GOLD AND SILVER.

THE AURIFEROUS GRAVELS OF THE TRINITY RIVER BASIN, CALIFORNIA.

By J. S. DILLER.

INTRODUCTION.

The Trinity River region, in northwestern California, has long been worthily noted for its mines, especially the placers, the working of which opened with a rush in the early fifties and has continued with more or less regularity ever since. Besides the La Grange mine, the largest hydraulic mine now in active operation, it contains the Hupp, the Union Hill, and a number of other hydraulic mines, particularly in the northern portion of the county. Large bodies of gravel of lower grade yet remain. Those near the river level are now being attacked by dredges, as at Trinity Center and Poker Bar, and the outlook for the future is encouraging.

The region is accessible by wagon road only from the Southern Pacific Railroad in the Sacramento Valley at Redding, the chief point of supply, via French Gulch 38 miles to Lewiston, and from Red Bluff via Harrison Gulch about 50 miles to Hay Fork. The new State road connecting Hay Fork with Humboldt Bay will soon be completed, and active surveys promise a railroad within a few years from the same bay through Hyampom and Hay Fork to the Sacramento Valley.

For much of the information used in this paper I am deeply indebted to Mr. Thayer, of Douglas City; Mr. J. J. Murphy, of the Union Hill mine; Mr. Pierre Bouery, of the La Grange mine; Mr. W. D. Ayers, of Poker Bar; and Mr. M. D. Pinkerton, of the Globe mine; but more particularly to Mr. H. L. Lowden, formerly county surveyor of Trinity County, who through many years by maps and conversation has given me much information concerning the distribution of the auriferous gravels.

LOCATION AND EXTENT.

The Trinity River basin lies wholly within the southern part of the Klamath Mountains. The course of Trinity River (see Pl. I) is roughly crescentic, concave to the north. The right arm represents the south and southwest upper course of the river to Douglas City, where the stream turns and flows northwestward to the Klamath.

The basin is bordered by prominent mountains. On the north, between the arms of the crescent, lie the Salmon Mountains [1] of the Sierra Costa cluster, rising to elevations over 8,000 feet. On the southeast and south are the Trinity, Bully Choop, and North and South Yolla Bolly mountains, ranging from 5,000 to 8,000 feet; on the southwest is the prominent, remarkably even crested ridge of South Fork Mountain, having an altitude of nearly 6,000 feet.

The Trinity River basin embraces the whole of Trinity County except the south end and also the part of Humboldt County about the Hoopa Reservation, the total area being nearly 3,000 square miles.

TOPOGRAPHY AND PHYSIOGRAPHY.

The even crest of the South Fork Mountains is part of an ancient plain of erosion, extensively developed in the Klamath Mountains and hence called the Klamath peneplain.[2] This plain is the result of the first cycle of erosion recorded in the topography of that region and has been differentially uplifted and deformed so that portions of the peneplain which appear in the Salmon, Trinity, Yolla Bolly, and South Fork mountains are now at different levels.

Trinity River and its branches, rejuvenated by the uplift, deepened and widened its valley during a second cycle of erosion until a second plain of erosion was produced within the borders of the Trinity basin. This second plain appears to correspond to the Sherwood peneplain on the coast.

The Sherwood peneplain of the Trinity basin is from 500 to 1,000 feet lower than the bordering mountains showing remnants of the Klamath peneplain. It is the general summit level or the plateau of the Trinity River basin far above the present streams. The irregularities of the plateau surface are due in part to the fact that the planation of the second cycle was not complete, in part to deformation in uplifting the Sherwood peneplain, but perhaps chiefly to subsequent erosion of the again rejuvenated Trinity River and its tributaries. During a third cycle of erosion the streams deeply trenched the Sherwood peneplain and by widening their terraced canyons have reduced the plateau to a succession of ridges of approximately equal elevation.

[1] Bull. U. S. Geol. Survey No. 196, 1902, Pl. I; footnote, p. 10. The Salmon Mountains have been called the Sierra Costa by O. H. Hershey (Am. Geologist, vol. 25, 1900, p. 76).

[2] Bull. U. S. Geol. Survey No. 196, 1902, p. 15.

These two peneplains, the Klamath and the Sherwood, correspond approximately to the remnants of old topographic cycles recognized by Hershey [1] in the Trinity region of the Klamath Mountains and to those recognized by Lindgren [2] in the Sierra Nevada. Both of these authors regarded the higher and older peneplain as of Cretaceous age and the lower and newer as Tertiary.

The relations of these physiographic features are illustrated in figure 1, a generalized section from the South Fork Mountains northeastward across the Trinity River basin to Thompson Peak. The flat summit of the South Fork Mountains and the gentle slope on the divide southwest of Thompson Peak belong to the Klamath peneplain (*a*). The flat-topped ridges (*b*) in the Trinity River basin are remnants of the Sherwood peneplain. They are about 1,000 feet below the Klamath peneplain. These remnants of the Sherwood peneplain are separated by terraced stream valleys (*c*) more than 2,000 feet deep and ranging from V-shaped canyons or narrow, terraced valleys to broad, flat valleys like that of Hyampom and Hay Fork.

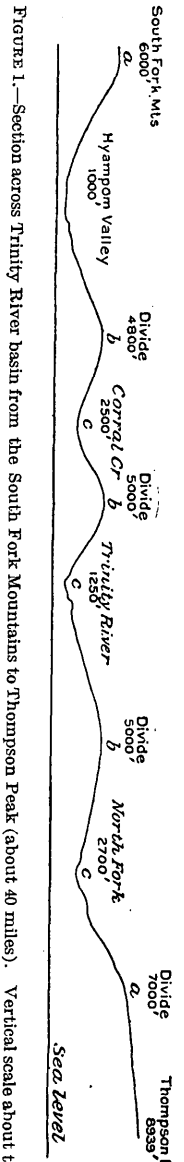

FIGURE 1.—Section across Trinity River basin from the South Fork Mountains to Thompson Peak (about 40 miles). Vertical scale about twice the horizontal.

GLACIATION.

The uplift which closed the second cycle of erosion and initiated the third cycle was sufficiently great to form mountains and was soon followed by the development of glaciers which extended for comparatively short distances from the highest summits down the deepening valleys of the rejuvenated streams. As shown by Hershey,[3] there were many advances and retreats of the glacial ice throughout a long period, and the glaciers were closely related to the development of the valley terraces during the third cycle of erosion, when the modern streams were trenching their present valleys so deeply below the general level of the Sherwood peneplain.

Glaciers are gravel mills, and the bowlders and gravel of the till of the earlier glaciers, having thoroughly decomposed, liberated all the gold for concentration by stream action in the gravels capping the terraces of the present

[1] Am. Geologist, vol. 25, 1900, pp. 86-87.

[2] Age of the auriferous gravels of the Sierra Nevada: Jour. Geology, vol. 4, No. 8, 1896, p. 894.

[3] The river terraces of the Orleans Basin, California: Bull. Dept. Geology Univ. California, vol. 3, 1904, pp. 423-475.

streams. As pointed out by MacDonald,[1] glaciers as agents of erosion forming the till and thus initiating the concentration of its gold in gravels have an economic aspect.

The only auriferous gravels commingled with glacial deposits, or "dead wash," in the Trinity River basin, are on the larger streams heading in the higher portions of the Salmon Mountains. The valleys of such streams as Coffee Creek, Swift Creek, and Stewarts Fork were occupied by glaciers of considerable size.

PENEPLAINS ARE HORIZONS FOR AURIFEROUS GRAVEL.

One of the most important conditions contributory to the formation of rich auriferous gravels is the deep weathering and disintegration of rocks that contain gold-bearing quartz veins. By this means the gold is liberated in the residual material and prepared for concentration by the streams in their gravel beds. That auriferous gravels commonly originate in connection with peneplains is evident in the Sierra Nevada, where the high gravels are associated with the low relief of a peneplain and contain a large amount of residual material resulting from the deep rock weathering on gentle slopes.

DESCRIPTION OF THE GRAVELS.

AURIFEROUS GRAVELS OF THE FIRST CYCLE (KLAMATH PENEPLAIN).

No auriferous gravels have yet been found in immediate connection with the Klamath peneplain on the borders of the Trinity River basin, but within the basin there are large masses of gravel whose origin may possibly be referred back to the Klamath peneplain. If this peneplain is regarded as Cretaceous, as claimed by Hershey, there is evidence on the eastern border of the Klamath Mountains in both Oregon and California that, locally at least, the marine gravels of that period are auriferous. H. W. Turner[2] in 1903 described "The Cretaceous auriferous conglomerate of the Cottonwood mining district of Siskiyou County, Cal.," and recently G. F. Kay[3] and others have shown that Cretaceous gravels at several localities in the northern part of the Klamath Mountains in Oregon are auriferous. This Cretaceous auriferous gravel at one time covered a large part of the Klamath Mountains, but it has been washed away and its gold content concentrated by stream action in richer gravels of later age. Of this the Cretaceous fossiliferous pebbles found in later gravels of Trinity River near Lowden's ranch afford good evidence.

[1] MacDonald, D. F., Bull. U. S. Geol. Survey No. 430, 1910, p. 50.
[2] Eng. and Min. Jour., vol. 76, 1903, pp. 653-654.
[3] Bull. U. S. Geol. Survey No. 380, 1909, p. 72.

AURIFEROUS GRAVELS OF THE SECOND CYCLE (SHERWOOD PENEPLAIN).

AGE AND DISTINGUISHING FEATURES.

Extensive deposits of auriferous gravel are associated in large part with the Sherwood peneplain, but their relations to it are such as to show that they are older than the final stage of the peneplain and most probably originated in connection with an early stage in its development.

The preservation of these ancient gravels is due to their having been faulted downward into basins where they were protected from erosion by a rim of harder rocks. These deposits are outlined on the map (Pl. I), and the areas will be considered separately in the following paragraphs. The deposits have a wide range in elevation and manner of outcrop, but by their tilted stratification and partial induration they may be readily distinguished from the much later terrace gravels in the deep trenches which Trinity River and its tributaries have cut in the Sherwood peneplain.

WEAVERVILLE BASIN.

The Weaverville Basin attracted attention in the early fifties, and ever since has been the scene of more or less vigorous activity in placer mining. The area was outlined by me [1] in 1893 and described more fully in 1903 by O. H. Hershey,[2] who has kindly furnished a geologic map of the region from which I have obtained the outline of the north end of the deposits. The area is about 20 miles in length from the La Grange mine to a point near Swift Creek and is from 1 to 3 miles wide. Its surface is a well-marked plain whose ends are of nearly equal altitude, approximately 3,100 feet, but whose east side is 600 to 800 feet lower than the west side, the plain sloping with the transverse drainage directly away from the Salmon Mountains toward the present Trinity River. The greatest thickness of the deposit in this area is probably not less than 1,000 feet, and the general attitude of the strata is monoclinal, with a dip of about 26° W., toward the fault which limits the deposit in that direction.

This fault was first pointed out by D. F. MacDonald [3] and illustrated, as in figure 2, by a section of the La Grange mine, where it lies between the auriferous gravels and Paleozoic black slates on the one hand and greenstones on the other. The general strike of the fault plane in the mine is N. 64° E. and the dip 22° SE., but its course varies. The fault plane is clearly marked by slickensided

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 414; see also Bull. 196, 1902, p. 44.
[2] Jour. Geology, vol. 11, 1903, p. 157.
[3] Bull. U. S. Geol. Survey No. 430, 1910, p. 51.

tracts of crushed dark slate on greenstone, and the striæ generally run directly down the slope. East of the La Grange mine and reservoir the strike of the fault is N. 87° E., but where the fault crosses the West Fork of Weaver Creek its course is nearly north and south. Beyond that point it has not been definitely traced.

The La Grange mine exposes about 600 feet of more or less distinctly stratified gravel, which belongs chiefly to the upper portion of the Weaverville Basin deposits. According to MacDonald [1]—

> The wash is fairly fresh and contains a great variety of rock; about 12 per cent of it consists of bowlders weighing from 100 pounds to many tons. Near the lower part of this bed is a lens-shaped layer of cement gravel having a maximum thickness of 50 feet. Below this indurated bed uncemented stratified wash forms the basal part of the younger gravel and rests with apparent unconformity on an older blue gravel.
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> The so-called blue gravel rests on an uneven surface of slaty bedrock. It presents a much more squeezed and sheared appearance than the upper gravel and shows many stones and bowlders flattened and fractured. Though not a cement gravel it has a

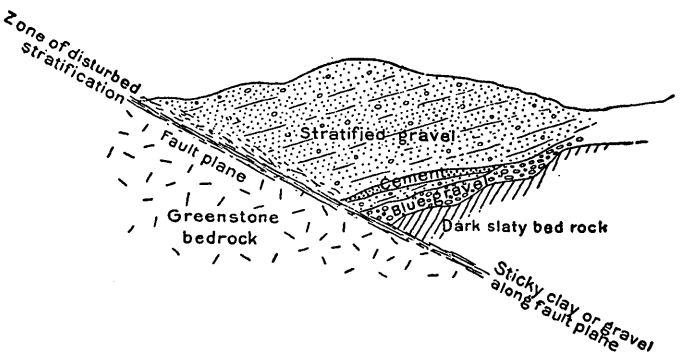


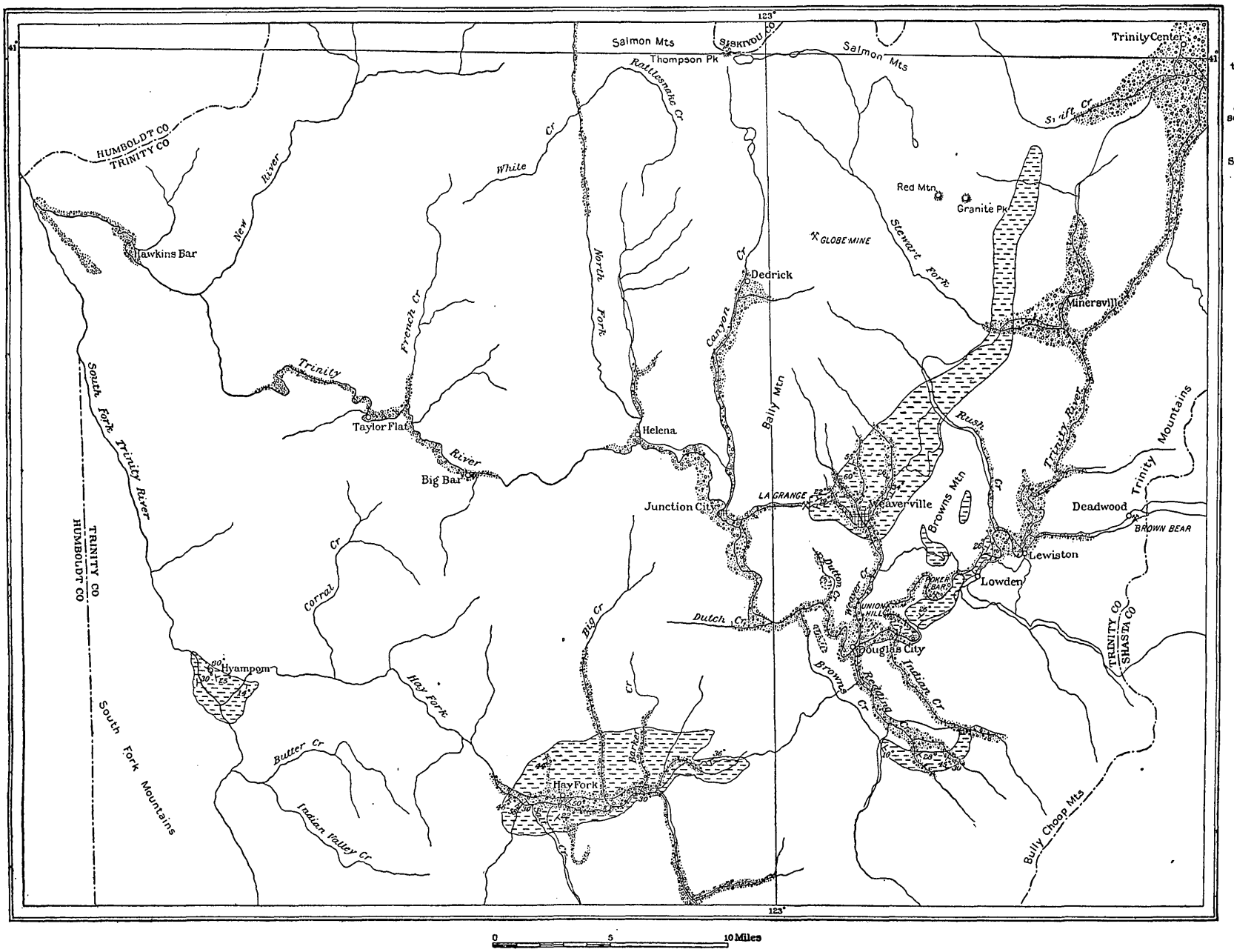
FIGURE 2.—Section of La Grange mine, near Weaverville. By D. F. MacDonald.

> much more resistant matrix than the overlying material and shows more small faults, the principal of which trend N. 40° E. and dip 65° SE. The coloring matter, which has given the name to the gravel, is probably iron reduced to ferrous compounds by an excess of organic matter.

The composition and general character of the deposits of the Weaverville Basin are best revealed along the branches of Weaver Creek in the vicinity of Weaverville, where hydraulic mining has been most extensive and is still in progress. The deposits as a whole are complex, consisting chiefly of an older succession of fine beds of residual material unconformably overlain by later gravels, some of which, at least, if not all, are undoubtedly due to the action of modern streams.

The relations of these gravels are illustrated in figure 3 by a section across the head of the Hupp mine as it appeared September 30, 1903. The soft rock, which is used in the Hupp mine as the bed-

[1] Op. cit., p. 52.



SKETCH MAP OF TRINITY RIVER BASIN, CAL., SHOWING AREAS OF AURIFEROUS GRAVELS OF SECOND AND THIRD CYCLES OF EROSION.

rock for hydraulicking the overlying gravels, is of special interest in that it is made up of residual products from the decomposed rocks of the developing Sherwood peneplain. Much of the sand is greenish or red from the decomposition products of the ferromagnesian silicates, or whitish from the kaolin of the decomposed feldspars. The quartz grains are sharp and angular, as if moved for a short distance only over gentle slopes from their source. Altogether these fine sediments tell a story of gentle relief and deep decomposition of the surface rocks about the time the Sherwood peneplain was forming, the free gold the rocks contained being thus liberated for concentration in the stream beds.

These soft beds, often called "false bedrock," are exposed from one side of the basin to the other and with few exceptions dip westward. On the east side of the basin, where the oldest beds are exposed, they consist almost wholly of fine sediments, but on the west side, as shown by the lateral gulches of the West Fork of Weaver Creek, the tilted soft beds contain a larger proportion of gravel and the fragments are generally angular.

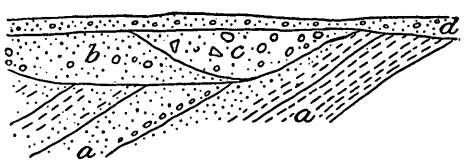


FIGURE 3.—Section across head of Hupp mine September 30, 1903. *a*, Soft bedrock composed chiefly of fine sand with some clay and fine gravel; *b*, sand and gravel, fairly well stratified, with few bowlders in some localities but many in others (fine gold); *c*, gravel, irregular, with large bowlders (coarse gold); *d*, capping gravel and sand (latest stream gravel).

In the eastern part of the basin there are some light-colored beds among the older ones and they appear to be tuffs, but positive evidence as to their volcanic nature could not be obtained even under the microscope. These beds contain fragments of leaves that throw some light on their age. The beds are evidently very much older than the gravels marked *b* in figure 3, from which they are separated by a marked unconformity that represents the tilting of the beds marked *a* and their extensive erosion before the deposition of gravels marked *b*.

The *b* gravels are evidently older than the *c*, and both may have been deposited by streams of water, although there are places where the material is unassorted and bowlders become prominent, so that the deposits somewhat resemble glacial till.

Figure 4 is a section made in the summer of 1910 of part of the Hupp mine near its head. The coarse layer of rotten bowlders that unconformably overlies the soft bed is made up of unassorted material, resembling glacial till, although no definite marks of glacial action could be found. Many of the bowlders are from 3 to 4 feet in diameter and some of them are completely decomposed. In the adjacent bluff the same bowlder bed is 25 feet thick and contains

much sand and clay, but its relation to the underlying soft beds of the mine is not clearly exposed.

The bowlder bed, with the overlying material, appears to form a large part of the prominent divide between Garden Gulch and the East Fork of Weaver Creek and is generally poor in gold. The material of which the pebbles and bowlders are for the most part composed is hornblende schist or diorite, like that of the mountains immediately northwest of the gravel deposit, and it is evident that the material was brought into the present gravel area from the northwest and not from the northeast, whence came the fine material of the soft bedrock.

In the inclined sand beds that form the false bedrock, as in the Hupp mine, small quantities of fine gold are widely distributed, and in the gravels of the same beds toward the western edge of the basin, as at the La Grange mine, the values are sufficient to afford very profitable mining when worked on a large scale. The gravels of the later stream beds, where the gold has been concentrated by stream

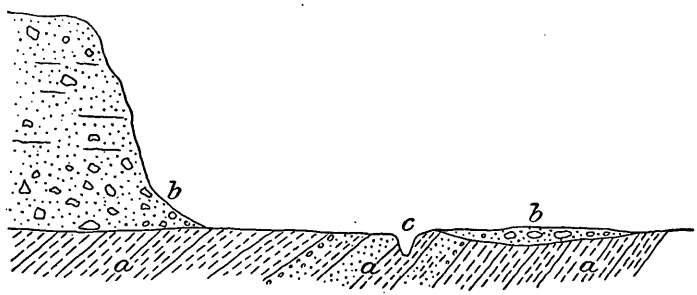


FIGURE 4.—Section across part of Hupp mine in August, 1910. *a*, Soft beds—tilted sand, clays, and gravels of false bedrock; *b*, bowlder bed in which 3 to 4 foot bowlders are common; *c*, flume.

action, have been successfully mined for many years, as in the Hupp mine. Within the Weaverville Basin the La Grange and Hupp mines are the most important placer mines now operating. The day of small placer mining is past, but there are yet at a number of places in the area large bodies of gravel that should yield a profitable return if worked economically on a large scale.

DUTTON CREEK.

A considerable area of the old auriferous gravels comparable with those of the Weaverville Basin is situated on Dutton Creek southwest of Weaverville, but it has not been definitely outlined. The gravel extends, but not continuously, for several miles from the head of Dutton Creek, at an elevation of about 3,550 feet, in the Sweepstake mine, down to the mouth of Dutton Creek, at an elevation of 2,200 feet above the sea, or about 400 feet above Trinity River, in the Dutton Creek mines.

In the Sweepstake mine over 100 feet of gravel is exposed. Some of it is fresh, but in the older portion, which is coarse, many of the pebbles are completely decomposed to red, yellow, or white residual products.

At the Dutton Creek mines the gravel is coarser, with bowlders 5 to 20 feet in diameter. Some of the pebbles are decomposed and many of them incline to the north, as if the stream came from that direction. The gravel extends over 600 feet up the slope toward the Sweepstake mine and is limited on the west by a north-south rim rock that may be due to the faulting which preserved the gravels.

BROWNS MOUNTAIN.

There are two areas of gravel about the summit of Browns Mountain. The larger area, just north of the Lowden road, rises to 2,900 feet about the summit and extends southeastward but does not reach the river. The northern area rises above 3,000 feet and some of its pebbles are over a foot in diameter. These gravels have not been mined and their thickness where greatest does not exceed 500 feet. They border the mica schist summit of Browns Mountain in such a way as to indicate that the mountain was an island in the broad stream that deposited the gravels.

LOWDEN AND TRINITY RIVER AREA.

The Lowden area of ancient gravel extends about 5 miles down Trinity River from a point near the mouth of Rush Creek. The gravel is partly cemented and forms the abutment of the new bridge above Lowden. Near the bridge on the right bank of the river there is a prominent bluff of stratified gravel which dips 26° W. and is separated from the granodiorite by a fault, as shown in figure 5. This fault dropped the gravel about 1,200 feet from the level of that on Browns Mountain. It strikes N. 25° E., approximately parallel to the general course of the river, and had much to do in determining the location of the present bed of the stream.

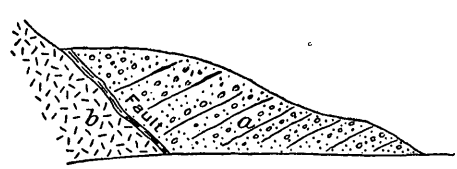


FIGURE 5.—Section of faulted gravel on Trinity River one-eighth mile above the Lowden bridge. *a*, Stratified gravel; *b*, granodiorite.

Southwest of Lowden the area widens and the gravel in the Last Chance mine, well stratified, with finer beds below, strikes approximately northeast and dips 26° NW. The gravels at the Last Chance mine are in many places firmly cemented and, like those near the Lowden bridge, require blasting in mining. The Last Chance mine is not now in operation. Its water goes to operate the Union Hill

mine, near Douglas City. The prominent terrace in the great bend of Trinity River between the Last Chance and Union Hill mines, as well as the flat ridge east of the lower portion of Browns Creek, may contain gravels like those of Last Chance, but these localities were not examined.

The gravels of the Union Hill mine, which is now in operation, are uncemented. They lie horizontally on one of the recent terraces of Trinity River and are much younger than the ancient gravels of the Last Chance mine and Weaverville Basin. So also are the gravels now being mined at Poker Flat, only a few feet above the adjacent river. These gravels belong to the youngest river terrace, being younger even than those of Union Hill.

REDDING CREEK.

The Redding Creek area lies 7 miles southeast of Douglas City. Its length is 5 miles, from Bigelow's, on Browns Creek, northeast across Redding Creek and Panwauket Gulch to Indian Creek; its

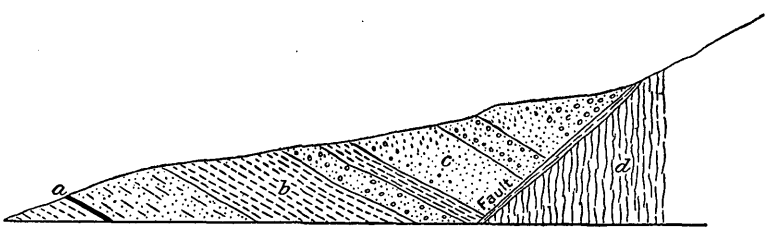


FIGURE 6.—Section of ancient gravels and tuffs in Redding Creek basin. *a*, Coal; *b*, tuff; *c*, stratified auriferous gravel; *d*, mica schist.

width is about a mile. The beds strike approximately N. 45° E. and the average dip is 27° SE., toward the limit, which is supposed to be due to a fault. Panwauket Gulch and Redding Creek afford the section shown in figure 6.

About 400 feet of partly cemented gravel overlies 250 feet or more of white tuff, in the upper part of which there is a 50-foot bed of gravel. Below the tuffs are shales and thinner beds of tuff and a bed of shaly coal ranging from 5 to 15 feet in thickness. This body of auriferous gravel, having a total thickness of approximately 900 feet, rests directly on the Horsetown formation, of Lower Cretaceous age.

Panwauket and Redding creeks have cut terraced valleys across the tilted gravels and tuffs and the terraces are capped by horizontal beds of gravel and sand to a thickness of generally more than 25 feet.

These later bench gravels are due in large measure to the erosion of the older gravels and the concentration of their gold. The later gravels have been extensively mined, especially in Panwauket Gulch and Indian Creek, and it is estimated on good authority that they have yielded nearly a million dollars in gold.

HAY FORK.

The Hay Fork area is one of the largest in the region and extends throughout the Hay Fork valley, but the beds are generally concealed by a great expanse of alluvium of the local peneplain developed on the soft beds. Like the Weaverville, Lowden, and Redding Creek basins, the Hay Fork basin is due to faulting. The great dislocation is along the south side, where in consequence the latest beds of the mass are to be found. Outcrops are numerous along the north side of the basin, where large bodies of more or less firmly cemented gravels occur and have been mined. At the Shock & Montgomery mine the section given in figure 7 was measured. There are 88 feet of whitish tuffs overlying 550 feet of gravels interbedded with small layers of sand, which rest with apparent conformity on Cretaceous shales. The pebbles of these gravels are rarely as much as 4 inches in diameter. The whole succession of strata strike N. 63° E. and dip 35° SE.

Gravels overlain by tuffs and associated with shales and shaly coal occur from 1 to 2 miles northwest of Hay Fork post office but are much finer and not so thick as those toward the east end of the basin. The gravels disappear entirely before reaching the southwest end of the valley, where the coal associated with shale rests directly on altered greenstone.

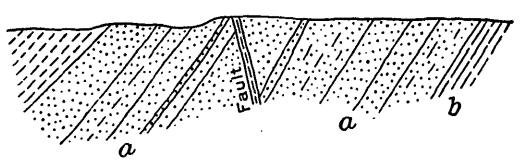


FIGURE 7.—Section of ancient gravels in Shock & Montgomery mine, Hay Fork valley. *a*, Stratified gravels; *b*, Cretaceous shale.

Shales and tuffs with a few thin layers of gravel and rarely shaly coal occur along Hay Fork in the middle portion of the valley as well as along its southern border, and locally they are full of fossil shells and leaves. The dip throughout is southerly, toward the fault which limits the beds in that direction. The newer beds lie along the southeast side of the basin and contain not over 15 per cent of gravel, all of which is fine. In this respect the Hay Fork and Redding Creek sections are in strong contrast.

The total thickness of the tilted gravels and shales in the Hay Fork area must be much over 1,000 feet. They are unconformably overlain throughout the greater portion of the valley by alluvial gravels from 5 to 12 feet in thickness. These later gravels have been mined locally in a small way.

HYAMPOM.

Hyampom Valley, at the junction of Hay Fork and South Fork of Trinity River, contains a large body of tilted gravels, sands, and

clays with a few beds of coal and tuff. The whole succession lies unconformably between the horizontal terrace gravels of the present streams and the much older igneous rocks.

Hyampom Valley has a length of 3 or 4 miles and a width of a mile or more. The area as outlined on the map (Pl. I) is a close approximation determined in the field. It is believed that the soft beds under consideration are limited to the valley proper.

Gravels appear on the northeast side of the valley nearly 1,000 feet above the valley floor and also on Pelletreau Creek along the west side of the valley, where 50 feet of gravel and sand is firmly cemented and dips 30° E. The most prominent exposures, however, are along Hay Fork at the mouth of its canyon, where the following section appears:

Section at mouth of Hay Fork canyon.

	Feet.
Conglomerate	100
Shaly coal	5
Sandstone, micaceous, residual; contains concretions	70
Conglomerate	25
Greenstone; bluff rises abruptly.	

In the middle portion of the valley there are some fine laminated shale, beds of tuff, and several exposures of shaly coal 5 to 10 feet thick, making the total thickness of soft beds in the Hyampom area nearly 1,000 feet.

These beds, as shown by their fossil contents, composition, attitude, and relation to other formations, belong to the same geologic horizon as the tilted beds of the Hay Fork area, although I am not sure that they are auriferous.

COXS BAR.

On Trinity River at Big Bar, sometimes called Coxs Bar, there is a small mass of soft shales, sandstones, and some gravels with inclined stratification like the beds in the Weaverville Basin. These, though sometimes mined, are generally used as bedrock for mining the bench gravels of Trinity River that cap the terrace.

These fine beds are especially rich in fossil leaves, among which F. H. Knowlton identifies four species that clearly show the beds to belong to the second cycle. They are associated with a small mass of Jurassic strata and have probably been faulted down into the older rocks and thus preserved.

VOLCANIC ASHES ASSOCIATED WITH THE GRAVELS OF THE SECOND CYCLE.

Light-colored tuffs are associated with the gravels of the second cycle in the Reading Creek, Hay Fork, and Hyampom areas and probably also in the Weaverville Basin. To judge from the decrease in the volume of the tuff toward the west, as well as in the size of the particles of which it is composed, its source appears to have been in the vicinity of Lassen Peak, where lavas of similar composition occur. For the purpose of comparison an analysis of the tuff from Hay Fork has recently been made by R. C. Wells in the United States Geological Survey laboratory. Other analyses of the tuff are given in the table below, and analyses of the acidic lavas of the Lassen Peak region may be found in Survey Bulletin 228, pages 211–213.

These tuffs associated with the gravels of the second cycle in the Trinity River basin are probably of essentially the same horizon as the rhyolite tuffs that overlie the bench gravels of the Sierra Nevada. This view, as we shall see presently, is fully sustained by the fossil leaves which they contain.

Chemical analyses of tuffs associated with auriferous gravels.

	Hyampom, near post office.	Hay Fork, near mouth of Salt Creek.	Rice's quarry, 6 miles southeast of Paskenta, Tehama County.	West Fork of Willard Creek, Lassen County.
SiO_2	70.40	63.55	65.78	70.01
Al_2O_3	13.50	17.10	14.87	12.61
Fe_2O_3	1.31	3.21	1.27	1.47
FeO	1.61	.92	1.00	.50
MgO	.37	.43	1.89	.72
CaO	.56	.82	2.41	1.06
Na_2O	2.11	2.12	2.58	1.94
K_2O	2.39	2.30	2.71	5.12
H_2O-	1.05	4.20	2.87	2.37
H_2O+	7.41	5.13	4.32	4.68
TiO_2	.....	.41	.....	.....
CO_2	.....	None.	.....	.....
P_2O_5	.08	.10	.08	.04
S	.....	Trace.	.....	.....
MnO	Trace.	.03	Trace.	Trace.
	100.79	100.32	99.78	100.52

AGE OF THE GRAVELS OF THE SECOND CYCLE.

