CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1929

PART I. METALS AND NONMETALS EXCEPT FUELS

THE NEW WORLD OR COOKE CITY MINING DISTRICT, PARK COUNTY, MONTANA

By T. S. LOVERING

INTRODUCTION

In the pioneer days of Montana the New World mining district was regarded as one of its most promising camps. In the early eighties Cooke had a population of over 2,000. Specimens of rich ore reputed to come from the vicinity of Cooke may be seen in many cities and camps remote from the district, but little information has hitherto been available as to the geology and mining. To supply this need the district was studied and mapped during the summers of 1922 and 1923.

FIELD WORK AND ACKNOWLEDGMENTS

The writer was at Cooke from June 5 to September 10, 1922, and spent most of this time in making the topographic map that accompanies this report. The interval from June 10 to September 5, 1923, was devoted to a study of the geology of the district. About six weeks in July and August, 1925, was spent in completing the reconnaissance maps of the Goose Lake area and studying the recent mining developments. The writer was assisted by W. C. Werner in 1922 and by C. W. Gray in 1922, 1923, and 1925.

It is impossible to acknowledge adequately the assistance rendered by all those encountered during the field work, but the writer wishes to express his appreciation of the uniform courtesy, help, and consideration which he received from everyone with whom he came into contact in the New World mining district. Special mention should be made of Messrs. L. H. Brooks, N. J. Tredennick, F. C. Byrne, Harry Stinson, Gus Solomonson, and Jack Allen, who furnished

valuable information which is incorporated in this report. Thanks are also due to Mr. J. T. Pardee, of the United States Geological Survey, for the use of material which he gathered in 1918.

BIBLIOGRAPHY

In the following bibliography the most comprehensive papers are marked with an asterisk.

REFERENCES ON THE NEW WORLD MINING DISTRICT

*Brooks, L. H., New World mining district: Min. and Sci. Press, May 14, 1921, p. 682.

*Gardiner, E. D., Northwestern mining districts: Min. and Sci. Press, vol. 108, pp. 880–884, 1914.

*Hague, Arnold, and others, Geology of the Yellowstone National Park: U. S. Geol. Survey Mon. 32, pt. 2 and atlas, 1899.

Hayden, F. V., U. S. Geol. Survey Terr. Sixth Ann. Rept., p. 47, 1873.

Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, p. 117, 1912.

Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains for 1874, p. 324, 1875.

Swallow, G. C., Montana Min. Jour., Nov. 30, 1889; May 10, 1890.

U. S. Geol. Survey Mineral Resources, 1906, p. 283; 1908, pt. 1, p. 638; 1917, pt. 1, p. 359; 1918, pt. 1, p. 293; 1919, pt. 1, p. 525; 1920, pt. 1, p. 214; 1921, pt. 1, p. 301; 1922, pt. 1, p. 480; 1923, pt. 1, p. 471; 1924, pt. 1, p. 358.

REFERENCES ON THE REGIONAL GEOLOGY

*Bevan, Arthur, Summary of the geology of the Beartooth Mountains, Mont.: Jour. Geology, vol. 31, pp. 441–465, 1923.

——— Rocky Mountain peneplains northeast of Yellowstone Park: Jour. Geology, vol. 33, pp. 563–587, 1925.

Condit, D. D., Relations of late Paleozoic and early Mesozoic formations of southwestern Montana and adjacent parts of Wyoming: U. S. Geol. Survey Prof. Paper 120, pp. 111–121, 1918.

Darton, N. H., Coals of Carbon County, Mont.: U. S. Geol. Survey Bull. 316, pp. 174–193, 1907.

Emmons, W. H., Geology of the Haystack stock, Cowles, Park County, Mont.: Jour. Geology, vol. 16, pp. 193–229, 1908.

Hague, Arnold, U. S. Geol. Survey Geol. Atlas, Absaroka folio (No. 52), 1899.

Iddings, J. P., U. S. Geol. Survey Geol. Atlas, Yellowstone National Park folio (No. 30), 1896.

——— and Weed, W. H., U. S. Geol. Survey Geol. Atlas, Livingston folio (No. 1), 1894.

Tomlinson, C. W., The middle Paleozoic stratigraphy of the central Rocky Mountain region: Jour. Geology, vol. 25, pp. 112–134, 244–257, 373–394, 1917.

Westgate, L. G., Deposits of chromite in Stillwater and Sweet Grass Counties, Mont.: U. S. Geol. Survey Bull. 725, pp. 67–84, 1921.

Woodruff, E. G., The Red Lodge coal field, Mont.: U. S. Geol. Survey Bull. 341, pp. 92–107, 1909.

The articles by Gardiner and Brooks give a very good summary of the history of mining and the conditions of mining operations up to 1921. They also contain brief descriptions of the general geology of the New World mining district and are the best accounts which have thus far appeared. Bevan's paper on the Beartooth Mountains is one of the best descriptions of the regional geology and also contains a good bibliography.

LOCATION AND MEANS OF ACCESS

The New World mining district is in Park County, Mont., in the mountainous country northeast of the Yellowstone National Park. As shown in Figure 1 the intersection of the 45th parallel and the 110th meridian makes its southwest corner. It is reached by way of Gardiner, Mont., from which it lies about 40 miles due east, or 57 miles by road. The district has an extent of about 10 miles from north to south and 5 miles from east to west. The only settlement is the small mining town of Cooke, which lies in the valley of Soda Butte Creek, in the southern part of the district, at an altitude of about 7,600 feet. As illustrated by Plate 2, Cooke is in the heart of a beautiful mountain region. At present the population ranges from about 75 in the winter to over 200 in the summer. Summer tourists and miners who have claims upon which assessment work must be done make up most of the summer population.

All supplies are freighted from Gardiner. Red Lodge, Mont., is closer to Cooke by air line, but some of the highest and most rugged mountains of Montana separate them, and there is no direct road between the two places. An automobile road is under construction which will eventually permit communication between them and provide Cooke with another outlet. A proposed route leads north from Cooke to Columbus, Mont., by way of the Stillwater River, but although the survey has been made and a railroad promised, construction work started at Columbus has been prosecuted in a desultory manner, and little progress has been made. Thus in 1925 the only practicable means of communication between Cooke and a railroad was by teams or automobile truck over the stage road to Gardiner. Freighting to Gardiner costs about 1 cent a pound, a rate that prohibits the shipping of any but high-grade ore.

Sporadic attempts have been made from time to time to run smelters near Cooke, but as the nearest coal fields are at Red Lodge, a long haul is now necessary to bring the coal from the mines to Cooke. If transportation should become available between these two towns, it might be possible to smelt ores economically in the district, but in 1922 coke cost $40 a ton at Cooke, and this price was prohibitive. In the early history of the camp charcoal was used, but cutting and burning of timber for this purpose has been forbidden by State law for a number of years.

GEOGRAPHY

REGIONAL GEOGRAPHY

The New World district lies in the vast area included in the Cordilleran Rocky Mountain system, in the physiographic province known as the northern Rocky Mountains. (See fig. 1.) The Yellowstone River, gathering volume from many divergent tributaries in the Yellowstone National Park, flows north through a wide intermontane valley separating the Gallatin Mountains on the west from the Snowy Mountains on the east. Near Livingston, Mont., 60 miles north of the park, the stream turns eastward around the north flanks of the Snowy Mountains. In the vicinity of Billings, augmented from the south by the waters of Clark Fork of the Yellowstone, it bends slightly to the north and follows a northeasterly course to the Missouri River through the Great Plains of eastern Montana and western North Dakota. The broad, rugged uplift delimited on the west and north by the Yellowstone River and on the east by Clark Fork of the Yellowstone is the northward continuation of the Absaroka Range of Wyoming. The steep eastern edge of the range is known as the Beartooth Mountains; the western part is called the Snowy Mountains. A high granite plateau, deeply carved by canyons, forms the backbone of the range and is termed the Beartooth Plateau. This plateau lies chiefly to the east of the center line of the uplift and contains the highest mountain country in Montana. Granite Peak, 12,850 feet above sea level, is the highest peak in the State and lies about 15 miles northeast of the Yellowstone National Park and a few miles northeast of the region mapped in this report. The Beartooth Plateau was formerly covered by an extensive ice sheet, which drained into the surrounding country through many valley glaciers. The tongues of ice radiating from the ice cap trenched valleys thousands of feet below the mountain tops. Hanging valleys, gemlike mountain lakes, polished granite ledges (roches moutonnées), and deeply scarred cirques mutely attest the tremendous sculpturing of the ice. A few glaciers still linger in the high country. The New World mining district lies in this region of rugged and inspiring beauty, where the Snowy Mountains merge eastward into the Beartooth Plateau and southward into the Absaroka Range of Wyoming.

TOPOGRAPHY AND DRAINAGE

The area discussed in this report is entirely mountainous. The valley floors range in altitude from 7,500 to 9,000 feet and some of the neighboring peaks reach more than 11,000 feet.

