. The usual sequence of deposition has been quartz pyrite (arsenopyrite), pyrrhotite, sphalerite, galena, chalcopyrite, and calcite locally, half the ore may be composed of pyrrhotite. In some places, the vein consists of several feet of massive sulphides of this type, but more generally is confined to seams replacing quartzite or disseminated more or less generously on the wall.

The portal of the upper main tunnel has an elevation of about 7,000 feet. A crosscut 180 feet long in granite was driven to intersect the vein with drifting carried both ways. The drift to the northwest is 185 feet long and is in sulphides the entire distance. The footwall is granite and the sulphides are in the quartzitic hanging wall, the distinction between the two being sharp because of a prominent gouge seam. For the first 85 feet, the sulphides are distributed through three or four feet of hanging wall, but the vein is most heavily mineralized the last 50 feet. In one place, a crosscut 10 feet long fails to extend entirely across the mineralization. Most of it consists of massive sulphides, coarse and fine-grained, in seams in the wall. The drift to the southeast has been carried for 250 feet. At the crosscut, mineralization extends through a zone about 15 feet wide, rather heavy with pyrite and sphalerite. The ore deposition continues for 175 feet more, averaging perhaps five or six feet wide of somewhat lower grade. The remaining 55 feet are only lightly mineralized and may be considered barren. For most of this distance, the vein trends N. 40° W. and dips 74° S. W. Near the south end of the drift, the fissure crosses granite.

The portal of the lower tunnel, near the cabin at an elevation of about 6,900 feet, lies several hundred yards southeast of the upper workings. The tunnel cuts 375 feet of granite before the vein is reached. Drifting extends to the northwest for about 495 feet and ends somewhere near the end of the south drift in the upper tunnel. In the first 175 feet, the fissure is only lightly mineralized or consists of barren quartzite above two to 10 inches of gouge which rests over the granite footwall. Then the drift pulls off the vein in crossing a granite apophysis, but is relocated 70 feet farther and for the next 80 feet has a shoot of sulphides several feet wide. The remaining 175 feet are only lightly mineralized in places, except the last 30 feet where fair ore is again exposed and continues into the face. The vein trends N. 50° W. for the first 240 feet and then swings more to the north with a strike of N. 44° W.

Results of systematic sampling of this vein were not available to the writer so that the value of this deposit could not be estimated. The deposit is the
largest of its kind in the district and is worthy of careful sampling. The values obviously are mainly in zinc, but lead is an important ingredient. It is possible, however, that the zinc and lead is so diluted by the iron sul-
phides that they are not commercially valuable, but analyses alone can determine this. The chief gangue is the wall rock broken in mining and that intimately associated with the ore, besides rather abundant pyrite and lesser pyrrhotite.

Silver Bell Mine

The Silver Bell property, consisting of 12 claims, lies along the South Fork of Lava Creek nearly three miles from Martin Post Office, mainly in Sec. 17, T. 2 N., R. 24 E., at an elevation of about 6,500 feet. Work had been carried on for several years in a desultory manner, but not until 1927 did development really start. In February 1928, a car of ore was shipped, the smelter returns on which were more than $50 per ton. It was this shipment of ore that attracted the attention of the Federal Mining and Smelting Company, which late in May 1928 acquired control of the property and began intensive prospecling, mainly in a long crosscut that was to tap the veins considered at the surface to have promise. Several additional veins were encountered in the crosscut, but the prospecting failed to disclose ore occurrences of sufficient size or width to make further development attractive and exploration was abandoned on January 31, 1929. The values of this property are in silver-lead and high grade samples have run as well as 68 per cent, and 84 ounces in silver.

The veins or lodes on this property are within latite and latite-tuff, mainly the latter. The country rock has been so extensively altered by the hydrothermal solutions that recognition of the original character is difficult, but in most places outlines of tuffaceous particles or fragments are still preserved. As usual, alteration has caused extensive bleaching and dissemination of pyrite as well as occasional cubes of galena in a silicified, sericitized matrix, which extends dozens of feet from the mineralized seams. The total number of mineralized fractures are unknown, but they are numerous, in general trending north. Another set trends nearly at right angles, but is only slightly mineralized. In general, mineralization throughout is very irregular and erratic, the sulphides confined to scattered masses or nodules or as irregular fillings in fractures.