The finer beds, especially the volcanic tuffs, associated with the gravels of the second cycle at Weaverville, Reading Creek, Hay Fork, Hyampom, and Coxs Bar contain fossil leaves which have been studied by F. H. Knowlton at different times from 1902 to 1910. His determinations are given in the following table:

Fossil plants from the auriferous gravels of the second cycle in Trinity River basin.

	Weaverville (Hupp mine).	Reading Creek.	Hay Fork.	Hyampom.	Coxs Bar.
Laurus californica Lx	×				
Laurus grandis Lx	×	×			
Laurus (?)	×	×			
Cercocarpus antiquus Lx	×				
Sequoia lanceolata Lx		×			
Sequoia angustifolia Lx		×	×	×	×
Sequoia langsdorfii (Brgt.) Heer				×	
Populus lindgreni Knowlton		×			
Populus heeri			×		
Populus zaddachi (??)		×			
Persea pseudocarolinensis Lx		××			
Acer benderi Lx		××	×		
Trapa natans			×		
Salix angusta (?) Al. Br			×		
Salix californica Lx			×		
Salix 2 sp				×	
Quercus convexa Lx		×	×		
Quercus dissecta Lx		×			
Quercus elænoides Lx			×		
Quercus (?)			×		
Ficus ungeri (?) Lx			×		
Ficus tiliæfolia Al. Br					×
Aralia whitneyi Lx			×		
Aralia (?)	×	×			
Juglans egregia		××	×		
Juglans schimperi Lx			×		
Juglans oregoniana Lx		××			
Rhamnus (?) sp			×		
Rhus typhinoides Lx		×	×		
Rhus myricæfolia Lx			×		
Taxites olriki (?) (Heer-Lx.)					×
Castanea ungeri Heer					×
Taxodium distichum miocenum Lx				×	
Magnolia californica Lx		×			
Magnolia lanceolata Lx		×			
Magnolia sp., perhaps new		×			
Taxodium tinajorum Heer		×			

All the fossil leaves thus far known in the auriferous gravels of the second cycle in the Trinity River basin are given in the table. Concerning the fossils collected in 1910 Knowlton makes the following report:

The plants enumerated above all belong to well-known auriferous-gravels species, and I have no hesitation in pronouncing them to be of the approximate position of the auriferous, namely, Miocene.

On looking back over reports made in previous years on material from the same or near-by localities it appears that the conclusion to be drawn is the same in all cases—that is, the age is approximately the same as that of the auriferous-gravels flora.

The fossil flora as interpreted by Knowlton leaves no doubt as to the essential synchroneity of the auriferous gravels of the Klamath Mountains and of the Sierra Nevada. To be more precise, taking into account the tuffs, the gravels of the second cycle in the Trinity River basin correspond to the bench gravels and gravels of the rhyolitic epoch in the Sierra Nevada, both of which are of Miocene age.[1]

[1] The only shell found in the leaf-bearing strata occurs abundantly at Hay Fork. W. H. Dall reports it to be a large *Vivipara*, compares it with a species found in the Cretaceous, and remarks that the genus is extinct in California recent fauna.

DRAINAGE DURING THE SECOND CYCLE.

The distribution of the gravels of the second cycle aligns closely with the Trinity River basin. It has the same prominent curve around the south end of the Salmon Mountains and represents the Miocene stage of Trinity River, which then flowed in the broad valley that finally became the Sherwood peneplain. It appears that at one time the master stream of the basin flowed with very low grade by way of Hay Fork and Hyampom. The faulting that displaced and preserved the gravels finally led to the shifting of the main stream to its present course.

MINES IN GRAVELS OF THE SECOND CYCLE.

The fact that the La Grange mine is in the gravels of the second cycle is an indication of their economic value where they are in large bodies practically uncemented and advantageously located. The La Grange mine is already well known. It has been described by D. F. Campbell[1] and D. F. MacDonald,[2] to whose publications reference should be made for details.

The Hupp mine, at Weaverville, is in gravel that is for the most part much younger than that of the La Grange mine and represents a higher degree of concentration, but the conditions are not so favorable for handling large bodies of gravel as at the La Grange. The bedrock of the mine, as shown in figures 5 and 6, is in the soft sandstones, shales, and gravels of the tilted strata that fill the Weaverville Basin, and the bedrock level at an altitude of 2,200 feet above the sea is only about 25 feet above that of the East Fork of Weaver Creek.

As far as I am aware, none of the gravel mines northeast of Weaverville are wholly in the gravels of the second cycle.

An attempt has been made to work the gravels of the second cycle near Lowden and also in the Last Chance mine, 3 miles southwest of Lowden, near the road to Douglas City. A good supply of water by a ditch about 8 miles in length was obtained from Grass Valley Creek. The gravel, though but weakly cemented, is so firm as to withstand the dash of the water as applied, and on this account the mine has made but little progress. The property is now controlled and the water used by the Union Hill Hydraulic Co.

In the Hay Fork area the gravels are feebly cemented but have been mined to a small extent by Shock & Montgomery at one place near the east end of the valley. The mining thus far has been confined to the disintegrated material of the surface. Deep cuts have

[1] Min. and Sci. Press, vol. 97, Oct. 10, 1908, p. 491.
[2] Bull. U. S. Geol. Survey No. 430, 1910, pp. 51-56.

been washed in the same gravels 2 miles farther northeast, at Macks, exposing a fine body of partly cemented gravel, but work was not long continued.

GRAVELS OF THE THIRD CYCLE.

The gravels of the third cycle are confined to the canyons and narrow valleys of the present streams and include not only the gravels capping the terraces on the valley slopes but also those in the present stream beds. Their distribution is roughly outlined in Plate I (p. 16) for the purpose of contrasting it with the distribution of the gravels of the second cycle.

In general, the gravels of the third cycle should contain the most highly concentrated values. Furthermore, they can be most easily and economically mined, because they are entirely uncemented and most readily reached by water for piping.

These are the gravels so extensively mined in the early days. The most available and probably the richest have been washed away, but still there is much left that may pay well for economical mining on a large scale.

The benches mined by hydraulic methods generally lay between 25 and 400 feet above the level of Trinity River. Many of these mines are still active during the spring. In 1908 there were in Trinity County 66 producing placers, of which 49 were hydraulic, 3 drift, and 14 surface. But few of them are in operation during the summer. About Weaverville and Douglas City the only placers in operation in July, 1910, besides the La Grange and Hupp mines, already noted, were the Union Hill and Poker Bar, concerning which brief notes are added here.

The Union Hill mine is working gravels of the third cycle on a large terrace 175 feet above Trinity River. The mine was started in 1862 by Marshall & Mason, who used water from Weaver Creek. It remained inactive for a number of years until purchased in 1906 by the present owner, the Union Hill Hydraulic Co., which obtained control of the water for the Last Chance mine and brought it to Union Hill. The source of the water is Grass Valley Creek. The ditches, flumes, pipes, and tunnels are said to be about 15 miles in length and carry sufficient water to run two 7-inch giants 23 out of 24 hours for nearly half the year under a head from the reservoir of 450 feet.

A section of the bluff on the east side of the mine is given in figure 8. In the upper 115 feet the deposits are decidedly red and not clearly stratified. Below this is 19 feet of blue gravels, sands, and clays, all of which are well stratified. Nearly all the values are found in the blue gravel at the bottom on the mica schist bedrock.

On the west side of the mine toward Weaver Creek there are several channels due to shifting currents during the deposition of the gravels. A rather striking feature of the gravels is the imbrication or overlapping of the pebbles to the northwest, indicating that the current by which they were placed in position was flowing in that direction from Trinity River toward Weaver Creek.

A matter of special interest is the occurrence of bones and shells in the strata associated with the coaly layer near the base of the bluff on the east side of the Union Hill mine. Among the shells [1] at the base of the coaly layer W. H. Dall has identified *Planorbis tumens* Carpenter, *P. vermicularis* Gould, and *P. centervillensis* Tryon, besides some young shells of two other genera. All these shells are living fresh-water species in California to-day.

The small lot of bones found in the layer overlying the coaly bed were examined by J. W. Gidley, who reports "representatives of the genera *Odocoileus*, *Elephas*, and *Megalonyx*." He says "the specimens are too fragmentary to determine the species with certainty."

These fossil shells and bones and the physiographic relations of the strata containing them show that the gravels of Union Hill are certainly Pleistocene in age and very much younger than the gravels of the earlier cycles.

The Poker Bar Dredging Co. began operations with a new plant in the summer of 1910 on a large bar only a few feet above the level of the adjacent Trinity River.

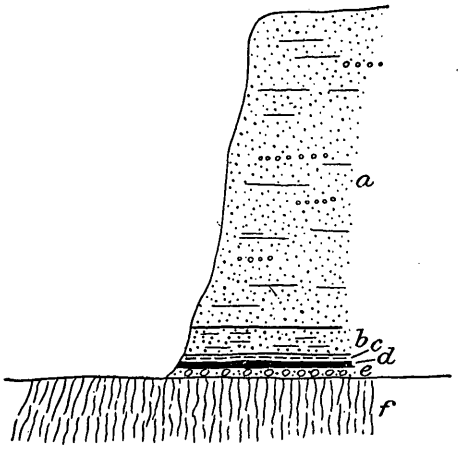


FIGURE 8.—Section of bluff east of Union Hill mine. *a*, Chiefly red clay, some sandy clay, and locally fine gravel, 115 feet; *b*, shaly sandy bed, some bluish gray, 8 feet; *c*, shaly fragments of schist, bluish gray, 2 feet; *d*, coaly layer, 2 to 3 feet; *e*, coarse gravel, bluish gray, 3 to 10 feet; *f*, mica schist bedrock.

The principal part of the plant is a stationary bucket dredge to raise the gravel 20 feet. The dredge pit is 20 feet deep, reaching through the gravel 5 feet into the bedrock. There are two centrifugal pumps to supply the nozzles with water—one from the river to wash the gravel into the pit to the elevator and the other from the pit to wash the gravel from the elevator down the flume.

[1] A number of good shells from this mine were presented to me by Mr. Pierre Bouery, of the La Grange mine. The other shells in their original matrix as well as all the bones obtained were presented by Mr. J. J. Murphy, superintendent at Union Hill.

The plant was not quite completed when I saw it in July, 1910. Seven men will be required in a shift, and it is expected that 500 cubic yards of gravel will be handled by three shifts in 24 hours. The sluice is 100 feet long, 2 feet wide, and 2 feet deep, with two rows of wooden blocks. A small dynamo supplies the electricity for lighting the plant.

OUTLOOK FOR PLACER MINING IN TRINITY RIVER BASIN.

It is probable that with a strong water supply under pressure having a head, as at the La Grange mine, of 450 to 650 feet, much of the gravel of the second cycle that is favorably located could be successfully mined. Some of it would probably require blasting. At the La Grange, however, by undercutting, the cemented portion is crushed by the superincumbent load. At this mine the gravels are most favorably exposed, but farther northeast, along the faulted border of the Weaverville Basin, these gravels have been in large part washed away by the mountain streams or covered up by the overlapping "dead wash" from the Salmon Mountains. It is probable, however, that there are considerable areas, including the Browns Mountain areas, which with the fine water supply available could be worked to advantage.

Browns Creek, Reading Creek, Indian Creek, and Grass Valley Creek each carries a considerable though not large water supply that might be turned in upon the gravels of the Reading Creek basin, where the conditions are favorable for mining.

In general, the gravels of the second cycle where too firmly cemented for hydraulicking are not sufficiently rich to warrant crushing. They should, however, be carefully prospected, for it is possible that some parts rich enough may be found. This perhaps is less probable if we consider the mode of origin. These gravels are of fluviatile origin, but gravels sufficiently rich to crush, as shown by G. F. Becker,[1] are generally of marine origin.

The gravels of the third cycle are more widely distributed but of less volume than those of the second cycle, and as they present less formidable obstacles to mining they are receiving more attention. Most of the country is timbered and dumping facilities are generally ample and not so restricted by antidébris laws as in the Sierra Nevada. With a fair water supply from the higher mountains conditions are favorable for mining.

[1] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 183.

In general, the gravels have been richest on streams heading in the Salmon, Trinity, and Bully Choop mountains and decrease somewhat in value as the distance from the source increases.

The large values of the Coffee Creek region are well known and it is believed that the extensive bodies of gravel on the bars and benches of the upper part of Trinity River are well worthy of investigation. If the dredges already started at Trinity Center and Poker Bar prove as successful as they promise to be a new impetus will be given to placer mining.

THE ECONOMIC GEOLOGY OF CARSON CAMP, HINSDALE COUNTY, COLORADO.

By ESPER S. LARSEN.

INTRODUCTION.

GEOGRAPHY AND TOPOGRAPHY.

The mining camp of Carson is located in Hinsdale County, Colo., within the area called the San Cristobal quadrangle, about 13 miles in an air line west of south of Lake City, which is the nearest railroad point. The Continental Divide is 12,360 feet above sea level at Carson Pass and the prospects of the camp are located on both sides of it. The topography is that characteristic of the high portions of the San Juan Mountains, with rugged peaks reaching nearly 14,000 feet, while the bed of Lake Fork of the Gunnison, only a few miles away, is over 5,000 feet below.

Carson is reached by a wagon road from Lake City, a distance of about 20 miles. The road up Lake Fork of the Gunnison is good, but from the mouth of Wager Gulch, where the Carson road branches from the main road, the climb to the Continental Divide is very steep and the wagon road has been washed out so as to be hardly passable to wagons. The road continues beyond the divide into Lost Trail Creek, but much of this part is very boggy. A good trail follows down Lost Trail Creek to the Rio Grande, where it joins the road between Creede and Silverton.

HISTORICAL SKETCH.

The camp was discovered about 1881 and reached its greatest development in 1889, when there were more than 250 people there. The prosperity of the camp was short lived, and in 1893 the mines were closed, owing, it is said, to the low price of silver. Since that time the camp has had only 10 or 20 prospectors and when visited in the summer of 1909 there were only six prospectors there. About 10 years ago the owners of the Batchelor mine carried on extensive prospecting, and for a time there was considerable activity at Batchelor, a part of the camp on the north side of the divide.

GENERAL GEOLOGY.

The ore deposits of Carson were examined during the summer of 1909 in connection with the geologic survey of the San Cristobal quadrangle, in charge of Whitman Cross. The general report on the geology of the quadrangle will be published as the San Cristobal folio.

ROCKS EXPOSED.

The principal rocks of the region are Tertiary volcanic rocks, but Lake Fork of Gunnison River has eroded through these volcanics and has cut for a considerable distance into the underlying pre-Cambrian rocks. The pre-Cambrian is made up chiefly of granite and quartz monzonite, but dikes of quartz-bearing diabase occur at Sherman and are there associated with the mineralization. The pre-Cambrian rocks extend up Wager Gulch to an elevation of 10,300 feet and are overlain by andesitic rocks which probably belong to the Silverton volcanic series, either to the pyroxene andesite or to the earlier Picayune andesite of that series.[1] A short distance to the west a considerable thickness of the Picayune andesite of the Silverton volcanic series underlies these andesites. Unconformably overlying the Silverton series is the Potosi volcanic series, consisting of flows, tuff-breccias, and intrusive rocks. The rocks most closely associated with the mineralization at Carson are the pre-Potosi andesites and the Potosi volcanic series.

PRE-POTOSI ANDESITES AND QUARTZ LATITES.

The series of andesites and quartz latites beneath the Potosi volcanic series is made up chiefly of lava flows, but thin breccia beds occur between the flows; intrusive rocks may also be present. The flows lie nearly flat, and in Wager Gulch they extend from the pre-Cambrian rocks to Carson Pass and attain a thickness of nearly 2,000 feet. A few miles to the east these flows overlie tuffs and flows that belong to the Picayune andesite of the Silverton volcanic series, and they may be an upper massive part of the Picayune andesite or they may belong to the overlying pyroxene andesite. This point has not yet been definitely determined. The rocks are green, gray, or purplish and show numerous plates of plagioclase, some biotite and hornblende, and locally pyroxene, in an aphanitic groundmass. Microscopically they are mostly holocrystalline, porphyritic, with numerous zoned crystals of plagioclase having an average composition of Ab_1An_1 and about equal quantities of biotite and resorbed hornblende in a groundmass of quartz and orthoclase in micrographic intergrowth. In places augite and hypersthene displace

[1] For a more detailed description of the Tertiary lavas of this region the reader is referred to the Silverton folio (No. 120), Geol. Atlas U. S., U. S. Geol. Survey, 1905.

the biotite and hornblende in whole or in part, and this is especially common in the lower flows. Some of the flows have little quartz and orthoclase in the groundmass. The rocks range from quartz latites to pyroxene andesites.

POTOSI VOLCANIC SERIES.

The Potosi volcanic series is itself made up of a complex of nearly horizontal lava flows, fragmental material, and intrusive rocks with compositions varying from that of a rhyolite to that of a basic andesite. The relations of the various rocks have not yet been fully unraveled and the conclusions of this paper are subject to modification.

Rhyolites and quartz latites.—The lowest member consists of several flows of quartz latites and rhyolites. The rocks are almost invariably light red in color and usually have a zone of black glass at the base and the top. The rhyolites are platy from flow and have numerous large, flattened gas cavities. They break down into soft slopes covered with small fragments of rock. Megascopically they show a few crystals of biotite and feldspar in a felsitic groundmass. Microscopically they are usually in part spherulitic in texture. The quartz latites are much nearer the rhyolites than are those of the underlying pre-Potosi rocks or of the basic members of the Potosi. They are also cavernous and break into thick plates. However, they are much more resistant than the rhyolites and usually outcrop as cliffs. The hand specimen shows numerous crystals of white plagioclase and biotite and some specimens contain glassy orthoclase, quartz, hornblende, and augite. The thin sections show numerous phenocrysts of plagioclase, about andesine-labradorite in composition, some biotite, and usually orthoclase, quartz, hornblende, and augite; zircon, apatite, iron ore, and sphene are accessory. As a rule the groundmass tends to be spherulitic. This series varies greatly in thickness and in places may be absent altogether.

Agglomerate.—The formation of this rhyolite series was followed by a period of erosion, after which there was erupted from a local center a large amount of fragmental andesite. This andesitic agglomerate occurs in a lenslike mass which attains a thickness of 1,500 feet or more in Lost Trail Gulch but becomes rapidly thinner to the southeast and pinches out entirely only a few miles down the Rio Grande. The material is rudely sorted and poorly bedded and consists of subangular blocks and waterworn bowlders, up to several feet in diameter, in a tuffaceous matrix. The pebbles are made up, for the greater part, of pyroxene andesite, but hornblende-pyroxene andesite is common and biotite andesite, quartz latite, and rhyolite are sometimes seen. Most of the rocks have much glass in the groundmass. Within the breccia and closely associated with it in origin are many dikes and sills of andesite and quartz latite. They are especially abundant near

Carson. A few lava flows occur within the agglomerate, and they are more numerous near the top of the series. The agglomerate appears to be a mass predominantly of andesitic material, deposited subaerially, with subordinate stream action, about a volcanic vent with its center near Carson.

Quartz diorite.—On the southeast shoulder of Bent Peak, just southwest of the Lost Trail mine, there is a considerable body of quartz diorite intrusive in the agglomerate. It is rather fine grained and is greenish gray in color. The thin section of the typical rock shows very numerous crystals of andesine-labradorite feldspar, considerable uralitized augite, and some biotite in a subordinate amount of interstitial quartz and orthoclase. Border phases of the rock contain more quartz and orthoclase and are distinctly porphyritic. A similar intrusive occurs a few miles to the southwest in West Lost Trail Gulch. A specimen of a similar rock was collected at the Batchelor mine.

Rhyolites and quartz latites.—During the period in which the andesitic breccia was accumulating about the Carson vent the normal rhyolites and quartz latites of the Potosi series were being extruded from other vents and these flows interfingered with the andesitic material to a greater or less extent. After the activity of the Carson vent ceased these rhyolites and latites covered up the andesitic series.

Quartz latites characterized by large phenocrysts.—The last stage of Potosi eruption represented near Carson is the series of flows and associated breccias made up of less siliceous quartz latites. They are characterized by the large size of the phenocrysts of feldspar, some of which are an inch or more across. The rocks are usually red or gray and in the hand specimen show, besides the feldspar, biotite, hornblende, green augite, and locally quartz. Under the microscope the rock shows numerous phenocrysts of labradorite, some augite and resorbed biotite, and in some sections hypersthene and hornblende in a holocrystalline mass made up of laths of andesine feldspar, quartz, and orthoclase.

ORE DEPOSITS.

The mineralization is confined to the vicinity of the Carson volcanic center and has affected chiefly the quartz latites and andesites beneath the Potosi series and the quartz diorite, but the agglomerate near the vent and other rocks may also be mineralized. Zones of decomposed and mineralized porphyry are very numerous. As a rule they do not seem to follow clear-cut fault planes but are associated with irregular fractures and gashes and are not generally continuous for more than a few hundred feet. Three types of alteration were noticed. In the most common type the rock is white, the feldspars are sericitized, the dark minerals are leached out, and pyrite is disseminated throughout the rock; the original porphyritic character of the rock is still easily

seen. In another type of alteration, which is usually found near the vein filling, the original texture is still perceptible, the rock has been enriched in quartz, and the original feldspathic material is represented by alunite and a little kaolinite; pyrite is abundant. The third type is due to more intense mineralization and consists of the complete replacement of the groundmass by quartz, while the feldspar phenocrysts are nearly or completely leached out and are represented by cavities lined with drusy quartz, enargite, sphalerite, or other sulphides.

The ore itself is invariably associated with the zones of decomposition in the porphyry. However, the decomposed porphyry was rarely observed to carry disseminated ore minerals, but these minerals are found chiefly filling open cracks and cavities in the decomposed porphyry. As a rule the cavities are only partly filled with vein material, leaving numerous druses and open spaces. The underground workings were not generally open to inspection, but from the observations which were possible and from the statements of the prospectors it appears that the ore material is usually not over a few inches in thickness, though it may reach 18 inches. It is said that in places the ore bodies are persistent for hundreds of feet, but as far as could be observed the ore is as a rule only locally developed within the vein and much of the mineralization took place at cross fractures. So far as can be determined from the meager data available, the veins do not all strike in the same direction, but there is probably some tendency for them to strike west of north, as does the St. Jacob vein.

The minerals of the vein filling are barite, quartz, enargite, pyrite, chalcopyrite, sphalerite, galena, marcasite, famatinite, etc. Barite, which is the chief gangue mineral, occurs as large flat tablets projecting into the cavities or as more massive vein filling. Quartz occurs rarely in drusy coatings on the wall rock. Enargite, the chief metallic mineral, occurs as well-developed crystals either embedded in barite or projecting into druses or as massive material cementing brecciated silicified country rock. Pyrite is sparsely disseminated through the enargite. It is more abundant in the decomposed country rock and is in places more or less concentrated as the vein filling is approached. In one of the tunnels in Wager Gulch a considerable body of massive pyrite is exposed. Fibrous, botryoidal marcasite was found coating crystals of barite and enargite. Chalcopyrite occurs sparingly in the enargite. Sphalerite and galenite usually occur together as botryoidal coatings on barite and enargite or as vein filling associated with gouge or filling cavities in the decomposed porphyry.

Four stages of the mineralization can be distinguished. During the earliest stage the country rock was altered to a quartz-sericite-pyrite rock, or to a quartz-alunite-pyrite rock, or finally to a quartz-pyrite rock. During the second stage the open spaces were partly filled with barite and enargite, with some pyrite, chalcopyrite, etc.

The third stage was characterized by the deposition of galenite and sphalerite. Finally, coatings of marcasite were deposited on the other minerals.

The recent glaciation and the rapid erosion in these rugged mountains has prevented the formation of a deep zone of oxidized ore. Moreover, while the underground water level is very irregular, it is everywhere near the surface. Indeed, the primary sulphide ore extends nearly or quite to the surface. However, some of the very rich ore mined in the early days of the camp and described as "soft talc ore" was probably secondary.

VALUES OF THE ORE.

Accurate data regarding the values of the ore were not available, but from the best information that could be obtained the following statements are made. The values lie chiefly in the barite-enargite ore, but much of the galena and sphalerite ore is rich in silver. The ore is said to have run from $50 to $500 a ton, or even higher, in carload lots. The chief value lies in the silver, as there are about 100 ounces of silver to 1 ounce of gold. The copper content reaches 15 per cent. The ores seem to be of high grade, but their occurrence in very narrow irregular veins renders mining expensive.

BOG IRON ORE.

Above the forks of Wager Gulch, about a mile below Batchelor, there is some limonite at the upper edge of a large bog. It may have been deposited by springs coming out from the base of the cliffs and flowing into the bog. The material was mined at one time and hauled to Lake City as a flux for the smelter at that place.

DESCRIPTIONS OF THE MINES.

A large amount of prospecting has been carried on at this camp and on several of the properties considerable development work has been done. Small bodies of ore are found at very many places, but only two of the mines have shipped ore. The data available for descriptions of the mines and the figures showing the production are rather meager but will afford some idea of the conditions.

St. Jacob group.—The St. Jacob group of mines is the only property which has produced any considerable quantity of ore. It was worked extensively for several years after 1889 and is said to have produced ore valued at $150,000. The ore was valuable chiefly for its content of silver, though it contained some gold and copper. The property is equipped with a steam hoisting plant and considerable work has been done. The main shaft reaches a depth of 300 feet and drifts have been run at this level for about 600 feet along the vein, which strikes

west of north. At a depth of 240 feet is another level of about the same length. The workings were not accessible, but it is said that the vein is about 2 to 3 feet across, with 4 to 14 inches of solid ore, and has been followed for about 600 feet. There are several less important shafts and levels on the property. The ore consists of enargite, barite, quartz, pyrite, chalcopyrite, galena, sphalerite, and marcasite. The galena and sphalerite occur as coatings on the barite and enargite; the marcasite as botryoidal, spherulitic crusts on the barite and enargite. Druses and open spaces are very common. The ore is frozen tightly to the wall rock, which is silicified porphyry.

Lost Trail mine.—The Lost Trail mine belongs to the Continental Mining Co. and is located south of the divide, just southwest of the St. Jacob. A lower tunnel has been run 1,200 feet into the hillside and an upper tunnel nearly as far. Some ore has been found, but so far as could be observed it occurs in stringers only a few inches wide and extends along the strike for only a short distance. The vein material did not completely fill the fracture, as drusy cavities are common. The ore is largely enargite with some pyrite and chalcopyrite in a gangue of barite. In some places the silicified country rock contains impregnations of the sulphides.

Continental group.—The Continental group, which also belongs to the Continental Mining Co., is located just north of the divide. One property of this group, the George III, is said to have produced about $50,000 worth of ore similar to that of the St. Jacob. It is said to have run from $40 to $140 a ton in carload lots. Several small ore bodies have been prospected in this property. A new tunnel a few hundred feet southeast of the George III has cut a stringer, about an inch across, of a soft ore rich in galena, with chalcopyrite, etc., in a soft gougelike gangue. To the west there is a prospect which has cut a crushed zone in the porphyry and this silicified porphyry is cemented by coarsely crystalline enargite with some pyrite, chalco, pyrite, and barite, giving an association of minerals which closely resembles that of the Lost Trail mine. As usual, the mineral does not fill the cavities.

About midway between the George III and the Batchelor mine there is a short tunnel which cuts across a large body of massive pyrite. The tunnel runs in solid pyrite for about 15 feet, but the form of the body could not be determined. Drusy cavities in the pyrite contain a very few crystals of sphalerite. This body is worthy of more careful prospecting.

Batchelor mine.—The Batchelor mine is located in Wager Gulch about a mile north of the divide. It is provided with two hoists and a rather elaborate surface equipment. The deepest shaft is said to reach a depth of 500 feet, and from the dumps it is evident that this is the most extensively developed property of the camp. From the

material on the dump some of the country rock appears to be rather coarser and more even grained than the normal pre-Potosi andesites and is probably an intrusive. Little definite information about the property could be had, but the mine contains some ore which is probably in the usual small, nonpersistent veinlets. The ore contains much sphalerite with galena and pyrite in a gangue of barite. Coatings of marcasite are common. As usual, the ore is associated with silicified country rock, with disseminated sphalerite and galena. Enargite was not recognized. It is said that $250,000 has been spent on the property, but that no ore has been produced. It is reported that the shafts could not be kept in alignment, owing to the movement of the ground. This is very probable, as there is a large landslide mass just northeast of the mine and the adjustment is probably still taking place and extends to the shafts.

WORKING CONDITIONS.

The camp is above timber line and the heavy snows and long winters are unfavorable conditions. Excellent water is plentiful and there is abundant spruce timber only a few miles away. Lake City, the nearest railroad point, is nearly 20 miles away, at an elevation about 3,500 feet lower; all supplies must be brought from that point and all the ore shipped from the camp was hauled there for shipment to the Salida smelter.

FUTURE OF THE CAMP.

There seems little likelihood that large bodies of ore will ever be found at Carson, and whatever the camp produces will probably come from small bodies of rich ore.

SUMMARY.

The ore deposits of Carson, Colo., occur in volcanic rocks of Tertiary age. The oldest rocks near Carson are flows of andesite and quartz latite, belonging to the Silverton volcanic series. After a period of erosion there followed the formation of a complex of andesites and rhyolites of the Potosi volcanic series. At the base of this series are flows of rhyolite and quartz latite. Above these is a lens-like body of andesitic breccia with associated flows and intrusive rocks which accumulated about an eruptive center at Carson. Flows of quartz latites and rhyolites, followed by andesitic rocks, covered up this accumulation. The ore occurs in gash veins within the pre-Potosi lavas and the intrusive rocks in the immediate neighborhood of the volcanic center. The country rock in the vicinity of the veins is everywhere much altered and is locally completely replaced by quartz and pyrite, although these minerals are not important constituents

of the vein filling. The chief vein minerals are barite, enargite, galenite, sphalerite, chalcopyrite, pyrite, and marcasite. Barite and enargite seem to have been deposited first, followed by galenite and sphalerite, and finally by marcasite. Pyrite continued throughout the early stages but is not abundant except in the wall rock. The values are chiefly in silver, with some gold and copper, and in much of the ore they reach several hundred dollars to the ton. The ore was deposited in open spaces, few of which are completely filled, and is always associated with zones of decomposition in the porphyry. It is in general not over a few inches thick, is not persistent, and is especially developed at cross fractures. Secondary enrichment has played an unimportant part.

GEOLOGY AND MINERALIZATION OF THE UPPER ST. JOE RIVER BASIN, IDAHO.

By J. T. PARDEE.

INTRODUCTION.

FIELD WORK.

The act making appropriations for the sundry civil expenses of the Government for the fiscal year 1910–11 included an item providing for the mineral classification of certain lands within the limits of the Northern Pacific Railway Co.'s grant, for which title under the original grant had been withheld pending such classification. The examination of these lands was assigned to the Geological Survey. A considerable area specified for classification is situated in northern Idaho, mainly in the drainage basin of upper St. Joe River, lying adjacent to and south of the Cœur d'Alene mining district. Three geologic parties and one topographic party spent a short and on some accounts unsatisfactory season in this particular area. Owing to the unexpected nature of the assignment, the work was late in starting, and on account of forest fires the season proved to be one of the most disastrous to life and property that has ever been known in this heavily timbered country. A considerable part of the area was reviewed, however, and the present report is a summary of the general evidence that has been collected. The map (Pl. II) is based on the control established by J. E. Blackburn, of the Geological Survey, and the geologic work is a compilation of the results obtained by F. C. Calkins and G. F. Loughlin in the area south of St. Joe River west of Avery; by D. F. MacDonald and E. L. Jones, jr., north of St. Joe River in a belt extending west from the valley of the North Fork; and by E. E. Smith and the writer in the upper St. Joe basin. The work as a whole was under the general charge of Hoyt S. Gale.

ACKNOWLEDGMENTS.

Acknowledgments should be made to the Chicago, Milwaukee & Puget Sound Railway for location and right-of-way maps of its main line within the area of the work, a preliminary location survey following upper St. Joe River, and topographic maps of a portion of the

Idaho-Montana boundary. A sketch map of the St. Joe drainage basin, by Con. Faircloth, a prospector, was also found useful. The descriptions of the different features of the area are taken from unpublished reports of F. C. Calkins and D. F. MacDonald, in so far as they relate to their respective portions as defined above. The microscopic determinations of rock sections used in this work were made by Mr. Calkins.

LITERATURE.

This region was described by Collier,[1] who made a reconnaissance within it in 1905, and neighboring areas have been described by Lindgren [2] and by Ransome and Calkins.[3]

HISTORY OF PROSPECTING.

Although this area is situated immediately south of the Cœur d'Alene district and but a few miles west of the older Cedar Creek placer district, it has until recently remained in part almost unexplored. About 1873 prospectors crossing to the headwaters of the St. Joe from Cedar Creek discovered gold placer deposits that lie a short distance southeast of this area and are said to be yet worked to some extent. During the excitement in the Cœur d'Alene district in 1884–85 parties from that district penetrated the western portions of this area in an unsuccessful search for placers that was soon abandoned. After the completion of the Cœur d'Alene branch of the Northern Pacific Railway, in 1890, prospecting and development work along the main divide was actively carried on, and since the recent opening of the St. Joe region by the Chicago, Milwaukee & Puget Sound Railway interest in its mineral possibilities has revived.

GEOGRAPHY.

VEGETATION AND BURNS.