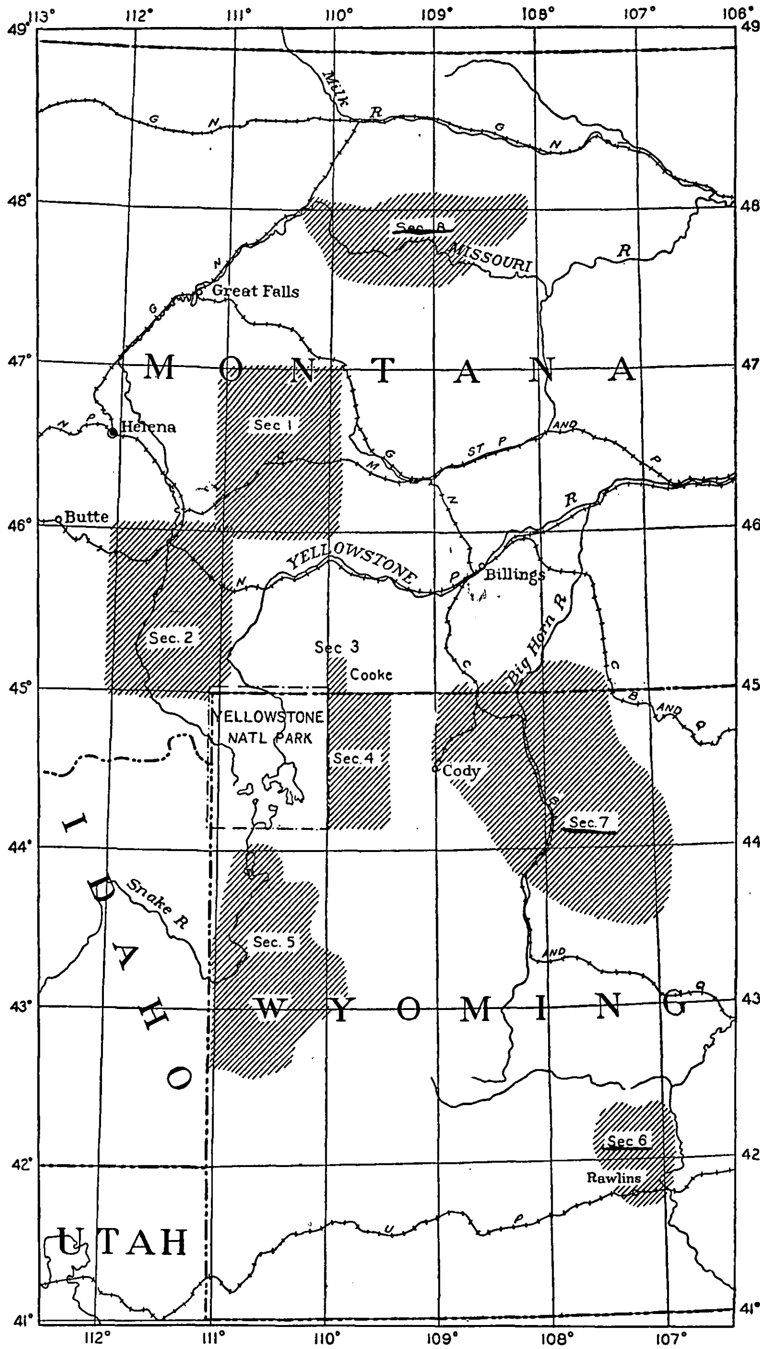

FIGURE 1.—Index map showing location of New World mining district, Montana. Shading indicates areas represented by sections in Plate 6

The district is drained by the headwaters of three tributaries of the Yellowstone River. (See fig. 1.) Soda Butte Creek and Clark Fork of the Yellowstone drain the southern part, and the Stillwater River and its tributary Goose Creek the northern part. Soda Butte Creek flows across the southwestern part of the district from east to west. It receives two major tributaries from the northwest, Sheep Creek and Miller Creek, and one from the south, Republic Creek, which joins it at the town of Cooke. Clark Fork of the Yellowstone follows a northerly course and is separated from the headwaters of Soda Butte Creek by a low divide less than a mile across. The Stillwater River heads in the northwestern part of the district and empties into the Yellowstone River near Columbus, 60 miles to the northeast. About 3 miles north of its source it is joined by Goose Creek, which carries the drainage of Goose Lake, a few miles to the east. Many of these streams occupy valleys which show the effect of profound mountain glaciation, and hanging valleys and steep-sided U-shaped valleys are characteristic features of the topography.

The course of many of the smaller streams is strongly influenced by jointing and faulting in the bedrock and is well illustrated by Republic Creek. Most of the numerous beautiful waterfalls in the district are caused by the presence of a hard mass of intrusive rock in the soft Gros Ventre formation, as shown in Plate 5, *A*. Only a few of the waterfalls are caused by differential erosion of hard and soft members of the sedimentary rock themselves.

There are only two mountains south of Soda Butte Creek within the district. Republic Mountain, in the south-central part is separated from Woody Mountain, to the east, by the valley of Republic Creek.

North of Soda Butte Creek an irregular divide trending northeastward runs diagonally across the district and separates the Stillwater River drainage basin from those of Soda Butte Creek and Clark Fork of the Yellowstone. This divide contains many lofty peaks, and prominent among them is Silver Mountain, towering above the valley of Soda Butte Creek in the southwest and giving the visitor to Cooke an impressive greeting as he leaves Yellowstone National Park. Against the dark background of the lavas which cap this peak its long silver-gray talus slides stand out conspicuously and give the mountain its name. Immediately across the valley of Sheep Creek, Miller Mountain rises as a knife-edged divide, reaching an altitude of 10,500 feet. At the head of Miller Creek Crown Butte stands out boldly as a steep-sided pile rising 600 feet above Daisy Pass. Henderson Mountain, between Miller Creek and the valley of Clark Fork of the Yellowstone, has a gentle western slope that presents a marked contrast to its precipitous eastern side. Red Mountain lies north of Henderson Mountain and derives its name from its iron-stained flanks. Scotch Bonnet Mountain, reaching an altitude of 10,485 feet, stands at the head of the valley of Clark Fork of the Yellowstone. East of it, Sheep Mountain rises to an altitude of 10,700 feet, and here again we find a gentle western slope and a very precipitous cliff-like slope on the east.

From the top of Sheep Mountain the region to the east and north presents a great contrast to that which lies to the south, southwest, and west. The granite country to the northeast was formerly covered by a great ice sheet and presents the knob and kettle topography so characteristic of glaciated surfaces. Scattered over this area are 15 or 20 small lakes, and to the west and southwest there is a wide expanse of rugged mountain peaks, sharp, deep valleys, and sparkling streams. Plates 3 and 4, *A*, well illustrate the characteristics of the heavily glaciated region. On a clear day the Grand Tetons may be seen, a hundred miles to the southwest.

Goose Creek occupies a canyon whose walls rise 1,000 feet above the stream. It has a steep gradient, for it heads in Goose Lake at an altitude of nearly 10,000 feet and empties into the Stillwater River, 4 miles to the southwest, at an altitude of less than 7,900 feet. Goose Lake is surrounded by the highest mountains of the district. Mount Fox, to the west, attains an altitude of 11,250 feet. The Sawtooth Mountains, to the north, rise to 11,600 feet, and Mount Zimmer, to the east, reaches 11,680 feet. Northeast of the lake, across Glacier Divide, is Grasshopper Glacier. This glacier, famous for the entombed grasshoppers which it contains, drains northeastward into East Rosebud Creek.

CLIMATE

Many of the mountains are snow capped the entire year, but the snow melts from the valleys in June, and automobile traffic between Cooke and Gardiner starts late in May. During June, July, August, and September the climate is ideal. Snowstorms may occur in any month of the year, but the snow seldom comes to stay until late in the fall, and automobile stage service with Gardiner sometimes continues until December. December, January, February, and March are the only months that bring much snow, but by spring drifts in the passes often attain a depth of 75 feet. Through this season mail service is maintained once a week by means of horses, dog teams, and snowshoes. There is seldom at any season of the year a distance of more than 8 miles which can not be traversed by horses. As the snows melt in April and May, these are the months of the spring floods, and during this time the snow disappears with great rapidity and makes travel of any sort very difficult. Mute evidence of the heavy winter snowfall is given by the snowslide scars illustrated in Plate 4, *B*.

VEGETATION

The southern part of the district is heavily forested, but toward the granite country, to the north, timber becomes noticeably less abundant, and north of Goose Creek it is practically absent. Close to the streams a heavy growth of willow and black alder is common, and the lower slopes of the mountains carry spruce, balsam, fir, lodgepole pine, and a small amount of cedar. The higher slopes support juniper and limber pine. The district lies in the Beartooth National Forest, and thus the timber is well guarded by competent rangers, and an adequate supply of lumber for mining operations is available.

Grass is abundant in the valleys and in many open, parklike spaces in the mountains, providing abundant forage for horses and for the wild game that abounds in the district, and these areas are also thickly carpeted with wild flowers.

INDUSTRIES

Ever since the early settlement of Cooke it has been an outfitting center for prospectors, and in recent years it has furnished supplies for the stock raisers, who yearly take advantage of the excellent summer forage found in the mountain valleys near by. Although mining has been the most important industry carried on for a great many years, in some seasons the revenue derived from the tourist camp erected in 1921 exceeds that coming from the mines in their semidormant state. Trapping is carried on to some extent in the winter.

REGIONAL GEOLOGY

The front ranges of the Rocky Mountains are in general broad arches or anticlinal folds along whose eastern and western fronts the formations have been tilted at very steep angles. Fracturing frequently accompanies such severe deformation, and along the borders of the mountains some of the folds pass into faults many miles in length. In these ranges erosion has stripped the cover most rapidly from the centers of the anticlines and exposed ovate areas of pre-Cambrian rocks girdled by Paleozoic and Mesozoic sediments. Igneous activity frequently but not invariably accompanied the formation of the front ranges; and in the Beartooth Range, in which the New World mining district lies, folding, faulting, intrusion, and extrusion have all played their part.

The Beartooth and Snowy Mountains constitute an elongated dome which rises in northern Wyoming near the canyon of Clark Fork of the Yellowstone River and extends northwestward to the valley of the Yellowstone near Livingston, Mont. Along the axis of this anticline there is an extensive belt of pre-Cambrian crystalline rocks 20 to 25 miles wide, bounded on both sides by sedimentary rocks that partake of the anticlinal structure.[1] Along the northeastern flank the whole Paleozoic and Mesozoic section is exposed, but on the opposite side the Mesozoic formations are mostly hidden by volcanic rocks of Tertiary age except at the ends of the long anticline.

The Paleozoic strata of the region are usually divisible into eight formations and include rocks of Cambrian, Ordovician, Devonian, Mississippian, and Pennsylvanian age. These formations consist predominantly of limestone and have a total thickness of 2,000 to 3,500 feet. Mesozoic rocks are lacking in the New World mining district but are well shown on the northeast side of the great uplift, where they consist largely of shale and sandstone and attain a thickness of over 5,000 feet. Both Paleozoic and Mesozoic beds formerly extended across the pre-Cambrian area, from which they have been removed by erosion since the upthrusting of the broad anticline near the end of Mesozoic time. Where the sedimentary rocks are now exposed they exhibit a very rugged surface, and it was upon similar topography that a thick series of Tertiary lava was spread in Eocene and Miocene time.