The workings on one of the veins were inaccessible and little could be learned of its geology, although probably it is similar to another from which most of the ore has been taken. This second, mentioned as the Big Vein, is explored by tunnel from the Creek. The work disclosed two ore shoots at 150 feet, both with a little galena and sphalerite and associated with considerable calcite, mostly later than sulphides. Neither shoot is extensive, only a few dozen feet long and scarcely more than a foot wide. The fissure is well defined and contains some gauge. Its trend is N. 30° E. and dip 85° N.W.

Higher on the ridge are some workings probably on the same vein, but perhaps on others. One tunnel occurs at an elevation of about 6,500 feet and follows the vein which here strikes N. 55° E. and dips 68° N.W. The tunnel is in 150 feet but disclosed nothing of value. Another tunnel 100 feet higher follows the vein which strikes N. 65° E. and dips 67° N.W. This vein occupies a well-defined fissure with distinct foot wall and a heavy seam of gauge, but shades into the hanging wall. A small shoot of good ore two to three feet wide, 10 feet long in the strike, and 20 feet on the dip, was encountered along the vein and it was this that largely served as incentive for driving the long crosscut about 200 feet or more below.

On September 4, 1928, the crosscut had been driven 250 feet through intensely

- 62 -
hydrothermally altered country rock, containing disseminated grains of pyrite and occasionally a grain of galena. A vein, which failed to show at the surface, was encountered near the tunnel portal. In fact, the tunnel exposed a regular system of fractures and fissures which had thoroughly shattered and brecciated the rock, many faults with several inches of gouge. The system of fractures trend in two general directions, one set N. 36° E. with dip ranging from vertical to 60° N.W. and the other N. 70° W. and dip 30° to 70° to the northeast. The first set shows the least movement (least gouge) and the greatest amount of mineralization. The second set shows the greatest movement, recorded by heavy gouge and great shatterings, and is more lightly mineralized. Thus the first set conforms to the general direction of the Champagne Creek mineralization, and the second with that common to the Lava Creek. Considerable post-mineral movement has also occurred especially along the second set of fractures, but the displacement generally has been slight. Perhaps the greater amount of gouge in the second set has prevented extensive mineralization. The tunnel was extended to the intersection with the known veins on the surface and encountered sporadic mineralization in a series of minor fractures of insufficient size to make further development attractive on a large scale. The values on this property have been too widely scattered through the shattered country rock and so lost commercially except for much pocket occurrences near the surface which may be handled on a small scale.

The chief mineralization has been in argentiferous galena and pyrite, and subordinate amounts of sphalerite and chalcopyrite in a gangue that includes quartz of two generations, calcite and probably some rhodochrosite. Apparently the quartz was deposited, first in the fractured rock and then in part replaced by the sulphides along with carbonates although quartz and carbonates are in part later as they fill fractures in some cases of the shattered ore. That there was movement along the fractures during mineralization is evident from the northeast of the pyrite and replacement by sphalerite and galena, and again by greater shattering of the sphalerite compared to somewhat younger galena. The sphalerite is black as usual and is filled with tiny grains of chalcopyrite. The sulphides and particularly the galena occur in veinlets from one-half to two inches wide, and as scattered nodules and lenses several inches in diameter. Much of it is cubical and granular. Considerable secondary ore occurs near the surface and the galena nodules are crusted with anglesite and cerussite, and stained with malachite and azurite. Smithsonite was noted also.

**Edna Mine**

The Edna mine, from which some silver-lead ore was shipped about 1910, lies along the North Fork of Lava Creek in Sec. 7, T. 2 N., R. 26 E., at an elevation of about 7,000 feet. It is most easily reached on foot from the base of the north lava vent, for from here the road which leaves Dry Fork Valley becomes difficult to travel. Total production here perhaps reached 20 tons of sulphide and carbonate ore mined from the outcrop. At the time of visit, a pile of ore of almost equal size was stored on the dump at the portal of a tunnel from the creek extended to intersect the veins at greater depth.

The property has a great many veins extending in all directions much like spokes from the hub of a wheel. The most pronounced fractures trend N. 86° E., N. 40° E. and N. 230° W., and most dip eastwardly or to the north. They are all enclosed in latite which shows the usual intense alteration, and especially replaced by sericite and pyrite and often with small amounts of other sulphides either as sparse disseminations or in minute veinlets filling fractures.