Except the highest summits and ridges, all of this area is or recently was clothed with a dense forest and denser underbrush. Bunch grass and other forage plants are abundant only in the nonforested areas excepted. A small amount of forage is to be had in some of the old burns, chiefly on steep south slopes. A large percentage of this area is scarred with burns in various stages of reforestation. The fires of 1910 made a clean sweep of all that portion of the area north of St. Joe River and west of Bird Creek. Also practically the whole basin of the St. Joe above Simmons Creek was cleaned out, and of the remainder of this area about one-fourth was burned over.

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[1] Collier, A. J., Ore deposits in the St. Joe River basin, Idaho: Bull. U. S. Geol. Survey No. 285, 1905, pp. 129–139.

[2] Lindgren, Waldemar, A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904.

[3] Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Cœur d'Alene district, Idaho: Prof. Paper U. S. Geol. Survey No. 62, 1908.

GEOLOGIC MAP OF THE UPPER ST. JOE RIVER BASIN, SHOSHONE COUNTY, IDAHO

BY J. T. PARDEE

Scale 1/250 000

5 0 5 Miles

1911

LEGEND

SEDIMENTARY ROCKS

TERTIARY

Bench gravels

Striped Peak formation

Calcareous shales (*probably upper part of Newland ("Wallace") formation*)

Thin-bedded sandstones, green shales, and impure limestones (*probably equivalent to lower part of Newland ("Wallace") formation and upper part of St. Regis formation*)

White quartzites (*probably equivalent to Burke and Revett formations and lower part of St. Regis formation*)

Prichard formation (*q, quartzite, sc, mica schist and gneiss*)

Belt series — ALGONKIAN

IGNEOUS ROCKS

Basalt

Monzonite and granodiorite

Anorthosite

Diabase (*Wisharde sill*)

Amphibolite

Strike and dip

Vertical dip

Fault with downthrown block

Horizontal beds

Mine

Prospect

Patented and surveyed mining claims

Ranger station

Base compiled from Land Office plats, official survey of the Idaho-Montana boundary, and topographic surveys by the U. S. Geological Survey and the Chicago, Milwaukee, and Puget Sound Railway

PRINTED BY THE U.S.GEOLOGICAL SURVEY

ACCESSIBILITY.

General statement.—This region as a whole is one of the least accessible to be found within the United States, owing mainly to the topography and the forest cover. Except in those areas recently burned, the brush and litter render progress even by a man on foot very slow and laborious. Certain recently burned slopes were swept so clean, however, that they may for the present be readily traversed, but in most of the burned areas the fire was accompanied or followed by extensive windfalls.

Navigability of streams.—Canoes are poled against the swift water of the St. Joe as far up as Goddards, which is about 25 miles up the main river from Avery, and in short stretches above. It was also observed that attempts had been made to transport freight up and down stream in barges by snubbing. Apparently these attempts had not been very successful owing to the rapid current and obstructions in the channel.

Condition of highways.—Railroads, roads, and the principal trails are shown on the accompanying map (Pl. II). The road from Saltese to the Monitor mine is in good condition and is used for the hauling of ore and machinery. A road built preliminary to the construction of the Chicago, Milwaukee & Puget Sound Railway is still available for wagons from the St. Regis Valley to the North Fork of the St. Joe. The county road from Wallace to Hoyt, on St. Joe River, needs many repairs to make it passable for wagons. Of the few trails that penetrate this region those within the recently burned areas are either temporarily blocked by windfalls or destroyed by slides. Some of the main trails are fairly good considering the rugged country they traverse, but all have many steep and rocky pitches. The De Borgia trail is a fairly good one and is the most convenient means of access to the St. Joe at Conrads and above. Except for two steep spurs over which it zigzags, the trail from Avery to Goddards is not hard for pack animals, but its continuation east from Goddards is in poor condition. The principal trail leading south from Avery goes up Fish Hook Creek and along the west rim of this drainage basin to Sliderock Mountain. From this point branches lead westward by which one may reach St. Joe and the mouth of Marble Creek. In 1910 the Marble Creek trail was in fairly good condition. The St. Joe trail, little of which was traversed, connects with numerous trails to homesteaders' cabins in Tps. 43 and 44 N., R. 3 E. The trail leading south from Sliderock Mountain has branches leading eastward into Montana and one leading southwestward to Clarkia, Idaho. From Avery to the southern boundary of T. 44 N., R. 4 E., the trail is clear and in fair condition. The usual route to the east is that leading down the Little North Fork of the Clearwater, which in 1910 was clear in the surveyed area but

rough and boggy in many places. The trail leading northeastward from Forty-nine Meadows, though once a route of some importance, had not been used for several years and was much obstructed with windfalls, but a pack train was taken over it nearly to the eastern boundary of T. 44 N., R. 5 E. The trail to Clarkia was kept open and much used by firefighters and settlers during the fires of 1910. The trail over Lookout Mountain has unfortunately become disused and obstructed by windfalls, which necessitates a long detour and a drop and climb of about 1,000 feet that would be avoided if this cut-off were kept open. "Mix's trail," at the southern border of the area investigated, is a short cut from the Clarkia trail to the Little North Fork. There are several trappers' and homesteaders' trails in Tps. 44 and 45 N., R. 4 E., and T. 44 N., R. 5 E., which are not kept open so as to be usable by horses.

SETTLEMENTS.

The recent building of the Chicago, Milwaukee & Puget Sound Railway caused settlements to be made along its line—some of the evanescent type always linked with the construction of railways in a new region; others, like Avery, dependent on the railway's continuing operation. Away from the railway the only habitations are a few forest-ranger stations and miners' cabins, mainly near St. Joe River, and homesteaders' cabins in the drainage basins of Marble Creek and Clearwater River.

SUPPLY POINTS.

Avery is a convenient outfitting point for prospectors and others desiring to explore the region to the south and west, or up St. Joe River as far as Goddards. Saltese and De Borgia, Mont., are the most convenient supply points for the area reached by the State line and De Borgia trails. In addition several smaller supply points lie along the railroad.

SURFACE.

Relief.—Steep slopes characterize the surface of at least five-sixths of this area. The remainder, of level or gently sloping ground, is found mainly on ridge summits or high rock-cut terraces. There is proportionately a small amount of level ground in the valleys of St. Joe River below Avery and upper North Fork. Elevations along St. Joe River are 2,300 feet at Big Creek, 2,500 feet at Avery, and 3,300 feet at Conrads. The highest summits attain elevations of 6,500 to 7,300 feet. In general the relief of the ridges separating the main streams is 2,000 to 3,000 feet.

Former base-levels.—The flats at approximately 6,000 feet elevation now forming the summits of ridges are apparently remnants of an extensive peneplain above which Wards Peak, the Three Sisters, and

other summits rise as monadnocks. This peneplain is probably to be correlated with the extensive dissected plateau of the Clearwater Mountains [1] and with the level ridge summits exhibited in the Cœur d'Alene district to the north and beyond.[2] In addition, remnants of later but less extensive base-levels are found, the principal ones being at elevations of about 5,000 and 3,500 feet.

Mantle.—The level and gently sloping surfaces are covered with a deep mantle and even the steeper slopes up to 32° bear an abundant soil held in place by the matting of vegetation.

Rock exposures.—Below 6,000 feet elevation good rock exposures are found only on the cliffy slopes that border the larger streams. On the Montana side of the main divide the excellent continuous exposures contrast strikingly with the deeply mantled surface of the Idaho slope. The explanation of this contrast is found in the prevalence of ice erosion during the last glacial epoch on the north and east slopes above elevations of 5,500 feet and its absence at corresponding elevations on the south and west slopes.

DRAINAGE.

Character.—The intricate drainage system of St. Joe River is evidently inherited from the former base-levels, upon which the streams flowed in sluggish winding courses. The main stream and its largest tributaries exhibit sets of meanders that are remarkable when their deep intrenchment in the solid rock is considered. The stream profiles are moderately steep, St. Joe River having an average grade of 20 to 30 feet to the mile. Its larger tributaries maintain similar grades well toward their heads.

Water power.—Owing to favorable natural conditions a great amount of power could be obtained from these streams without undue expense for the construction of plants. As an instance, a particularly favorable power site was noted at an oxbow of St. Joe River about half a mile below Conrads. There the river falls 60 feet while rounding the included promontory, whose neck or isthmus is but 800 feet through. Conditions here also favor the obtaining of additional head by damming.

GEOLOGY.

STRATIGRAPHY.

FORMATIONS.

Most of the sedimentary rocks of this area are considered to be the equivalents of the Algonkian formations of the Cœur d'Alene district.[3] They are briefly described as follows:

[1] Lindgren, Waldemar, op. cit., p. 59.
[2] Ransome, F. L., and Calkins, F. C., op. cit., p. 75.
[3] Idem, pp. 25 et seq.

Generalized tabular section of sedimentary rocks in the St. Joe River basin.

System.	Formation.	Description.
Tertiary.....	.....	High bench gravels.
Algonkian (Belt series).	Striped Peak formation.	Light-gray to greenish flaggy sandstones, graywackes, and quartzites.
	Probable equivalent of upper part of Newland ("Wallace") formation.	Bluish limy shale grading upward into greenish-banded to greenish shale.
	Probable equivalents of lower part of Newland ("Wallace") formation and upper part of St. Regis formation.	Pale-greenish, indistinctly banded shale with thin interbedded layers of sandstone, probably equivalent in part to the St. Regis, overlain by gray, thin-bedded, slightly sericitic, white-weathering sandstones, with which are interbedded considerable amounts of buff-weathering gray-banded argillite, greenish limy shales, and blue to gray limestone. In the metamorphosed areas all these shales are altered to pale-greenish and chocolate-brown hornstones, which are, in many places, studded with white grains of scapolite about the size of buckshot.
	Probable equivalents of the Burke and Revett formations and the lower part of the St. Regis formation.	White, rather flaggy, slightly sericitic quartzites, grading into grayish and brownish quartzites and schists.
	Prichard formation (possibly including some older beds).	Coarse-grained garnetiferous mica schists (including some gneisses and amphibolites of igneous origin not differentiated on the map), overlain by about 1,000 feet of pure thick-bedded quartzites, and these in turn by gray and brown mica schists.

HORIZONTAL VARIATIONS.

The rocks assigned to the Prichard formation in this area differ from the typical Prichard formation of the Cœur d'Alene district in containing thick strata of pure quartzite. It is not known, however whether these quartzites are lower than any beds in the Cœur d'Alene section or represent a horizontal variation. The dominant rock here is mica schist, instead of slate, as in the Cœur d'Alene district, but this is due to the strong metamorphism that prevails in the parts of the region where the formation occurs.

The supposed equivalent of the Revett quartzite is more micaceous and thinner bedded here than in the type locality and therefore less distinct from the beds which are believed to represent the Burke formation.

The beds which are believed to represent the Newland ("Wallace") formation are apparently much thicker than that formation in the Cœur d'Alene district, and toward the southeast they show a proportionately greater development of sandstones. The white and gritty weathered surfaces of these sandstones also generally show red and yellow specks of iron oxides. The characteristic purplish bands of the St. Regis formation are here lacking. The strata representing the upper part of the Newland ("Wallace") and the Striped Peak

are like those formations in the Cœur d'Alene district, except that the equivalents of the Striped Peak show fewer reddish bands. The high bench gravels are found mainly west of Avery, as shown on the map. In addition there are a few very small patches adjacent to the river above Avery. These gravels lie on the base level at 3,500 feet and are thought to be equivalent in age to similar gravels in the Prichard Creek district and other parts of the Cœur d'Alene region. In this area, however, they are not gold bearing so far as known.

HORIZONS AT WHICH ORGANIC (?) REMAINS OCCUR.

Forms suggestive of organic origin were found at two horizons in the beds representing the Newland ("Wallace") formation. The lower horizon is about 1,000 feet above that of the Wishards sill and the upper about 1,000 feet above this. On the summit of Quarles Peak the lower horizon is represented by a bed of grayish limy shale about 3 feet thick, crowded with flattened globular forms from half an inch to an inch in diameter that suggest bivalves of some sort.

The localities at which observations were made at the upper horizons are three-fourths of a mile southwest of the summit of Quarles Peak and in rock cuts along the line of the Chicago, Milwaukee & Puget Sound Railway about half a mile below the Adair loop (station 395 + 50 west of East Portal) and about 2 miles above the loop (station 243 + 50 west of East Portal). At these localities a bed of bluish limy shale or impure limestone contains numerous flattened cylindrical forms resembling mashed trilobites. Dr. Walcott has examined the specimens brought in from the field and states that they "are elongated, more or less corrugated calcareous nodules, and some of them suggest organic origin."

IGNEOUS ROCKS.

GRANITIC ROCKS.

Granitoid gneiss.—The gneiss intercalated with the schists near the base of the section is chiefly a gray, strongly laminated rock of medium-coarse granular texture modified by recrystallization under great pressure. The chief constituents are soda-lime feldspar (oligoclase), quartz, orthoclase and microcline much inferior in amount to the oligoclase, biotite, and epidote, locally with more or less hornblende.

Anorthosite.—In the southern part of T. 43 N., R. 4 E., is a large area of whitish rock consisting essentially of soda-lime feldspar with the average composition of labradorite. This anorthosite shows no very conspicuous evidence of pressure except in local phases that contain small amounts of hornblende and other dark minerals which are drawn out into streaks and give the rock a gneissoid banding. Microscopic sections of the more purely feldspathic variety, however,

show it to have been thoroughly crushed and sheared. It has suffered, in fact, about the same amount of dynamic metamorphism as the gneiss above described.

Pegmatites.—Pegmatites that form numerous and conspicuous dikes and sheets in the gneisses and schists of T. 43 N., R. 4 E., consist chiefly of orthoclase and quartz, and most of them contain small amounts of mica and of soda feldspar. Their most interesting feature is the great variation in the amount of the quartz. Gradations can be traced from pegmatites with quartz subordinate to feldspar into those composed almost wholly of quartz; and it is probable that many quartz veins free from feldspar in the area where pegmatites are abundant are of magmatic origin.

Granodiorite.—In the southern part of the territory examined are two areas of granitoid rock evidently much younger than the strongly foliated intrusive rocks described, for while they occur in close proximity to these rocks, they are not appreciably sheared. They presumably represent part of a vast intrusion which occupies hundreds of square miles to the south[1] and which has probably caused the greater part of the contact metamorphism observed south of St. Joe River.

The rocks of the two areas are very similar and remarkably uniform. They are of medium granular texture, and consist essentially of plagioclase (andesine and oligoclase), subordinate orthoclase, quartz, and biotite, locally with a little hornblende.

A few small dikes of granodiorite porphyry cut the strata representing the Newland ("Wallace") formation in the vicinity of St. Joe River a short distance above Avery. This rock shows abundant phenocrysts of white feldspar and altered biotite and hornblende in a pale-greenish groundmass.

Porphyritic monzonite of Black Prince Creek.—The intrusion crossed by Black Prince Creek and the neighboring smaller intrusions show much variation but consist chiefly of a porphyritic monzonite containing abundant large phenocrysts of microcline in a groundmass about as coarse as average granite and composed essentially of plagioclase, microcline, quartz, biotite, and hornblende. The quartz is in rather small amount. The rock has been much fissured and affected by innumerable small faults along curved slickensided surfaces that are well exposed in railway cuttings. The chief interest of this monzonite lies in its marked resemblance to the dominant rock in the intrusions of the Cœur d'Alene district. This resemblance is significant in view of the evidence that the monzonites of the Cœur d'Alene district have been concerned in the mineralization of that richly productive area.[2]

[1] Lindgren, Waldemar, op. cit., p. 17.

[2] Ransome F. L., and Calkins, F. C., op. cit., pp. 135 et seq.

Camptonite.—A few dikes of camptonite with north-south course cut the strata representing the Newland ("Wallace") formation on the spur west of Maylan Creek. It is a light greenish gray rock showing slender prisms of hornblende in a feldspathic groundmass similar to some north-south dikes in the Cœur d'Alene district.

DIABASE.

Wishards sill.—A striking lithologic feature of this area is a thick and persistent diabase sill intruded near the middle of the strata representing the Newland ("Wallace") formation. A prominent knob of the Idaho-Montana divide near milepost 153, known as Wishards Peak, is formed from this rock, hence the name Wishards sill may be appropriately applied to it. From this point it outcrops in a narrow band that closely parallels the divide to the St. Paul tunnel of the Chicago, Milwaukee & Puget Sound Railway and beyond. In the opposite direction to the southeast its outcrop continues toward St. Joe River, leaving the divide at Wishards Peak. Again, from Goddards to Maylan Creek the sill forms picturesque cliffs and knobs, set slightly back from the river's south bank. The river channel from Conrads down to Goddards is a narrow gorge cut in this rock. Seen at a distance, outcrops of this rock appear nearly black; at close range they are dark rusty greenish and on fresh fracture dark dull green in color. In texture the Wishards sill varies from that of a basalt at its margin to that of a characteristic diabase, showing to the unaided eye white feldspar laths embedded in a dark-greenish crystalline groundmass of the ferromagnesian minerals. Locally its texture is coarse like that of a gabbro. The microscope shows it to be of a rather siliceous type, free from olivine, and composed essentially of labradorite, augite, ilmenite, and interstitial micropegmatite.

Other sills and dikes.—Diabase essentially similar to that of the Wishards sill forms many smaller sills and dikes in the strata representing the Newland ("Wallace") and underlying formations. The largest of these basic intrusions below the Wishards sill, in T. 43 N., R. 4 E., is shown on the map. It forms a thick lenticular mass in the upper part of the schists correlated with the Prichard formation. It extends east of the area examined, and the dark and jagged Monumental Peaks appear from a distance to be carved from the same rock.

The diabase has suffered contact metamorphism together with the intruded sediments, and where the sediments have been altered to coarse mica schists the diabases have been altered to schistose amphibolites.

BASALT.

The basalt caps shown on the map (Pl. II, p. 40) are remnants of a comparatively recent lava flow, presumably to be correlated with the great Tertiary lava floods of the Columbia basin.

STRUCTURE.

FOLDS.

Packsaddle syncline.—The most prominent structural feature of this area is a large, open, fairly symmetrical syncline whose axis trends about N. 65° W. The position of its axis is shown by small areas of the Striped Peak formation lying between Packsaddle Mountain and Striped Peak. It will be referred to as the Packsaddle syncline. The trough involves an area roughly 5 miles wide and 20 miles long ending to the southeast in canoe form near Bird Creek and to the northwest in a somewhat similar manner.

Other folds.—Another fold that may be commensurate with the Packsaddle syncline is an anticline shown by the plotted dips south of Lookout Mountain in T. 43 N., R. 4 E. There was no opportunity to determine its full extent, but it is known to persist for at least 5 miles. It is complicated, as the Marble Creek section shows, by minor folds and has an eastward pitch, which also characterizes the numerous other less persistent folds in the southwestern part of the area examined. Small compressed pitching folds whose axes vary in trend but as a rule course west-northwest are characteristic of the area lying between St. Joe River and the most northeasterly outcrops of the Wishards sill, except the portion occupied by the Packsaddle syncline. Except in a small flexure trending northwest through Wards Peak the area northeast of the sill outcrop mentioned exhibits moderate southwest dips only. On the other hand, northeast dips prevail in the area southwest of the Packsaddle syncline, hence the structure of this area as a whole may be perhaps defined as that of a northwestward-trending geosyncline succeeded to the south by an anticline.

FAULTS.

Steeply inclined faults exhibiting the dominant northwesterly trend are numerous in the areas of complex folds. They are in many places but not everywhere accompanied by thick breccias. The course of St. Joe River from Avery up to Conrads seems to have accommodated itself somewhat to a zone of faults, some of which have caused considerable displacement. Of these, the St. Joe fault, having a downthrow to the north of at least 1,500 feet, brings up the

Wishards sill south of the river, and the Skookum fault drops the blue shales which represent the upper part of the Newland ("Wallace") formation against the middle beds of that formation. This fault is accompanied by a breccia in places 300 feet wide.

There is a great fault of west-northwest trend that follows the general course of St. Joe River near the mouths of Marble and Mica creeks. Its downthrow is on the north and is great enough to bring the strata representing the Newland formation into close proximity to the quartzites far down in the Prichard.

The distribution of the rocks near the boundary of Tps. 44 and 45 N., R. 4 E, is hardly explainable without much faulting, but the exposures here are so poor that it is doubtful whether the structure could ever be satisfactorily deciphered. There is strong evidence of the existence of a fault or fault zone with downthrow to the south, following the general course of Boulder Creek. Brecciation has been observed in the quartzites both north and south of that stream.

A great fault of nearly north-south trend has been found in the southern part of the Fish Hook basin. Its throw must amount to thousands of feet, for it brings rocks representing the Newland on the west against beds several thousand feet below the top of the Prichard formation.

CRUSHED AND SHEARED ZONES.

Zones in which the rocks are sheared and crushed are numerous in the areas of complex folds. These zones are not well defined and can not be exactly bounded, and the degree of crushing or shearing in them is variant, but areas in which the quartzitic rocks are crushed to the semblance of a breccia may be from a few hundred feet up to a mile or more across. The shaly beds of the Newland ("Wallace") and the diabase intrusions are commonly sheared.

METAMORPHISM.

The sedimentary rocks and the older intrusive rocks are strongly metamorphosed in about half of the area examined. The intensity of the metamorphism is least toward the northeast and increases toward the west and south. A distinction is to be made between the thermal metamorphism due to the monzonitic intrusions exposed near Copper Prince and the much more intense metamorphism, partly thermal and partly dynamic, chiefly developed in the southern part of the area, presumably due in the main to a huge batholith that occupies great areas to the south of the territory here considered and is probably represented by the nonfoliated granite found at the head of the Clearwater. It is doubtless due in part also to the old granites, anorthosites, and diabases (pp. 44–46), now altered to gneiss and am-

phibolite, but these have suffered more metamorphism than they have caused. The diabase, where it occurs apart from other intrusive rocks, can be seen to have caused relatively slight metamorphism.

The metamorphic effect of the monzonites is first perceived on going down the railway from Avery, near the mouth of Slate Creek, where the buff-weathering blue and gray Newland beds grade into hard fine-grained hornstones coarsely banded and mottled in pale green and chocolate-brown. While the metamorphic nature of these rocks is not very evident to the unpracticed eye, and their general appearance faintly suggests that of the St. Regis formation, microscopic study shows the brown layers to be rich in biotite and the green layers rich in pyroxene and amphibole and proves that they are metamorphosed calcareous sediments. Farther on the shaly beds of the lower formations are represented by mica schists even more clearly showing the effect of contact metamorphism.

Near the western limit of the area the metamorphism due to the monzonites merges with that of other origin. At the east, however, the monzonite has had no effect and the increase of metamorphism toward the south can be clearly observed. In the vicinity of the State line and Packsaddle Mountain a very slight metamorphism is shown by a faint brownish banding only in some argillites. Toward the river some of the sandy shales gradually become micaceous, resembling schists, and the argillites grade into greenish and chocolate-brown hornstones, the latter thickly studded with round grains of scapolite that stand out on weathered surfaces suggesting so many white fish eggs.

The metamorphism in its extreme degree is best observed in T. 43 N., R. 4 E. The general aspect of the old sediments and intercalated intrusive rocks is such that they would probably be assigned to the Archean were it not that they are conformable with the overlying Algonkian. The quartzites are coarsened by recrystallization and the less pure beds contain conspicuous crystals of garnet or cyanite. The argillaceous beds are represented by coarse mica schists, garnetiferous for the most part, some of the garnets in which are nearly as large as a tennis ball. Pegmatitic material permeates these rocks very intimately in the form of minute veins or lenses parallel to the bedding, and even in isolated feldspar crystals. The rocks where this material is abundant are properly characterized as injection gneisses. The foliation of the granitoid gneisses and sheared anorthosite shows most clearly how large a part pressure as well as heat has played in the metamorphism. Of all the igneous rocks, the diabases have suffered the most radical change of texture and mineral constitution. Where metamorphism is thorough, the diabase is altered to a black schistose amphibolite studded with red garnets.

MINERALIZATION.

GENERAL FEATURES.

Mineralization of the country rock by the introduction of specks or grains of such minerals as pyrite, chalcopyrite, and siderite is found in certain formations or under certain conditions. The most noteworthy example of this is the occurrence of grains of siderite (spathic iron) generally disseminated in the sandstones of the strata representing the lower part of the Newland ("Wallace") formation. Siderite is somewhat more sparingly present in the sandy shales also. This phenomenon is most characteristic of the areas of complex structure. This mineral replaces other constituents of the rock in a way similar to the mode of its occurrence in the Cœur d'Alene district, where, however, it is found in the Burke and Revett quartzites instead of in the Newland ("Wallace") formation. The bluish-greenish shales and slate which represent the upper part of the Newland formation show little or no general mineralization except a sparing distribution of pyrite in some areas. The strata representing the Burke and Revett formations and the lower quartzites and schists contain specks and crystals of pyrite more or less generally disseminated, and in small areas a little chalcopyrite.

LOCAL FEATURES.

Lodes.—Lodes of the more or less pockety or replacement type are numerous in certain areas, mainly those occupied by the strata representing the lower part of the Newland formation. All the lodes contain chalcopyrite and pyrite as the chief or among the chief ore minerals. Galena and sphalerite are found in a small area. Siderite is the chief gangue mineral in most of the lodes; quartz and calcite in others.

Fault breccias and crushed zones.—Crushed zones and fault breccias found in the sandstones of the Newland formation are usually cemented to a greater or less extent by siderite and some calcite.

Sheared zones.—Sheared zones in the diabase are generally mineralized by the introduction of calcite, quartz, and siderite that form "knife-blade" seams or veinlets and irregular bunches, and by the introduction also of varying amounts of pyrite and chalcopyrite.

ASSAY VALUES.

Some reported assay values are given in the descriptions of the prospects, from which it appears that the lodes containing pyrite and chalcopyrite carry up to $10 or more to the ton in gold and a little silver. In addition assays of samples [1] collected in the field indi-

[1] These samples were assayed for gold and silver at the United States assay office, Helena, Mont.

cate that in general the outcrops of the large sideritic lodes contain traces of gold and a little silver, usually less than 1 ounce to the ton, and that outcrops of the sheared zones in diabase showing "knife-blade" seams of quartz or calcite contain from traces up to $3.60 to the ton in gold, from traces up to 4 ounces of silver to the ton, and traces (less than 0.1 per cent) of copper.[1] Assays of the lodes showing galena, chalcopyrite, or pyrite other than the reported ones referred to are not at this time available.

TABULAR SUMMARY.

For the comparison of the mineralization and general geology this area may be conveniently subdivided into four portions. These portions can not be exactly bounded, but their location and approximate limits and their chief characteristics may be given, as follows:

[1]The determination of copper in these samples was made by the laboratory of the United States Geological Survey.

Principal features of subdivisions of upper St. Joe River basin, Idaho.

St. Joe area.

Location and approximate limits.	Chief characteristics of lode mineralization.	General mineralization.	Character of country rock (sedimentary formations).	General character of structure.	Character of intrusive rocks.	Degree of contact metamorphism.
Mainly area north of St. Joe River and east of Avery except Packsaddle Mountain. At the northwest is in Idaho, a narrow zone along the main divide and continuous with the copper belt of the Cœur d'Alene. To the south it broadens, curving around Packsaddle Mountain as far as St. Joe River and extending southeastward. Includes also a strip 3 or 4 miles wide south of St. Joe River from Burton Creek to Siwash Creek.	Siderite and calcite as gangue, chalcopyrite as ore.	The sandy shales and sandstones contain generally disseminated grains of siderite in amount comparable to that contained in the quartzitic rocks of the Cœur d'Alene district.	Shales, sandstones, sandy and limy shales, impure limestones.	Complex (folds, faults, and crushed and sheared zones).	Basic. (The diabase has no genetic relation to the ore deposits.) Subordinately granitic (dikes of granodiorite porphyry).	Slight to moderate.

Black Prince Creek area.

Includes area west of Slate Creek adjacent to St. Joe River, extending 3 or 4 miles north and 1 or 2 miles south of the river.	Quartz as gangue, chalcopyrite as ore.	Pyrite generally and chalcopyrite locally disseminated.	Sandy and limy shales and quartzites.	Complex (folds and faults).	Granitic.....	Moderate, locally intense.

Sliderock Mountain area.

All the area south of St. Joe River and west of Avery except those portions included in the St. Joe and Black Prince Creek areas.	Quartz as gangue, chalcopyrite as ore.	Small specks and crystals of pyrite sparingly disseminated.	Quartzites, schists, and sandy and limy shales.	Moderately complex. In the northern part rather large folds and faults.	Granitic.....	Strong to intense.

Slate Creek area.

Area north of St. Joe River and mainly west of Avery, except those portions included in the St. Joe and Black Prince Creek areas.	Siderite and calcite as gangue, galena and sphalerite as ore.	Pyrite disseminated locally.	Bluish to greenish shale and slate.	Simple.....	Intrusive rocks practically absent.	Very slight.

CONCLUSIONS.

In the St. Joe and Black Prince Creek areas is found the combination of factors most favorable to ore deposition and of evidences that such deposits occur. Thorough prospecting of these two areas is certainly warranted by the favorable conditions of structure, degree of metamorphism, and general and special mineralization. So far as the evidence at hand goes, the chief values are to be expected in gold and copper. Considerable promise is held out by many of the better-defined lodes. That portions of the mineralized shear zones in diabase may be found to constitute low-grade ore is indicated by the few assays available. Increase of values in depth should in general not be expected, for it appears that oxidation of the lodes and shear zones has reached a slight depth only and that secondary enrichment is absent. The Slate Creek area, however, in addition to generally scant evidences of mineralization, is structurally unfavorable for ore deposits. The Sliderock Mountain area shows generally a too intense metamorphism and too few direct evidences of mineralization to be considered favorable for ore deposits. It appears as if erosion has planed away all but the roots of the lodes that had been developed in this area. While for these two areas the general conclusion is drawn that they are unfavorable for ore deposits, it must not be construed to mean that they contain no ore deposits whatever or that none of the prospects already located will develop into paying lodes.

DESCRIPTIONS OF MINES AND PROSPECTS.

ST. JOE AREA.[1]

Ward.—The Ward mine is situated on the southeast spur of Wards Peak, near milepost 161 of the Idaho-Montana boundary, and lies within the two States. It is one of a group of claims lying mostly in Montana, the others of which were not visited. It is developed by an adit level and drifts aggregating 1,200 feet in length, a shaft 80 feet deep, and some minor openings. The country rock is pale greenish banded shale with thin quartzite beds, representing the lower part of the Newland ("Wallace") formation. A vertical diabase dike of irregular width trending about N. 75° W. cuts the shales. A mineralized shear zone 50 feet or more wide trending west-northwest affects the diabase principally. Within it are numerous seams and veins of quartz, calcite, and siderite, carrying small amounts of chalcopyrite, pyrite, and chalcocite. Specks of the chalcopyrite and pyrite have been also introduced along the innumerable shearing planes of the zone, and the whole mass is said to assay

[1] This and the following subdivisions are defined in the tabular summary on page 53.

$4 and more to the ton in gold. At the time of visit a few tons of this ore was being shipped to a smelter as a test sample.

Monitor.—The principal mines adjacent to and on the Idaho side of the State line are the Monitor, Richmond, and others in the midst of a large group of claims lying between the divide and the loop of the Chicago, Milwaukee & Puget Sound Railway. Considerable development work was done on the two claims mentioned, but their hoists and other improvements were completely destroyed by the forest fires of 1910, and they were for the time being inaccessible. These deposits are all in limy and shaly sandstones representing the lower part of the Newland ("Wallace") formation, near the horizon of the Wishards sill. From the mine dumps it appears that the upper workings are in oxidized material, carrying large percentages of iron and some copper carbonates. In depth this is succeeded by chalcopyrite and pyrite in a gangue consisting mainly of calcite and siderite.

Big Elk.—The Big Elk prospect, located just above the Chicago, Milwaukee & Puget Sound Railway tracks, about 2 miles northwest of Adair, was seen before the fires reached that vicinity. This is a replacement along a shear zone that can be traced for half a mile or more, trending N. 40° to 70° W. in the lower part of the sandy shales regarded as belonging to the Newland formation. It is developed by a 40-foot shaft, a 15-foot winze, and some short adits. The shear zone has been mineralized up to 6 feet in width by the introduction of chalcopyrite, pyrite, calcite, and quartz. Within this mineralized portion are found irregular bunches up to 2 or 3 feet thick of chalcopyrite with a calcite and quartz gangue. This ore is said to assay $10 in gold and 2 or 3 ounces of silver to the ton and 30 per cent of copper.

Silica.—A quarter of a mile north of the north line of sec. 6, T. 46 N., R. 6 E., the Silica Gold & Copper Mining Co. has a group of claims located on three parallel veins, which cut limy, buff-weathering sediments representing the Newland formation. The chief lode seems to consist of a fault zone which is 6 feet or more in width and is filled with crushed rock and more or less angular fragments of quartz. It trends about N. 70° W. and may be a continuation of the faulting shown on the railroad cut in the southern part of sec. 4. A few little local bunches of pyrite and chalcopyrite occur, apparently where side fissures intersect the main brecciated zone. The sulphides are said to carry gold to the value of $4 to $12 a ton. Siderite and calcite also occur in varying amounts. The so-called middle lode is 150 feet north of the one just described and roughly parallel to it. The development work consists of an open cut 20 feet long which shows a great siderite lode approximately 20 feet wide, trending S. 80° E. and dipping steeply south. No pyrite or chalcopyrite was observed here. About 1,200 feet north of this lode occurs another almost par-

allel vein. It consists of a shear zone in siliceous sediments representing the Newland formation, where quartz has replaced some of the crushed country rock. No other mineralization was observed here, although it is said that specimens of auriferous pyrite and chalcopyrite had been found in the vein.