The New World mining district lies on the southwest flank of the great Beartooth-Snowy Mountain anticline, within the region where erosion has bitten deeply into the uplift and exposed both Paleozoic sediments and rocks of the crystalline complex. Thick accumulations of effusive volcanic rocks rest with marked unconformity upon the earlier formations. In the Yellowstone National Park six sets of extrusive rocks have been distinguished.[2] Only two of these, the early acidic breccia and the early basic breccia, are generally present in the northeastern border of the volcanic plateau region of the park, although basalt flows representing a third set occur in the high mountains immediately southeast of Cooke. On the basis of fossil plants occurring in tuffs and intercalated sediments an Eocene age has been assigned to the early acidic breccia.[3] Neither the original nor the present extent of this formation can be determined, as it had been deeply eroded before the extrusion of the basic breccia began, and it is widely buried by younger effusive rocks, which in many

[1] Bevan, Arthur, Jour. Geology, vol. 31, pp. 448, 457, 1923.

[2] Iddings, J. P., U. S. Geol. Survey Geol. Atlas, Yellowstone National Park folio (No. 30), 1896.

[3] Idem, p. 2.

places rest on formations older than the early acidic breccia. The early acidic breccia is exposed only where formerly buried masses, some of which are of mountainous proportions, have been exhumed by the stripping and trenching of the younger volcanic rocks. The flora found in the early basic breccia at Specimen Ridge was first assigned to late Miocene time,[4] but recent work by Knowlton[5] suggests that it may be much earlier, although it probably should still be classed as Miocene. A discussion of its probable age will be found on page 31. Valleys that were several thousand feet deep were filled by the Miocene breccias and basalts, and the volcanic activity of this time completely obliterated the preexisting topography.

The source or sources of the volcanic rocks is an interesting problem to the volcanologist. At three localities in the Crandall quadrangle, south of the New World district—in the Sunlight mining district, at Hurricane Mesa, and at Sunlight Basin—composite bodies of gabbro, diorite, and syenite occur with the form of typical stocks and are thought to be the volcanic conduits of the early basic breccias near by. The localities named are about 15 miles apart and they define a triangle so oriented that the apex at Hurricane Mesa is directed toward the New World district, 15 miles distant to the northwest. Near Cooke gabbro stocks and other intrusive masses occur along the pre-Cambrian and Paleozoic boundary, and near Goose Lake, 7 miles farther north, there are stocks of three sorts of granular rocks cutting pre-Cambrian granite. At Haystack Peak, 12 miles northwest of Cooke, a stock composed of gabbro, diorite, and related rocks occurs at the edge of the pre-Cambrian terrain, just where the ancient rocks are overlapped by the acidic breccia that constitutes the base of the volcanic series.

The bodies of granular rocks in the Crandall quadrangle break through several thousand feet of rudely bedded basic breccia, and, as shown by Iddings,[6] the stocks occupy the pipes of volcanoes that were active during the later part of the basic breccia epoch. The stocks at the three localities to the northwest, though more deeply eroded, are believed to be volcanic necks belonging to the same general period.

Southeast of the New World district for many miles the Paleozoic formations exposed along the border of the pre-Cambrian terrain are not invaded by bodies of igneous rock other than narrow dikes. From the locality of Cooke northwestward as far as the valley of Yellowstone River the pre-Tertiary sediments, especially those mak-

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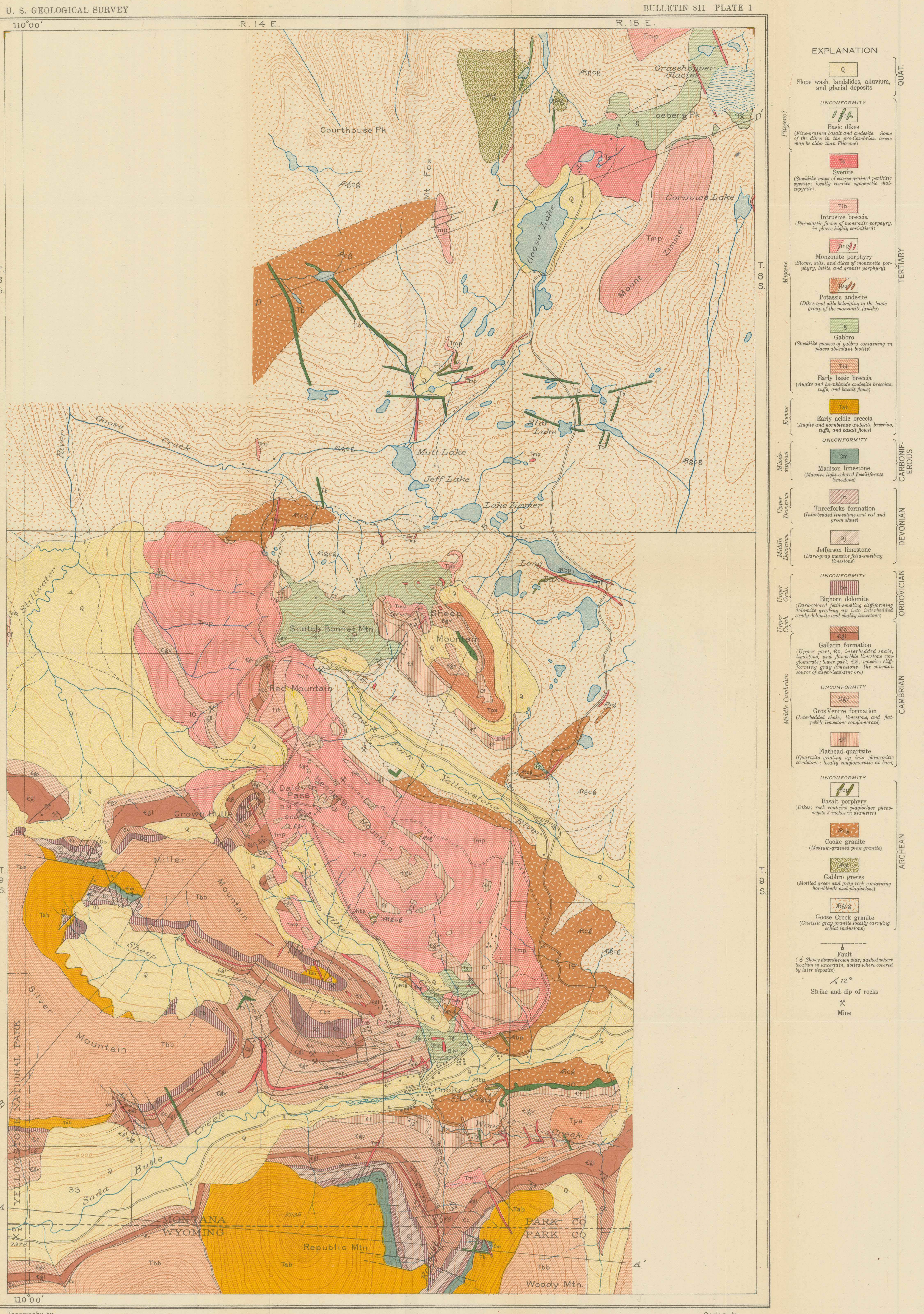
[4] Hague, Arnold, The age of the igneous rocks of the Yellowstone Park: Am. Jour. Sci., 4th ser., vol. 1, pp. 451–452, 1896.

[5] Knowlton, F. H., Flora of the Latah formation of Spokane, Wash., and Coeur d'Alene, Idaho: U. S. Geol. Survey Prof. Paper 140, p. 17, 1926.

[6] Iddings, J. P., Geology of the Yellowstone National Park: U. S. Geol. Survey Mon. 32, pt. 2, p. 232, 1899.



Topography by T. S. Lovering Surveyed in 1922 and 1923

Geology by T. S. Lovering, 1923 and 1925

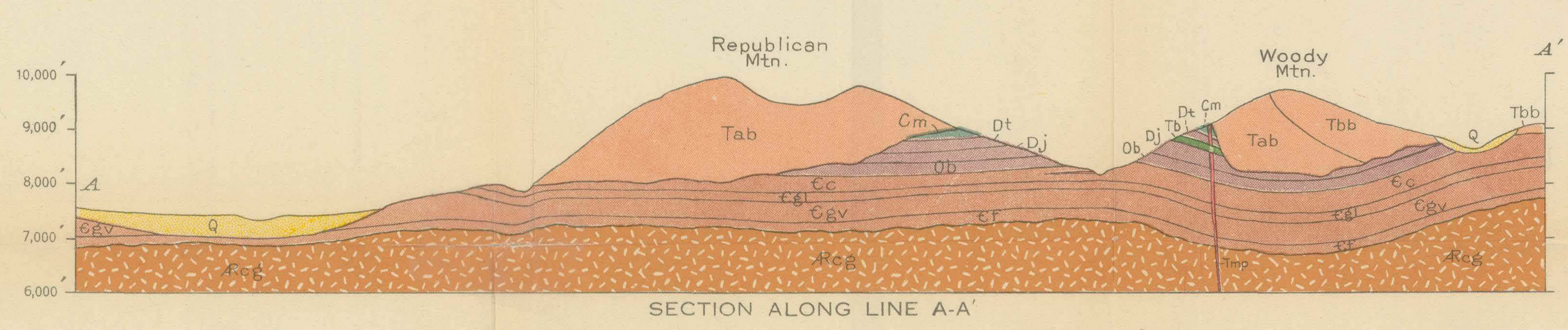
TOPOGRAPHIC AND GEOLOGIC MAP AND SECTIONS OF THE NEW WORLD MINING DISTRICT, MONT.—WYO.