The most pronounced lode at the surface trends N. 230° W. and dips nearly vertically. This vein shows considerable brecciation of the rock in its core.
and is traceable for a long distance, 300 feet or more. It shows variable amounts of mineralization for eight to 10 feet of its width and shows hydrothermal alteration for much greater distances. The surface is stained with iron oxides and contains some lead carbonate, as well as some residual galena and pyrite. It is this cropping that furnished the early production. Intersecting it are other veins or fissures, showing signs of hydrothermal alteration, and also of small shoots of sulphides. These appear to trend in all directions and the structure is very difficult to work out.

The crosscut from the creek, to be driven beneath the large cropping has intersected several fissures, one well mineralized and others only slightly less so. The first fissure encountered strikes N. 85° E. and dips 75° S. This fracture zone has a well-defined gouge zone, but for 60 feet only slightly is mineralized. The other 35 feet that it has been explored, however, carries as much as a foot of sulphides ranging down to four inches, most of it massive but containing some stringers. In the face, the sulphides, pyrite and galena, occur in seams or veinlets cementing the highly fractured rock. A short tunnel to the north encountered another mineralised fissure trending N. 40° E. and dipping 85° S. E. This has a gouge seam several inches wide with only insignificant amounts of pyrite and galena.

The largest and most valuable vein, however, is followed by drift from where the first vein mentioned above was encountered and apparently is to be followed until the vein whose outcrop at the surface is so pronounced is cut. This mineralised fissure strikes N. 40° E. and dips 76° S. E. The drift in going to the southwest disclosed 40 feet of good sulphides ranging from four to 14 inches wide and composed mainly of galena and sphalerite. The shoot then pinched for 20 feet and again widened from four to 12 inches. Again it pinched somewhat and then widened to 20 inches of high grade which persisted for more than a dozen feet and then passed into several feet of milling ore. This marked the stage of development when the property was examined.

The walls of the veins are fairly distinct, but replacement has also played a role. Much of the ore which includes pyrite, cubical galena, and metallic steel gray sphalerite occurs in compact seams or lenses, usually as a single mass, but also in several seams, and also as a filling and replacement along tiny fractures in the wall. In the larger lenses the pyrite tends to form a casing next to the wall with galena near the center. As a whole the shoots are lenticular, pinching and swelling both on the strike and dip. The increase in thickness is in those parts of the veins where the country rock has been most severely shattered or brecciated, and the decrease where there has been less shattering and also more gouge developed. Apparently greatly brecciated or open spaces have favored ore migration and deposition. For this reason, intersection of cross fractures should be especially examined as they might favor localization of the more valuable ore shoots.

Quartz is the chief gangue mineral but is not particularly abundant in the mineralized shoots and occurs as scattered crystals in the sulphides and in a younger system of veinlets which traverse the sulphides. A little calcite was noted in the vein. In polished surfaces, a few grains of argentite and also considerable chalcopyrite was found with the sulphides. The chalcopyrite is abundant as minute grains in the sphalerite but occurs also in larger grains cementing and in part replacing the other sulphides, especially pyrite. Some galena, assayed for the writar, contained 10 ounces in silver to the ton. Most of it is reported to run about 25 ounces to the ton. All ore in sight is primary.
The Golden Chariot Mine lies high on the flank of the ridge a little over a mile southwest of Martin in Sec. 15, T. 2 N., R. 24 E. It is reached by a notably steep road. The property was first prospected prior to 1890 and has been continued for many years. Early values are reported to have been in gold, but the production was small.

Several veins outcrop on the property, two considered as silver-lead veins and one as a copper vein. These occur in the latites and the latite-tuff not far from the granite stock outcropping at the top of the ridge. As usual, the wall rock about each of the veins is highly altered and the black biotite latite is changed to a pyritized gray or white rock, silicified and sericitized. The first silver-lead bearing vein is explored by a lower tunnel 300 feet long at an elevation of 6,025 feet. The vein follows a well defined fissure which strikes N. 85° W. and dips 82° S. It is very lightly mineralized with little streaks of galena and sphalerite scattered uncertainly. The vein is less than a foot wide and has seams of gouge about an inch thick along parts of it. Near the face the vein branches into several seams about an inch thick. The upper tunnel lies about 115 feet higher and explores the vein for 175 feet. The vein dips more steeply and is somewhat larger than below. The vein is about four inches wide for most of its length but broadens to 18 inches near an intersecting fracture. This shoot is about 30 feet along the strike and has been stope nearly to the surface. An underhand stope also goes down about 15 feet. The ore on the dump is practically all oxidized and contains much limonite and pelomelane as well as cerussite and some residual grains of galena and sphalerite. In this the galena and sphalerite are more or less disseminated in small grains and granules through vein quartz in part as a filling and in part as a replacement. It is accompanied by a little chalcopyrite.