St. Joe Quartz and vicinity.—At the prospects located along St. Joe River the most development work has been done on a claim at Goddards owned by the St. Joe Quartz Mining Co. A tunnel 400 feet long penetrates a mineralized shear zone in the Wishards sill. The zone trends about east and west and contains irregular seams and bunches up to 3 feet wide of quartz, calcite, and chalcopyrite. A few tons of of the ore had been sacked and piled on the river banks. Half a mile above this a short adit on the Black Bear claim exposes a 4-foot vein striking N. 85° W. and consisting chiefly of scapolite with relatively small amounts of sodic plagioclase, calcite, epidote, and garnet. It contains an irregular streak of partly oxidized pyrite a few inches thick and is separated into two unequal layers by a 6-inch parting of diabase. The vein is vertical and has one slickensided gouge-lined wall upon which post-mineral faulting has occurred. The diabase is well exposed here and contains many shear zones. These are more or less mineralized, usually showing veinlets of quartz and calcite and the green stain of copper carbonates.

Eureka.—Half a mile to the east of Goddards a location by Isaac Hegarty is based on a persistent quartz outcrop trending N. 68° W. This lode is in metamorphosed sandstones representing the lower part of the Newland ("Wallace") formation and is apparently a replacement along a crushed zone. It varies from 1 to 10 feet in width and consists of massive white quartz together with heavily ferruginous porous quartz and some undecomposed siderite and pyrite.

Conrad's crossing.—In the vicinity of Conrad's crossing on St. Joe River a few short adits and trenches have been made on small veins that are numerous in the diabase. The country rock is severely sheared and more or less mineralized in many places. The mineralization consists in the introduction of minute crystals of chalcopyrite and pyrite along shear planes, and the development of seams and irregular bunches up to 3 feet or more wide of calcite, quartz, and siderite carrying chalcopyrite and pyrite. The green stain of copper carbonate may be seen at many places on weathered surfaces of the diabase.

Alice.—Some locations about a quarter of a mile east of the mouth of Bird Creek are known as the Alice group. Here an extensive replacement deposit occurs along a shear zone in the middle part of the quartzites regarded as belonging to the Newland ("Wallace") formation. It is developed by a 70-foot adit which shows the following section:

Section in adit of Alice group.

	Ft.	in.
Ocher		6
Vein quartz containing pyrite	1	
Quartzite	1	
Ocher		6
Crushed quartzitic shale containing much calcite	21	
Ocher		6
Calcite and siderite with some pyrite	30	
Ocher		6

The strike of the several layers here is N. 50° W. and the dip 35° SW.

Blue Bird.—On Blue Bird Creek near the southeast corner of T. 46 N., R. 6 E., a recent discovery known as the Blue Bird claim was being developed at the time of visit. The shallow discovery pit was about 8 feet square and located in the bottom of the canyon at the stream level. The top of a lode or pocket of quartz and calcite carrying considerable chalcopyrite and pyrite was exposed, occupying the whole pit. However, development had not proceeded far enough to show its thickness. The country rock consists of bluish and grayish sandy shales near the upper part of the strata representing the Newland ("Wallace") formation.

MINES EAST OF THE IDAHO-MONTANA BOUNDARY.

Along the State line from Wards Peak northwestward on the Montana slope are a number of mines and prospects reported as valuable and promising, such as the Bald Mountain, St. Lawrence, Buffalo, and Wishard. They were not visited for lack of time.

BLACK PRINCE CREEK AREA.

Copper Prince.—The most promising prospect so far shown in the metamorphosed strata representing the lower part of the Newland ("Wallace") formation is the Copper Prince, near the mouth of Black Prince Creek. It is situated in sec. 10, T. 45 N., R. 3 E., 800 feet south of sec. 3, but its trend may bring it within this section, though it can not at present be traced there because of the mantle of surface débris. Toward the east it is traceable across the line into sec. 11 and there is lost under the surface soil. Altogether it can be followed for nearly a third of a mile. The Copper Prince lode trends about N. 70° W. and is nearly vertical. It is a series of parallel slopes in highly metamorphosed shales representing either the Newland ("Wallace") formation or the St. Regis formation and is in close proximity to intruded masses of granitic and monzonitic rocks, aplite, and diabase dikes. The chief minerals are pyrite and chalcopyrite, with siderite, quartz, and calcite, and these occur in small fissures and joints and in little irregular bunches replacing the country rock.

This scattered and bunchy replacement type is characteristic of the lode so far as developed near the mouth of Black Prince Creek, but 1,000 feet north of this it seems to be better defined and to show a shear zone 4 to 5 feet wide filled with quartz, which has largely replaced the crushed material and some of the wall rock. Here, however, the evidence of mineralization is not very pronounced. About 100 feet still farther west a 10-foot tunnel shows the lode to be 3 feet wide, fairly well defined, filled with crushed, iron-stained country rock and quartz, and giving much more evidence of a possible definite ore body than it does farther to the east. The development work, in addition to the short tunnels and few small open cuts on the west end of the outcrop, consists of three tunnels—one on the west side of Black Prince Creek, 60 feet; another on the east side, 75 feet; and a third just over the line in sec. 11, driven in 40 feet deep. In some places the lode is wholly in sedimentary beds and in others it occurs as a shear zone between the sediments and the intrusive rocks. It seems to show local changes of direction, possibly due to intersecting side fissures, and such intersections might reasonably be expected to contain ore bodies.

Kelly.—Near the contact of the Prichard formation with the overlying quartzite along the railway a mile east of Marble Creek, a prospect is mapped (Pl. II). This location, made by Kelly Bros., of Avery, is on a branch vein which shows a maximum width of 12 inches and pinches out above. It suggests a quartz differentiation from or an end product of an aplite dike. Some postmineral shearing has occurred along its walls. The vein is filled with quartz, somewhat stained with iron and a trace of manganese oxide, and contains pyrite and chalcopyrite. Small stringer veins, aplite dikes, and a few shear zones occur in this formation and all carry a little pyrite with a few crystals of chalcopyrite.

Theriault.—Another prospect which gives some promise is that located by E. I. Theriault in strata believed to represent the basal part of the St. Regis formation. Here a diabase dike trending N. 65° W. and dipping 75° S., about 2 feet wide, has been sheared and well mineralized. The pyrite in it is said to carry gold values to the extent of $3 to $10 a ton. The gangue is principally quartz and iron-stained dike rock. The vein averages about 10 inches in width and has been exposed by open cuts both below and above the railroad track. Close to this lode and more or less parallel with it are other smaller and less important shear zones, which show more or less mineralization. The metamorphosing influence of the granitic intrusive rocks can be detected almost as far east as Slate Creek and is shown in the aplite dikes, quartz stringers, local areas which carry pyrite and some chalcopyrite crystals, iron-stained, metamorphosed-looking shear zones, and irregular bunches of calcite.

SLIDEROCK MOUNTAIN AREA.

Floodwood Creek.—A prospect that shows evidence of valuable mineralization is at the head of Floodwood Creek, near the center of sec. 27, T. 43 N., R. 4 E. The country rock is a crumpled injection gneiss composed of alternating thin layers of dark mica schist and white pegmatite. The average strike is northwesterly and the dip northward at moderate angles. The development consists of a tunnel about 35 feet long, an open cut about 30 feet long and 10 feet deep, and some other small open cuts that show nothing of interest. The direction of the tunnel appears to have been ill calculated, for it crosses at an acute angle a vein which appears just beside the portal and, so far as observed, it taps no others. This vein is about 6 inches thick, is nearly parallel to the bedding, has a quartz gangue, and contains a small proportion of chalcopyrite and probably other minerals in particles too small for identification.

More conspicuous indications appear in the largest open cut. This shows no well-defined persistent vein but rather a number of groups of small veins nearly parallel to the bedding. There are two principal groups. One, about 2 feet in aggregate breadth, is composed of several rather poorly-defined veins with a maximum thickness of about 3 inches. Another, about 5 feet from this, consists of two veins each 1 foot to 2 feet thick, divided by thin partings. All the veins seem more or less lenticular and uneven in thickness. The composition is similar to that of the vein at the tunnel.

Collier [1] quotes a report that an average sample taken across the ledge yielded $2.48 in gold, silver, copper, and lead and states that a picked sample was found to contain a trace of gold, 0.8 ounce of silver, and 2.1 per cent of copper. No further assays are at present available.

Fish Hook Creek.—On Fish Hook Creek, in T. 45 N., R. 5 E., about half a mile north of the point where the trail leaves the stream, there is a shallow opening on a quartz vein 2 feet thick, parallel to the bedding of the country rock (representing the Newland formation), which dips 35° N. The quartz contains rusty hollows from which pyrite or some other sulphide has probably been leached.

Large quartz outcrops.—In the southern part of this area there are numerous quartz veins, some of which attain a thickness of several feet. Many are remarkable for the purity and whiteness of the quartz composing them; others are discolored to a slight extent by decomposed pyrite. Farther north veins are less commonly seen, owing in part no doubt to the general poverty of the exposures. The largest vein seen cutting the strata representing the Newland formation is one of

[1] Collier, A. J., Bull. U. S. Geol. Survey No. 285, 1905, p. 136.

quartz near the head of Siwash Creek, in T. 44 N., R. 5 E. It forms a bold outcrop about 50 by 20 feet in extent, elongated in an east-west direction, but it does not seem persistent.

SLATE CREEK AREA.

Silver Spray.—In sec. 11, T. 46 N., R. 4 E., is the Silver Spray prospect, which consists of two tunnels and several open cuts. Tunnel A bears about N. 24° W. and enters 700 feet from the mouth of Prospect Creek. It has been driven 58 feet into bluish slates representing the upper part of the Newland ("Wallace") formation, which are here interbedded with some buff-weathering to light-gray fine-grained shales and quartzite beds. The mineralization occurs in a quartzite bed 1½ to 2½ feet thick, which dips 10° N. and consists of siderite, pyrite, crystals of chalcopyrite, galena, a little micaceous hematite, and some zinc blende. These minerals occur as small irregular replacement bunches peppered through the quartzite bed. An open cut higher up the hill shows other similar quartzite beds also more or less mineralized. Tunnel B, on Slate Creek 200 yards north of the mouth of Prospect Creek, has been driven 50 feet into the same formation and the mineralized conditions here are practically identical with those above described.

Sailor Boy.—The Sailor Boy prospect is located in the NW. ¼ sec. 13, T. 46 N., R. 4 E. The mineral conditions here are practically the same as those in the Silver Spray. The mineralized quartzite bed is about 2 feet thick and shows the same minerals in the same sparse proportions. A tunnel 75 feet long has been driven and a 30-foot crosscut and 20-foot shaft have been added to the main working.

Mastodon.—The Mastodon or Rochester group of claims is in sec. 8, T. 46 N., R. 4 E. Tunnel A of this group is driven about 75 feet into blue and light-gray slates and shales, which dip 8° N. It shows fine-grained quartzite beds containing a few small gash veins which are filled with siderite, pyrite, and some calcite, but no general vein or lode. Tunnel B, in the same formation, has been driven in 75 feet on the west side of the creek. Little irregular bunches of mineral occur here, sparingly disseminated through a bed of quartzite about 2 feet thick, which is interbedded with the slates, as in the Silver Spray and Sailor Boy prospects. The minerals observed are pyrite, galena, siderite, calcite, and zinc blende. Tunnel C, driven some 200 feet into the same formation, shows a few very small stringer veins but no mineralization except a little iron-stained quartz and some weathered siderite. Tunnel D, driven 150 feet into the same formation, opens what appears to be a bedding thrust, the mineralization of which has partly replaced some of the sheared wall rock. The vein material is mostly siderite, now largely altered to iron oxide,

and some pyrite. Its maximum thickness is 4 feet, but in some places it thins down to less than a foot.

Setser.—The Setser claim is located near the summit of Packsaddle Mountain, about 4 miles northeast of Avery. Development work consists of an adit and several open cuts. A shear zone is exposed, the planes of which bear irregular "knife-blade" seams of ore consisting of galena and sphalerite, with some chalcopyrite and pyrite. Fairly large pieces of "float" galena, said to have been found in the vicinity, indicate a possible occurrence of larger ore bodies. The shear zone trends apparently east and west. The country rock is bluish and greenish shale representing the upper part of the Newland ("Wallace") formation.

GOLD-BEARING GROUND MORAINE IN NORTHWESTERN MONTANA.

By F. C. SCHRADER.

INTRODUCTION.

Although many morainal deposits contain particles of gold, the metal is very rarely so abundant in them as to make their treatment profitable. This is, of course, due to the fact that running water has not had opportunity to concentrate the precious metals scoured by the glacier from the decomposed surface of the mountains.

Geologic literature contains very little relating to such occurrences. According to Waldemar Lindgren,[1] a morainal deposit on the northern slope of Deep Canyon, just west of Duncan Peak, in eastern Placer County, Cal., has been worked on a small scale for many years. The locality is known as the Bob Brown claim. The rough gold, which is distributed throughout the deposit, evidently came from the vicinity of Duncan Peak, which is rich in small gold-quartz veins. In Trinity County, Cal., MacDonald [2] noted sharp-cornered "colors" occurring in glacial till, which was called "dead wash" by the early miners, because they found it practically barren. In the Juneau district, Alaska, Spencer [3] observed low-grade auriferous gravel in morainal deposits on Gold Creek, which, however, seem to be composed essentially of modified drift.

Gold-bearing ground moraines were recently observed by the writer during hasty visits in connection with work in land classification at a number of places in mountainous portions of the Northwest, notably on the slopes of the Continental Divide about 50 miles west of Denver, Colo., and in the Cabinet Mountains in northwestern Montana. The deposits of greatest economic importance are located in Montana and are known as the Kennedy Creek and Libby Creek placers. The writer is indebted to Messrs. John A. Scott, Frank Thomas, Vaughan, Howard, and Brockman, proprietors and operators, for courtesies and information regarding these occurrences.

[1] Oral communication.

[2] MacDonald, D. F., The Weaverville-Trinity Center gold gravels, Trinity County, Cal.: Bull. U. S. Geol. Survey No. 430, 1909, p. 50.

[3] Spencer, A. C., The Juneau gold belt, Alaska: Bull. U. S. Geol. Survey No. 287, 1906, pp. 84-85.

KENNEDY CREEK PLACER.

LOCATION.

The Kennedy Creek placer, owned by the Kennedy Creek Gold Mining Co. and comprising essentially the exploited part of the deposits here described, is located near Stark, in the Ninemile district, about 30 miles northwest of Missoula, Missoula County, Mont. The nearest railway station is Huson, a small place 14 miles to the southeast, on the Cœur d'Alene branch of the Northern Pacific Railway and the Chicago, Milwaukee & Puget Sound Railway, with which the property is connected by a good county wagon road of easy grade. Huson is also on Missoula River, which, uniting with Flathead River at Paradise, 30 miles to the northwest, forms Clark Fork of the Columbia.

TOPOGRAPHY AND DRAINAGE.

The topography of the region is hilly to mountainous but for the most part not rugged. The property under discussion ranges in elevation from about 3,300 feet in the open valley of Ninemile Creek on the southwest to 4,000 feet on the northeast, where it is backed by a steeply rising upland and a group of mountains culminating in Squaw Peak (also called Skiotah Peak) at 6,000 feet or more above the sea. The crest of the range here forms the line between Sanders and Missoula counties and the southwest boundary of the Flathead Indian Reservation. These mountains, as yet unnamed, seem in a general way to be the southeasterly extension of the Cabinet Mountains, with whose axis they are in alignment but with which they are not closely connected. They are separated from the Cœur d'Alene and Bitterroot mountains on the west by the valleys of Ninemile Creek and Missoula River.

The drainage flows southwestward through Kennedy Creek, a small stream a few miles in length, into Ninemile Creek, a vigorous stream which flows southeastward and joins the Missoula at Ninemile, a few miles below Huson. For nearly a mile in the middle portion of its course the valley of Kennedy Creek is a V-shaped gulch a few hundred feet deep, forming a narrow necklike outlet for the upper portion. This upper portion widens into a crudely fan-shaped, nearly flat-bottomed basin about a mile in diameter. A low divide separates the basin from the drainage of Butler Creek, a similar but stronger tributary of Ninemile Creek on the east, and a lower divide separates it from McCormick Creek on the west. The basin is openly timbered with stately pines and forms a pleasing natural forested park. With slightly rolling, benched, or terraced topography it inclines to the southwest, from an elevation of about 3,900 feet at the foot of the mountains and the Butler Creek divide to 3,600 feet at the outlet.

GEOLOGY.

The deposits lie within the area which has been mapped by the United States Geological Survey as undifferentiated Belt series,[1] comprising a great thickness of tilted, folded, and faulted Algonkian rocks, chiefly sandstone and shale, and their slightly altered equivalents, quartzites and hard argillites. To judge from the materials composing the gravels, the country rock in the surrounding hills and mountains includes representatives of the formations well known in the Cœur d'Alene district as the Prichard, Burke, Revett, and St. Regis formations.[2]

At the camp and the lower end of the gulch the creek crosses a zone of younger beds of soft sandstone and shale containing several beds of lignite, all dipping about 35° NE., toward the mountains. These beds are seemingly of Neocene age and are unconformable with the underlying Algonkian rocks.

Covering the bedrock nearly throughout the region is a surface mantle of mingled clay and gravel. The general aspect of this mantle, with its flowing surface contours, low mounds, hummocks, shallow undrained sinks, and other topographic forms, well seen in the Ninemile Creek valley, at once suggests its origin as a ground moraine. It ranges from 8 to 20 feet in thickness, averaging about 15 feet. It is thinnest where it has been eroded by Kennedy Creek and its tributaries. It is commonly known to the mining men who have examined it as ancient lake gravel, but it seems plainly to be a subglacial or ice-laid deposit of till—a ground moraine. This is clearly shown by topographic criteria, as stated above, and also by the character of the material itself, the complete absence of stratification, the coarseness and subangularity of the gravel, the planed, polished, and striated surfaces of many of the pebbles, the typical bowlder-clay matrix, and the rock-flour silt impounded by the tailings dam below the outlet.

The gravels, which form a large part of the deposit, range up to a foot and a half in diameter. They are composed mainly of quartzite, sandstone, and softer argillaceous rocks, with some quartz, hematite, and barite, all apparently derived from the formations of the Belt series. The matrix is typical brownish and bluish bowlder clay, with usually a small percentage of arenaceous or gritty material. A remarkable feature of the deposit is its high degree of consolidation, necessitating vigorous effort with the miner's pick to loosen almost every individual pebble in it, however small.

The material seems evidently to be derived from the upland and mountains on the northeast, whence as sedentary soil, oxidized rock

[1] Calkins, F. C., A geological reconnaissance in northern Idaho and northwestern Montana: Bull. U. S. Geol. Survey No. 384, 1909, p. 28, Pl. I.

[2] Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Cœur d'Alene district, Idaho: Prof. Paper U. S. Geol. Survey No. 62, 1908, Pl. II.

débris, and talus it was scoured off the surface by the ice sheet, shoved or dragged down the slopes, crushed, ground, and finally compressed beneath the ponderous ice mass into its present condition. The ice sheet probably covered the basin with a thickness of a thousand feet or more for a period of centuries.

OCCURRENCE OF THE GOLD.

The gold is detrital. It is contained in the ground moraine or till that floors the basin and extends down the creek outlet to a point below the camp. This material is seemingly gold-bearing throughout. The gold is of average coarse size, although no large nuggets have yet been found. The pieces are usually flattened but rough and irregular in shape and many pieces have quartz adhering to or embedded in them, denoting that the metal is of comparatively local derivation. It is probably derived from quartz veins in the equivalent of the Prichard slate, the chief gold-bearing formation of the Cœur d'Alene district,[1] which seems to be developed in the adjoining mountains; but unfortunately the mountain region could not be examined during this work. The slate is probably also the chief source of the bowlder-clay matrix in the deposit. The gold has a good color and is reported to run about $19 a fine ounce. With the gold in the deposits is associated considerable fine black sand.

The deposit on the whole, in view of its glacial origin, is remarkable for the large amount and the regular distribution of the gold it contains. A most unusual feature is the fact that this glacial deposit does not seem to have been concentrated by later streams, nor to have derived its gold from preexisting placers. If this view is correct there must occur in the mountains or uplands to the northeast, in the path of the ice that deposited the moraine, some rich gold-bearing vein or bedrock area as yet undiscovered.

As during the period of glacial activity a considerable quantity of till similarly derived from the mountains was transported through the basin and apparently had to be raised 100 feet or more to cross the rim rock, it seems possible that in this process of transportation some of the gold may have been left behind and helped to enrich the deposit which now floors the basin.

The gold seems to be distributed areally throughout the deposit with remarkable uniformity. Vertically considered its concentration increases with increase in depth and is greatest on bedrock and in the lower part of the gravel.

Tests made of the deposit in six different shafts fairly well distributed over about half a square mile in the southerly part of the basin show the gold content of the deposits to range from 20 cents

[1] Ransome, F. L., and Calkins, F. C., op. cit., p. 141.

a cubic yard near the surface to about $5 a cubic yard in the bottom foot of gravel next to bedrock, from which it is readily apparent that the deposits contain considerable gold. By some mining men the amount of gold present has been estimated at $18,000,000. From the data obtained in the present tests, after reasonable allowance is made for bowlders, which in the lower part of the section constitute about 10 per cent of the material, the deposit in the southerly part of the basin seems to contain on the average about 80 cents a cubic yard, including everything from the surface down to bedrock, or about $4 a bedrock yard. This would amount to about $17,360 an acre, or more than $5,500,000 for the Kennedy placer portion of the area examined. The estimate does not include the neck of the deposit in the downstream outlet, which in places attains a thickness of 80 feet or more and is known to carry considerable gold. In the basin as a whole, if gravel of this grade is present throughout, there is probably more than twice this value.

Ample water for working the ground is available; it is supplied through a 5-mile ditch from Butler Creek on the east. Some of the gold has been mined by hydraulic methods, about a thousand dollars' worth having been taken out by the present company in the last few years, mainly from the lower part of the ground. Owing, however, to the extreme consolidation of the material and the stickiness of the bowlder-clay matrix, which adheres to the gravel and thus tends to carry the gold along with the gravel into the tailings, ordinary hydraulic methods are not adapted to this deposit. It will require apparently a very powerful dredge or hydraulic elevator, first, to loosen the gravel which was so firmly consolidated by the heavy overlying ice mass, and, second, to agitate the material forcibly in order to free the gold from the sticky clay matrix. Any attempt to treat the deposit by methods adapted to ordinary water-laid gravel seems certain to prove a failure. The gentle slope, softness, and smoothness of the bedrock floor and the ample water supply are favorable conditions for dredging, but owing to the unusual character of the deposit the greatest care should be exercised in selecting a plant adapted to it.

Some mining men hold that soaking of the banks of the material successively exposed to the dredge pond after operations are begun will go a long way toward solving the problem. The experience of the writer, however, in obtaining samples from shafts which had just been unwatered for the purpose seems to show that little if any benefit can be expected from this mode of procedure, for the deposit is normally moist if not saturated and is not hardened by drought or baking as in an arid country. Blasting will probably prove the best means of loosening the material from its bed, after which, apparently, crushing or coarse grinding under a strong current or head of water

will be required to free the gold from its bowlder-clay matrix. In such a process the arenaceous or gritty material, though present only in small amount in the matrix, promises to prove an important feature, without which the deposit could probably not be worked.

Attention should also be directed to the ridges forming the low divides between Kennedy Creek and Butler Creek on the east and McCormick Creek on the west. In the western part of the basin, a short distance above the outlet, the McCormick ridge rises to a height of about 100 feet above the floor of the basin with a narrow, rounded, almost crested top in places and with side slopes of 30° to 40°. In the half mile or more of its extent the ridge has a serpentine course. Similar features also characterize the Butler Creek ridge.

The form and topography of these ridges and the vicinity and the little that could be seen of their geology indicate pretty clearly that during the melting of the ice at the close of the glacial period, while the basins and valleys were yet occupied by the ice masses, the drainage from the mountains in the rear found its way out to Ninemile Creek through subglacial tunnels or open ice-walled canyon-like channels coinciding in course with the present divides. In these narrow ice-bound channels the streams rapidly built up their beds with deposits of gravel and finer glacial débris, in some places to a thickness of 100 feet or more. When later the glacial streams and ice vanished, the stream-bed material remained and formed the present ridges, whose side slopes are due to slumping down of the upper portions of the material as the confining ice walls melted away.

These eskerlike ridges accordingly consist mainly of stream-laid materials which differ totally from the ground moraine of the basin and in which there has been much greater opportunity for concentration of the gold. The ridges should therefore be crosscut at favorable points, preferably toward the base of the mountain, where the gold is most likely to have been dropped by the currents. Owing to the general looseness of these deposits and the rapidity with which they were laid down their gold is likely to be concentrated almost entirely in their lower portion.

Placer deposits reported to be similar to those of Kennedy Creek are also worked on a small scale on McCormick Creek, to the west, but were not visited in this work.

SKETCH OF NINEMILE DISTRICT.

Since the foregoing description of the Kennedy Creek placer was put in type data for the following sketch of the Ninemile district, in the southeastern part of which the Kennedy Creek area is located, have been received through the kind efforts of Mr. Frank Thomas and pioneers of the district.

From Kennedy Creek the Ninemile district extends northwestward up the Ninemile Creek valley nearly to its head, a distance of 16 miles. The valley has a general width of about 8 miles; the portion to the northeast of Ninemile Creek, on the side of the higher mountains, is a mile or two wider than that on the southwest.

The description of the topography given for the Kennedy Creek region applies to the district as a whole, but in the upper part the area is more heavily timbered, logging and lumbering having long been the chief industry. The sides of the valley are scored by numerous small tributary creeks or gulches which join Ninemile Creek at about right angles. These tributaries are largest on the northeast, where they number 12 or 15, and average about 4 miles in length. The area generally is easy of access; the county wagon road extends up Ninemile Creek nearly to its head, to St. Louis Creek, the head of the placer workings several miles above the pioneer town of Martina, which has long been a center of operations and was the seat of the early placer workings.

The gold placers of the district, so far as shown by the present developments, are contained in approximately a mid-valley belt about 3 miles in width and 14 miles in length, extending from Kennedy Creek to a point several miles above Martina. In this belt the deposits seem to floor the valley in the form of a sheet whose continuity is interrupted by bedrock outcrops and stream-eroded areas. The deposits are best manifested and developed on the tributary streams, all of which carry gold. In the lower part of the district the deposits occur chiefly on the northeast side of Ninemile Creek; in the upper part they are found on the southwest side, and also continuously along the creek itself for a distance of about 6 miles. The deposits are said to be similar to those of Kennedy Creek and seem to be chiefly of glacial origin.

The first placer mining in the district was done in 1874, Messrs. Dickson, Barrett, Wolfe, Keim, Dickinson, Kennett, and Murphy being among the earlier locators. In the middle seventies these men and others mined Ninemile Creek and its tributary gulches for about a mile above the present site of Martina and for a somewhat greater distance below. That much gold was produced is indicated by the amount of ground worked, the cost of working it, its richness, and the fact that with only the crude methods of operation then in vogue, several considerable fortunes were made out of the diggings.

The amount of this early production, which by some is estimated at several million dollars, is not known. As there was no assay office at Helena in those days, the gold was mostly sent to New York, San Francisco, Philadelphia, and elsewhere, in shipments of which no records are available.

As this was prior to the advent of the Northern Pacific Railway in Missoula, supplies had to be freighted by team and wagon to

Missoula and then packed on the backs of animals to Martina, a distance of 150 miles or more. The wage of a common miner, who could handle only a few cubic yards of dirt per day, was $6. Ground that would not pay more than this amount per man per day was not considered. The richness of the gravel is further indicated by the fact that most of the ground is patented.

Since the early period of activity some of the many properties distributed throughout the district have not been worked for lack of sufficient water; others are now working and have been producing continuously on a small scale for many years. Among the latter are those of Fobert & Jamison, on McCormick Creek; Henry Bros., on Dutch Creek; the Chinamen, on Beecher Creek, and the Kennedy placer, on Kennedy Creek. On Beecher Creek, near Martina, a party composed of several members holds a 90-year lease on a property which it has worked with success for the last 12 years. On Kennedy Creek a California dredging company has just completed a thorough sampling of the ground with good results and is installing a dredge which is expected to be in operation in a few months.

A considerable area of good ground, too flat for successful sluicing, on a south side tributary opposite Soldier Creek, about 2 miles below Martina, is being negotiated for by Boston men with a view of putting in a dredge.

On Marion Creek the Marion Creek Gold Mining Co.'s property is being worked by lessees, and on Petty Creek the Hensolt placer, with a sawmill now on the ground, will commence mining as soon as the timber can be cleared off. On Ninemile Creek itself the deposits were mined wherever there was fall enough for sluicing.

The conditions encountered in the district—lack of sufficient fall and meagerness of water supply for successful sluicing on much of the ground, the consolidated condition of the deposits, and the favorable consideration given the ground by those interested in dredging—suggest that the dredge or possibly some powerful plant of the hydraulic-elevator type may furnish the best means for working the deposits.

Data for making an adequate forecast of the future of the district are not at hand. However, in case the gravels of the district as a whole compare favorably with those of the Kennedy Creek placer above described, as they seem to, it may be stated that after deducting more than half the volume of the gravel sheet for postglacial stream erosion and bedrock wastage, and making due allowance for the fact that most of the gravels hitherto worked were probably secondary, as in the earlier workings on Kennedy Creek, in which concentration of the gold had taken place by glacial and recent streams, by rough estimate the district probably contains about $100,000,000 worth of gold.

Much of this gold, to judge from the attention the district is receiving, will probably be won in the near future. The Chicago,

Milwaukee & Puget Sound Railway Co. has made a preliminary survey for a branch line up Ninemile Creek into the Flathead country on the north and is investigating, with reported good results, the lignite coal on Kennedy Creek with reference to its efficiency for locomotive steam fuel. The building of this railroad through the district, by affording cheaper labor, supplies, and freight rates, will greatly advance the placer-mining industry.

LIBBY CREEK PLACERS.

LOCATION.

The Libby Creek placers are located about 85 miles northwest of the Kennedy Creek placer above described, on the opposite or northeast side of the Cabinet Mountains, in the southern part of Lincoln County, formerly a part of Flathead County. They are about 12 miles east of the Idaho State line and about 20 miles south of Libby, the nearest station on the Great Northern Railway, whence they are reached by wagon road.

TOPOGRAPHY AND DRAINAGE.

The deposits are located on the headwaters of Libby Creek, which, heading on the northeast slope of the high, rugged Cabinet Mountains, drains northward into Kootenai River or North Fork of the Columbia at Libby. The broad gravel-floored valley of Libby Creek trends obliquely to or nearly parallel with the mountains and has a width of about 12 miles. It lies in open country and is sunk from 100 to several hundred feet below the general land surface. It and its main tributary valleys, according to Calkins,[1] are located on approximately parallel faults trending northwest. The valleys are separated by long, sloping ridges, which toward the mountains merge into a narrow belt of low rounding foothills. The topography is not rough, the irregularities of the bedrock being smoothed out by a mantle of glacial débris or lake deposits, producing gentle slopes of smooth contour up to elevations of about 6,000 feet. In the foothills and lower parts of the mountains the valleys are deeper but in few places V-shaped or canyon-like.

GEOLOGY.

The bedrock of this valley[2] consists essentially of members of the tilted, folded, faulted, and eroded Belt series, as at the Kennedy Creek placer and in the Cœur d'Alene district, Idaho. A considerable area of the gold-bearing Prichard slate forms the crest of the range at the head of the valley.

[1] Calkins, F. C., A geological reconnaissance in northern Idaho and northwestern Montana: Bull. U. S. Geol. Survey No. 384, 1909, p. 77.

[2] Idem, Pl. I.

Overspreading the eroded bedrock floor, especially in the upper part of the valley, and rising in the mountains to 6,000 feet, is a sheet of glacial drift which in the valleys and low places attains a known thickness of nearly 100 feet. This drift consists almost wholly of typical ground moraine and was deposited by the ice sheet that moved from the mountains down the valley. In places about 75 per cent of the drift is made up of subangular glacial gravels whose pebbles range from mere grains up to bowlders 10 feet or more in diameter, all embedded in a typical bowldery clay matrix.

The deposits lie within the area of continental glaciation as outlined by Chamberlin,[1] and it is quite possible that they may be complicated by movements of ice belonging to the continental sheet. So far as present observations extend, however, it does not seem necessary to refer the origin of the deposits, especially of their gold content, to continental glaciation.

OCCURRENCE OF THE GOLD.

Placer gold is reported to have been discovered in this region as early as 1867, but owing to the hostility of the Indians, by whom several prospectors were killed, little work was done on the deposits for some time. All the earlier workings are said to have been in the recent stream-washed gravels in or immediately along the present stream beds, and for a long time they furnished the principal mineral production of the Libby Creek and Cabinet Mountain district. These gravels were evidently concentrated by stream action from the sheet of glacial drift or ground moraine, on which they still in large part lie.

For the last 20 years or more, however, the gold has been derived principally from the till itself, where it occurs as placer gold. It is being mined at several points, principally at the Libby Placer Co.'s mine and the Vaughan-Greenwell mine. The placer production of the district for the period from 1902 to 1909, almost the whole of which came from these two mines, is $52,178.[2]

The workable deposits seem to be confined to the valleys and low places. Attempts to open ground on the higher slopes and benches have not yet been successful. A large area of the higher deposits examined by the writer in this work was found to contain from a cent to a maximum of 6 cents in gold to the cubic yard, which is obviously too low a grade to constitute workable ground.