Scale $\frac{1}{31,680}$

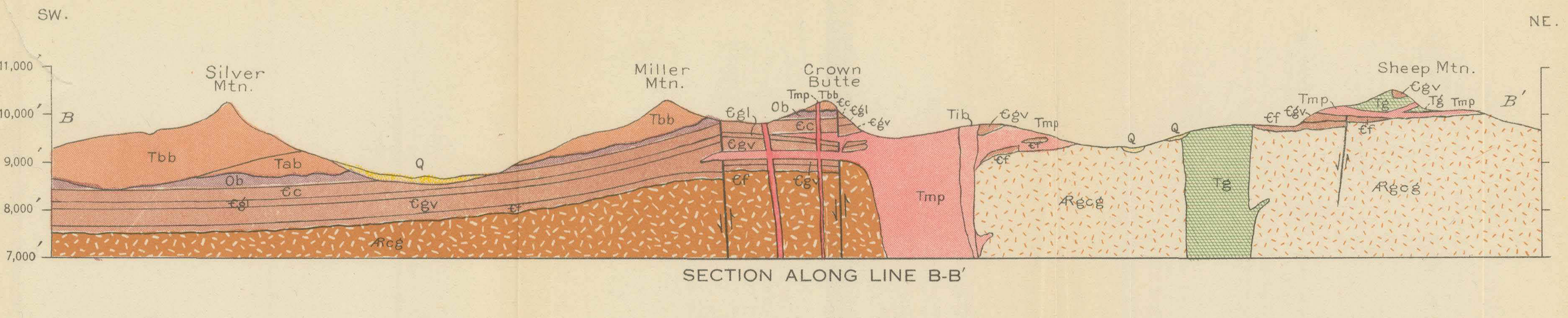
0 — 2 Miles

Contour interval 100 feet

1929



SECTION ALONG LINE A-A'



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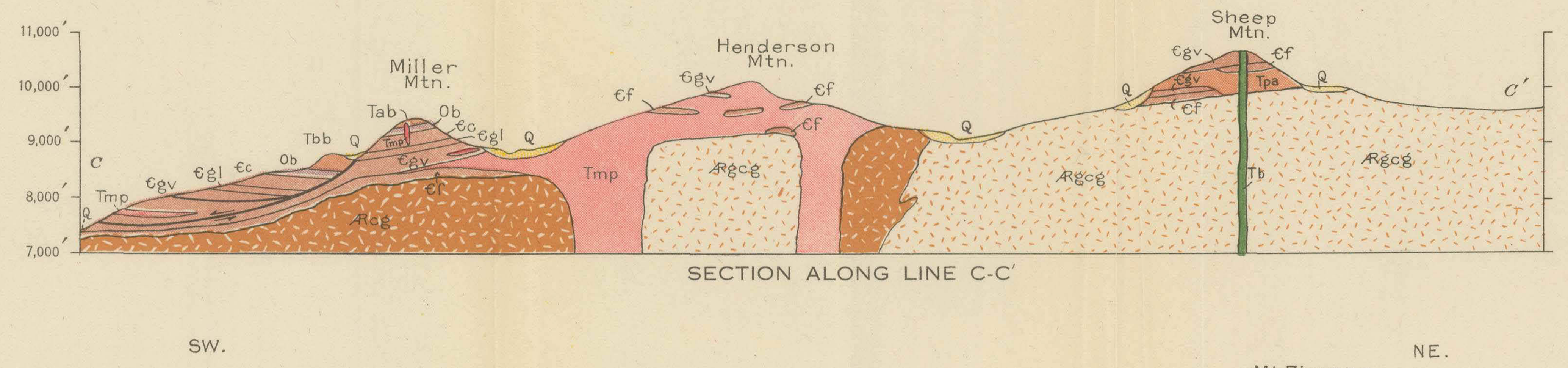

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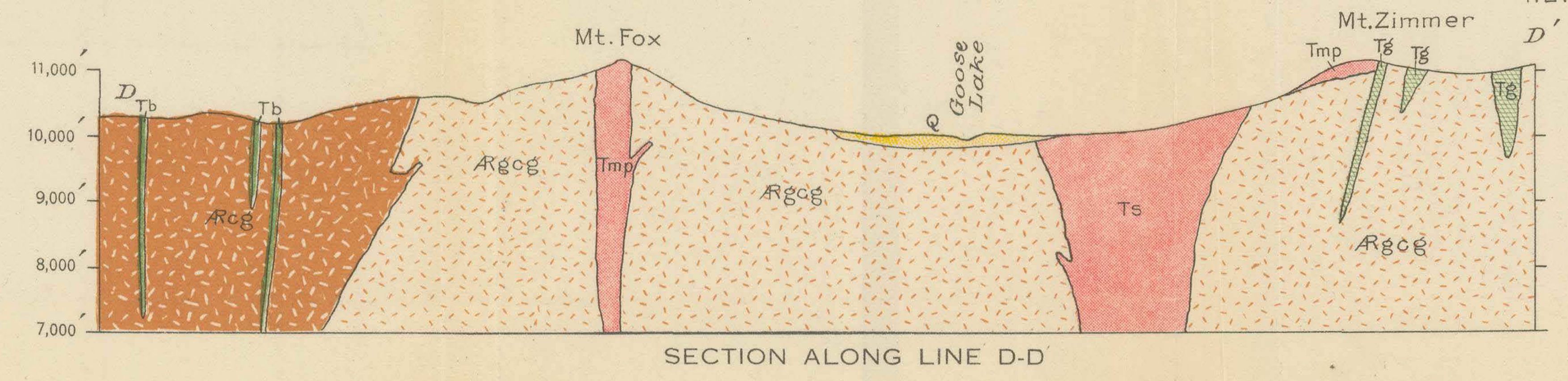

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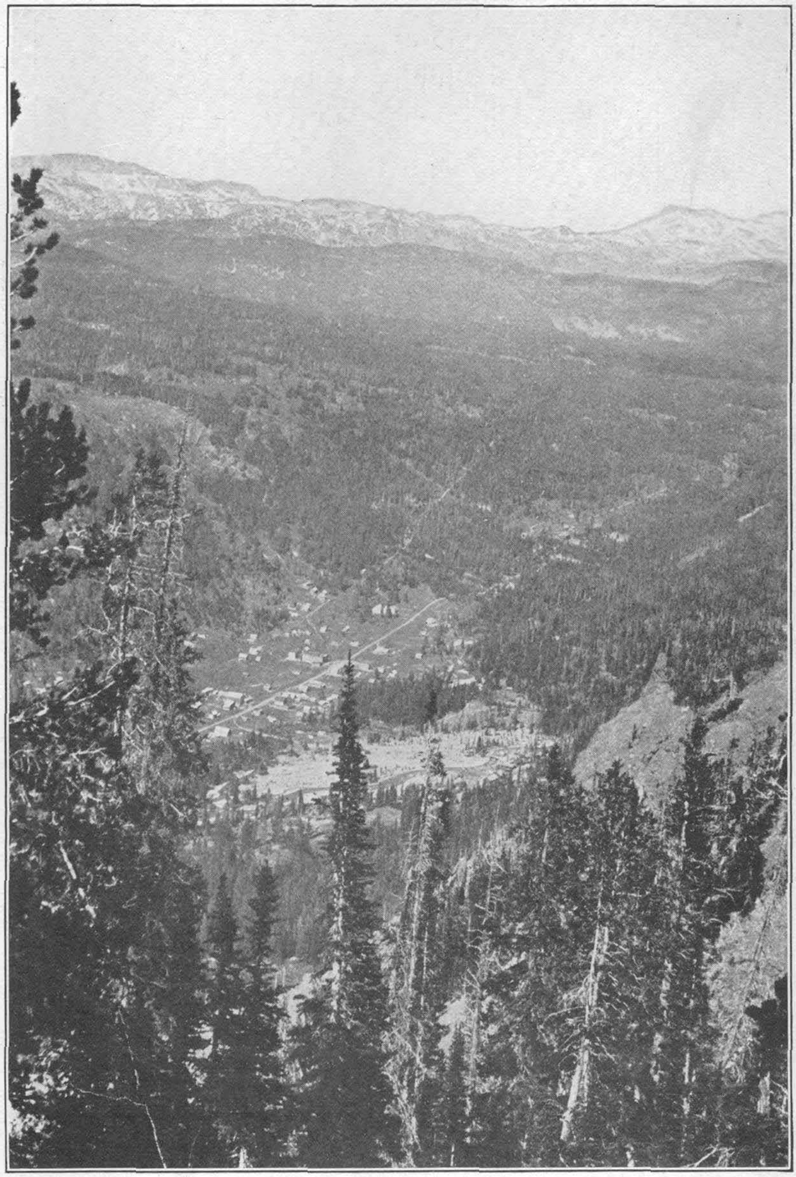
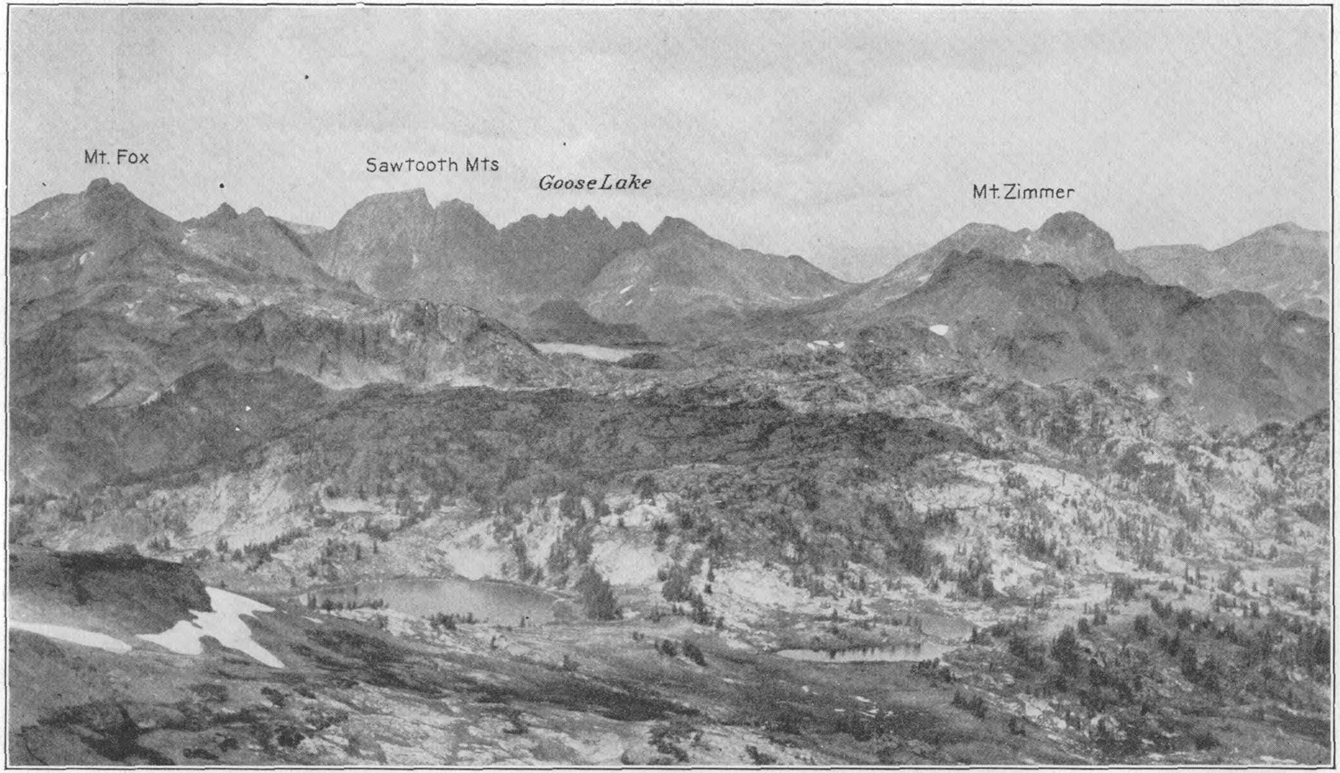