The second vein differs greatly and has been called a fault breccia and considered as drag ore. In this, boulders of ore occur in a large brecciated zone in the hydrothermally altered latite. A tunnel about 50 feet long and a shaft 30 feet deep does not adequately explore the brecciated zone and whether the boulders represent drag ore or the original filling is difficult to determine. The ore boulders are mainly of galena, chalcopyrite, and sphalerite in quartz, crusted with their secondary products. These boulders show shattering and the fractures have been filled with younger calcite. Nodules of calcite in the brecciated zone are distinctly younger than the movement. As the fault zone trends about N. 85° W., the same as other veins, and as calcite is usually a late mineral in all veins after the sulphides have been more or less shattered, it is probable that the boulders are not drag from other veins. More likely they represent the original filling in the vein or of crush breccia, more or less rounded by the movement along the vein concurrent with mineral deposition. In this vein, movement during mineralization probably has been greater than in any other. Other old workings occur nearby.

The copper vein lies across the gulch on the south at the top of the ridge very near the granite body. It is enclosed in latite-tuff in a fissure that strikes N. 75° E. and dips 75° N.W., and may be traced for several hundred yards. The outcrop has been explored by several small cuts and a short tunnel at an elevation of 7,150 feet. The vein consists of several seams a few inches wide in the fissure zone, but nowhere is the entire vein more than a foot wide. The vein mainly carries drusy quartz, in part amethystine, with numerous bladed crystals or plates of specularite, and occasional grains of chalcopyrite, all moderately stained by secondary products of the chalcopyrite. The vein also carries a little lamellar/orhackly quartz in addition to quartz crystals, many an inch and a half long.
Silver Tip Mine

The Silver Tip lies a short distance below the Edna along the North Fork of Lava Creek in Sec. 7, T. 2 N., R. 24 E., at about 7,000 feet. A little ore was shipped in early days of mining activity, with values in silver and lead. The underground workings total about 75 feet, but a cave-in near the portal prevents full examination of the vein.

The country rock is the Tertiary lava (latite) which here is thin as limestone outcrops a short distance down the creek. The vein, wholly within the lava, strikes N. 60° E. and dips 77° W. Movement along the fissure developed a gouge seam about 12 inches wide and this vein, unlike most others, shows sharp walls, probably due more to post-mineral slippage than lack of replacement. Silicification and seritization extends for many feet on either side, near the portal from 15 to 20 feet of white, altered ground.

The vein filling shows in part a banding and crust formation, with some small vugs containing tiny crystals of drusy quartz and some small lenses of galena. Much of it, however, is like vein replacement of the neighboring deposits and has disseminated pyrite with masses and grains of galena. The pyrite and galena are the most abundant sulphides, particularly the former, in part replaced and in part cemented or enclosed by galena. A little steel gray sphalerite with usual chalcopyrite inclusions and some microscopic grains of tetrahedrite (?) and pyrrhotite in the galena were also recognized. Locally, pyrrhotite is abundant and occurs in grains in association with pyrite. Most of the sulphides occur in a band about four inches wide lying near the gouge seam. It is reported that the vein filling carries as much as $5 in gold.

Diamond Prospect

The Diamond group of five unpatented claims lies in Sec. 18, T. 2 N., R. 24 E., along the North Fork of Lava Creek several hundred yards beyond the Edna. This property is a recent discovery and has no production. The vein outcrops along the creek at an elevation of about 7,200 feet and has been explored by several small tunnels and cuts scarcely penetrating the oxidized zone.