Within the deposits the gold is irregularly distributed, in some places sporadically throughout the body of the till from top to bottom and in others in irregular, crudely horizontal but not definitely

[1] Chamberlin, T. C., Rock scorings of the great ice invasions: Seventh Ann. Rept. U. S. Geol. Survey, 1888, Pl. VIII.

[2] Mineral Resources U. S., volumes for 1902 to 1909, U. S. Geol. Survey.

stratified zones, beds, or streaks which may possibly contain slightly modified till. The oxidized zone, several feet in thickness at the surface, is usually barren.

The gold is mostly coarse or in nugget form. In about 8 ounces of it shown to the writer by Mr. J. T. Vaughan, at Libby, the pieces ranged in size mostly from that of a pea to that of the end of a man's finger, with some $8 to $10 nuggets. Some pieces showed considerable quartz adhering to or embedded in them. Others showed considerable wear or rounding, apparently more than could have been effected by transportation in the till from the crest of the range to their present location, a fact which suggests that some of the gold may have been gathered by the glaciers from preglacial placers.

The gold has a bright color; much of it is deep yellow; rarely it is coated reddish. It runs 0.926 to 0.945 fine as a rule,[1] but some is reported to run as high as 0.970 fine.

LIBBY PLACER CO.'S MINE.

Of the two mines here described the older is the Libby Placer Co.'s mine, also locally known as the Howard mine. It is located on the Goldhill-Montana-Kootenai claim group, about 20 miles south of Libby, on Libby Creek, which here flows between steep bluffs 80 feet or more high, carved in the glacial drift. The mine is in the east or right bluff, in which the gold is distributed from base to top and for a known distance of an eighth of a mile or more parallel with the course of the stream.

At the time of the writer's visit the mine was in quarantine and a close examination could not be made. From oral reports of the operators, and from the apparent continuity of the deposits with surrounding exposures that were examined, the deposit containing the gold, which is well exposed in the face of the bluff, seems to be typical ground moraine throughout, with a bowlder-clay matrix and subangular gravel and bowlders ranging up to 10 feet or more in diameter. To judge from a break in the continuity resembling an erosional unconformity above the middle of the section, two epochs or periods of deposition seem to be represented.

The ground is worked by hydraulic methods under a powerful head of water, both ground and box sluicing being employed.

VAUGHAN & GREENWELL MINE.

The mine owned and operated by Vaughan & Greenwell is located on the Eldorado claim group a short distance upstream from the Libby placer mine, on Howard Creek, an important east tributary of Libby Creek. It has been producing for about 20 years; in the

[1] Mineral Resources U. S. for 1908, pt. 1, U. S. Geol. Survey, 1909, p. 450.

period from 1904 to 1908 it yielded about $5,000 a year in the hands of lessees. The rate of production is limited by the water supply of Howard Creek for sluicing, which requires a very strong head of water.

The mine is opened and worked principally at two points about half a mile apart. The lower opening is on the east side of the creek, which here flows at an elevation of about 3,700 feet. From the creek the deposit rises gently eastward for about an eighth of a mile, to a height of about 150 feet; its extent parallel with the creek is somewhat greater. It rests upon a streamward-sloping bench or roughly eroded surface of quartzite which dips gently to the east, away from the range.

The deposit seems to be ground moraine. It is nowhere much over 30 feet in thickness and probably averages about 15 feet. Two periods of deposition are apparently represented. The basal part of the section is consolidated and cemented somewhat like hardpan, and its gravels are decidedly subangular. Blasting is employed to loosen it from its bed.

The gold is distributed more or less irregularly throughout the deposit. It is obtained by ground sluicing, in which it collects in the rock joints and cavities that serve as riffles, box sluices being too fragile to withstand the impact of the coarse gravel. The topography suggests that the deposit was probably derived from the high mountains to the west of Libby Creek, and if so its normal course of transportation by the ice was probably disturbed by the Howard Creek glacier at this point and by the rim-rock hill, on whose stoss side therefore the deposit lies, the conditions being similar to those at the Kennedy Creek placer.

At the other opening, located about half a mile farther upstream, the deposit is reported to be about 100 feet in thickness and to consist likewise of till or bowlder clay in which the gold is irregularly distributed throughout.

The source of the Libby Creek gold is commonly thought to be a porphyry "dike" or "ledge" which, to judge from a specimen shown to the writer by Mr. Brockman at Libby, is a coarse siliceous granitic and pyritic rock allied to granite porphyry. The dike has a width of about 200 feet. It is said to extend across Howard Creek at a point about a mile above the Vaughan-Greenwell mine and across Libby Creek at a point about a mile above Howard Creek; it is best exposed at the latter point. It is mostly covered, but not deeply, by glacial drift. No gold, it is said, has yet been found on the upstream side of the dike. The dike has not yet been prospected, and whether it is associated with quartz veins is not known.

That this dike may be a contributory source of the gold mined seems probable. However, the heterogeneous character of the drift

and the wide distribution of the gold in it indicate that most of the gold has probably come from points much farther up in the mountains, probably in large part from the area of the Prichard slate that is bounded on the west by the great Snowshoe fault, along which and in neighboring parallel fissures occur gold-bearing quartz veins and the important mineral deposits of the Snowshoe and other mines.[1] It is likewise probable that the drift-covered rocks here contain gold-bearing blanket veins or ore beds parallel with the stratification, similar to those on the head of Fisher River, 10 miles to the east, described by Calkins,[2] and that these may be an important source of the gold.

CONCLUSIONS.

Probably much remains to be learned concerning the extent and nature of the deposits above described. That the gold occurs in what is essentially a ground moraine there seems to be no doubt; that all the gold, however, is in primary placers and none of it derived from preexisting placers is not so certain.

More extended field work by a geologist with practical training in glacial deposits would result in much benefit to the placer industry in both the Ninemile Creek and the Libby Creek districts. As a result of such work the more important of the deposits, not only in the ground moraine but also in other forms of drift, could be located by topographic and geologic criteria, and positions of esker-like ridges and other more or less buried and obscure channels of glacial streams, along whose courses maximum opportunity for concentration of the gold occurred, might be pointed out.

It seems probable also that glacial placers similar to those here described may yet be found in other auriferous districts in the glaciated mountainous portions of the Northwest.

[1] Calkins, F. C., A geological reconnaissance in northern Idaho and northwestern Montana: Bull. U. S. Geol. Survey No. 384, 1909, Pl. I, pp. 54, 103.

[2] Idem, p. 103.

GEOLOGIC RELATION OF ORE DEPOSITS IN THE ELKHORN MOUNTAINS, MONTANA.

By R. W. Stone.

INTRODUCTION.

In the summer of 1910 the writer examined ten townships in the Elkhorn Mountains included within the land limits of the Northern Pacific Railway to determine the mineral or nonmineral character of the odd-numbered sections. The area is a small part of the Fort Logan and Helena quadrangles mapped by the Northern Transcontinental Survey on a scale of 1:250,000, or 4 miles to the inch. A 2-mile strip along the west side of the mountains is shown in greater detail, 2 miles to the inch, on the Boulder topographic map of the United States Geological Survey. The area had not been subdivided, except two townships which were subdivided in the spring of 1910 and plats of which were not available. In order, therefore, to establish the locations of the mineral deposits found and to depict the character of the region, it was necessary to prepare a suitable topographic map. Elkhorn and Crow peaks, the positions of which are known, were used as a base. This base line was very short, being little over a mile in length, but nevertheless proved satisfactory. A system of triangulation was developed over the entire area and township and section corners on range lines on the east and west sides of the area were located by this method. The positions of the townships having thus been established on a scale of 1 mile to the inch, the detailed mapping was done by transferring such portions of this triangulation as were needed to other sheets and making individual township plats on the scale of 1:31,680, or about 2 inches to the mile. The work was begun July 20 and, although hindered at times by smoke from distant forest fires, was carried on continuously and completed October 14, 1910. A topographic map of nine townships was drawn, T. 5 N., R. 2 W., being omitted. W. R. Hill, of Seattle, Wash., was topographer of the party, and Blaine McLeon, of Helena, Mont., acted as station recorder. The writer examined hundreds of mineral prospects and made a reconnaissance geologic map of the area. Work was begun near Elkhorn and proceeded north to McClellan Creek, east to Winston, south to Radersburg, and thence west and north to Jefferson, thus completing a circuit covering the whole area.

Numerous section corners found in T. 8 N., Rs. 1 and 2 W., made it possible to locate accurately on the topographic map each section in those two townships. The east side of the area examined is the Montana principal meridian and a number of section corners found along it, together with corners on the first standard parallel north, which is the south boundary of T. 5 N., Rs. 1 and 2 W., and corners along the west side of R. 3 W., controlled the position of the land net in the other eight townships. The resulting map shows the location of mines and prospects in the correct quarters of the 40-acre tracts. Although many of the geologic boundaries are drawn accurately, others are only approximate, especially those of the granite intrusions, which were crossed by a traverse in one direction only and could not, for lack of time, be traced in detail.

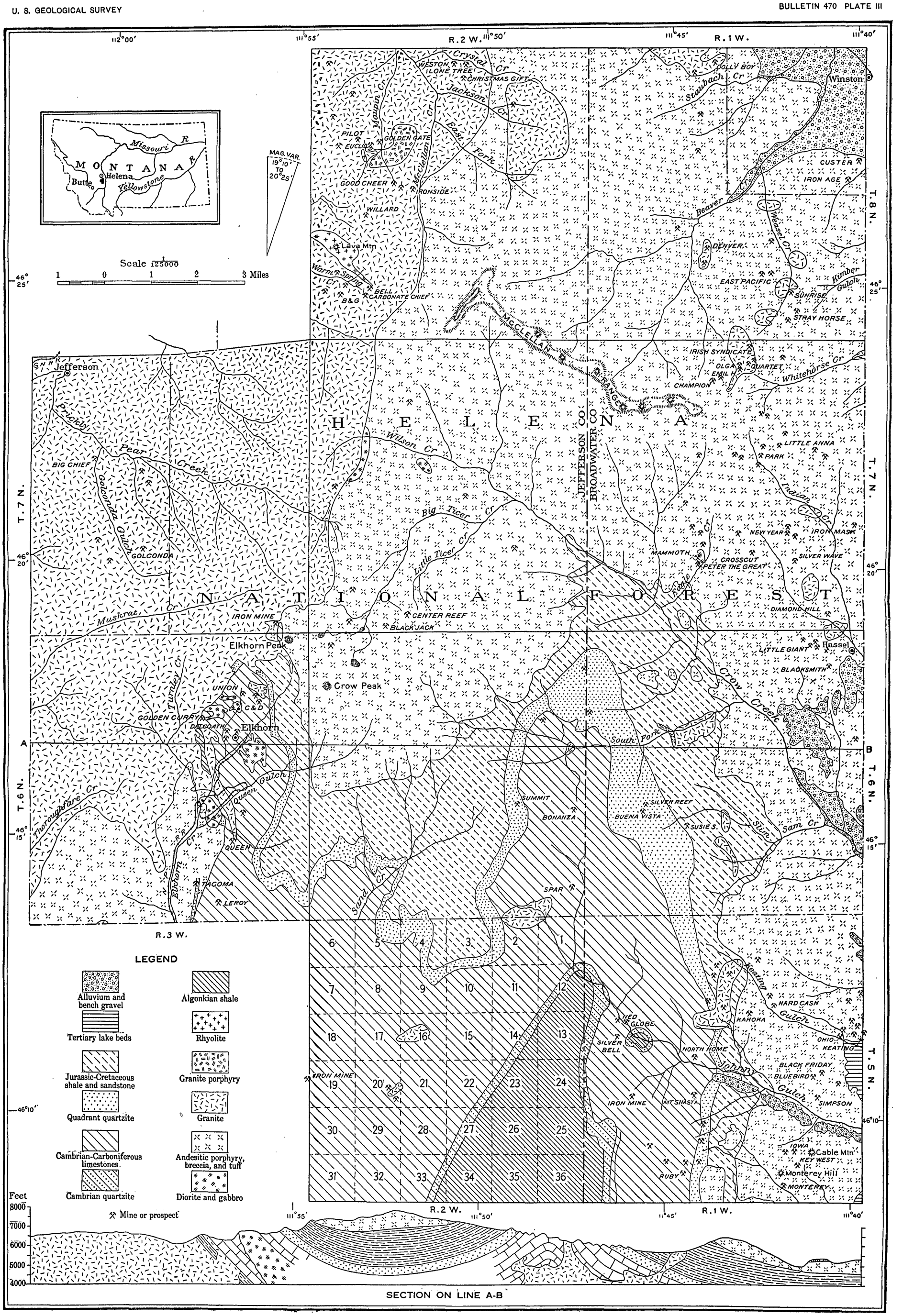
LOCATION.

The area described in this paper includes T. 5 N., Rs. 1 and 2 W.; T. 6 N., Rs. 1, 2, and 3 W.; T. 7 N., Rs. 1, 2, and 3 W.; and T. 8 N., Rs. 1 and 2 W. As shown on the accompanying map (Pl. III), it is located southeast of Helena, in Broadwater and Jefferson counties. It lies between Missouri River on the east and the Helena-Butte branch of the Great Northern Railway on the west. It is in the Helena land district and includes the Elkhorn National Forest. The region is mountainous, ranging in elevation from 4,600 feet at the Keating mine to 9,380 feet at the top of Elkhorn Peak. There are two main mountain masses, separated by the valleys of Prickly Pear and Crow creeks. The largest area of comparatively gentle topography is a shale flat in the southeastern part of T. 5 N., R. 2 W.

The drainage, which is tributary to the Missouri, flows mainly in the headwaters of Beaver, McClellan, Warm Spring, Prickly Pear, Muskrat, Elkhorn, and Crow creeks. On account of the forest cover and the precipitation of both snow and rain throughout the summer, all the streams are perennial. These streams have in places cut through the volcanic rocks and been superimposed on the underlying folded sedimentary rocks, with a result that some of them have cut straight across upturned quartzite and limestone. Johnny Gulch is an especially good example, passing from a broad, open shale area through limestone canyons and out into shale again.

MINING DEVELOPMENT.

The Elkhorn Mountains have been producers of precious metals almost since the earliest settlement in this part of Montana. In 1858 gold placers were worked extensively on the heads of Wilson and other creeks, and in the sixties numerous quartz locations were made throughout the mountains. The district attracted more attention when the Elkhorn mine became a producer in 1870. This mine, on which work has progressed spasmodically to the present time, has



RECONNAISSANCE GEOLOGIC MAP OF THE ELKHORN MOUNTAINS, MONT.

been one of the prominent silver mines of the country and in 1910 was in active operation. Besides this well-known district there are also a number of other groups of mines of more or less value. The principal ones to be mentioned in this paper are those at Radersburg, where are located the Keating and Black Friday mines, large producers at the present day; Hassel, formerly known as St. Louis, on Indian Creek, which is variously estimated to have produced from $2,000,000 to $8,000,000 in gold from lodes and placers; the Park mines, on the head of Indian Creek, where there are several miles of underground workings; the Custer and Iron Age mines, near Winston, which have produced several hundred thousand dollars in gold but are now idle because of litigation; the Stray Horse and East Pacific mines, on Weasel Creek, which are reported to have yielded several million dollars in gold and silver. Also among the former producers are the group on Maupin Creek, including the Pilot, Euclid, and Golden Gate mines, on which a mill was operated for a number of years; and those in the district at the head of Warm Spring Creek, where are the Carbonate Chief, Bell, B. & G., and others that have produced considerable amounts of gold and silver but were standing idle in 1910. The above-mentioned mines include only those which have several hundred feet of underground workings and probably employed at one time a score or more of men each. Throughout the mountains in each of the townships there are numerous small pits or prospects representing the work of a few days or a number of months, many of them showing sufficient mineral values to be worthy of some exploitation.

The only geologic work done in the area by the United States Geological Survey previous to 1910 consists of a reconnaissance by W. H. Weed in the western part of the area and a detailed examination and report on about 9½ square miles in the vicinity of Elkhorn. Weed first visited the Elkhorn district in the summer of 1896 while studying the general relations of the granite area in which the Butte ore deposits occur. In 1897 he spent a fortnight in the reconnaissance of the Elkhorn district and determined on a detailed mapping and study of the geology and ore deposits near Elkhorn. R. H. Chapman made a topographic map in the immediate vicinity of Elkhorn in the summer of 1899, and Joseph Barrell mapped the distribution of the rocks. The underground work in the Elkhorn district was done by Weed. The resulting report [1] was published in the Twenty-second Annual Report of the Survey. The only other geologic report which the writer has found covering any part of the area here described is a paper by D. C. Bard, M. E., of Butte, Mont.[2]

[1] The geology and ore deposits of the Elkhorn mining district, Jefferson County, Mont.: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1901, pp. 399–550.

[2] Notes on the geology of the Radersburg district, Montana: Jour. Assoc. Eng. Soc., vol. 45, No. 1, July, 1910, pp. 14–17.

GENERAL GEOLOGIC FEATURES.

This mountain group lies on the eastern edge of the great Boulder batholith or mass of granite which extends from Helena southward to a point 20 miles beyond Butte and from Elkhorn west to Deer Lodge. This batholith is composed chiefly of granite but includes also considerable masses of aplite and granite porphyry. The mountains include an area of folded limestone, shale, and quartzite, which are intruded and overlain by a great outpouring of volcanic rocks, mostly andesitic in character. These volcanic rocks consist very largely of porphyry, breccia, and tuff, but the different phases are so intimately intermingled and the time for doing the work was so short that it was not possible to differentiate them in mapping the geology. Both the folded sedimentary rocks and the volcanic rocks contain intrusions of granite. The sediments, which are exposed on north-south folds, range in age from Algonkian to Cretaceous. They retain their normal character in the southermost townships but are highly metamorphosed where they lie in contact with granitic intrusions.

GEOLOGIC HISTORY.

After the deposition of the Cretaceous shale, probably Benton, which is the youngest consolidated sediment in the region, this area was subjected to strong dynamic forces which warped the strata into north-south folds. This folding took place certainly not earlier than middle Cretaceous nor later than Laramie time. Subsequent to the folding there was an intrusion of gabbro the main bodies of which are found near Elkhorn. This gabbro is the oldest igneous rock in the mountains. No evidence is to be had as to the former extent of the mass, for it is cut off abruptly by the granite. There is some evidence that the mass cooled under a great cover of sediments, now largely worn away.

In early Tertiary time there was a period of great volcanic activity and large quantities of igneous rock were injected into the sediments and poured upon the surface. It is possible that some of this material was derived from vents several miles to the west, in the area now occupied by the Boulder batholith, but it is equally evident that some of it was of local origin. Elkhorn and Crow peaks and the McClellan Range, north of Crow Creek, are in the writer's opinion the source of a considerable part of the volcanic rocks which must have covered the whole region to a considerable depth. This opinion is based on the occurrence of considerable amounts of volcanic breccia on these peaks and along the top of the range, and also on the radiate drainage of the area. It will be seen by reference to the accompanying map (Pl. III) that the streams radiate rather markedly from Elkhorn and Crow peaks as one center and from the McClellan Range as another. This suggests that they were originally developed on two domes.

Consequent streams on the lava flows on the flanks of a volcano would flow away in all directions, and it is fancied that these streams assumed their present courses on such lava flows, which were long ago worn away. The surface on which the breccia and lava were poured out was a highland of more or less rugged character, possibly as rugged as the present mountains.

Later in the Tertiary period came the intrusion of the great mass of granite already mentioned as the Boulder batholith. Patches of metamorphosed andesites resting on the granite at several points in the batholith and inclusions of andesite along the border of the mass are evidence of its later age. It is believed that the granite was intruded in the andesites and possibly at or near the contact with the underlying sediments. At least it is practically certain that the granite was under a cover of about 1,000 feet of volcanic rocks. The heat of the great granite intrusion metamorphosed the andesites and also the sediments with which it came into contact. Since the intrusion of the granite subaerial erosion has removed the thick volcanic cover from a great part of the batholith and cut into the granite to depths of 2,000 and 3,000 feet. After the removal of the cover from the granite, but possibly before it had been deeply intrenched, there were several outbursts of rhyolitic magma, some of which remains in the Elkhorn Mountains, as, for example, the rhyolite cap of Lava Mountain at the head of Warm Spring Creek and small masses of obsidian and rhyolite observed at a number of other points in the west half of T. 8 N., R. 2 W.

Since Miocene time there has been no further marked disturbance of the region. A few small faults have been observed in the vicinity of Elkhorn and more or less sheeting or distortion of the granite has taken place. Ordinary atmospheric agencies have carved the region to its present form. By this process, as already mentioned, at least a thousand feet of volcanic cover have been removed from the batholith and the granite has been deeply trenched. Local glaciation has had a marked effect on some of the topography, as shown especially by three superb cirques on the flanks of Elkhorn and Crow peaks. Each of these cirques holds a small lake. There are a number of glacial moraines around the highest peaks, one of the most conspicuous being a morainal ridge just above the town of Elkhorn which completely dams the valley.

A general tilting which ponded the rivers of the State formed the great Tertiary lakes. Into the lake which occupied the valley of Missouri and Boulder rivers the streams from these mountains carried their great quantities of waste and deposited them as stratified beds of clay and sand, now known as the Tertiary lake beds. A small area of these deposits at the Keating mine, on the east side of T. 5 N., R. 1 W., is shown on Plate III (p. 76).

IGNEOUS ROCKS.

Igneous rocks occupy about seven-tenths of the area shown on Plate III. To judge by the numerous granitic intrusions in the sedimentary rocks, it may be concluded that a body of granite lies not far below the surface of much of the remaining three-tenths of the area. The varying character and different origin of these rocks and their relation to the ore deposits make them the leading feature of the geology. The geologic map shows their occurrence so far as known at present.

Rocks of andesitic type are most abundant, occupying an area equivalent to about five townships. They embrace a wide variety of both intrusive and extrusive origin and include porphyry, breccia, and tuff. They vary from light gray to dark in color and from rocks devoid of phenocrysts to distinctly porphyritic forms, the latter being commonest. Breccia is common on Elkhorn Peak and along the McClellan Range but so far as observed is nowhere very coarse, included angular fragments rarely measuring more than a few inches across. Tuffs found in the same localities are the finer fragmental ejectamenta from volcanic eruptions and in some places show pronounced bedding or stratification. Examination with a hand lens shows that the white grains making conspicuous bands or flow lines are crystals and angular fragments of feldspar.

Granite occupies an area equivalent to two townships and is found everywhere in the valleys of Thoroughfare, Muskrat, Prickly Pear, and Warm Spring creeks and on the west of McClellan Creek. In this region it is rather basic in character, halfway between granite and diorite and therefore, strictly, a monzonite. It is readily recognized as the coarse granular rock occurring all along the west side of the mountains. This rock varies somewhat in appearance, depending on the size of the grains and on the abundance of the ferromagnesian minerals. A later intrusion into the granite mass from a more acidic magma, called aplite, is distinguished by lighter color and finer grain. This phase is common on the west flank of Elkhorn Peak and along the border of the batholith, especially in the valley of McClellan Creek, but the purely reconnaissance character of the geologic mapping did not permit its differentiation. Another phase of the same granite magma found at a number of places is a rather reddish coarse-grained granite porphyry, containing large pink orthoclase phenocrysts. It was observed in the trail gap just west of the head of Turnley Creek; near the Olga mine, at the head of Whitehorse Creek; and near the Pilot mine, on Maupin Creek.

Gabbro and diorite are the oldest igneous intrusions in the mountains and occur only in very small patches. The largest area of gabbro is around Black Butte near Elkhorn and is about half a mile across. Two smaller areas lie 1,000 feet north and east. The main outcrop

of diorite is on the ridge east of Elkhorn, just north of the upper railroad bridge in Queen Gulch. It is a little more than half a mile across and is completely surrounded by limestone. There are basic granular igneous rocks on Wilson and Eagle creeks, forks of Crow Creek, but neither their extent nor their exact character was determined.

Rhyolite is the youngest igneous rock found in the mountains. It is light gray, has felsitic texture and flow structure, and occurs principally as the cap of Lava Mountain and of several smaller buttes just west of the west boundary of T. 8 N., R. 2 W. Besides these large bodies there are several small ones a few rods in extent. Black obsidian occurs at a number of points, as near the Carbonate Chief mine and at Fritz Invay's prospects, which lie between the Good Cheer mine and the Willard claims.

SEDIMENTARY ROCKS.

Consolidated sedimentary rocks occupy about three-tenths of the area. The units shown on the geologic map (Pl. III) are lithologic but also in part represent formations. They can be readily distinguished both by the rock composition and by the topographic effect.

Algonkian shale.—In the southeastern part of T. 5 N., R. 2 W., there is an area of 6 or 7 square miles underlain by red shale including some green shale and thin beds of sandstone. This corresponds to the red shale at Townsend and is the oldest rock in the region. It is believed to represent the Spokane shale of areas to the east. It makes a sage-covered flat of very gentle relief compared with the rough quartzite and limestone ridges on the east and west.

This shale, metamorphosed to hornstone by proximity to igneous intrusions, is seen on the ridge southwest of Elkhorn in a long, narrow outcrop and has been called by Weed the Turnley hornstone. The thickness of the formation is not known, for the base is nowhere exposed.

Cambrian quartzite.—Overlying the red shale is a formation of white to pink quartzite about 125 feet thick. It is correlated with the Flathead quartzite, the base of the Cambrian in central and southern Montana. Its outcrop is confined to short interrupted sections near Elkhorn, to a circular outcrop near the Silver Bell mine on Johnny Gulch, and to a conspicuous loop along the boundary between T. 5 N., R. 1 W., and T. 5 N., R. 2 W. Here, because of its superior hardness and tilted position, its dip ranging from 30° to 70°, it forms a sharp ridge or wall.

Cambrian to Carboniferous limestones.—Above the quartzite just mentioned is a series of formations composed very largely of limestone and approximately 4,000 feet thick, which in this paper are con-

sidered as a unit. The base is a shaly series possibly corresponding to the Wolsey shale. It is well exposed in secs. 19 and 20, T. 5 N., R. 1 W. Above this are Cambrian limestone formations named and described by Weed in the report on the Elkhorn mining district, a shale possibly of Devonian age, and at the top the Madison limestone (lower Carboniferous, Mississippian), 1,500 to 2,000 feet thick. The Madison is massive, is light colored to white, stands at a high angle, and makes conspicuous cliffs and ledges. It outcrops prominently in the five townships of the southern half of the area.

Quadrant formation.—The Quadrant formation (upper Carboniferous, Pennsylvanian), which in this region is mostly quartzite and about 380 feet thick, immediately overlies the Madison limestone. Like the upper part of the Madison it is very light colored, and where it is tilted to a high angle, as along its north-south course in Tps. 5 and 6 N., R. 1 W., it forms a hogback ridge and can be traced very readily. It is metamorphosed to hornfels north of Elkhorn, where it is in contact with granite and aplite. It is possible that the formation as mapped in the east half of the area may include more than the Quadrant. The writer surmises that further study might show the presence of the Sundance formation (Jurassic) or its equivalent on the heads of Slim Sam Creek and Keating Gulch, for an outer and lower ridge of a sandy nature is closely overlain by shale having the stratigraphic position and general appearance of the Morrison formation (Jurassic or Lower Cretaceous).

Jurassic to Cretaceous beds.—The sedimentary rocks lying between the Quadrant formation and the andesites were all included by Weed in his Crow Ridge series, because they are so highly altered around Elkhorn that the different formations composing the series could not be distinguished. East of Queen Gulch, at a distance of several miles from the Boulder batholith, the rocks are unaltered, and further study probably would separate this unit into two or three formations. The writer is confident of the presence of the Morrison formation extending north and south through the middle of T. 5 N., R. 1 W., and thinks that the youngest beds, dark shales widely exposed in the basin of Slim Sam Creek, are Benton. The thickness of this unit has not been measured anywhere except near Elkhorn, where it is 1,680 feet, according to Weed.

Tertiary lake beds.—The lake beds of Tertiary age, consisting of clays and sands of very light color and possibly including some volcanic ash, are seen just south of the Keating mine and east of the Black Friday mine. The southeast corner of T. 5 N., R. 1 W., also is on these beds. They are the edge of a wide deposit which filled the valley of the Missouri when the drainage was ponded by warping of the crust.

STRUCTURE.

The geologic structure of the mountains is shown by the cross section at the bottom of Plate III (p. 76). This section represents the relations of the rocks along an east-west line through Elkhorn, and shows that the sedimentary rocks are folded in an elongated double curve, with a synclinal axis on Sand Creek and an anticlinal axis close to the line between Rs. 1 and 2 W. There are minor folds just west of Sand Creek and a prominent structural dome on Johnny Gulch at Parker's. The andesites lie comparatively flat in the central part of the area but dip to the east along the principal meridian. The relations below the surface shown on the cross section are necessarily more or less hypothetical.

RELATION OF ORE DEPOSITS.

The ore deposits in the vicinity of Elkhorn, as described in Weed's report, are closely related to intrusions of gabbro, diorite, and granite. A study of the map, which shows the location of mines and prospects, makes clear the fact that at a number of places in the mountains the ore deposits are closely related to intrusions of granite or granitic rock. Fissure veins occur in the granite some distance from any known contact and also in the volcanic rocks, where, on the surface at least, there is no evident relation to other types of rock. An intrusion of granite porphyry and aplite in granite is the locus of mineralization on Maupin Creek, and a body of diorite (?) in Eagle Gulch 4 miles northwest of Hassel is the center of a small mineralized tract. There are some small accumulations of ores in limestone and quartzite which appear to be related to green porphyry sills, while others, apparently replacement deposits in limestone, so far as discovered have no relation to any intrusive rock showing at the surface but may be due to a mass of igneous rock lying close below the surface and not exposed near the deposits.

DESCRIPTION OF MINING DISTRICTS.

As only a part of the area here described has ever been surveyed and marked out by townships and sections, the simplest method of description is by drainage basins. In part these coincide with mining districts. The discussion will therefore begin with the northernmost streams and proceed southward.

The purpose of the field work, as already mentioned, was to determine the mineral or nonmineral character of the land in the Northern Pacific Railway land-grant limits. The question raised in this classification "is not whether the evidence, construed as in an ordinary contest between an agricultural and a mineral claimant,

shows as a present fact that the land is more valuable for mineral than for agricultural purposes, or vice versa, but whether the evidence shows that it is reasonably probable that the land in controversy contains valuable mineral deposits." (30 Land Dec., 447.) Hundreds of mines and prospects were visited and evidence taken, but many shafts were partly filled with débris or water, tunnels were caved, padlocked, or otherwise inaccessible, and prospects had been so long abandoned that information could be had only from the dump. Under these conditions when a fair showing of ore was found the fact was noted and the kind of ore specified, but little or no information was obtained as to the character, size, or position of the ore body. It is therefore impossible for the writer to give more than a brief description of the distribution, relation, and character of the ore deposits.

BEAVER CREEK.

The Beaver Creek mining district is situated southwest of Winston, on the Northern Pacific Railway, and in 1907 ranked third in tonnage from Broadwater County. In 1908 the output of this district was produced by five deep mines and one placer and consisted of $26,134 in gold, 19,314 ounces of silver, 7,056 pounds of copper, and 180,191 pounds of lead.[1] The mines nearest to Winston are the Iron Age and Custer, which are on vertical pyrite-bearing quartz veins in andesite and andesite porphyry. In some of the ore shipped from these mines the gold has equaled the silver in quantity, and the copper has amounted to 3 pounds to each ounce of gold and silver. The Custer mine has a vertical shaft 600 feet deep and another 300 feet deep. The total length of its underground workings is nearly 4 miles. The Iron Age mine also has a deep shaft and extensive levels. Both were idle in 1910 on account of litigation. There are a number of smaller mines in the immediate vicinity.

In sec. 4, T. 8 N., R. 1 W., considerable development work has been done on east-west quartz veins in granite, but little ore has been shipped. At the Dolly Boy there is a shaft and two slopes on a 3-foot vein of quartz carrying sulphides, which looks like a fair grade of ore. This mine is adjacent to a group of claims including the Gold Hill, Bell Abraham, Homestead, Washington, Green Mountain, Silver Smith, and Neptun, which are said to aggregate about 1,000 feet of underground tunnels and to be on a quartz vein 1½ feet wide, carrying 8 per cent of copper and $10 in gold and 37 ounces of silver to the ton. This statement was made by the owner, George Uffel. All these claims are in a granite intrusion in the andesites.

The East Pacific mine, on Weasel Creek, has a vertical shaft 1,000 feet deep and four tunnels, the longest of which extends for 3,700 feet.

[1] Mineral Resources U. S. for 1908, pt. 1, U. S. Geol. Survey, 1909, p. 447.

This mine is said to have 2 miles of underground workings and to have produced at least $2,000,000. It is equipped with a 75-ton mill using concentration and amalgamation and has shipped ore containing lead, silver, gold, and copper. The mine is in dark, finely porphyritic andesite, locally called "diorite" and "blue lime." The ore is in an east-west vein ranging from 3 inches to several feet in width and standing nearly vertical, with siliceous gangue. Galena and zinc blende with chalcopyrite and iron pyrite are the associated minerals. The ground was located in 1867 and patented in 1889; mining operations ceased a few years ago. More recently lessees have been sorting the dumps and getting concentrates by jigging which are reported to average $45 a ton after deducting $6 or $7 smelter charges. These concentrates run $4 to $5 in gold and the rest in silver and lead. Five men were working here in September, 1910.

One mile west of the East Pacific mine there is a granite intrusion in the volcanic rocks which has caused some mineralization and is the site of several small claims, including the Monte Cristo, St. John, Denver, and others. Most of the tunnels and shafts have been long abandoned and are caved. The lode in some places seems to be a cream-colored lava from which numerous cubical pyrite crystals have been dissolved out. On one dump siliceous gangue carrying small quartz stringers and pyrite was found.