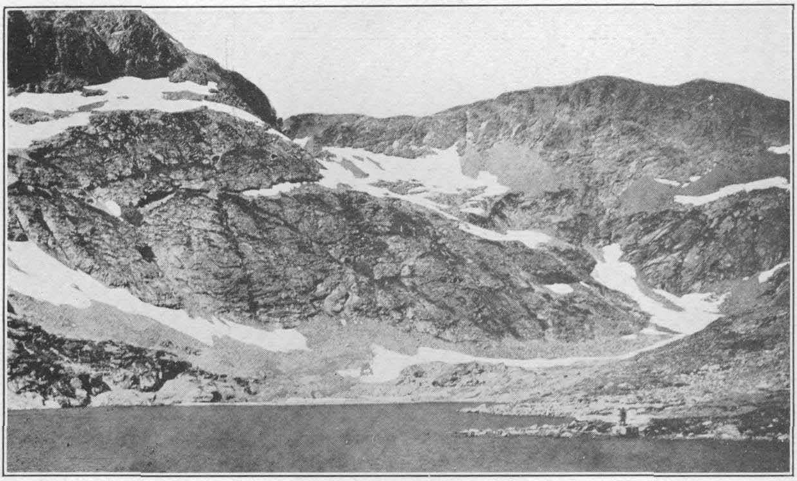
COOKE, MONT.

View looking east from north slope of Republic Mountain. A cliff of early acidic breccia stands in right foreground



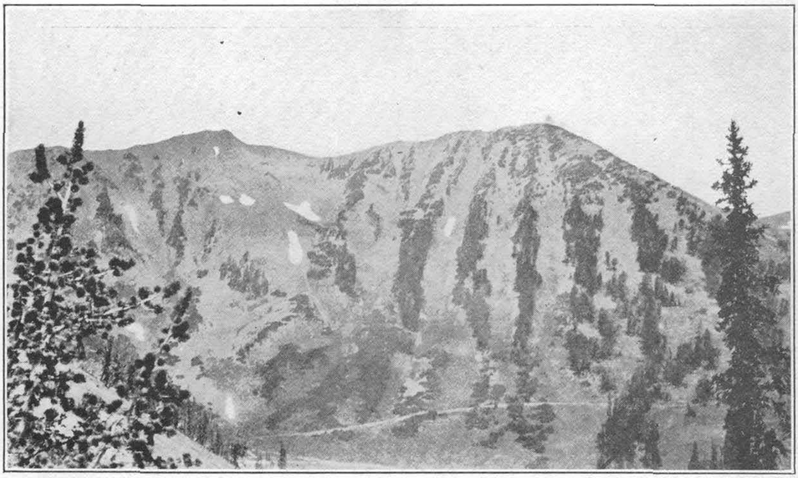
VIEW LOOKING NORTH FROM THE TOP OF SHEEP MOUNTAIN, MONT.

The rugged topography is typical of the heavily glaciated granite area



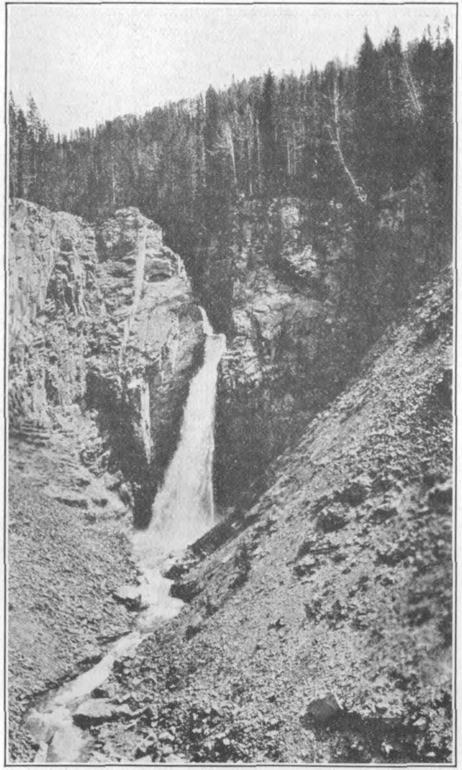
A. CORINNES LAKE, A STEEP-WALLED TARN NEAR GRASSHOPPER GLACIER, MONT.

This recent cirque shows the effect of vigorous glacial sapping. Iceberg Peak in left background. The man in right foreground indicates the scale



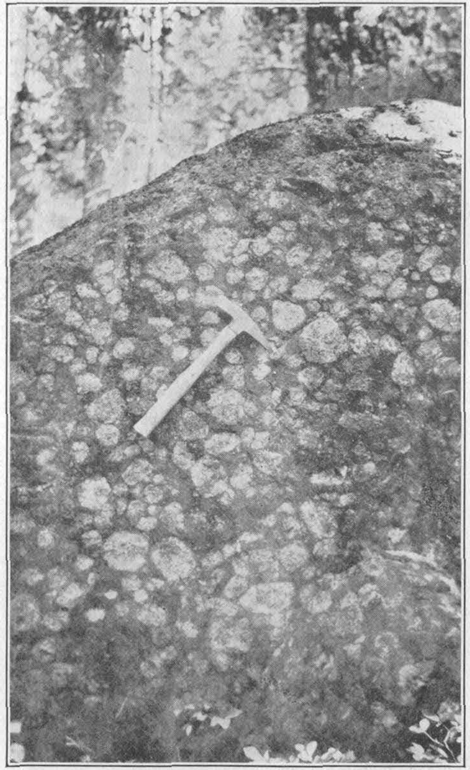
B. SCOTCH BONNET MOUNTAIN, MONT.

View looking north from Henderson Mountain. The course of recent snowslides is clearly shown



A. HAYDEN FALLS, WOODY CREEK, MONT.

The falls are caused by a thick sill of potassic andesite porphyry in the soft Gros Ventre shales



B. COARSE-TEXTURED ARCHEAN BASALT PORPHYRY NEAR COOKE, MONT.

ing up the lower part of the section, have been intruded in many places by sills of basalt, dacite, or andesite. In a few places along this border, in addition to dikes and sills, there are large masses of the same or closely related rocks, some of which are irregular laccoliths, and others break directly across the sedimentary bedding planes.

Emmons regards the andesite-dacite sills that invade the Cambrian sandstone, shale, and limestone in the vicinity of Haystack Mountain as the oldest Tertiary intrusive rocks of this district,[7] but he makes no definite statement concerning the relative age of the stocklike bodies of similar rock that occur east and south of the Haystack stock of gabbro and diorite.

At Emigrant Gulch, on the east side of the Yellowstone Valley a few miles north of Gardiner, a large mass of dacite-andesite porphyry associated with monzonite porphyry breaks through the early basic breccia,[8] and some of the large bodies of similar rocks occurring in the southeastern part of the Livingston quadrangle west of the New World district probably exhibit the same relation.

In the New World district a large mass of porphyritic monzonite which breaks through the Paleozoic formations is known to be younger than part of the basic breccia from the fact that the lower beds of the volcanic formation, though not actually in contact with the igneous rock, are found to be considerably metamorphosed in its vicinity. Where gabbro and porphyritic monzonite (belonging to the acidic porphyrite group) are in contact, the monzonite is believed to be younger than the gabbro. Elsewhere rocks of the granular and porphyritic groups are not known to come together.

All the formations that have been mentioned are cut by narrow dikes of many varieties of basic rocks. Such dikes are especially numerous near some of the old volcanic vents, and from this fact it appears that they represent the latest extrusions from these centers of igneous activity.

Close to the igneous intrusions the country rocks are more or less indurated and metamorphosed, the degree of alteration varying with the physical and chemical character of the invaded rocks, on the one hand, and with the form, size, and composition of the invading masses, on the other. Within the major uplifts of this part of the Rocky Mountains mineral deposits containing sulphides of iron, copper, lead, and zinc with or without noteworthy amounts of silver and gold occur mainly in or close to those large intrusive masses of stocklike character. This association is illustrated in the

[7] Emmons, W. H., Geology of the Haystack stock, Cowles, Park County, Mont.: Jour. Geology, vol. 16, p. 201, 1908.

[8] Iddings, J. P., Geol. Soc. London Quart. Jour., vol. 52, p. 612, 1896.

Boulder, New World, and Sunlight mining districts and 40 miles farther to the southeast in the Kirwin district. The occurrence of the ore in these localities goes hand in hand with the presence of intrusive rocks, but such ores usually occur in or near stocks of essentially even-grained rocks that include gabbro, diorite, and syenite. This mode of occurrence is typical of the ore deposits of Montana and other Northwestern States, where most of the metallization is related to granites or granitoid rocks, whereas intrusive rocks that have dense or porphyritic instead of granular texture, even though large and of cross-breaking form, are usually accompanied by metallization on only a moderate or minor scale. In Montana ore deposits are rarely found in or near porphyries except where the porphyries are cut by younger bodies of granular rock, but the region under discussion is an exception to this general rule. In the Emigrant mining district, on the east side of the Yellowstone Valley north of Gardiner, at a few points near the west side of the Livingston quadrangle, and in the New World district there are ore deposits closely associated with cross-breaking masses of rocks belonging in the acidic porphyrite group of Iddings. In the New World district the rock of this group is a monzonite porphyry. Ore deposits associated with monzonite porphyries are fairly common in the Southwest but unusual in this part of the Rocky Mountains.

GEOLOGY OF THE DISTRICT

OUTLINE OF THE GEOLOGY

The bedrocks over about half of the New World district are of pre-Cambrian age. Paleozoic sedimentary rocks cover about one-third of the district. Mesozoic sediments are lacking. Some water-laid tuffs of Tertiary age are present in the volcanic breccias. A thin mantle of glacial drift covers the older rocks in many places but has not been mapped except where doubt exists as to the distribution of the bedrock formations which it hides. Landslides are abundant, and alluvial deposits are present in most of the stream valleys.