Mineralization is in a fracture zone trending N. 50° E. and dipping 45° S.E., which cuts both latite and a granite porphyry stock. The lode may be traced for several hundred feet and approximately parallels the creek. The hydrothermal alteration has been particularly severe and has been described elsewhere. The altered rock is white and studded with numerous small pyrite crystals. Mineralization extends in part through a zone 20 feet wide. It shows tiny seams and veinlets of galena, and nodules of galena cemented by cerussite and anglesite. Generally the surface has more carbonate ore than sulphide ore, but this zone probably is shallow, and the carbonate occurs mainly in scattered pockets. The original sulphide mineralization appears restricted to small seams and scattered nodules in the fractured rock. Minor amounts of black sphalerite, and also a little tetrahedrite, were noted in the specimens. Development has not been sufficient to determine the merits of this prospect.

Pandora

The Pandora group of claims lies on the north side of Boyle Mountain at an elevation of 8,950 feet. Development on this property has not been extensive although probably first worked in the first period of mining activity. The vein has been unsatisfactorily exposed in a few places by surface cuts and two shallow shafts less than 25 feet deep.

- 66 -
The vein occurs in limestone and strikes N. 72° E., and dips steeply southeast. It may be traced by the line of open cuts for several hundreds of yards. For most of the distance, the vein is from 10 to 20 inches wide and has sharp walls. Only the oxidized portion of the vein has been entered and little could be learned of the primary mineralization. A lot of oxidized ore has been strewn on the dumps, showing considerable cerussite as well as being heavily stained by malachite, chrysocolla and iron and manganese oxides. Some cerussite is associated with anglesite and some contains residual grains of galena. A little pyromorphite was also noted in the iron-stained ore. Lead and copper mineralization is not uniform as more copper shows in some places than in others. The main vein filling appears to be quartz. Development has been insufficient to determine the value of the deposit, although lack of development suggests the vein is not viewed with much promise.

Sam and Tom

The Sam and Tom property lies on the north side of Boyle Mountain adjoining the Pandora at an elevation of about 9,000 feet. The property is old, having been worked shortly after the first discoveries were made and a number of times after. The last production was in 1924 when 15 tons of silver-lead ore were shipped.

The vein is in limestone and a small syenite sill not far from a larger body of syenite. The vein begins near the larger syenite body and trends N. 85° W. and has a dip of 85° N. E., cutting the limestone and sill which strike N. 20° W. and dip 55° S.W. The vein is about 12 to 18 inches wide in the limestone but narrows to one to two inches in the sill. Work did not continue across the sill, nor did values appear to increase on the other side as seen on the surface. Only the oxidized ore could be seen and primary mineralization remains in doubt, though probably galena. A short crosscut intersects the vein and some stopping has been done both above and below. The stoping above was carried to a drift on the vein 40 feet higher, but as the under-stope was filled with water, depth could not be determined. The stope probably is less than 50 feet long. Apparently all ore in sight has been removed. The vein is in a fissure of slight displacement and the walls are sharp. Probably both fissure filling and replacement played a part in its formation. The dike has caused a small amount of contact metamorphism near the vein but the new minerals are silicates, mainly diopside and garnet, without sulphides.

Copper King Group

The Copper King is one of the old prospects and has been relocated many times the last in August 1928 as the Lucky Strike mining claims. This prospect lies in the first large gulch west of Little Cottonwood sinks at an elevation of 6,300 feet in Sec. 28, T. 2 N., R. 24 E. An old road stops at the property, but is no longer passable.

Studies of this prospect were unsatisfactory, for the workings are old and the main tunnel was half filled with water, making entrance undesirable. Apparently the tunnel had been but recently cleaned out and some assessment work done. The vein lies in the Tertiary lava (latite) about 150 yards from the granite contact. It is exposed in a small cut about 100 yards from the portal of the tunnel and strikes N. 60° E. and dips 60° N.W. The movement has not been along a single fissure, but along several small ones producing a sheeted zone. The alteration has been most extensive in the hanging wall and has bleached the black latite over a zone more than six feet wide. No sulphide occur in the cut and the white altered rock is only slightly iron stained.
Damp material at the portal of the main tunnel shows considerable evidence of hydrothermal alteration and the white, sericitic rock contains numerous small cubes of pyrite and shows rather extensive silicification. Apparently the latite had been thoroughly brecciated before mineralization filling many fractures with tiny seams of pyrite and occasionally sphalerite. Calcite is also present in seams from a fraction of an inch to two inches wide and these seams cut the sulphides, indicating that calcite was the last mineral to be deposited. Unfortunately, the size of the vein and mineral distribution remain unknown.