The January and Sunrise mines, on Weasel Creek half a mile south of the East Pacific mine, have yielded several thousand dollars each. The ore of the January mine carries galena and pyrite and is said to have produced $35,000. At the Sunrise mine free-milling gold ore was crushed in a 5-stamp mill. The tunnel is caved but seems to be in andesite near a granite intrusion. The ore is auriferous pyrite in quartz.

The Stray Horse mine, at the head of Weasel Creek, consists of five tunnels and at least one deep shaft, the underground workings aggregating several thousand feet. The ore is galena and pyrite carrying gold, silver, and copper, and the mine, which has not been operated for several years, is said to have produced $200,000. It is on vertical east-west veins in andesite porphyry.

About a mile south of the Stray Horse mine, on the mountain between Beaver and Whitehorse creeks, is a group of mines in a granite intrusion, including the Irish Syndicate (Big and Little Casino), Cynosure, Quartet, Emil H., Little Olga, and Champion. These are on north-south and east-west quartz veins, of which the former carry gold and the latter silver. Two of the properties were being worked in 1910 by three or four men each.

The Irish Syndicate is on an east-west lode in porphyritic granite. It is said that $6,000 was taken in sinking the first 40 feet. Although the mine is not more than 150 feet deep, it has about 700 feet of underground workings and is said to have yielded $45,000, mostly in silver.

The Cynosure mine has a 180-foot tunnel and an 80-foot raise to the surface and was being worked in 1910. Ore from this mine is pyritiferous quartz said to carry gold and a little copper and lead, netting $35 a ton.

The Emil H. is on the same lode as the Little Olga, on an adjoining claim. It has about 800 feet of workings and yielded about $20,000, mostly in gold, according to verbal report.

The Little Olga shaft is 125 feet deep and the vein was followed for 100 feet. The ore is largely argentiferous galena and yielded 5 pounds of lead to each ounce of silver. The ore assayed about 0.7 per cent of copper and $2 a ton in gold. The mine produced about $25,000 in gold and silver.

The Champion mines are on a quartz vein carrying limonite, pyrite, and a little malachite and galena. The values are principally in gold. After several hundred feet of shafts and tunnels had been opened the work was abandoned, and the property has been idle for several years.

McCLELLAN CREEK.

On the north branch of Jackson Creek, half a mile above the forks, in the northern part of sec. 11, T. 8 N., R. 2 W., there is a tunnel in very light colored fine-grained granite close to the contact with andesite. The ore on the dump seems to be mineralized country rock with small bunches of quartz carrying chalcopyrite, pyrite, and molybdenite. Some of the coarser granite is highly pyritized. Molybdenite, of which only a few square inches was seen, occurs as a thin incrustation on a joint plane.

On the ridge south of Crystal Creek, in secs. 3 and 4, T. 8 N., R. 2 W., there are several prospects on quartz veins carrying pyrite. One of these, the Christmas Gift, is on a N. 60° E. vein dipping 50° S., which has been developed by three slopes and two pits. The ore is pyrite, arsenopyrite, and chalcopyrite. An assay made by the United States assay office at Helena, Mont., shows 0.10 ounce of gold and 1.2 ounces of silver to the ton. A 130-foot tunnel on the property of Mr. Weston in the bank of Crystal Creek is on a vertical quartz vein, in places 2 to 3 feet wide, which is said to assay from $2.50 to $27 in gold to the ton. The ore mineral is mostly iron pyrite. In the immediate vicinity there are several other claims on similar ore, including the Lone Tree, which has a 50-foot shaft.

In the northwest quarter of T. 8 N., R. 2 W., mostly in secs. 8 and 17, there is an irregular area of granite porphyry, aplite, and some rhyolite surrounded by granite. In this area there are many prospects and a few small mines, located on quartz lodes trending nearly east and west and standing vertical. The principal lode has been developed for over a mile and on it are located the Pilot, Euclid, and Golden Gate mines. The ore mineral is mostly iron pyrite, and the

principal value is in gold. The Pilot mine is said to have a 330-foot shaft and a 1,200-foot tunnel. At the Euclid mine there are nine shafts and a crosscut. The main shaft is 200 feet deep. It is said that some shipments from this mine carried over $80 a ton in gold. The vein is on or near the contact between normal granite and a granite porphyry intrusion. This mine has been shut down since 1894.

The Golden Gate mine, located in 1884, is reported by the owner, Joseph Garneau, to have a shaft 200 feet deep and 500 feet of levels on a quartz vein 70 feet wide bearing N. 88° W. and pitching south at a very high angle. A 30-ton mill and concentrator operated here were burned several years ago, and the mine is now full of water. Mr. Garneau says that the mine produced about $31,000 gross, mostly in gold, and that the bulk of the ore averages about $23 a ton.

The Good Cheer mine, at the head of Maupin Creek, in the SE. ¼ sec. 17, T. 8 N., R. 2 W., has a shaft 165 feet deep and 400 feet of levels. It is on a 4½-foot vertical east-west quartz vein on or near the contact between granite and granite porphyry or acidic granite. The quartz carries pyrite, chalcopyrite, and galena. In 1910 Mr. Garneau, the owner, was shipping a little first-class sorted ore carrying over $15 a ton and said that up to that time the mine, which is still in the development stage, had produced about $8,000.

The Black Bear claim, on the hilltop, a quarter of a mile southeast of the Good Cheer mine, is on an east-west quartz vein in granite and is reported by Mr. Garneau to carry 12 ounces in silver and $1.70 in gold to the ton. Short black crystals of tourmaline were found in the ore on the dump.

The Skookum lode, near the Euclid mine, has an 18-foot shaft on a quartz vein between a granite hanging wall and granite porphyry footwall. The vein is 20 inches wide and has an 8-inch stringer carrying galena, chalcopyrite, azurite, and malacite. No ore has been shipped, but it is said to carry gold, silver, lead, and copper.

In the hill back of a cabin on the bank of McClellan Creek in the southern part of sec. 16, T. 8 N., R. 2 W., is the Ironside claim. It is on a 3-foot vein of quartz striking N. 87° W. and dipping 85° N. The drusy quartz gangue carries iron pyrite and limonite, and an assay of selected specimens made by the United States assay office at Helena, Mont., shows 0.30 ounce of gold and 5 ounces of silver to the ton.

WARM SPRING CREEK.

The mines in the Warm Spring Creek district are mainly at the head of the middle fork, and are easily reached from Alhambra, on the Great Northern Railway. They are in an area of granite just south of the mass of rhyolite and obsidian on Lava Mountain. The mines are all on vertical east-west quartz veins carrying galena, chalcopyrite, arsenopyrite, and iron pyrite. The Carbonate Chief

mine is opened by three tunnels, the longest about 1,700 feet. The Bell mine has three tunnels 500, 1,000, and 1,200 feet long. These two mines are reported by R. A. Bell to have yielded $800,000 net (smelter returns) in gold, silver, and lead. Near them is the Mocking Bird, which has a vertical shaft 250 feet deep. These three mines were operated extensively in 1907 but have been idle since then. They produced in that year 41,829 tons of ore, which had a gross value of $952,327, mainly in gold and silver, though copper and lead were recovered. In 1906 the yield was 1,237 tons, with a value of $47,756.

Half a mile west of these mines is the Eagles Nest group, consisting of 27 claims, including the B. & G., Bland, Eagles Nest, and others. The B. & G. mine has an incline shaft 250 feet deep and three levels, aggregating about 1,200 feet of underground workings. The ore consists of pyrite, chalcopyrite, and galena and has assayed as high as $40 a ton in gold, silver, lead, copper, and molybdenite. Ore carrying 22 per cent of copper was found in the bottom of the shaft.

About 800 feet east of the B. & G. is the Eagles Nest mine, which has a shaft at least 100 feet deep, sunk in the winter of 1909–10 and showing the same ore as the B. & G. A 5-ton shipment is reported to have netted over $40 a ton. The Mocking Bird mine, below the Eagles Nest, is on similar ore and is reported to have produced $10,000 to $12,000.

The Willard group of claims, in sec. 20, T. 8 N., R. 2 W., at the head of the north fork of Warm Spring Creek, consists of the Dover, Relief, Osage, Alpha, and Union. They are located on two east-west nearly vertical quartz veins said to be from 8 to 20 feet wide. The Union shaft is reported to be 270 feet deep, with short crosscuts, but is now full of water. The Relief shaft is 60 feet deep and the Dover shaft is down 73 feet. Over 300 tons taken above water level in the Relief shaft is said to have netted over $40 a ton, and a carload of ore from a pit on the east end of the claim netted $55—2 ounces of gold and the rest silver and lead. From a short tunnel below the discovery shaft on the Relief claim was shipped over 100 tons that yielded $40 a ton net. Small shipments of ore have been made at infrequent intervals since 1889. The property was idle in 1910. A sample of oxidized ore from a shallow pit assayed at the United States assay office at Helena showed 0.40 ounce of gold and 16.2 ounces of silver to the ton.

Fritz Invay's claims, in the southwest corner of sec. 17, T. 8 N., R. 2 W., on the head of Maupin Creek, are developed by small tunnels and shafts, the deepest shaft being 60 feet deep. In this shaft a body of green obsidian was encountered. The quartz vein, which is about 1 foot wide, carries impure sphalerite, galena, chalcopyrite, pyrite, and siderite.

PRICKLY PEAR CREEK.

The Prickly Pear Creek district is adjacent to the Corbin district and is entirely in granite. Only at two or three localities in it have ore deposits of any moment been found. One of these is at the mouth of Golconda Gulch, in sec. 17, T. 7 N., R. 3 W., where the Big Chief mine has opened up several hundred feet of tunnels on a quartz vein carrying pyrite and galena ore. To judge from the appearance of the property, which has been idle for several years, probably a considerable quantity of ore was shipped from this mine reputed to carry values mostly in gold and silver. Farther up the gulch there are a number of prospects on small quartz veins probably carrying some gold, and on the mountain side in sec. 28 a quartz lode carrying free gold has been recently discovered in the Golconda group of claims. Rusty quartz from the property carried 0.40 ounce of gold and 2.6 ounces of silver to the ton, according to the United States assay office at Helena. Development work was progressing on this property in 1910 by driving a short tunnel to undercut the vein.

Golconda Gulch and Prickly Pear Creek have been washed for gold-placer ground at a number of places.

INDIAN CREEK.

The Park mines are located in sec. 15, T. 7 N., R. 1 W., about 5 miles northwest of Hassel, on Indian Creek. The claims are mostly on quartz veins in andesite and the development amounts to several thousand feet of underground workings. The ore of the Park mines is mostly pyrite, with some arsenopyrite and galena, and the principal value obtained is in gold. The entire group of mines was idle in 1910 and apparently had not been operated for several years. A mill and cyanide plant were once built here to handle the ores, but the recovery of precious metals by the processes used was not successful.

Half a mile east of the Park is the Little Anna mine, which has a slope driven northwest at an angle of 35°. The ore is quartz carrying arsenopyrite and pyrite. The size of the dump indicates that there are several hundred feet of underground workings. The mine has been idle and full of water since 1904. The Iron Mask mine, in sec. 24, has a vertical shaft probably over 200 feet deep on a quartz ledge in coarse andesite porphyry. The ore is mostly oxidized iron and galena. This mine yields silver and lead but was idle in 1910.

The Silver Wave mine, in sec. 26, is working on a lode that trends N. 60° W. and dips 80° N. The country rock is fine-grained black andesite and the ore is mainly pyrite and galena. It is said to net $35 a ton, the main value being in gold, with some silver and lead. The shaft is 350 feet deep, and 24 men were engaged here in September, 1910. Just north of this mine is the New Year group of claims, on

similar ore deposits, and a mile to the west is the Crosscut mine, consisting of two shafts more than 50 feet deep and one shaft probably 250 feet deep on a vertical vein in green and black fine-grained andesite. The ore seen on the dump is quartz carrying pyrite, with values probably mostly in gold. There are numerous other small prospects in this vicinity, many of them showing small amounts of ore.

In 1908 nine quartz properties in the Park district and at Hassel yielded $5,313 in gold, 2,939 ounces of silver, 8,901 pounds of copper, and 27,374 pounds of lead.[1]

Hassel is located 6 miles west of Townsend, on the Northern Pacific Railway, on Indian Creek in the northeast corner of T. 6 N., R. 1 W., in an area mainly of andesite porphyry. There are, however, in this vicinity at least two intrusions of granite which probably were the cause of extensive mineralization. This district first began to produce about 1860, when the creek was discovered to be good placer ground. The working of this placer led to the discovery of veins in the immediate vicinity carrying good values in gold and of irregular masses of mineralized porphyry in Diamond Hill. Open-pit mining and long tunnels in these large bodies produced approximately $500,000 in gold. One tunnel 2,800 feet long is said to be all in ore assaying from 80 cents to $2.50 a ton. Three small stamp mills were built and it is reported that one of them used to yield $500 a day when water could be obtained. The Little Giant mine, originally developed on east-west lodes dipping about 80° S. in country rock consisting mostly of andesite breccia, was an extensive operation. A single vein seems to have been developed by open cuts and two tunnels. It is reported that the lower tunnel was driven for 1,500 feet on the vein and stoped ore the whole distance, and the upper tunnel, 1,000 feet long, was also all in ore. As seen now in the open cuts the ore body appears to be mineralized country rock along a fracture. The vein has smooth walls and ranges from a few inches to several feet in width. The dumps show various deeply iron-stained andesite porphyries and breccias. Almost no quartz is found, the gangue being a cream-colored soft rock carrying red oxidized iron. It is generally reported that the Little Giant mine produced nearly $300,000, for the present company has smelter returns of about $200,000. Some believe that 40 per cent of the values were lost in the tailings and that thousands of tons of ore on the dumps carry good values in gold. In 1910 the Little Giant Mining Co. was driving a tunnel to undercut the lode which was formerly worked by two long tunnels on the vein. This new tunnel in September, 1910, was about 500 feet long.

The Blacksmith mine, at Hassel, has a deep vertical shaft on a body of ore said to be 30 feet wide, assaying about $10 a ton. Large quantities of ore from this mine have been milled, but some metal-

[1] Mineral Resources U. S. for 1908, pt. 1, U. S. Geol. Survey, 1909, p. 447.

lurgical difficulty was not overcome and the mine has been closed since about 1905. The dump shows a variety of andesites in the country rock and the ore seems to be a soft iron-stained rock which is probably andesite porphyry altered and impregnated with iron and gold.

CROW CREEK.

The largest group of mines and prospects in the upper valley of Crow Creek is located on Eagle Creek in secs. 21 and 26, T. 7 N., R. 1 W. A number of these, including the Mammoth, Peter the Great, Jumbo, Toronto, and Blue Granite claims, are closely related to a small intrusion of diorite or gabbro in the andesite porphyry country rock. Some of the prospects appear to be on lodes of pyritized porphyry and some are on quartz veins. The ores include iron and copper pyrites and galena, some of them being of value principally for gold and others for silver. Ore from one of these properties is said by the owner to net $56 a ton, including 2 ounces of gold.

In the valley of Crow Creek, besides the mines of Eagle Gulch already noted, there are a few scattered claims worthy of mention. The first of these is the Sadie S. claim, on Slim Sam Creek, in sec. 28, T. 6 N., R. 1 W. This claim, which has been developed by six test pits and a tunnel about 30 feet long, seems to be related to a small intrusion of granite in impure limestone. Between the granite and the impure limestone there is a coarse-grained rock composed almost wholly of crystals of green garnet. The ore, which rests on the mass of garnet, is a decomposed iron and copper stained quartz. An assay made by the United States assay office at Helena shows 0.60 ounce of gold and 3.9 ounces of silver to the ton. In sec. 20 of this township are two claims known as the Silver Reef and Buena Vista. The Silver Reef is developed by a shaft 50 feet deep, undercut by a tunnel about 75 feet long. The vein, which consists of white quartz, is said to be 14 inches wide in the bottom of the shaft and to carry 2.98 ounces of gold to the ton and a little copper and lead. Pieces of ore picked up around the shaft and probably derived from this vein assayed less than half an ounce of gold and 200 ounces of silver to the ton, according to the United States assay office at Helena. The Buena Vista claim lies about 250 yards south of the Silver Reef and is on a blanket vein in white quartzite developed by shallow pits. The quartzite lies nearly flat, dipping only slightly to the west. The ore, which shows some copper stain, assayed at the United States assay office at Helena 320 ounces of silver and 0.01 ounce of gold to the ton.

The Bonanza mine, in sec. 24, T. 6 N., R. 2 W., on the divide between the head of Johnny Gulch and the South Fork of Crow Creek, consists of about 10 tunnels on veins in limestone. The ore seems to be on the bedding plane, which dips 25° N. It is mainly

galena carrying some impure sphalerite. The principal value is in silver. No work was being done here in the summer of 1910. One mile west of this locality, on the divide between the heads of the South Fork of Crow Creek and Sand Creek, there are several prospects in quartzite and in limestone on the top of a bare knob. Several pits and trenches show iron-stained quartz veins, but only a small quantity of ore is visible. That at the Summit claim is siliceous rock with a few grains of hematite and a little copper stain, having the general appearance of a gold ore, but it assayed only a trace of gold and 0.5 ounce of silver to the ton. Small pieces of pyrite and galena were found at a shaft by the upper cabin 50 yards west of the Summit claim, mixed with brecciated limestone cemented with quartz. This ore probably carries several ounces of silver to the ton.

On Crow Creek in T. 7 N., R. 2 W., placer ground has been worked in the canyon below the mouth of Wilson Creek and as early as 1858 extensive placer mining was done on the head of Wilson Creek. The headwaters of Big Ticer Creek, just north of Crow Peak, also have been the location of gold-placer operations. Prospects in sec. 22, on the hill between Big Ticer and Wilson creeks, have been opened by George Dunges. Several pits have been sunk here in andesite porphyry on iron-stained quartz veins which have the appearance of gold ore. A tunnel was being driven in 1910 to undercut one of the veins and was at that time about 150 feet long. One sample taken here assayed a trace of gold and 1.3 ounces of silver to the ton, and another carried 0.30 ounce of gold and 1 ounce of silver. About a mile north of Wilson Creek, on the trail leading to the divide at the head of McClellan Creek, there are two shafts and several small pits. The country rock on the north and west is coarse andesite porphyry and on the south and east is fine-grained andesite, in part finely porphyritic. Between these there is a narrow belt of aplite in which are zones of crushed altered porphyry cemented with quartz and iron. A sample of this crushed material taken from a few tons in the shaft house is reported by the United States assay office at Helena to carry 0.40 ounce of gold and 2.1 ounces of silver to the ton.

The Center Reef mine of Ballard Bros., in sec. 33, T. 7 N., R. 2 W., on the head of Little Ticer Creek, is the principal operation in the upper Crow Creek valley. This mine is on a siliceous gold-bearing vein along a vertical crushed zone in andesite. The vein has been developed by two or three shafts and a tunnel 200 feet long driven to undercut it. Ore has been shipped from this mine for the last five years, some of it running as high as $225 a ton. The principal value is in gold. Four men were working here in August, 1910. Half a mile southwest of this mine is the Black Jack claim, which has been developed by one 60-foot and two 30-foot shafts. So far as

known no values have been obtained here, but the claim is interesting as it is located on a mass of brecciated andesite 75 feet in diameter, carrying a large amount of rusty quartz and radiating black crystals of tourmaline.

KEATING GULCH.

The mines in Keating Gulch are in the Cedar Plains mining district near Radersburg, which is located at the mouth of the gulch 2 miles east of the Keating mine. Under this heading will be mentioned only those mines and prospects within a mile or so of the Keating mine. Only a very short examination was made here, because of the perfectly apparent mineral character of the land. There are scores of prospects in the vicinity, many of which show more or less ore, but they are so numerous and so small that it was not possible to visit them in the time allowed. All that was required in this examination was to determine the mineral or nonminera character of the land.

Mining began at Radersburg about 40 years ago, when gravels west of the town were worked as placers and several hundred thousand dollars in gold was recovered. This led to prospecting for lodes, and quartz mining began about 1870. The principal lode mines are along a north-south belt of veins close to the Montana principal meridianl 2 miles west of Radersburg. Oxidized ores were mined at a number of places within a radius of 1 mile and amalgamated after crushing in crude arrastres. Sulphide ores were encountered at a depth of about 100 feet and this retarded mining activities for a number of years, but in the last year or so there has been a revival of interest and 150 to 200 tons of ore a day was being shipped in the later part of 1910. The ores are in narrow fissure veins having a north-south course and steep westward dip. They occur in andesite porphyry and consist of quartz and calcite gangue with principal values in auriferous pyrite. Other minerals occurring less commonly are chalcopyrite, marcasite, pyrrhotite, galena, sphalerite, and chalcocite. In some parts of the district Tertiary lake beds mask the bedrock. Hot-spring deposits of tufa found in these unconsolidated clays carry traces of gold and in a number of places seem to cap and be the upper continuation of the fissure veins in the andesite. This suggests the possibility that the hot-spring deposits are the latest or final stage of mineralization.[1]

The Keating mine, which is the largest in the Radersburg district, is developed by a 300-foot vertical shaft and a 600-foot incline. On the 400-foot level a drift has been run north along the vein for a full 1,000 feet and south for 1,200 feet, making 2,200 feet on this one level alone. The vein is from 2 to 4 feet wide. About 100 men are

[1] Bard, D. C., Geology of the Radersburg district, Montana: Jour. Assoc. Eng. Soc., vol. 45, No. 1, July, 1910, pp. 14-17.

employed. In October, 1910, about 100 tons of ore was being shipped daily, averaging $19 a ton, and in December the mine was shipping about 2,100 tons a month, averaging $24. The value is mostly in gold. Some ore taken recently on the 400 and 500 foot levels carries 17 per cent of copper. There is a small value also in silver.

The most conspicuous ore on the dump is a highly pyritized rock having the appearance of gray quartzite and called by the miners "porphyry." A thin section of this rock, which is mineralized wall rock, shows that it is a porphyry, composed of a fine glassy groundmass with numerous fragmental feldspars altered to sericite. Pyrite and quartz are secondary.

The Ohio-Keating mine, about 2,200 feet farther west, on a vein of similar ore, has a shaft 220 feet deep and several levels. The lower 100 feet of the shaft is said to be all in ore averaging $16.25 a ton in value. Farther up Keating Gulch are the Hard Cash mine, which is developed by two long tunnels on auriferous pyrite-bearing quartz veins, and the Kahoka claim, which has a 70-foot shaft and several pits on a vertical vein 2 to 3 feet wide consisting of quartz stained with iron and malachite and probably carrying a little gold.

About three-fourths of a mile north of the Keating mine, just east of the range line, is the Radersburg Rena mine, on ore similar to that of the Keating mine and in pyritized porphyry. This mine was being actively developed and nine men were employed in September, 1910. Just west of the Rena mine there is a considerable number of small shafts and pits on north-south lodes in andesite, ore from one of which was milled in an arrastre.

The Black Friday mine, which is situated about a mile southwest of the Keating mine, is similar to it geologically. It has a 500-foot shaft and about 1,900 feet of levels. The mine produced over 1,150 tons of ore between June, 1909, and August, 1910, and the ore is reported by the superintendent to average $50 to the ton, mostly in gold, with 1 to 2 per cent of copper, a little silver, and no lead.

JOHNNY GULCH.

The first mine encountered in going up Johnny Gulch is the Simpson, on the Cyclone claim. It is located about half a mile due south of the Black Friday mine, near the North Home mill. The Simpson mine has several hundred feet of underground workings, including a deep shaft and a long tunnel. It is on a vein of pyritiferous free-milling gold ore, which was treated in a stamp mill on the property. This mine was idle in 1910.

At the head of the gulch on which the Simpson mine is located, 1,000 feet west of the Black Friday mine, is the Bluebird. In October, 1910, a new shaft had reached a depth of 60 feet on a 4-foot vein of

yellow porphyry and iron-stained quartz. The ore is gold-bearing porphyry like that at the Black Friday mine.

On the south of Johnny Gulch is Cable Mountain, on which there are a score or more of prospects and small mines, and also Monterey Hill, a highly mineralized butte in which many of the prospects have found more or less copper ore. These two hills are all in andesite porphyry, carrying numerous vertical veins which strike in all directions. Among the small mines are the Monterey No. 1, which has an 80-foot shaft and a 180-foot crosscut, said to be all in low-grade iron ore carrying little bunches of silver and copper. The Key West and Keystone or Iowa mines have pyritiferous ore carrying both gold and copper; the latter is said to have a 150-foot shaft and a 600-foot tunnel, but they are now caved.

About 3 miles up Johnny Gulch from the North Home mill is the North Home mine, which has about 450 feet of shafts and tunnels in a silver-bearing vein in highly tilted Madison limestone. From 1 to 2 miles north of this mine, in a body of granite intruded in the Jurassic and Cretaceous beds, there are a number of prospects and small mines in and around the granite which show promising ore. Among these are the mines owned by George Horn and John Rothfus on the road up Keating Gulch. These mines on the contact between granite and more or less calcareous beds show, besides a considerable amount of garnet, an ore carrying various copper carbonates and at one prospect at least, some free gold. On the south side of Johnny Gulch, along the hogback ridge made by the Quadrant formation, there are a number of prospects worthy of mention. The first of these is the Mount Shasta claim, in the upper part of the Madison limestone. Samples of galena ore assayed 32 ounces in silver to the ton according to a report fron the United States assay office at Helena. Half a mile south of the Mount Shasta claim, on top of the quartzite hogback, is a claim belonging to C. C. Smith on an east-west vein which dips 85° N. and is about a foot wide. The ore is mainly iron and galena and carries in the porous part of the vein numerous orange-colored crystals of wulfenite (lead molybdate) and a small amount of barite. Farther south along this line of hogbacks and north of the Ruby mine are the Daisy, Santa Clara, Silver Nuget, and Diamond lodes, all developed by small shafts and showing gold, silver, lead, copper, and iron ores. The Ruby mine, in sec. 33, T. 5 N., R. 1 W., was developed by two large 45° slopes and shipped a large amount of ore, the principal value in which was gold, with some silver and lead. Other prospects and small mines in this vicinity are too numerous to mention except the old iron mine in the southeast corner of sec. 20, which was worked many years ago and is said to have shipped for flux thousands of tons of iron ore that

carried about $1 a ton in gold. The ore on the dump shows a little malachite. There were probably about 1,000 feet of underground workings on this ore deposit, which seems to be on or near a contact between limestone and intrusive andesite. Farther up Johnny Gulch, in sec. 18, are the Silver Bell, Ned, and Globe mines, in limestone and near a thick porphyry intrusion. It is said that 1,000 tons of ore from the Silver Bell mine was sold on the ground for $105 a ton and hauled to the Wicks smelter. These are all silver-lead mines carrying a little copper. Near the head of Johnny Gulch is the Spar mine, which has a shaft probably 100 feet deep, now caved, and a slope nearly 200 feet long in limestone on a calcite vein carrying silver, lead, and copper. This mine is near the axis of the anticline.

ELKHORN CREEK.

The Elkhorn is the principal mining district in the Elkhorn Mountains and is reached by a triweekly train on the Northern Pacific Railway or by stage from Boulder. As already stated, it is the subject of a detailed report by W. H. Weed, and for this reason it is not necessary here to describe the ores or their occurrence. It is sufficient to say that through an area of highly tilted limestone and quartzites there have been injected gabbro and diorite and later granite, which have metamorphosed the sediments, and that the following mineralization resulted in the deposition of considerable bodies of ores of gold and silver. The Elkhorn mine, which has been one of the largest silver producers in the country, is on silver-bearing calcite ore shoots between a hornstone hanging wall and dolomite footwall. Up to 1900 this mine had produced 8,902,000 ounces of silver, 8,500 ounces of gold, and 4,000,000 pounds of lead. It was then considered worked out, but has since been bought by successful mine operators, who, after expending two years' time and $60,000 to $80,000 in pumping out the water, have again put it into operation. In the summer of 1910 between 75 and 100 miners were employed. The only other mine in the district actively producing at the same time was the Golden Curry, which was originally developed by tunnels on a mass of iron ore, apparently a mixture of hematite and limonite, occurring on the contact between granite and Cambrian limestone. The tunnels caved and the ore is now taken out by the open-pit method. In July, 1910, according to the manager, John Rothfus, this mine was shipping 20 tons of iron ore daily, which averaged $35 a ton in gold and 2½ per cent of copper and went to the East Helena smelter for flux. At the time of the writer's visit a block of copper ore about 2 feet in diameter was found in the midst of the limonite which carried besides malachite a small amount of native copper.

The C & D mine has produced several thousand dollars in gold and silver from an ore body in marbleized Madison limestone near a granite contact. After being idle for many years it was prospected again in 1910, but the writer understands that after a few months of unsuccessful exploration operations ceased here. The mine has a shaft 250 feet deep with several levels and a crosscut through the limestone to the granite contact. Other mines in this district are the Keene, Dolcoath, Midnight Bell, and Queen. On the north side of Elkhorn Peak there is an iron mine on a contact between andesite and marble from which a considerable quantity of ore has been shipped to smelters for flux. The ore is along the bottom of the marble mass and is probably a replacement of it. It is a fine-grained magnetite showing grains of chalcopyrite and garnet. Malachite is found on the weathered ore. It probably carries small values in gold.

South of Elkhorn valuable minerals have been found at several places, but only a few of them will be mentioned. The Queen mine, 2 miles due south of Elkhorn, appears to be on a north-south quartz vein of considerable width and dipping 80° E. The vein, which is said to be 24 feet wide, has a limestone footwall and porphyry hanging wall. It was developed by a deep vertical shaft and by a slope, both with levels. The slope is now caved to an open pit, showing the great width of the ore body. The ore is quartz carrying pyrite. It was sorted by hand, and the appearance of the bins suggests that a considerable quantity was shipped. It is reported that during May and June, 1900, more than 1,000 tons of ore was shipped to East Helena. Although the quantity of ore is large, the values are low. The boilers, hoisting engine, cage, skips, etc., are all in place, although the mine has not been operated for several years.

In the bottom of the gulch just east of the Queen mine a 100-foot tunnel has been driven on a galena-bearing quartz vein between a porphyry footwall and limy shale hanging wall. At the head of a side gulch half a mile north of the Queen mine there is a series of tunnels on the contact between a porphyry footwall and limestone hanging wall. The ore is said to carry a little lead and silver; low-grade copper carbonate ore was found on the dump.

The Tacoma mine, which consists of ten tunnels and pits on or near the contact between andesite porphyry and Cambrian limestone, shows galena ore and is said to carry values in gold and silver. All the openings were caved in 1910 except one in which two miners were working. This tunnel is in porphyry and shows a flat-lying siliceous vein 1 to 4 inches thick carrying lead carbonate.

The Leroy quartz lode is situated on the top of a ridge at the end of a graded road about three-fourths of a mile southeast of the

Tacoma mine. It is a vertical vein 2 to 3 feet wide having a N. 25° E. course, in limestone which strikes S. 50° E. and dips 30° to 48° SW. The vein has an iron cap. It has been developed for 100 yards by five pits and tunnels, and an ore bin was built but never used. A sample sent to the United States assay office at Helena contained a trace of gold and 5.3 ounces of silver to the ton.

SUMMARY.

In the foregoing pages it is shown that mineral deposits of considerable value have been mined at a number of places in the Elkhorn Mountains and that active mining operations are now being carried on at two places, at Elkhorn and at Keating Gulch, near Radersburg. Ore deposits in these mountains occur on contacts between granitic rocks, such as granite, gabbro, and diorite, and intrusive and extrusive volcanic rocks and sedimentary formations; they occur also as fissure veins in the granite area and in the andesite porphyry and as replacement deposits in limestone.

In the Pennsylvanian limestone phosphate rock may possibly be found. Specimens of float collected by the writer in the valley of Slim Sam Creek analyze as high as 27.29 per cent of P_2O_5.

NOTES ON THE ECONOMIC GEOLOGY OF THE RAMSEY, TALAPOOSA, AND WHITE HORSE MINING DISTRICTS, IN LYON AND WASHOE COUNTIES, NEVADA.

By J. M. Hill.

INTRODUCTION.

During a part of July and August, 1910, the writer examined certain lands in the White Horse or Olinghouse district, Washoe County, Nev., on which suit had been brought by the Department of Justice. After the completion of this examination a few days were spent in visiting the other mines in this district and those in the Ramsey and Talapoosa districts of Lyon County.

The writer is indebted to the mine operators in these districts for their consideration and assistance, particular thanks being due to Mr. J. A. Ingalls, of Reno.

GEOGRAPHY.

The White Horse or Olinghouse district lies on the east side of the Virginia Range, north of Truckee Canyon. It nominally includes Tps. 21 and 22 N., R. 23 E. of the Mount Diablo principal meridian. In reality the productive area covers about 6 square miles located about the town of Olinghouse (1, fig. 9), at the south end of the district, 9 miles west-northwest of Wadsworth and about 7 miles northwest of Derby, stations on the Southern Pacific Railroad.

Ramsey (2, fig. 9), a town of about 100 inhabitants, is 17 miles south-southeast of Clarks station, on the Southern Pacific Railroad, with which it is connected by a good road traversed daily by a mail stage. It is in Lyon County, near the center of a basin about 3 miles in diameter on the southeast flank of the Flowery Range, a spur of the Virginia Range. The principal mines, the Ramsey-Comstock, Ramsey, and San Juan, are north of the town. To the south there are several prospects at which more or less work has been done.