The Snowy Mountains, in which the New World mining district lies, are due to a broad anticlinal Laramide uplift that trends northwest. As the region is slightly to the west of the axis of this uplift the pre-Tertiary sediments have a general dip to the southwest. The rocks present include pre-Cambrian schist, gneiss, and granite, Paleozoic sedimentary rocks, Tertiary volcanic and intrusive rocks, and Quaternary deposits. Erosion has removed the Paleozoic and younger formations from the northeastern part of the district, exposing the Archean complex, but in the southwest the pre-Cambrian is not uncovered.

Stocks and other intrusive rocks of Tertiary age are well developed in the center of the district, and numerous dikes and sills attest intrusive activity in the southern part. Faulting took place in Tertiary time, and four main systems of faults and related fissures are recognized. In their probable chronologic order from oldest to youngest, these trend east, N. 20° W., N. 55° E., and N. 30° E. The stresses that produced these faults have also produced joints parallel to the corresponding faults in the more competent beds.

Extensive mineralization has taken place. Contact metamorphism has developed gold and copper deposits in the vicinity of Henderson Mountain, and in the surrounding region lead-silver-zinc ores commonly occur as replacement deposits and veins. At Goose Lake, in the northern part of the district, there is a deposit of chalcopyrite formed by magmatic segregation which carries appreciable quantities of platinum. The region near this deposit has not been thoroughly prospected but is known to contain some promising lead-silver veins.

GEOLOGIC HISTORY

In pre-Cambrian time the country suffered intense regional metamorphism and the intrusion of many different granite magmas. An enormous period of time elapsed during which erosion cut this district to a nearly featureless peneplain exposing these acidic plutonic rocks to a great depth. Early in Paleozoic time subsidence took place, and basal conglomerates and sandstones (Flathead quartzite) were deposited in the shallow Middle Cambrian sea. As the waters deepened the deposits became argillaceous, and evidence of offshore deposition is found in the interbedded limestone and shale that make up the Gros Ventre formation. A slight oscillation in the sea bottom toward the end of the Gros Ventre epoch lifted the sea floor, so that Cambrian limestone was exposed to the wave action and limestone conglomerate was formed. In Upper Cambrian time the waters again advanced, and during a long period in which conditions were nearly uniform the massive lower member of the Gallatin limestone was deposited. Successive beds of shale, flat-pebble conglomerate, and thin limestone and sandstone above the thick limestone member indicate varying conditions of deposition during late Cambrian time.

After the Cambrian period sedimentation ceased until Upper Ordovician time, when the Bighorn dolomite was deposited. The oldest part of this formation was a siliceous dolomite, and above it sandy and shaly limestones were laid down, indicating the advance of the sea and its later shoaling.

It is probable that this region emerged from the sea in the Silurian period but without appreciable tilting. Erosion cut into the sediments, removing nearly all the beds overlying the massive siliceous member of the Bighorn dolomite.

Only slight differences of relief existed when the Devonian sea advanced and covered this erosional surface, and the base of the Jefferson limestone, the lowest Devonian formation, is a subangular limestone breccia. Warm, clear water must have existed for some time, as the Jefferson limestone is thick and uniform and shows no conformable sandstone or shale at its base. Later in the Devonian period the water shoaled, and light-colored sandy limestone was formed, constituting the lower part of the Threeforks formation. This sandy limestone is overlain by alternate layers of green and red shale and a few thin beds of purple limestone. The predominant red or pink color is presumably due to the iron oxide washed from the Devonian shore.

The transition from the Upper Devonian (Threeforks) to the Mississippian epoch was very quiet, and no evidence of uplift marks the passage from one to the other. It is probable that the land surface which supplied the clastic sediments lay practically awash in late Devonian time, and at the end of the period deposition was slight. Conditions favorable to extensive limestone deposits again returned, and the uppermost shale of the Devonian is decidedly limy, foreshadowing the great thickness of limestone which was formed in the Mississippian epoch.

Limestone was deposited upon a sinking bottom in the Mississippian sea, and over 1,500 feet of calcareous material (Madison limestone) was laid down before a decided change in the conditions of deposition took place. The shoaling of the sea toward the end of the Paleozoic era is indicated in neighboring regions by quartzite, sandstone, reddish shale, and a little impure limestone formed during Pennsylvanian and Permian time.

If the geologic history were to be interpreted solely from the evidence in the New World district the formations overlying the Paleozoic sediments would bespeak volcanic activity after sufficient time had elapsed to allow erosion to etch a fairly rugged topography in the uplifted sediments, but no clue would be given to the history represented by the unconformity between the volcanic rocks and the sediments. South of Cooke Tertiary fossils have been found in volcanic ash that rests on Mississippian beds, showing that Mesozoic rocks are lacking here. Study of the surrounding region indicates that beds thousands of feet thick were eroded in this district before Tertiary volcanic activity began. Reconstruction of the history of this interval from evidence obtained in the surrounding country shows that thin Triassic beds of red shale and sandstone were formed—presumably as arid continental deposits—after the uplift that marked the end of Paleozoic time. During the succeeding period the land was again submerged, and marine sandstone, shale, and limestone preserve an incomplete record of the Jurassic deposition.

In Cretaceous time—when Mesozoic seas had their maximum extent in North America—sediments thousands of feet in thickness accumulated in Montana. This system is predominantly marine shale and sandstone, with minor amounts of limestone and chalk. Toward the end of this period volcanic activity commenced, and thick beds of andesitic tuff occur in the Livingston formation, forecasting the great igneous activity of the Tertiary period. During late Cretaceous or early Tertiary time a pronounced uplift of the region caused the final withdrawal of the seas from this part of North America. The anticline in which the New World district is situated probably had its birth in these early movements of the Rocky Mountain revolution

From that time to the present erosion has been active, and early in Tertiary time it had completely removed Cretaceous, Jurassic, Triassic, and late Carboniferous rocks from the New World mining district, developing a land surface of moderately strong relief.

The first result of the volcanic activity that characterized the Tertiary period is found in the early acidic breccia, of Eocene age.[9] This material probably represents a volcanic outburst of great magnitude, although the beds in the vicinity of Cooke are not extensive.

Erosion cut away the greater portion of this early lava in Oligocene time and reduced the range to a nearly featureless peneplain.[10] This surface was then uplifted about 2,000 feet and tilted slightly to the southwest, and remnants of the ancient peneplain can be seen to-day in the smooth, gently inclined granite summits of the Beartooth Mountains.

During Miocene time there was an extrusion of more basic lava,[11] which was accompanied by the intrusion of numerous dikes and sills. Nearly contemporaneous with the basic lava were intrusions of gabbro, and later granodiorite and related rocks appeared. Faulting, fracturing, and mineralization attended this igneous activity. Some time during the later part (Pliocene?) of the Tertiary period basalt dikes were intruded, cutting all the rocks previously mentioned.

A second epoch of peneplanation began in the Pliocene epoch, but long before its completion it was interrupted by an uplift of great magnitude. This last movement, according to Bevan,[12] occurred in early Quaternary (Pleistocene) time, and although nearly

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[9] Hague, Arnold, The age of the igneous rocks of the Yellowstone National Park: Am. Jour. Sci., 4th ser., vol. 1, p. 450, 1896.

[10] Bevan, Arthur, Rocky Mountain peneplains northeast of Yellowstone Park: Jour. Geology, vol. 33, pp. 563–587, 1925.

[11] Iddings, J. P., U. S. Geol. Survey Geol. Atlas, Yellowstone National Park folio (No. 30), 1896.

[12] Bevan, Arthur, op. cit., p. 587.

vertical it may have been accompanied by a slight tilting to the west. It renewed the erosional activity of streams, and valleys were rapidly carved in the newly formed plateaus. Probably glaciers were formed in the higher part of the range very soon after the uplift occurred.

A deep mantle of snow and ice covered the New World district in Pleistocene time, and the more conspicuous topographic features now observed have been produced by heavy glaciation. Since this comparatively recent ice action streams have been at work cutting narrow gorges in the old U-shaped ice channels and otherwise modifying the glacial topography.

ARCHEAN ROCKS

Half of the bedrock mapped in the New World district is of pre-Cambrian age, but this proportion would be diminished to about one-fifth if the Goose Lake area were excluded. These rocks unconformably underlie the Flathead quartzite, the oldest Cambrian formation in the region. The period in which they were formed is not certainly established, although they are mapped as Archean in adjoining regions and are believed to be of that age. They are therefore herein classified as Archean.

The pre-Cambrian rocks mapped are all of igneous origin, unless the scattered schist inclusions in the granite should prove to be fragments of greatly metamorphosed sediments. Granitic rocks make up the bulk of the Archean rocks exposed and occupy extensive areas to the east and north of the district. They cover practically all of the Goose Lake country and appear along the eastern and northern edges of the New World district.

Goose Creek granite.—The oldest rock is a gneissic gray granite, locally carrying inclusions of biotite or hornblende schist. It is most widely exposed in the northern part of the district, and as Goose Creek flows over this rock for practically its entire length, it is here named the Goose Creek granite. In metamorphic texture the rock ranges from a strongly banded biotite gneiss to a granite distinguished by granulated feldspar. The usual gray color is in places masked by an abundance of garnet, which makes it superficially resemble the younger pink granite. Mineralogically the Goose Creek granite commonly consists of about 65 per cent of gray feldspar (oligoclase and orthoclase), 20 per cent of quartz, and about 15 per cent of biotite. Medium to coarse grained textures predominate, and fine-grained facies are rare.

Narrow masses of hornblende and chlorite schists cut the gneiss near Mount Fox and probably represent early basic intrusive rocks which were rendered schistose by the same agency that gave the gneissic structure to the granite.

Gabbro gneiss.—The north end of Mount Fox is made up of a gabbro gneiss which apparently is younger than the Goose Creek granite. This is the only locality in the New World district where this rock is found. It has a striking appearance, consisting of coarse-grained hornblende and plagioclase that weather dark green and white respectively. The structure of the mass suggests an ancient plug or small stock, and the schistose dikes referred to in the preceding paragraph may be related to this gabbro gneiss.