Antimony Prospect

The single deposit of antimony lies along the north branch of Lava Creek about one and one-quarter miles north of the Hub mine in Sec. 4, T. 2 N., R. 24 E. Nothing is known of the early history of the prospect, but it appears to be one of the deposits in the district that is relocated annually, the last time in July 1927, as the Pickup claim. The outcrop is near the stream at an elevation of 6,250 feet near the lower end of a small gorge cut through limestone.

The country rock is a silicified limestone of grayish color which nearby carries Mississippian fossils. The limestone overlies a dense, nearly black quartzite which together strike about N. 30° E. and dip to the southeast at a moderate angle. The overlying andesite or latite has been stripped by erosion, but the contact is less than 50 yards distant.

The antimony occurs in a gently brecciated zone or crush zone in the limestone. The limestone along the zone of brecciation has been so extensively silicified that its original character cannot be clearly recognized and was identified only because it merges with limestone on either side. The silicified zone is as much as 80 feet wide and may be traced N. 70° W. for several hundred feet. It shows considerable irregularity as to thickness and the silicified zone probably ranges from 10 to 60 feet wide. The limestone apparently was first greatly shattered and then partially replaced by silica so that the vein resembles a quartzose breccia. The stibnite occurs locally in shoots in the silicified zone as a cement between the breccia fragments, and is confined to those places where most intense shattering has occurred and open fractures were most numerous. Curiously none of the fractures have been filled with drusy quartz.

Development has not been extensive and includes a short tunnel caved at the portal and several small cuts on the surface. A small pile of good ore has been stored alongside the dump, mostly high grade with many chunks of solid stibnite a foot or more in diameter. In these chunks the stibnite is more or less porous with radiating groups of columnar and bladed crystals. The ore apparently has come from a shoot about eight to 10 feet wide and 20 feet long as exposed in a surface cut. Entire extent of this shoot could not be determined, but it probably continues for several dozen feet on the strike of the lode ranging down to two feet. Secondary alteration has affected the stibnite slightly and has formed a minor amount of valentinite, stibiconite, and covellite, the oxides of antimony. Development is insufficient to give an adequate idea of the size of the deposit, but it is evidently considered of small promise.

Wolframite Prospect

The Wolframite prospect, containing Hübnerite as its ore mineral and curiously named after the iron tungstate, wolframite, lies near the very summit of
Blizzard Mountain at an elevation of approximately 9,350 feet. The outcrop is about 200 yards northwest of the triangulation monument on Blizzard and on the crest of the ridge overlooking the head of Lava Creek. It thus barely lies within Butte County and in all likelihood, if the vein continues, probably extends into Blaine County. The outcrop may be reached on foot or horse-back, but only after a very strenuous climb.

The tungsten occurs in a greatly brecciated zone at the contact of the Miocene (?) granite and the Mississippian limestone and quartzite, and is in part in granite and part in sediments. Apparently, the movement has followed very closely the intrusive contact and has brecciated both the invading rock as well as the invaded rock. The zone of brecciation extends N. 30° E. and dips steeply to the northwest. The vein ranges from two feet to five feet in width and is made up of veinlets and bunches of quartz in the crushed igneous and sedimentary rock. The granite shows intense hydrothermal alteration and has much sericite and a little chlorite in it. The fragments of rock are in the main crusted by quartz crystals which point inward toward a well-defined median plane with drusy surface. Vugs lined with inward projecting quartz crystals are very numerous and quite characteristic of the vein filling. The hübnerite occurs in scattered platy aggregates and isolated plates in the coarse textured quartz. It began its crystallization soon after that of the quartz, but was deposited long before the quartz had completed its crystallization.

Development has not been extensive and includes a small tunnel, that is caved and usually hidden by snow throughout the summer, and a cut at the surface. Practically all the work has been on the surface cut which has opened the vein for about 40 feet and has disclosed much oxidized material, consisting of vein quartz lightly coated with black psilomelane and a little limonite. Little of the hübnerite is to be seen in the manganese stained rock and fresh specimens of either the hübnerite or its oxide, tungsite, are difficult to find. Apparently, the lode has been only lightly mineralized, and judging from development efforts is not considered promising.