The Talapoosa camp (3, fig. 9) lies in a small valley 14 miles south of the new town of Fernley, on the Southern Pacific Railroad, and 5½ miles northwest of Hawes siding, on the Tonopah branch of the Southern Pacific. There are several prospects of minor importance in this camp and one, the Justice, at which a larger amount of work has been done.

GEOLOGY.

The northern part of this area, as far south as latitude 39° 30′ north, was covered by the geologists of the Fortieth Parallel Survey, is shown on their atlas, and is discussed in detail in their report.[1] The region is largely underlain by Tertiary volcanic rocks, except

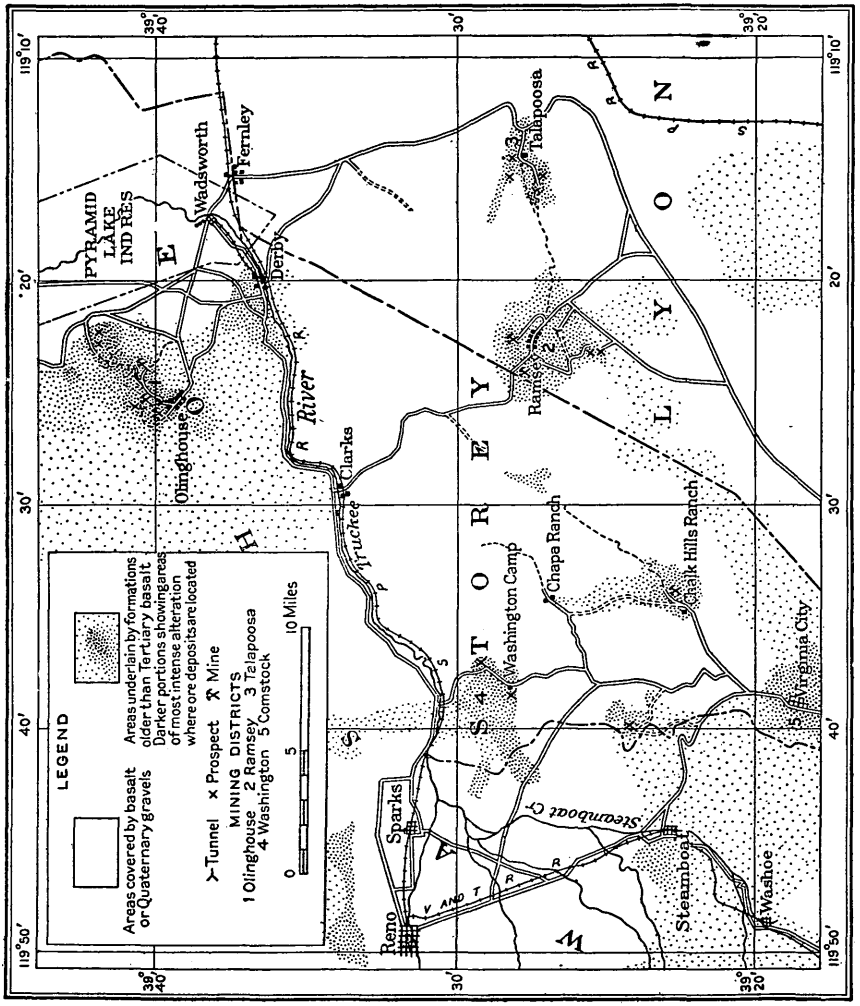


FIGURE 9.—Sketch map of a portion of west-central Nevada. Adapted from the Reno, Wadsworth, Carson, and Wabuska topographic sheets of the United States Geological Survey.

for small isolated areas of prevolcanic rocks and the valleys that are covered with silts and gravels of Quaternary age.

SEDIMENTARY ROCKS.

Northward from Wadsworth, in the Pyramid Lake Indian Reservation, Truckee River has cut deeply into soft thin-bedded sand-

[1] King, Clarence. U. S. Geol. Expl. 40th Par., Atlas sheet 5; vol. 2, 1878, pp. 817–844.

stones of buff to gray shades, fully described by King as Pliocene.[1] These beds are in turn covered by Quaternary gravels and silts.

About 3 miles south of Ramsey on the road to Dayton there is a small area of poorly exposed dark thin-bedded limestone and shales. No fossils were found in this locality, so the age of the rocks is not known. They are capped by andesite and rhyolite, however, and are therefore pre-Tertiary.

Near Steamboat Springs, in a portion of the region not visited by the writer, is a series of metamorphosed sedimentary beds of Mesozoic age that have been mapped and described by Becker.[2]

The fourth locality in which there are sedimentary rocks is in the head of Long Valley, at the Chalk Hills ranch, where there is a bed of diatomaceous earth interbedded with rhyolitic and andesitic tuffs, capped by basalt.

IGNEOUS ROCKS.

Granodiorite.—Granitic rocks are exposed at only one locality in the area under discussion, about 3½ miles south of Ramsey. The rock is coarsely granular, much weathered, and of a light-gray color. It consists of quartz, orthoclase feldspar, plagioclase feldspar, and biotite, and should probably be classed as granodiorite. This formation is marked by a low, rounded topography in contrast to the jagged forms of the lavas. The area underlain by the granite is small and the relations are not at all clear. The rock appears to be intrusive into the dark thin-bedded sediments, though this is not certain, and is capped by Tertiary lavas.

Older andesite.—The oldest Tertiary lava of this region is a dark-purple, green, or brown, in places tuffaceous andesite, exposed best on the east side of the Olinghouse district (1, fig. 9), where a fault has tilted the flows to the west-southwest at low angles. Russell shows this fault line in his report on Lake Lahontan.[3] The andesite is fine grained, but the individual crystals can usually be distinguished with the pocket lens. Under the microscope the slides examined, though not fresh, showed the rock to be a typical andesite porphyry. The phenocrysts of andesine and hornblende are set in a groundmass composed of minute crystals of andesine or oligoclase and a small amount of magnetite and hornblende. In one slide a few rounded grains of original quartz were noted, showing a tendency toward dacite. This tendency is particularly well shown in the region south of the town of Ramsey (2, fig. 9), where blebs of quartz up to one-fourth inch in diameter are rather prevalent in the rocks.

Rhyolite.—The andesite is cut by dikes of a light-colored rhyolitic rock which also caps the older rock. Just east of Washington camp

[1] King, Clarence, op. cit., pp. 817–824.

[2] Becker, G. F., Geology of the quicksilver deposits of the Pacific slope: Mon. U. S. Geol. Survey, vol. 13, 1888, pp. 333–334.

[3] Russell, I. C., Geological history of Lake Lahontan: Mon. U. S. Geol. Survey, vol. 11, 1885, Pl. II.

(4, fig. 9) occurs the most typical rhyolite flow seen during the reconnaissance. The rock is gray in color and shows thin-bedded fluidal structure; the flow is at least 350 feet thick. The more usual occurrence of rhyolite in the region is in the form of dikes varying from a few feet to several hundred feet in width. The smaller dikes are apt to be confused with silicified bleached andesite, which occurs in the vicinity of the mines.

At the mouth of Fort Defiance Canyon (Berkshire Canyon of King ?) there is a large white hill composed of a coarsely porphyritic to granular rock, which is probably a phase of the acidic intrusion. The rock consists of orthoclase and quartz with almost no ferromagnesian minerals. The slide examined would be called alaskite porphyry, but in the mass of the rock there is sufficient dark mineral to make it a granite porphyry. This large mass appears to grade out on both the north and the south into finer phases and finally into dikes of rhyolite porphyry.

Later andesite.—Dikes of a very fine grained dark-gray to black rock cut both the older andesite and rhyolite of the region. These dikes are composed of trachytic andesite in which the phenocrysts are small and rather scarce or entirely lacking. Where present the phenocrysts are andesine, hornblende, and augite. In some slides the augite prevails, making the rock an augite andesite. In only one slide was biotite surely determined, though its presence in others was indicated by aggregates of chlorite and magnetite assuming the form of biotite.

The cap rock of the mountains north of Truckee Canyon and west of Olinghouse is a reddish-gray porphyry with distinct phenocrysts of biotite and plagioclase feldspar. King [1] has mapped this formation as trachyte, and Hague and Iddings [2] describe these rocks as hornblende-mica andesites. The single thin section from specimens taken by the writer contains phenocrysts of cinnamon-brown mica, plagioclase feldspars with beautiful zonal growth ranging from oligoclase to andesine, and a white mineral whose index of refraction is a little less than that of Canada balsam and which may be either orthoclase or sanidine. The groundmass of this rock is much altered but is apparently composed of glass with some few crystals of plagioclase feldspar.

Basalt.—The greater part of the area shown on the sketch map (fig. 9) is covered by vast flows of basalt which range in color from black through chocolate-brown to gray. The groundmass of this rock is glassy and vesicular. In this glass base there are fragments and crystals of plagioclase, hornblende, augite, and olivine, with

[1] King, Clarence, U. S. Geol. Expl. 40th Par., Atlas sheet 5.

[2] Hague, Arnold, and Iddings, J. P., On the development of crystallization in the igneous rocks of Washoe, Nev.: Bull. U. S. Geol. Survey No. 17, 1885, pp. 23–24.

scattered specks of biotite. The composition of the basalt is not at all constant. South of Truckee Canyon olivine is absent or is present in very small amounts and the rock is lighter colored than at the head of the canyon, where typical black olivine basalt is exposed.[1]

ECONOMIC GEOLOGY.

HISTORY AND PRODUCTION.

The Talapoosa ore deposits are said to have been worked in a small way as early as 1864 by prospectors from Virginia City, but so far as can be learned there has been no production from this camp.

The town of Ramsey was built in 1906, after the excitement caused by the opening of the Ramsey-Comstock ore body. Prospectors from Virginia City are said to have located this property in the late sixties, but no work was done until the beginning of the twentieth century. The production of the camp so far has come from one mine and is said by the operators to be $80,000 gross.

The White Horse or Olinghouse district was first prospected in 1860, and locations were made in Fort Defiance Canyon in 1864. In 1874 the Green Mountain mines at Olinghouse were located by Frank Free. The geologists of the Fortieth Parallel Survey make no mention of mining in this vicinity, though they give sections along Truckee and Berkshire (Fort Defiance?) canyons.[2]

The period from 1901 to 1903 witnessed the greatest activity in the camp, three mills running most of the time. In July, 1910, there were four mines in the district at which work was being done, and two small mills were taking care of the ore.

The placer and deep mines are estimated by Mr. J. A. Ingalls, of Reno, an operator in the district, to have produced from 1897 to the present time about $775,000. Statistics collected by the United States Geological Survey for the period from 1902 to 1909, inclusive, give the total production of the district at $235,671, of which about 99 per cent was gold and 1 per cent silver.

OCCURRENCE OF THE ORE DEPOSITS.

On the sketch map (fig. 9, p. 100) the areas in which the mines and prospects are located are indicated by dark stippling. They occupy depressions, usually of erosion, from which the basalt capping has been removed, thus exposing the older volcanic rocks. It is not meant by this that in all places where the andesites and rhyolites are exposed there are prospects, as the productive areas are those in which these rocks are much altered. The later andesite intrusion

[1] King, Clarence, U. S. Geol. Expl. 40th Par., vol. 1, 1878, pp. 676–677.
[2] Idem, vol. 2, 1879, pp. 817–844.

appears to have had the most marked effect and to be the cause of most of the ore deposits. Where the older andesite and rhyolite are cut by dikes of this younger andesite they are usually leached, having a white to gray-green earthy appearance. At some places along the dikes they have been silicified and the resulting hardened rock resists erosion longer than the surrounding formations. This silicification was noted in all the districts but is strongest at Ramsey and Talapoosa.

Ore occurs in quartz veins but more commonly in ledges of altered silicified country rock somewhat similar to the ore bodies at Goldfield described by Ransome.[1] Developments have so far hardly penetrated to water level, and as a consequence the ores are all oxidized. Free gold and probably a little silver chloride are the only valuable minerals, though chalcopyrite was noted at the Justice mine at Talapoosa, and pyrite is always present in the ore. Tellurium was determined by E. E. Burlingame, of Denver, in high-grade ore from the Buster properties at Olinghouse but was not noted elsewhere.

WHITE HORSE OR OLINGHOUSE DISTRICT.

Outline of geology.—The prevalent formation in the White Horse district is the older andesite. The eastern hills consist of green to purplish-brown flows dipping west-southwestward at low angles. They are in general rather fine grained porphyries, but several of the beds are tuffaceous. Porphyritic rhyolite and the later andesite intrude this thick series as sills and dikes. The rhyolite is confined largely to the area east and north of the town of Olinghouse; the later andesite is found all over the district but is most abundant on Green Hill, just north of the town. The principal mines are located within a radius of 1½ miles of this hill, which seems to be the center of the andesite intrusion.

Green Hill mines.—The Gold Center, Butte, and Don Dero mines, located on the southeast flank of Green Hill, are reported to have been large producers of high-grade ore. They were not being worked in 1910 and could not be examined. The dumps of the lower tunnels are extensive, and a number of shallow pits and shafts are scattered over the surface. The ore is reported to have been largely quartz and calcite, with free gold occurring in pockets along a zone of soft altered andesite which in places showed slickensided surfaces.

Keystone-Nevada mine.—The Keystone-Nevada mine is about three-fourths of a mile northwest of Olinghouse, in a small side canyon. The country rock is the older andesite, which is cut about a quarter of a mile north of the mine by a dike of rhyolite. The ore

[1] Ransome, F. L., Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada: Bull. U. S. Geol. Survey No. 303, 1907, pp. 28-34; The geology and ore deposits of Goldfield, Nevada: Prof. Paper U. S. Geol. Survey No. 66, 1909, p. 150.

body consists of two tabular masses of brecciated silicified andesite having the form of veins which strike a few degrees east of north and dip at about 65° to 80° W. This body ranges from a few inches to several feet in thickness and is made up largely of smoky quartz with a few fragments of the silicified andesite. Pyrite is disseminated throughout this mass and a little free gold is seen in some specimens. The vein has been fractured and the spaces filled with white quartz and calcite, neither of which apparently contains any metallic minerals.

The property is developed by two tunnels on the hanging and foot walls and several shafts. Most of the ground in the hanging vein above the tunnel level has been stoped. Between the footwall and hanging-wall veins there is a horse of somewhat silicified andesite, with some pyrite disseminated throughout. The two veins apparently diverge with increasing depth.

The mine, which is worked under lease, is producing daily about 7 to 8 tons of ore that is said to run from $15 to $40 a ton. The ores are treated at the Slip mill at Olinghouse. The crushing equipment consists of two 3½-foot Huntington mills driven by a gasoline engine, and the values are saved on amalgamation plates.

Tiger group.—The Tiger group is located near the head of Tiger Canyon, about a mile and a quarter north of Olinghouse. The country rock here is earlier andesite cut by a northeast-southwest dike of late andesite. The vein strikes N. 30° E. and is almost vertical. It is a fault zone along the contact of the country rock and the intrusive. The ore is quartz carrying pyrite and a minor amount of chalcopyrite. The development consists of a 600-foot tunnel and a shaft 150 feet deep with drifts at the 75 and 150 foot levels. The drifts are entirely in the "vein," the upper one being 650 feet and the lower one 780 feet long. It is said that the best values occur in shoots pitching northeast in the vein and that three of these have been cut in each of the levels. No ore has been shipped.

Buster mines.—The Buster mines are located about 1¾ miles northeast of Olinghouse, on the divide between Frank Free and Tiger canyons. The older andesite is here cut by both rhyolite and andesite. In the area covered by the claims there are several nearly parallel north-south zones of alteration and silicification. The principal ones are on the Maciza and Dispensia claims. They occur along a contact of older andesite and rhyolite near a dike of later andesite.

On the Maciza a tunnel about 150 feet long exposes a vein of drusy quartz from 5 to 20 inches in width, which strikes on an average about north, though there are minor irregularities in its course, and dips to the west at high angles. The vein is clearly divisible into two parts. One, a rather massive yellow-stained quartz, is said to

run as high as $80 a ton. This usually follows the footwall and is from 4 to 8 inches wide. The rest of the vein is white drusy quartz, stained yellow in places, and runs from $5 to $18 a ton. A 75-foot winze dipping 60° to 75° E. runs out of ore about 20 feet below the tunnel level, but it is said that since the writer's visit an 18-foot crosscut to the west about 25 feet below the tunnel has exposed the vein.[1] The lower part of this winze is in very soft, much decomposed altered andesite, showing the action of hot water.

On the Dispensia claim an irregular incline pitches to the west in soft altered andesite. From this andesite was taken, it is said, a very rich kidney of ore, which assayed as high as $4,000 a ton in gold and silver. The ore had been entirely removed from this pocket in August, 1910, but a sample said to have come from this place is a brownish-yellow heavy mass, consisting of fragments of sericitized andesite, cerusite (?), argentite, and possibly a telluride of gold and silver. This yields gold in the pan, and a sample assayed by E. E. Burlingame & Co., of Denver, gave as high as 1 per cent of tellurium.

Several other tunnels and shafts show a zone of crushed altered andesite about 20 to 40 feet wide to be mineralized, and this is said to carry from $2 to $4 a ton in gold and silver.

RAMSEY DISTRICT.

Outline of geology.—The Ramsey district (2, fig. 9) occupies a basin, from which the basalt capping has been removed, exposing the andesites and rhyolites. The northern part of this basin is underlain by rather coarsely porphyritic andesites, some of which contain quartz blebs. There is very little rhyolite in this part of the district, though a few small dikes were noted. The hills forming the southern limit of the district are made up of rhyolite of light-buff shades, apparently in large part flows.

About a mile north of the town an east-west fracture zone, marked by intense silicification, runs across the basin. This "dike" is stained a dull brownish red and stands well above the surrounding andesite. In the field this body has the appearance of a rhyolite dike. Slides of the rock show it to be entirely quartz, and there is no clue as to whether it was originally andesite or in reality a rhyolite dike.

Ramsey-Comstock mine.—The ore body of the Ramsey-Comstock mine lies in this "dike." The development consists of a 400-foot shaft dipping 57° to 60° N., which is on the footwall of the dike at the surface but 90 feet south of the wall at the 400-foot level. Below the 60-foot level the dike is much shattered. Two series of joints cut it in northeast-southwest and northwest-southeast directions. Pyrite is disseminated throughout the quartz mass but is particularly

[1] Letter from J. A. Ingalls.

abundant on the hanging-wall side of the joints running northeast. The general tenor of the dike is said to be from $6 to $10 a ton, but in the lenses on the northeast joints the values are said to run up as high as $50 or $100 a ton. The dike at the 200 and 400 foot levels is about 40 feet wide. The hanging wall throughout is marked by a fault zone on which there is from 5 to 15 feet of greenish-black clay gouge composed of crushed andesite. This soft material grades into fairly fresh quartz-bearing andesite porphyry about 40 feet north of the hanging wall. Permanent water was encountered at a depth of 120 feet. At 160 feet the ore was largely pyrite, with only here and there a showing of free gold.

The surface equipment consists of a 32-horsepower gasoline hoist. The mill is equipped with an Ellspass crusher and two regrinders. The values are saved on amalgamation plates and three Gates tables. The concentrates are entirely of pyrite and are said to carry about $100 in gold to the ton.

Ramsey shaft.—About 500 feet west of the Ramsey-Comstock shaft is the shaft of the Ramsey Mining Co. This was closed at the time of the writer's visit but is apparently on the same "dike" as the Ramsey-Comstock.

San Juan mine.—San Juan Hill lies about 1¼ miles northwest of Ramsey, west and south of the road to Clarks. The main mass of this hill is andesite, but this rock is cut by a dike or silicified zone somewhat similar to that at the Ramsey-Comstock. The San Juan mine is located on the northwest side of the hill. It could not be visited owing to the absence of one of the partners, the other not being willing to allow anyone to examine the property. It was said that some very rich specimens had been taken from the 150-foot shaft.

Other prospects.—The Best & Belcher prospect, 1½ miles southwest of town, is in an 80-foot zone of somewhat altered andesite striking N. 17° E. A trench across this belt is said to have shown the values low but distributed about equally throughout the body.

On the Spencer claim, 2½ miles south-southwest of Ramsey, a belt of kaolinized quartz-bearing andesite near a dike of later andesite has been prospected by a 60-foot shaft and a crosscut. It is asserted that for a distance of 15 feet from the dike the altered country rock carrying pyrite has an average value of $5 a ton.

The Garavanta claims are half a mile south of the Spencer. Several rather long tunnels have been driven into altered andesite below a thick flow of rhyolite. In one of these tunnels there is a fault zone striking N. 25° to 40° E., along which quartz, calcite, and gypsum occur in seams. It is said that some pockets of rich ore have been taken from this tunnel.

One mile south-southeast of Ramsey, on the top of one of the rhyolite hills, is the Hawks Nest prospect. The vein apparently strikes nearly east and west and consists of quartz.

TALAPOOSA DISTRICT.

The Talapoosa district (3, fig. 9) has only one prospect of importance—the Justice. The croppings of the vein are prominent, being very hard. Rhyolite is here cut by an andesite dike about 150 feet wide, which can not be traced westward for over 200 feet, as it is capped by basalt. The dike dips 40° SW. Above the dike, to the south, the "ledge" is from 8 to 28 feet wide and consists of brownish-stained drusy quartz. A 650-foot tunnel is driven along the south side of the quartz ledge in soft altered rhyolite showing no mineralization. Several crosscuts are driven northward into the vein proper, which consists of bluish-gray quartz cut by stringers of white quartz and calcite. As far as noted only the dark quartz contained metallic minerals. These were pyrite and chalcopyrite, probably with some argentite and silver chloride.

WASHINGTON CAMP.

At Washington camp (4, fig. 9) there are a few prospects in much altered rhyolite cut by dikes of later andesite. No work was being done in this vicinity at the time of the writer's visit. The prospects so far as seen showed only stringers of calcite and gypsum.

CHALK HILLS.

The Chalk Hills are about 9 miles northeast of Virginia City, near the head of Long Valley. This region is one of low relief, being a fairly level basin surrounded by basalt hills. The floor of this basin is also largely basalt, except along the wash, where it has been removed. Under the basalt there is a series of thick beds of rhyolitic and andesitic tuff dipping north at low angles. Interbedded with these rocks is at least one bed of fine-grained white diatomaceous earth. This bed at the mine is folded with the tuffs. The body was formerly worked by open-cut methods, but lately a tunnel about 150 feet long has been driven in on a level with the bottom of the pit, which is 100 feet long, 30 to 40 feet wide, and 40 feet deep. The first-grade material is about 36 inches thick and the whole bed is from 30 to 40 feet thick. It strikes N. 60° W. and dips 65° NNE. The better grade is broken separately, some brown stains on joints being removed with a hatchet and sacked. The poorer grade can, by the liberal use of the hatchet, be made to yield about 40 per cent of good material.

It is said that the company operating the property ships from this mine yearly from 7 to 9 cars of infusorial earth, which is used in the manufacture of electro-silicon.

THE ORE DEPOSITS NEAR PINOS ALTOS, NEW MEXICO.

By SIDNEY PAIGE.

INTRODUCTION.

Pinos Altos lies in northeastern Grant County, N. Mex., about 6 miles northeast of Silver City, which is reached by the Deming and Silver City branch of the Atchison, Topeka & Santa Fe Railway. A narrow-gage railroad and good wagon roads afford connection with Pinos Altos. The town is situated on the eastern slope of the Pinos Altos Mountains at an elevation of about 7,000 feet.

At the time of the writer's visit only one deposit of the fissure-vein type was accessible, and that only in part. A brief history of the district and an account of the geology and mines, by L. C. Graton, was published in 1910.[1] The present paper contains a map showing the geologic relation of the ore bodies in more detail and brings together what could be learned of the inaccessible portion of the veins. The inaccessible condition of the mines made original underground observations impossible. The mine dumps, however, were studied with some care and, though a systematic account of the ore deposition can not be given, some information could be gleaned from these sources. Acknowledgments are due to Mr. W. C. Chandler, both for much of the quoted information which follows and for the many courtesies which he extended to the writer.

The replacement deposits known as the Cleveland group have been more extensively developed since Graton's visit and additional data are therefore at hand regarding them.

GEOLOGY.

GENERAL RELATIONS.

The geology of the Pinos Altos district is simple. (See fig. 10.) A roughly elliptical mass of granodiorite intrudes a complex of diorite porphyry and associated dikes;[2] fissure veins have been formed in both masses and cut across their contact without interruption, and to

[1] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: Prof. Paper U. S. Geol. Survey No. 68, 1910, p. 297.

[2] The granodiorite has been considered the oldest rock by previous workers (Prof. Paper U. S. Geol. Survey No. 68, 1910, p. 298), but their work was of a reconnaissance nature.

the north trachytic and other lavas of later age than the veins cover the intrusive masses.

Almost 2 miles northwest of Pinos Altos, on the western slope of the Pinos Altos Mountains (not shown on the map), Paleozoic limestones are intruded by diorite porphyry and in consequence replacement ore bodies were formed. The diorite porphyry forms the crest and much of the main mass of Pinos Altos Mountains. The granodiorite is found along the lower eastern slope and in the territory to the east.

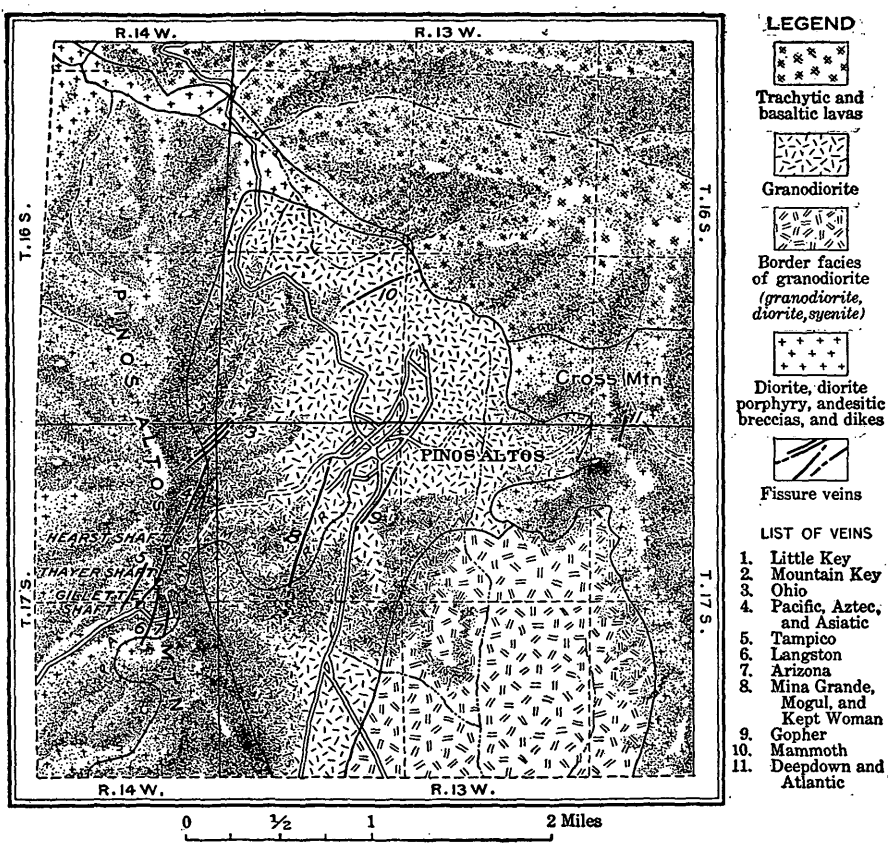


FIGURE 10.—Map showing geologic relations of fissure veins near Pinos Altos, N. Mex. Stippling indicates relief.

ROCKS.

GRANODIORITE.

The granodiorite may be divided into two parts—(1) a very homogeneous pure mass of pear-shaped outcrop, with Pinos Altos near its center, and (2) a more basic and less homogeneous phase of this mass at its southern and southeastern border. The boundaries between the homogeneous mass and its more basic phase and between the

pure mass and the diorite porphyry may be drawn with considerable sharpness. On the other hand, the eastern and southern contact of the basic phase of the granodiorite with the diorite porphyry complex is not so easily to be placed on the map, for along the southern border especially offshooting dikes and fine-grained border facies of the granodiorite form a ragged edge and obscure the relations.

The pure granodiorite mass is a fairly coarse grained, holocrystalline granitoid rock with a pinkish cast. Hornblende is the prominent ferromagnesian mineral. The rock varies somewhat in texture but within the area mapped as pure granodiorite is a remarkably homogeneous unit. In the field it is unmistakable; it forms locally almost bare rocky knolls and cliffs, is well jointed, and weathers differently from the other rock of the vicinity, in large angular blocks whose dimensions are determined by the spacing of joint planes. Mineralogically the rock is a holocrystalline coarse-grained aggregate of orthoclase, albite, andesine, and andesine-labradorite feldspars with quartz and abundant colorless to light-green hornblende. Magnetite, apatite, titanite, and a little zircon are present, as is usual in such granitic rocks. The secondary minerals are chlorite, sericite, and calcite.

Though the border facies is in a broad way mineralogically similar to the main mass, it differs in being less homogeneous; that is, within it are a number of related types presenting minor variations in composition and texture. The essential mineralogical differences are the development of pyroxene and biotite at the expense of hornblende and a lower content of free quartz. A finer grain along the borders and a general lack of textural homogeneity are also evident. It is believed that fragments of the surrounding intruded diorite porphyry are present in this area. Some of the types mapped together are undoubtedly offshooting dikes from the main mass, very similar to it in composition and texture, though locally finer grained and porphyritic; but the more striking variations in composition are probably a result of successive but related injections of differentiated magma.

These pyroxene-biotite rocks, however, may also be classed as granodiorites. Two specimens within this area, one from the southwestern and one from the northeastern border, show, when examined under a microscope in thin section, the striking peculiarity that large anhedral orthoclase feldspar crystals are the hosts in which have crystallized numerous perfect laths of andesine-labradorite feldspar and pyroxene. Large pleochroic biotite plates likewise inclose plagioclase feldspar; a little interstitial quartz is present, also apatite. The whole is a beautiful example of poikilitic growth.

At the extreme south end of the Pinos Altos Mountains, associated with the rock just described, are two phases of the pyroxene grano-

diorite. One has a dark-green aspect, owing to the abundance of biotite and pyroxene. The other is lighter in color and has a pinkish cast on weathered surfaces.

The darker phase consists essentially of abundant pyroxene and biotite with interlocking andesine-labradorite feldspar laths and subsidiary orthoclase. The biotite occurs in large plates and much of it surrounds grains of pyroxene and titaniferous magnetite. Apatite is abundant. The orthoclase feldspar has a tendency to inclose the plagioclase poikilitically—that is, it is later than the plagioclase.

The more acidic phase is a granitoid rock consisting of abundant orthoclase (with subsidiary plagioclase) and biotite with numerous and relatively large pyroxene prisms. Perhaps it might better be called a pyroxene syenite.

It may be said with a considerable degree of assurance that the granodiorite is of later age than the diorite porphyry complex which surrounds it. Evidence for this conclusion consists mainly in the three facts that (1) offshooting dikes, some exactly similar in composition and texture to the main mass and some presenting porphyritic phases, may be found in the surrounding complex; (2) there seems to be a distinct fineness of grain developed locally near the contact; and (3) the increasing basicity of the magma near the contact is a phenomenon observed in other regions at the border of intrusive masses.

DIORITE PORPHYRY AND ALLIED ROCKS.

The group of rocks into which the granodiorite is intruded is characterized by a dark-green or steel-blue color and by a fine-grained porphyritic or nearly aphanitic texture. In the vicinity of Pinos Altos much of the rock is diorite porphyry or fine-grained diorite. The area represented on the map is but a part of a widespread series of rocks which have been grouped together as a unit, by the writer, for convenience in mapping the Silver City quadrangle. The series includes andesitic flow breccias, intrusive andesite porphyries, pyroxene andesite porphyries, diorites, diorite porphyries, and allied rocks.

Though andesite breccias may be seen in Pinos Altos Mountain, the main portion of that mass is essentially fine-grained diorite and diorite porphyry.

It is this complex, then, generally dark in color and fine grained in texture, which forms the country rock into which the granodiorite was intruded. The diorite consists essentially of andesine-labradorite feldspar in interlocking stout prisms, a subordinate but noteworthy amount of orthoclase, abundant well-developed crystals of pyroxene, much biotite in small grains and large plates, a little green hornblende, and numerous grains of iron oxide.

The diorite porphyries have essentially the same minerals. The groundmass is either a fine granular mixture of orthoclase and plagioclase or a mat of interlocking rodlike plagioclase crystals throughout which may be seen some orthoclase. In some specimens hornblende is more abundant than in the diorite. Apatite needles are abundant in some specimens. Phenocrysts may consist either of plagioclase, orthoclase, or pyroxene, or of all of them. Much alteration of pyroxene to hornblende is evident. Secondary calcite, chlorite, and sericite are plentiful in some specimens.

The andesitic rocks are light brown, olive-green, purple, or gray-blue in color. They have a glassy or partly glassy groundmass in which are set numerous short, stout andesine-feldspar and pyroxene phenocrysts. Chlorite and zeolites may be seen filling gas cavities. The andesitic flow breccias are, it is believed, the oldest of this group. Several generations of dikes are present.

LAVAS.

The lava flow which to the north covers both the granodiorite and the diorite porphyry is a part of a great series of flows of latitic, rhyolitic, and basaltic facies and interbedded tuffs with sediments. The area shown on the map is covered by lavender-colored lava flows of rhyolitic and latitic type. Some portions of this mass are fine grained and glassy, some medium grained and crystalline, others decidedly rough in appearance. They all consist essentially of clear oligoclase or sanadine feldspars, leached bronze-colored biotite, a very little quartz, and a glassy or partly glassy groundmass.