Cooke granite.—An ancient but unmetamorphosed granite cuts the Goose Creek granite at many places. It is well exposed near Cooke and apparently extends to the southwest under the Paleozoic sediments. The Cooke granite, as this formation is here named, lacks the gneissic structure of the Goose Creek granite. It is essentially a medium-grained pink granite in which quartz and pink orthoclase make up the bulk of the rock, and the ferromagnesian minerals, such as biotite and hornblende, are but sparingly represented. The size of the crystals varies but little, and the grains usually measure about 3 millimeters in diameter. Pegmatitic facies occur rarely and are usually found within the Goose Creek granite areas or near the borders of the Cooke granite. Inclusions of both schist and Goose Creek granite have been observed but are very uncommon.

Basalt porphyry.—A fresh-appearing basalt porphyry containing feldspar phenocrysts 3 inches in diameter cuts the Goose Creek granite in a few places. The dikes of this porphyry are usually short and irregular, and for this reason the rock is seldom seen in place, but the great size of the light-colored phenocrysts make it conspicuous in stream débris. The borders of broad dikes of the basalt porphyry are practically free from black minerals and strongly resemble fine-grained anorthosite. Small phenocrysts of feldspar appear a few inches from the sides and grow progressively larger as the center of the dike is approached. Many of these phenocrysts are 4 inches in diameter, and their striking appearance is illustrated in Plate 5, *B*. The age of the porphyry is thought to be pre-Cambrian, as it was not found cutting rocks younger than the Archean at any point in the district.

PALEOZOIC ROCKS

GENERAL FEATURES

Sedimentary rocks of Paleozoic age cover about one-third of the district, and their distribution is shown on Plate 1. They include formations of Cambrian, Ordovician, Devonian, and Mississippian age, which are readily correlated with the formations of the Yellowstone National Park, where careful work has been done by W. H. Weed, J. P. Iddings, and others. Nearly continuous exposures of the Paleozoic formations can be seen from the vicinity of Cooke to points in the valley of Soda Butte Creek, where detailed sections were made by Weed.[13] In mapping the Paleozoic sediments the lithologic units which had been used in mapping the adjacent quadrangles were adopted with two exceptions. The "Flathead formation" and the Jefferson limestone of Hague and his associates have both been subdivided in the New World district. Following Blackwelder,[14] the writer has mapped the formation overlying the basal Flathead quartzite and underlying the mottled limestone member of the Gallatin limestone as the Gros Ventre formation. The Jefferson limestone of the Yellowstone Park and Absaroka folios includes Ordovician as well as Devonian rocks.[15] It is almost certain that the lower part of Weed's Jefferson limestone in the detailed sections referred to above should be correlated with the Bighorn dolomite of Wyoming, and that the upper part of his Jefferson and some of the lower members of his Threeforks formation correspond to the Jefferson of the type locality in western Montana. Accordingly, the continuation of the rocks mapped as Jefferson in the northeastern part of the Yellowstone National Park is subdivided into Bighorn dolomite and Jefferson limestone in the New World district. A generalized columnar section is shown in Figure 2, and a correlation diagram of the region near by is given in Plate 6.

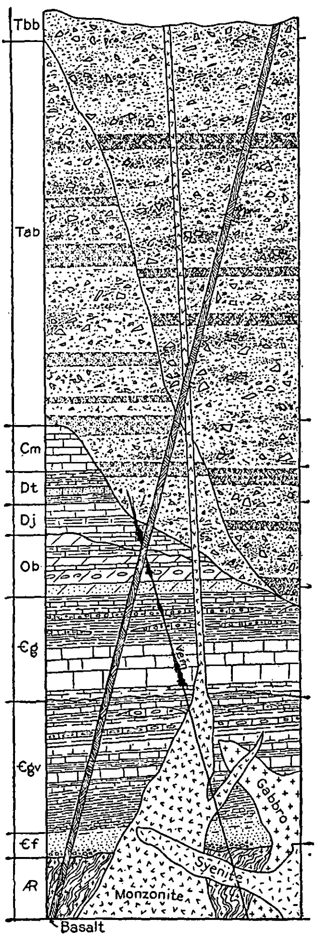

FIGURE 2.—Columnar section of the New World mining district

CAMBRIAN SYSTEM

Both Middle and Upper Cambrian beds are present in the New World district and have a thickness of approximately 1,000 feet. The Flathead quartzite (Middle Cambrian) consists chiefly of quartzite and sandstone, but the overlying Gros Ventre formation (also Middle Cambrian) is very shaly and rarely crops out conspicu-

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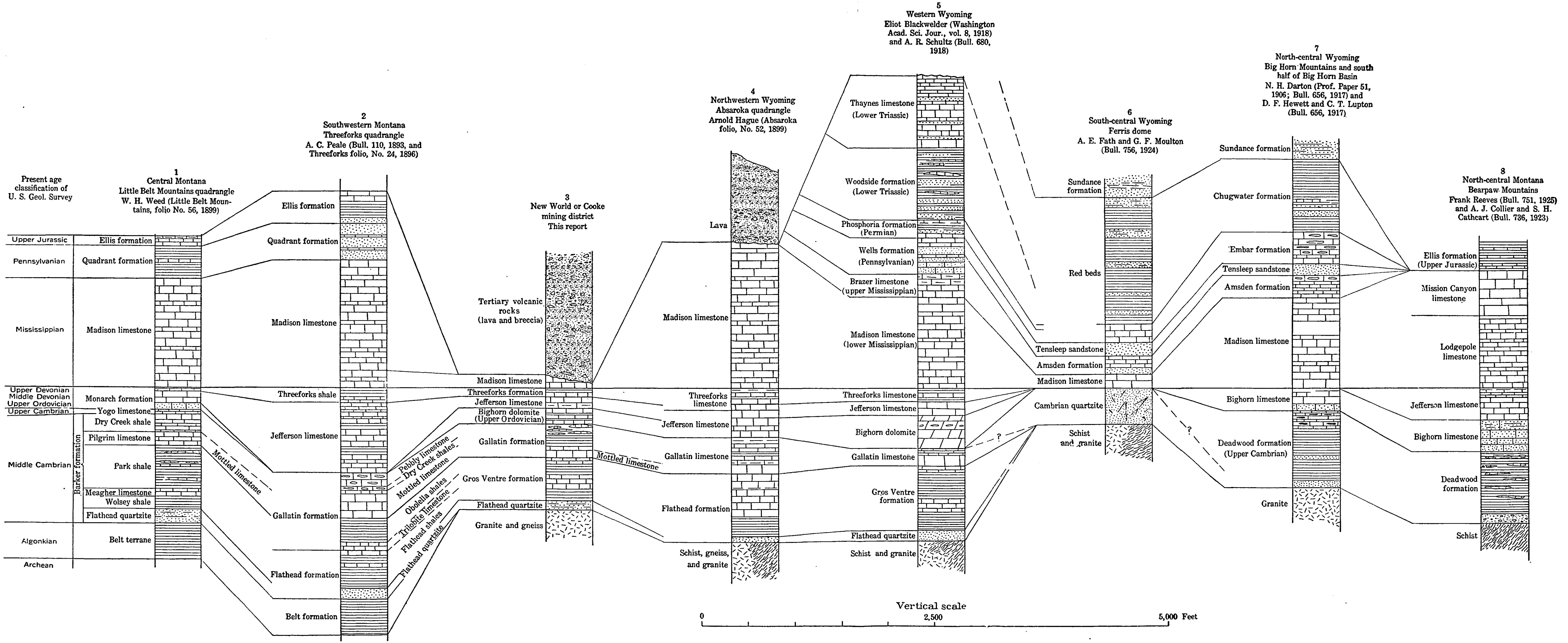
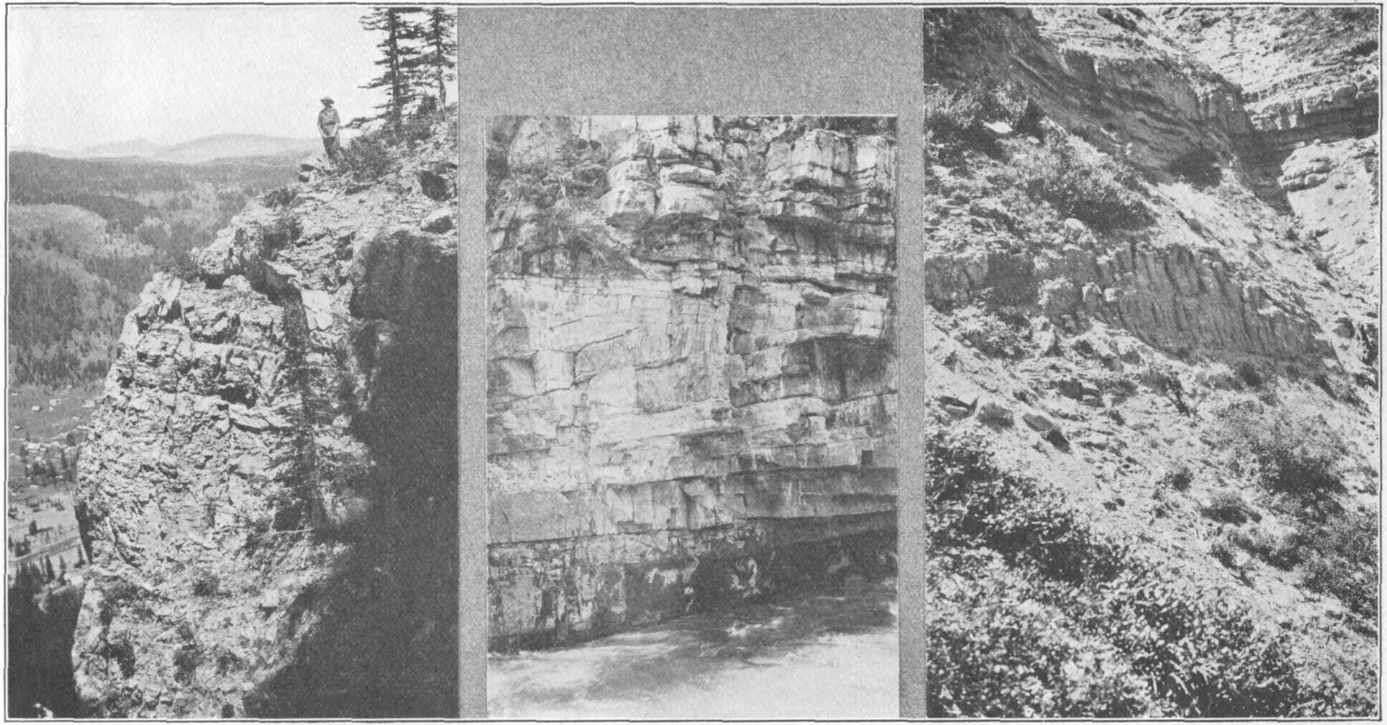
[13] U. S. Geol. Survey Mon. 32, pt. 2, pp. 212–213, 1899.