DEPOSITS IN THE LEAD BELT REGION

Deposits near the head of Lead Belt are valuable mainly for their lead and silver. The veins are in the sedimentary rocks, but not far from granite porphyry dikes of Tertiary age. The deposits appear similar to those near the summit of Boyle Mountain a few miles to the south. The Lead Belt area is the most difficult to approach and must be reached from Antelope Creek over a road which in its upper course is bad. The deposits lie at elevations of nearly 7,500 feet. Only two have been extensively developed.

Butte-Antelope Mine

The Butte-Antelope or the Foot Wall group is held under lease and option by the Butte-Antelope Mining Company. This property consists of 14 unpatented claims located near the head of Lead Belt Creek in Sec. 13, T. 3 N., R. 23 E. It is one of the old properties in the district, its discovery dating back to about 1890 along with that of the Lead Belt. Practically all work was done early and the property has been idle until recently when a car of silver-lead ore was shipped. The old workings consist of open cuts, short tunnels and drifts scattered along the side of the hill. These are all inaccessible and the present work consists in driving a crosscut below the older workings to cut the vein at depth. In 1928, the tunnel was in 200 feet and extended another hundred feet during the year, mainly through a black, carbonaceous shale. The portal of this tunnel has an approximate elevation of 7,250 feet.
The vein was not seen in place, but is in the area of limestone rocks. It is reported to trend nearly north (possibly one of the Lead Belt veins) and dips steeply west. The ore is said to occur in small stringers, several inches wide, and as scattered nodules or lenses along the fissured limestone. Specimens of ore were collected from several of the old dumps and these show mainly galena and calcite (in part manganiferous) with minor amounts of sphalerite, tetrahedrite, and pyrite. The sulphides have replaced an earlier filling of calcite along a fine system of fractures and have been, in turn, fractured and cemented by more calcite. The ore is reported to carry from 150 to 300 ounces of silver, the richer near the surface in the partially oxidized zone, but some selected samples with considerable galena were assayed and these carried only 51 ounces in silver.

Lead Belt Mine

The Lead Belt mine lies very near the head of Lead Belt Creek at an elevation of approximately 7,200 feet and mainly in Sec. 13, T. 3 N., R. 23 E. It is reached by road from Antelope Creek and has Darlington as its nearest shipping point. This mine was located about 1890 but was not extensively developed until 1905. Several shipments of silver-lead ore were made in 1908. Again in 1910, a little work was done and three carloads of ore were shipped, but the principal production was in 1913 when the output was 21 cars of 50 tons each, averaging 16 per cent lead and 16 ounces of silver to the ton. Little work has apparently been done since then, but in 1929 diamond drilling was begun by the Lead Belt Mines Syndicate.

Known ore bodies lie wholly in the limestone forming the south side of the gulch along which the locations have been made. Rocks on the north are the Tertiary lavas, mainly andesites. The ore bodies apparently occur as northward trending veins, dipping westward beneath the lavas. Little was to be learned at the time of visit, for the workings, except one, were inaccessible. Development includes about 2,000 feet of workings, comprising a tunnel and shaft along the creek and two small shafts and a tunnel 600 feet farther up the gulch. Smaller cuts and drifts are also scattered about the property. A section of missing ladder in the shaft in the valley floor prevented examination of the vein from which the production was made in 1913. Unfortunately, no ore was found in the dump and little can be said of the vein filling except that calcite and rhodochrosite seem abundant.

The most recent development has been some distance below the shaft where a short tunnel has a raise to the surface as well as a winze of unknown depth. Some ore was concentrated in hand jigs. The vein occupies a fissure which strikes north and dips 35° West. The ore shoot is very irregular and more or less chimney-like. The sulphides, mainly galena, occur in small bunches or lenses in a calcite vein two to three feet wide but with great irregularity in thickness. The stope is not over 40 feet along the strike of the vein and apparently pinched with depth. The vein is a filling of fractured and fissured limestone. There probably are numerous similar veins in this region and it is likely from veins such as this that the past important production has come. They are probably all characterized by a very pockety and uncertain distribution of the sulphides.

Other Properties

Many more locations have been made in the district, mainly inspired to a great degree by the entry of the Federal Mining and Smelting Company. Some have been new locations and many more re-investigations of old. A number of old prospects some of which have produced a little ore are scattered along the head of Dry Fork of Antelope Creek. These are mainly in the quartzites and shales. Galena was apparently the mineral mined, but none remains on the dumps at present.