FISSURE VEINS.

General relations.—The important fissure veins of the district trend from nearly north to northeast, most of them lying between N. 18° E. and N. 30° E., one nearly north and one N. 55° E. They cut both diorite porphyry and granodiorite and cross the contact between these rocks. (See fig. 10, p. 110.)

The dips are steep and incline both to the east and west. The veins may be traced various distances on the surface, from a few hundred feet to nearly a mile. All of them die out on the surface in a horizontal direction by spliting up or fingering out into ramifying veinlets. The distance between the walls of the veins differs in different deposits and also in individual deposits, from a few inches to 6 feet or more. Generally, though not invariably, the walls are good.

The only mine map available to the writer showed that at one place a vein split into two parts and came together again along the strike.

Mineralogy.—The veins as a group are characterized by a decided similarity in their mineral content. In all of them may be found quartz, iron pyrite, chalcopyrite, and calcite, and most of them contain in addition to these minerals rosin-colored, brown, and black sphalerite and galena. In some of them barite and rhodochrosite were noted. Gold and silver are present in all the veins.

It is true, however, that though so similar in their mineral content these veins would, if opportunity were afforded to study them underground, reveal individual combinations and arrangements of their ores and gangue which might be characteristic. No such study could be made.

Origin of the veins.—The veins are without doubt the result of open-fissure filling; tensional stresses were powerful enough to fracture the rocks and to keep open the fractures formed; and there is evidence in the veins that fractures closed by vein filling were reopened by renewed fracturing.

The process of open-fissure filling is beautifully demonstrated in a specimen from the Pacific vein found on the dump at the Hearst shaft. (See fig. 11.) The specimen covers the entire width of the vein and its polished surface is therefore a perfect cross section. Five distinct bands proceeding from each wall inward to the center may be counted. Each of these bands has an almost perfect counterpart on the opposite side of the vein. The first band, that next to the wall, contains quartz and pyrite. Its inner edge is outlined by the crystalline terminations of quartz prisms, a beautiful example of comb structure. The succeeding band is composed of zinc sulphide (sphalerite) and chalcopyrite. The chalcopyrite grows more abundant toward the inner edge and in fact forms two subsidiary bands separated by a thin band of sphalerite. The next layer, a thin band, contains quartz and chalcopyrite. It is followed by a narrow band of sphalerite, which is in turn followed by a thicker band of quartz that contains fine grains of disseminated chalcopyrite and locally fails to join with its corresponding band on the opposite side, leaving an open crystalline cavity at the center.

On one wall of the vein is a secondary narrow vein, evidently a reopened fissure. Its walls are outlined by narrow bands of quartz (with a little chalcopyrite and a little galena), between which is a pinkish cream-colored mass of ferriferous and magnesian carbonates and quartz. The narrow quartz bands forming the walls of this little vein have locally been broken, and pieces of the wall now lie at varying angles across the vein embedded in the vein filling.

On the opposite wall of the main vein a fragment of country rock is included in and surrounded by the vein material of the large vein. This fragment of country rock is interesting because of the earlier veining which it displays. First, it contains parallel hairlike frac-

tures filled with sphalerite and iron pyrite; second, crosscutting heavier fractures filled with sphalerite and iron pyrite; and third, disseminated pyrite apparently not related to any fractures.

From these data the history of the mineralization of this particular vein may be deduced. A fracture was formed in the country rock and filled by solutions carrying zinc and iron sulphides. Fracturing

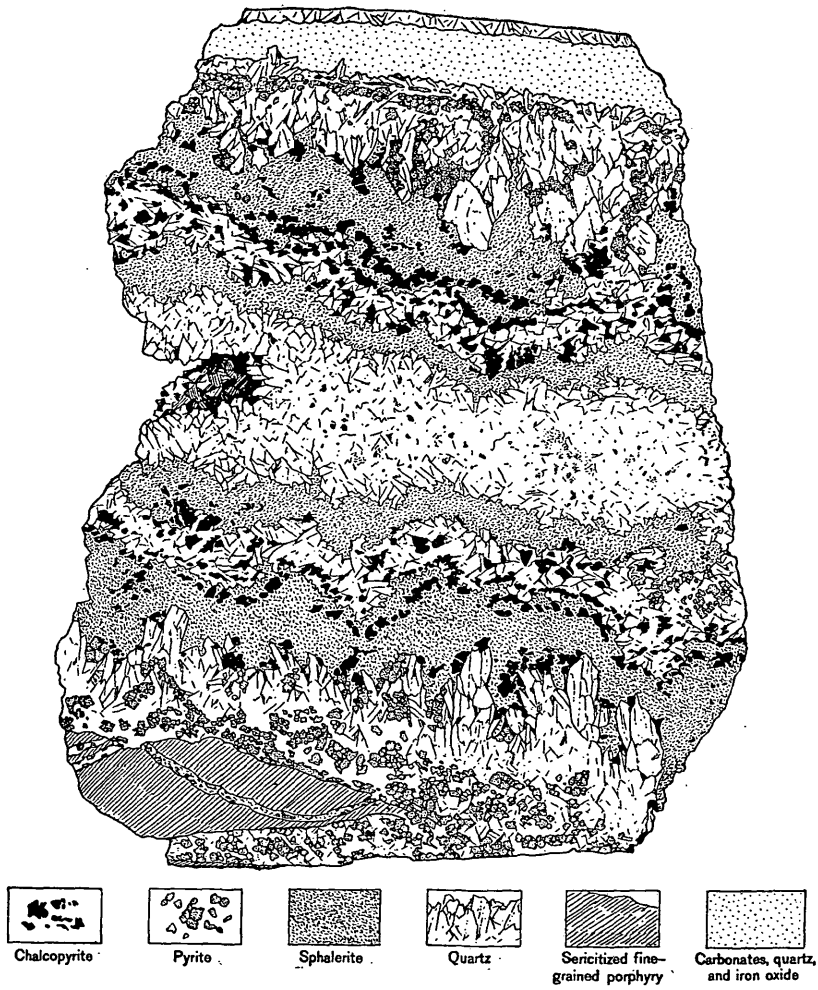


FIGURE 11.—Specimen from Pacific vein, showing evidence of open-fissure filling. One-half natural size.

continued and cross fissures on a small scale were opened. The forces, of whose presence this initiatory fracturing was but a preliminary mark, finally succeeded in producing an open fracture measured by the width of the vein described, and solutions carrying silica and iron sulphide and a trace of zinc sulphide and lead circu-

lated through the open spaces thus afforded. Along both walls simultaneously quartz and pyrite were precipitated, and continued to be precipitated, apparently, until solutions ceased to circulate or ceased to carry sulphur, iron, and silica, for the boundary between this first band and the succeeding one is sharp in point of both demarcation and mineral content. When next mineralizing waters flowed past the walls zinc sulphide and chalcopyrite were deposited, and it is evident from the specimen that, although copper, sulphur, and iron were present during the remaining history of the vein, though growing markedly less toward the end, the zinc sulphide and silica content fluctuated, first a layer of one and then a layer of the other being precipitated. Parts of the vein along the center were probably never completely filled, not because there was a lack of material, but because deposition fortuitously isolated open geode-like spaces within which circulation ceased.

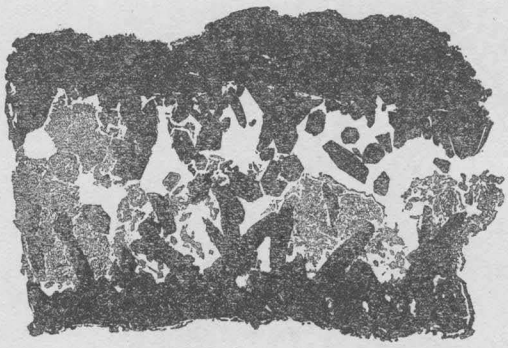


FIGURE 12.—Cross section showing comb structure in a small vein. Black areas indicate quartz; white areas, calcite; shaded areas, ferriferous carbonates.

The small vein at the edge of the large one points to a continuation of fracturing in the region and the advent of carbonated waters marks a distinct change in the mineralizing solutions. So far as this specimen is concerned, these carbonated waters, carrying also silica, close the record of mineralization. Worthy of note is the relatively late and sudden introduction of the copper-iron sulphide (chalcopyrite), also repeated alternations between sphalerite and quartz.

Figure 12 represents a cross section of a smaller vein but illustrates beautifully the comblike structure of the quartz lining each wall. The central portion of this small vein contains carbonates and a very few crystals of chalcopyrite. The undisturbed crystallization of the inner ends of the quartz prisms leaves no doubt of the open character of the fissure.

Details of veins.—In the accompanying table is summarized such information as was gathered in mapping the veins and studying the dumps and any additional facts regarding the mines that were reported to the writer. Eleven veins are represented on the map (fig. 10). They include all but one of the extensively developed veins of the district. The Silver Cell is not shown, nor a small vein known as the Alaska vein on the east border of Pinos Altos, nor could

other slightly developed veins in the territory northeast of the Hearst shaft be mapped.

A word of explanation is necessary regarding the interrelation of the Aztec, Pacific, and Langston veins. From the south the Pacific and Langston veins approach each other and meet on the surface about 50 feet south of the Thayer shaft. The Aztec vein, therefore, becomes the northward extension of this pair, provided they do not cross each other. If they cross, then the Aztec may properly be considered the northward extension of the Langston. A map of that portion of the Pacific mine between the Hearst shaft and the Aztec tunnel does not show any crossing of two veins, nor was any such crossing seen on the surface. It is true that some distance northeast of the Aztec shaft in the territory east of the Aztec vein there occurs a vein, as yet but little developed, which might represent the northeast extension of the Pacific. But that this vein could be traced continuously southward to a juncture with the Pacific vein at or near the Hearst shaft has not been proved. This vein corresponds somewhat closely in strike and dip with the Pacific vein, and the ore is reported by Mr. W. C. Chandler to resemble closely the ore of the Pacific vein. However, as there is no determinate evidence to the contrary, the Langston vein must for the present be considered a split-off from the Aztec-Pacific vein.

In the Mountain Key mine during the time of its original operation ore was lost in the main shaft between the 600-foot and 700-foot levels. It is reported that since that time a crosscut into the hanging wall on the 700-foot level again struck the vein, and a drift was driven northeast 175 feet and southwest 200 feet. The last 600 tons taken from the mine and referred to in the table came from this drift.

On what are known as the Monarch and Ontario claims, in the territory east and northeast of the northeast extension of the Aztec vein, is a vein which strikes N. 25° E. and dips 57° W. This vein throughout these two claims has been worked with arrastres down to a depth of 15 to 20 feet, and rich values are reported. Unaltered sulphides are said to have been struck at a depth of 40 feet.

Summary of information relating to principal Pinos Altos fissure veins.

Name.	Owner.	Depth of shaft (feet).	Development.	Production.	Vein.	Walls.	Mineralogy.	Values.	Remarks.
Tampico.....	Savannah Copper Co.	300	Little.....	Not much worked.	Strike N. 25° E.; No 1 on map.	.....	Quartz vein, some zinc, very little lead and copper, principally gold and silver.	.....	Vein is a few hundred feet west of the south end of Pacific vein.
Pacific.....	Savannah Copper Co., lease and bond to Corrigan & McKinney.	[a] G, 900 H, 700±	Very extensive in past. Much stoped-out ground. 9 levels from Gillette shaft, 6 from Thayer shaft, 6 from Hearst shaft, all connected.	$1,000,000+ up to 1905 (Pacific mine).	Strike N. 46° E. between Gillette shaft at southwest end and old Thayer shaft on hill, N. 25° E. from old shaft to the northeast; dip steep northwest.	Good foot, poor hanging, average 3½ feet between.	Quartz, pyrite, chalcopyrite, galena, sphalerite, calcite, rhodochrosite; galena only with sphalerite in more or less isolated shoots; not rich in gold; little argentite.	$22 in gold and silver in past, now about $10 to $12; 20 per cent is silver value, 2½ per cent copper in lower levels.	Silver is with the gold; if no gold is found, silver is absent also. Gold is often in pure quartz, also in sulphides. Shoot containing ore said to be 1,500± feet long and to pitch to the southwest.
Langston.....	Bennet & Thompson, Silver City.	.....	Worked to depth of 160 feet.	.....	Strike nearly north; dip 61° W.	Good walls, 18 inches to 2 feet apart.	Considerable zinc, gold, silver, etc., sphalerite, pyrite, chalcopyrite, quartz, barite.	Rich pockets, one reported worth $6,500.	Vein is probably an offshoot from the Pacific vein, which it joins near the Thayer shaft.
Aztec and Asiatic.	Nathan Frank and others, St. Louis, Mo.	300+	.....	.....	Strike N. 15° to 20° E.; dip 61° NW.	18 inches to 2 feet apart.	Sphalerite, pyrite, chalcopyrite, quartz, barite, galena, gold, silver.	.....	Aztec is the northeast extension, probably, of the Pacific; the Asiatic the northeast extension of the Aztec. Two parallel veins may be traced throughout the Asiatic-Aztec claims. These veins must either cut the Mountain Key, pinch out, or swing to the east, probably the last.

Arizona	Curry and others, Einstein and others, St. Louis, Mo.	[b]100±(?) 250+		Worked steadily for a year, $30,000 to $40,000.	Strike N. 21½° E.; dip steep west; 2 veins 10 to 20 feet apart.		Sphalerite, galena, pyrite, chalcopyrite, quartz, barite, gold, silver.	$15 to $60	Vein is 400 feet east of the Langston.
Ohio	Savannah Copper Co.		Tunnel 100 feet on the vein, driven southwest, no stoping. 115 feet above this tunnel a 600-foot tunnel on the vein stoped to the surface.		Strike N. 44° E.; dip steep northwest.	Good; 4 feet apart.	Sphalerite, galena, pyrite, chalcopyrite, quartz, carbonates, gold, silver.	$5 in gold, 7 ounces silver, 1½ per cent copper, 8 per cent zinc.	Vein is known by development and surface croppings for a distance of 1,600 feet; is 140 feet east of Mountain Key at Mountain Key shaft.
Mountain Key	T. C. McDermot and W. C. Chandler.	750	Seven levels all developed southwest of shaft. First level, 600 feet; second, 500 feet; third, 700 feet; fourth, 550 feet; fifth, 450 feet; sixth, 340 feet; seventh (?).	$500,000 up to 1905 in bullion and concentrates.	Strike northeast; dip 50° W.	6 inches to 2 feet; locally, 3 feet apart.	Galena, sphalerite, pyrite, chalcopyrite, quartz, carbonates, gold, silver.	Average of last 600 tons taken out, $26—$15 gold, 3½ per cent copper, 11 ounces silver, 20 per cent iron, 20 per cent sulphur, 40 per cent silica.	Operated 3½ years. Copper seemed to gain in depth. Vein contained many nuggets; is known for 1,500 feet.
Little Key	do	200	Drifted 200 feet southwest of shaft and worked out to surface. Very little drifting northeast of shaft.			Good; 2 feet apart.	do	$25 in gold, silver, copper, zinc. No pay for copper.	100 feet west of the Mountain Key at the Mountain Key shaft. Approaches the Mountain Key in a southwest direction.

[a] G, Gillette shaft; H, Hearst shaft.

[b] On hill 100± feet; in gulch 100 feet lower 250 feet.

Summary of information relating to principal Pinos Altos fissure veins—Continued.

	Name.	Owner.	Depth of shaft (feet).	Development.	Production.	Vein.	Walls.	Mineralogy.	Values.	Remarks.
One vein.	Mina Grande.	Savannah Copper Co.	500±	A tunnel 150+ feet below collar of shaft enters hill and is developed for 750 feet, stoped to surface. A drift connects with the Mogul to the north; two together aggregate 1,350 feet.	.....	Strike N. 13° to 14° E.; dip 70° W.; 20-inch ore streak follows hanging wall.	4 feet apart....	Quartz, pyrite, chalcopyrite, sphalerite, galena, carbonates, good deal of zinc, gold, silver.	Average, $10—$7 to $8 in gold, $2 to $3 in silver, some zinc and lead. Average $7 total also reported. Rich pockets.	Vein is traced by surface cuts to the Mogul shaft and thence may be traced to the Kept Woman shaft. Also connected by drift with Mogul. Said to be too low grade to pay.
	Mogul.....	.....do.....	300	.....	.....	Essentially same as Mina Grande.	Essentially same as Mina Grande.	Essentially same as Mina Grande.	.....	.....
	Kept Woman.	.....do.....	300	Drift southwest 300 feet and northeast 175 feet on the 300-foot level; also 150 feet northeast and 200 feet south on the upper levels.	.....	Strike N. 13° E.; dip 70° W.	Hard walls, essentially same as Mina Grande.	Essentially same as Mina Grande; dump shows less galena.	$5 in gold (save $3), 5 to 6 ounces silver, 6 to 7 per cent zinc, 2 per cent copper. Second report, $15 in gold and silver; zinc and lead not counted.	Dump said to sample $9.25, 1,000 tons. Copper said to increase with depth.
	Gopher (Golden Giant).	Alvin White and others, Silver City.	520	North 450 feet and south 500 feet on the 400-foot level. On four remaining levels 300 to 500 feet south and in general about 300 feet north.	.....	Strike N. 30° E.; dip 70° W.; 10 inches of pay.	3 feet apart....	.....	$20 in gold, $5 in silver, some copper near bottom.	Ore shoot in the upper levels about 700 feet long, on the bottom 150 feet (60 feet below the 500-foot level). A rich stringer 2 feet wide was followed south on the 400-foot level; carried up to $75 or $80.

Mammoth	do	[a] 250		2 years; 10 to 15 tons a day.	Strike N. 48° E. to N. 55° E.; dip nearly vertical. At the shaft are two parallel veins each 1 foot wide, separated by a foot of gangue.	2 to 6 feet apart.		$4 to $5 in gold, saved $2 to $2.50; 4 to 5 ounces silver, 1 to 1½ per cent copper. $6 also reported.	Pay averages 2 feet wide.
Deep Down and Atlantic.	Savannah Copper Co.	[b] 700	Largely southwest of shaft, 600 feet on the 400-foot level; no stoping below this level.	Not much ore extracted.	Strike N. 6° E.; dip 60° E.; width 18 inches to 2 feet; 3 feet at bottom.	Good	Abundant sphalerite, with galena, pyrite, chalcopyrite, quartz, carbonates, gold, silver.	$5 in gold, 6 to 7 ounces silver, 2 per cent copper, 15 per cent zinc. Another report, $18, of which 20 per cent was silver.	Said to have not paid.
Silver Cell	Fred Coopir, Pinos Altos.	400		$100,000 up to 1903; little produced since.	Strike northerly; dip 75° E.; width 2 to 8 inches.		Chlorides of silver and argentite; dolomite.	Rich in native silver.	

[a] 2-compartment shaft.

[b] 2 shafts 300 feet apart.

REPLACEMENT DEPOSITS.

Geologic relations.—Carboniferous limestone forms a part of the west flank of the Pinos Altos Mountains. The area of limestone is not large; a rectangular mass about 1½ miles long in a north-south direction and less than a mile in width is exposed. The strata dip eastward, into the mountain, and are unconformably overlain by basal Cretaceous quartzite beds. A few feet of limy shale overlie the quartzite.

The Paleozoic limestones are cut off on the west by a normal fault which drops Cretaceous shales and portions of the igneous complex against them. On the north, south, and east the limestone is bounded by intrusive igneous rocks of the andesite-diorite group.

A normal fault, with the western block downthrown, passes in a northeasterly direction through the center of the area. A sedimentary block, therefore, broken by and partly limited by faults, lies practically surrounded by intrusive rocks.

Figure 13 is an ideal section of the structure near the Cleveland group of claims. Limestones capped by quartzite dip southeastward, into

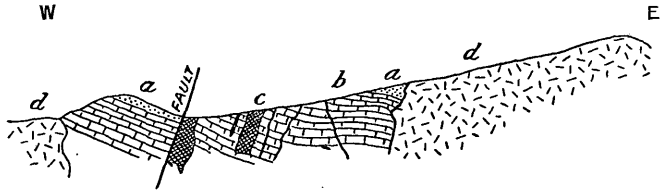


FIGURE 13.—Ideal structure section near Cleveland group of claims. *a*, Basal Cretaceous quartzite; *b*, Carboniferous limestone; *c*, diorite and andesite dikes; *d*, diorite porphyry and allied rocks.

the mountain, and are intruded by the igneous complex which makes up the mountain. A fault followed by a dike drops the quartzite beds and limestone to a relatively low level west of the fault, and igneous rocks cut off the limestones on the west.

Sulphide ores carrying ferriferous sphalerite, pyrite, and chalcopyrite occur as replacements of the limestone. Veins are also present but were not examined by the writer. An excellent opportunity to examine the ore bodies of the replacement type was afforded in a development tunnel on the Cleveland group of claims, the property of George H. Utter, of Silver City. Bodies of the same type are also present on claims of C. Amory Stevens, which join the Utter property on the west.

The ore is an intimate intergrowth of sphalerite, chalcopyrite, pyrite, quartz, and ferriferous carbonate. The relative proportion of these constituents may vary considerably, but the ore is usually this mixture. The sphalerite is well crystallized and locally is arranged in roughly linear fashion, the elongated structure of the crystal giving the appearance of banding. Broken transversely to this banding the

mass appears as an irregular mixture of the component minerals. (See fig. 14.)

The sphalerite is apparently crystallized in chains of tetrahedrons. An examination of it with a hand lens shows that very finely crystallized iron and copper sulphides are intergrown with it. Fine crushing would be necessary to make a clean separation.

The main tunnel is 815 feet long and is driven into the hill; the deposits are further prospected by about 1,000 feet of drifts. In addition there are many surface cuts.

An examination of the tunnel and drifts suggests that the ore has replaced definite beds of the limestone in a fairly regular manner. The impression is gained that two distinct ore layers are present, separated by 4 to 15 feet of the limestone. The lower layer is about 12 feet thick; the upper 25 feet or more. These layers are cut by basic dikes and displaced by faults. Figure 15 shows a profile along the main tunnel. It will be seen that the ore layers change their dip from easterly to westerly near the middle of the tunnel, and also that they are cut off apparently by a fault. A drill hole in the floor of the tunnel, 620 feet in from the face, struck ore and it is possible that the missing layers are beneath the floor. Using the data supplied by Mr. Utter on the map of the tunnels and drifts, the writer has constructed a stereogram (fig. 16) to represent pictorially the character of the ore layers, on the assumption that they retain the thickness and attitude suggested by the mine workings. The stereogram is more regular than the ore body can possibly be but serves to suggest its nature and shape. The extension of the ore body to the north and south of the tunnel can be proved only by more developments, for replacement deposits in limestone are as a rule extremely irregular. The work already done, however, has revealed a considerable body of ore.

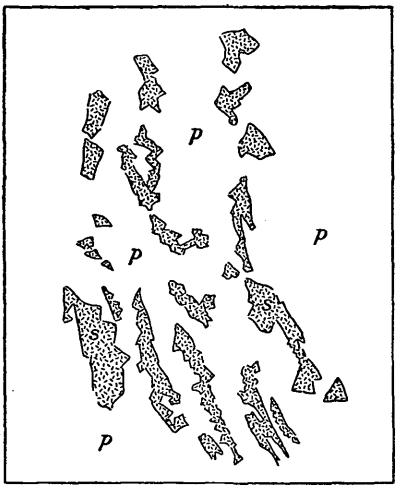


FIGURE 14.—Sketch showing linear arrangement of sphalerite in the Cleveland ore. *s*, Sphalerite; *p*, pyrite.

On the surface extensive gossans are forms composed of a mixture of limonite, zinc carbonate, azurite, and earthy material, with a dark-brown material containing manganese, copper, and iron. Some of the zinc carbonate undoubtedly may be considered ore. It is important to note that a number of these gossans outcrop to the north at an elevation above the sulphide bodies developed under-

ground and may represent the protruding edges of higher replaced ore-bearing beds.

The following assays are reported to be composite assays representing three separate samplings, including that of new ore exposures in the fall and winter of 1909–10. The ground sampled is, for convenience, divided into five blocks. (See plan, fig. 15.)

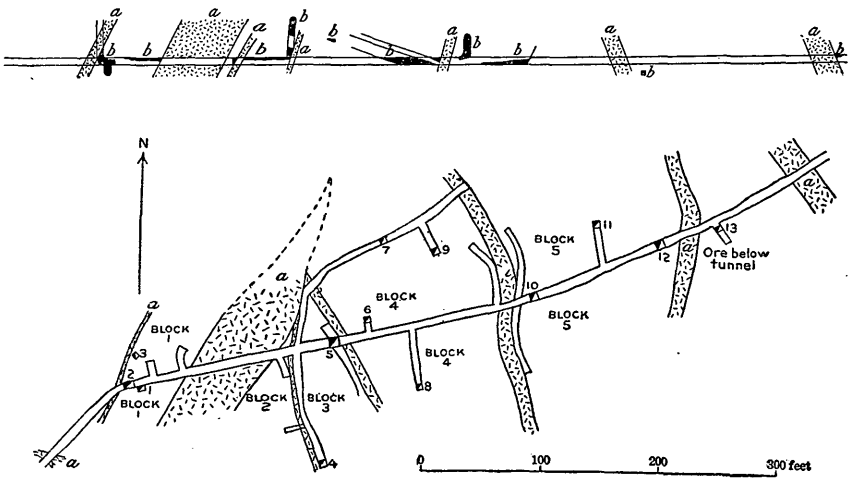


FIGURE 15.—Plan and approximate profile of Cleveland tunnel, showing dikes and location of ore block. *a*, Dikes; *b*, ore; 1, 9-foot winze in ore; 2, 46-foot upraise, gossan and carbonate; 3, 35-foot shaft in carbonates; 4, 10-foot upraise to upper ore body; 5, 47-foot upraise, a lower 12-foot layer of ore separated from an upper 16-foot layer of ore by 12 feet of limestone; 6, 30-foot upraise, ore at top; 7, 22½-foot upraise; 8, 15-foot upraise, ore probably 5 or 10 feet higher; 9, 30-foot upraise, 26+ feet of ore; 10, 26-foot upraise, 18 feet of ore; 11, 25-foot upraise, no ore; 12, 20-foot upraise, no ore; 13, 30-foot upraise, no ore, drill hole to ore 7 feet below raise.

Assays of ore from Cleveland group.

	Silver.	Copper.	Zinc.
	Ounces.	*Per cent.*	*Per cent.*
Block 1	4.80	1.34	16.08
Block 2	2.34	1.68	18.95
Block 3	3.30	2.80	19.00
Block 4	2.67	1.10	19.60
Block 5	2.42	.75	17.11

The samples from which the above assays were computed are reported to include a large number taken from a mixed material adjoining the ore bodies and containing small values, thus reducing the averages. This material will not have to be mined.

In addition to these metals, gold is reported ranging from 20 cents to $1 a ton. The iron and copper pyrite when separated from the sphalerite is reported to average $3 in gold. A car of ore containing an excess of silica and a quantity of wall lime rock was shipped to Denver to be sampled and worked by the Huff process. The ore assayed gold 0.02 ounce, silver 2.80 ounces, copper 1.15 per cent,

zinc 15.32 per cent, iron 22.60 per cent, silica 27.14 per cent, lime 5.60 per cent, and sulphur 23.30 per cent.

The Stevens property, which adjoins the Cleveland group on the west, has many of the characteristics of the deposits just described. From the developments in a tunnel on the property, however, the impression was gained that the limestone was more irregularly replaced, perhaps without definite relation to bedding planes. Silver values are reported to be considerably higher on this property and galena is an important part of the ore mixture.

Origin of the ores.—The ores occurring as beds or irregular masses in the limestones are probably related genetically to the basic rocks which have intruded these limestones. The question might be raised whether the small dikes or the large intrusive mass caused the mineralization. The little evidence that was observed to aid in such a decision is conflicting. As against the introduction of ore by the smaller

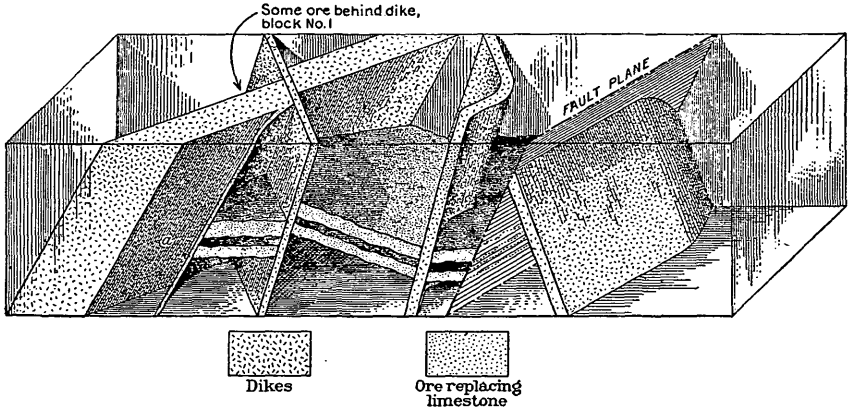


FIGURE 16.—Stereogram showing character of ore layers in Cleveland mine. Ore block No. 2 belongs at point marked "*a*," but is not shown.

dikes it could be said that in the Cleveland tunnel the dikes cut the ore bodies and the ore planes so far as developed continue on their strike and dip irrespective of the dikes. On the other hand, near the face of the Cleveland tunnel, a small patch of ore lies directly against a dike, suggesting a local origin, but this patch was not completely exposed and may have entered from the roof. Against the small dikes is also the fact that some of the dikes cut the limestone with no apparent contact effect on it. Therefore, though it is admitted that the intrusion of the main mass and that of the smaller dikes were probably very close in point of time, it is believed that the major effects of mineralization were produced by the larger body. It is a fair assumption on this hypothesis that more ore will be found as the main igneous mass to the east is approached, and also that other ore layers or bodies may be encountered below as well as above the exposed layers.

SURVEY PUBLICATIONS ON GOLD AND SILVER.

The following list includes the more important publications by the United States Geological Survey, exclusive of those on Alaska, on precious metals and mining districts. Certain mining camps, while principally copper or lead producers, yield also smaller amounts of gold and silver. Publications on such districts are listed in the bibliographies for copper and for lead and zinc. When two metals are of importance in a particular district, references may be duplicated.

These publications, except those to which a price is affixed, may be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.; the monographs from either the Director of the Survey or the Superintendent of Documents.

ARNOLD, RALPH. Gold placers of the coast of Washington. In Bulletin 260, pp. 154–157. 1905. 40c.

BAIN, H. F. Reported gold deposits of the Wichita Mountains [Okla.]. In Bulletin 225, pp. 120–122. 1904. 35c.

BALL, S. H. Geological reconnaissance in southwestern Nevada and eastern California. In Bulletin 285, pp. 53–73. 1906. 60c. Also Bulletin 308. 218 pp. 1907.

BANCROFT, HOWLAND. Reconnaissance of the ore deposits in northern Yuma County, Ariz. Bulletin 451. 130 pp. 1911.

BARRELL, JOSEPH. Geology of the Marysville mining district, Montana. Professional Paper 57. 178 pp. 1907.

BECKER, G. F. Geology of the Comstock lode and the Washoe district; with atlas. Monograph III. 422 pp. 1882. $11.

——— Gold fields of the southern Appalachians. In Sixteenth Ann. Rept., pt. 3, pp. 251–331. 1895.

——— Witwatersrand banket, with notes on other gold-bearing pudding stones. In Eighteenth Ann. Rept., pt. 5, pp. 153–184. 1897.

——— Brief memorandum on the geology of the Philippine Islands. In Twentieth Ann. Rept., pt. 2, pp. 3–7. 1900.

BOUTWELL, J. M. Economic geology of the Bingham mining district, Utah. Professional Paper 38, pp. 73–385. 1905.

——— Progress report on Park City mining district, Utah. In Bulletins 213, pp. 31–40 (25c.); 225, pp. 141–150 (35c.); 260, pp. 150–153 (40c.).

CALKINS, F. C., and MACDONALD, D. F. A geologic reconnaissance in northern Idaho and northwestern Montana. Bulletin 384. 112 pp. 1909.

COLLIER, A. J. Gold-bearing river sands of northeastern Washington. In Bulletin 315, pp. 56–70. 1907.

CROSS, WHITMAN. General geology of the Cripple Creek district, Colorado. In Sixteenth Ann. Rept., pt. 2, pp. 13–109. 1895. $1.25.

CROSS, WHITMAN. Geology of Silver Cliff and the Rosita Hills, Colorado. In Seventeenth Ann. Rept., pt. 2, pp. 269–403. 1896.

CROSS, WHITMAN, and SPENCER, A. C. Geology of the Rico Mountains, Colorado. In Twenty-first Ann. Rept., pt. 2, pp. 15–165. 1900.

CURTIS, J. S. Silver-lead deposits of Eureka, Nev. Monograph VII. 200 pp. 1884. $1.20.

DILLER, J. S. The Bohemia mining region of western Oregon, with notes on the Blue River mining region. In Twentieth Ann. Rept., pt. 3, pp. 7–36. 1900. $1.50.

——— Mineral resources of the Indian Valley region, California. In Bulletin 260. pp. 45–49. 1905. 40c.

——— Geology of the Taylorsville region, California. Bulletin 353. 128 pp. 1908.

DILLER, J. S., and KAY, G. F. Mines of the Riddles quadrangle, Oregon. In Bulletin 340, pp. 134–151. 1908.

——— Mineral resources of the Grants Pass quadrangle and bordering districts, Oregon. In Bulletin 380, pp. 48–79. 1909.

ECKEL, E. C. Gold and pyrite deposits of the Dahlonega district, Georgia. In Bulletin 213, pp. 57–63. 1903. 25c.

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