[14] Blackwelder, Eliot, New geological formations in western Wyoming: Washington Acad. Sci. Jour., vol. 8, pp. 417–426, 1918.

[15] Tomlinson, C. W., The middle Paleozoic stratigraphy of the central Rocky Mountain region: Jour. Geology, vol. 25, pp. 112–134, 244–257, 373–394, 1917.



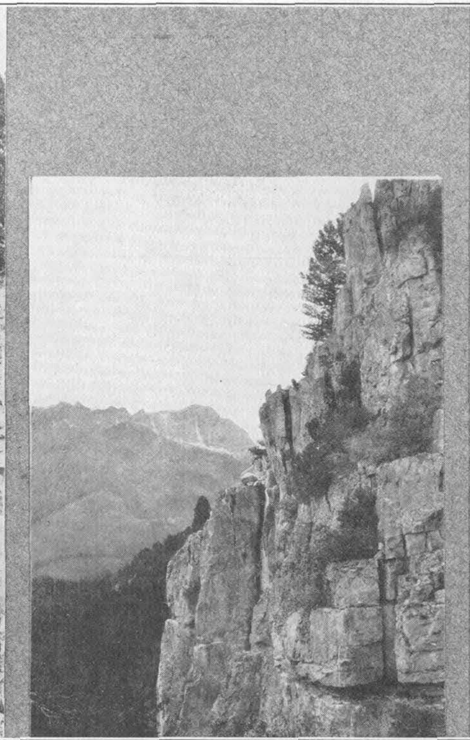
CORRELATION DIAGRAM OF THE NEW WORLD MINING DISTRICT AND SURROUNDING REGION



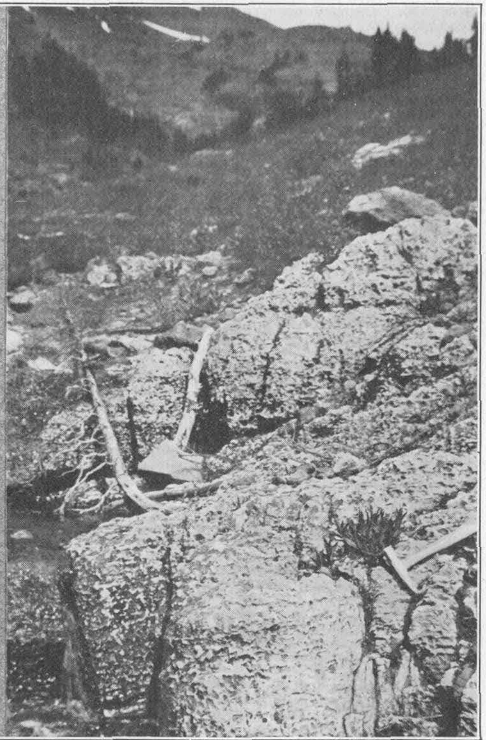
A *B* *C*

A. CROSS-BEDDED FLATHEAD QUARTZITE ON *REPUBLIC CREEK*, MONT.
B. MOTTLED LIMESTONE, THE LOWER MASSIVE CLIFF-FORMING MEMBER OF THE GALLATIN FORMATION
C. COLUMNAR WEATHERING OF LIMESTONE IN THE UPPER MEMBER OF THE GALLATIN FORMATION ON REPUBLIC MOUNTAIN, MONT.

A



B



C

A. WHITE CRACKLED LIMESTONE MEMBER OF THE BIGHORN DOLOMITE, SHEEP CREEK BASIN, MONT.
B. TYPICAL EXPOSURE OF THE DARK MASSIVE CLIFF-FORMING LOWER PART OF THE BIGHORN DOLOMITE, SILVER MOUNTAIN, MONT.
C. CHARACTERISTIC EXPOSURE OF THE MASSIVE BUFF ROUGH-SURFACED MEMBER OF THE BIGHORN DOLOMITE

ously. The lower part of the Gallatin formation is a remarkably persistent cliff-forming member and can be seen on both sides of Soda Butte Creek from Cooke to the western limits of the area mapped. The Gallatin formation is classified by the United States Geological Survey as Middle and Upper Cambrian.

FLATHEAD QUARTZITE

The basal quartzite bed of the Flathead quartzite is well exposed on Sheep Mountain, the west side of Red Mountain, and the north side of Scotch Bonnet Mountain, where it forms conspicuous reddish ledges. Good exposures can also be seen near Cooke, on Republic Creek 1,000 feet above its mouth. The upper sandstone member is exposed on the Daisy Pass road half a mile due north of Cooke.

Generalized section of the Flathead quartzite

	Feet
Flathead quartzite:	
Brown glauconitic sandstone	35
Gray quartzitic sandstone	10
Green fossiliferous glauconitic sandy shale	1
Gray basal quartzite	50
Conglomerate	2
Archean granite.	

The Flathead quartzite is the oldest recognizable sedimentary rock in the district. Its base is light colored, ranging from white through pink to gray, and grades near the top into a chocolate-brown sandstone. Locally a basal conglomerate of granite, white quartz, and schist pebbles occurs, but more commonly the base is a coarsely cross-bedded arkose as illustrated in Plate 7, *B*. The overlying quartzite member consists of quartz with small amounts of feldspar and muscovite well cemented by silica. About 50 feet from the base a thin fossiliferous bed of sandy glauconitic shale occurs. Immediately above this member is a light-colored quartzitic sandstone, but a little higher it grades into brownish glauconitic sandstone, which becomes shaly as the Gros Ventre formation is approached.

GROS VENTRE FORMATION

Near Three Forks Peale[16] originally divided the Cambrian into the units shown in section 2 of Plate 6. Since that time the names Gallatin and Flathead have been used in different senses by various writers. In 1912 the United States Geological Survey adopted the term Flathead quartzite, the name by which the basal Cambrian quartzite of this region (of Middle Cambrian age) had been known

[16] Peale, A. C., The Paleozoic section in the vicinity of Three Forks, Mont.: U. S. Geol. Survey Bull. 110, p. 20, 1893.

since Peale named it in 1893, and discarded the broader uses of the name Flathead. At the same time Gallatin limestone was adopted for the Cambrian beds above the base of the heavy mottled limestone member of Peal's 1893 classification. In central and southern Montana the beds intervening between the Flathead quartzite and the Gallatin limestone have been named Wolsey shale (at the bottom), Meagher limestone, and Park shales (at the top).[17] (See first column of pl. 6.) In the New World district the sequence of the beds below the Gallatin is strikingly similar to the Wolsey-Meagher-Park succession, although the beds differ in detail and in thickness, and it would be impossible to make an exact correlation.

As the beds of the New World district that overlie the Flathead quartzite and underlie the Gallatin limestone correspond in age, lithology, and stratigraphic position to Blackwelder's Gros Ventre formation [18] of northern Wyoming, they are considered equivalent and are herein mapped as the Gros Ventre formation.

The Gros Ventre formation is about 450 feet thick in the New World district and consists chiefly of shale and limestone. The limestone is medium to thin bedded and is not resistant to erosion; as a result the entire formation is soft and weathers in smooth slopes except where intrusive rocks have baked the shale or altered the limestone. Good exposures of the unaltered beds occur in the gorges of Republic and Woody Creeks south of Cooke, and good exposures of indurated Gros Ventre beds can be seen on Henderson Mountain, Sheep Mountain, and the upper slopes of Miller Mountain.

Lower shale member.—Overlying the Flathead quartzite is a persistent bed of green to chocolate-brown shale about 90 feet thick. This shale is laminated and micaceous and crumbles readily where it has not been indurated. At the top of Henderson Mountain it has been baked by intrusive monzonite into a dense, hard purple-brown rock resembling hornfels. This facies has been developed in a few other localities under similar conditions.

Lower limestone member.—Medium-bedded limestone 200 feet thick overlies the lower shale member. The beds are commonly about 10 feet thick, range in color from white through gray to black, and are interbedded with grayish-green shale. The limestone immediately above the lower shale is sandy in many places, and locally thin lenses of buff sandstone are present. Shale partings are abundant in the limestone, and seams of shale from 1 inch to 2 feet thick are common. The shale does not make up more than 20 per cent of this part of the section but effectually prevents the limestone from cropping out conspicuously. Most of the limestone is dense and dark gray, but some

[17] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Little Belt Mountains folio (No. 56); Fort Benton folio (No. 55), 1898.

[18] Blackwelder, Eliot, op. cit., p. 418.

nearly white beds occur, and the uppermost limestone of this member (about 200 feet above the lower shale) is generally a black thin-bedded stratum which weathers into rough, irregular laminae.

The limestone is well exposed near Lower Hayden Falls, on Woody Mountain. Locally on Henderson Mountain it has been extensively marmarized, and magnetite, chlorite, actinolite, garnet, and other contact minerals have been developed.

Upper shaly limestone member.—Above the lower limestone member shale, limestone conglomerate, and thin-bedded limestone make their appearance. This uppermost member of the Gros Ventre formation is well exposed on the north slope of Republic Mountain about a mile west-southwest of Cooke.

Soft green shale containing a few thin limestone lenses overlies the black limestone bed for about 90 feet. This shale rarely crops out. At the top of this member limestone layers become abundant, and some flat-pebble conglomerate appears. The conglomerate is intraformational and consists of flat limestone pebbles in a limestone matrix. Above the green shale the Gros Ventre is made up of thin layers of limestone, flat-pebble conglomerate, and shale. These thin-bedded alternations persist nearly to the Gallatin limestone, 120 feet above the soft green shale. As the base of the Gallatin is approached, the limestone becomes more massive, the flat-pebble conglomerate disappears, and the shale becomes calcareous. In places a distinct break can be observed between the Gros Ventre and the unconformable Gallatin limestone, especially where the lower limestone of the Gallatin is sandy. More commonly there is no definite lithologic break between the two formations but rather a transitional zone covering 30 feet or more, in which the limestone beds become more and more massive.

The upper member of the Gros Ventre has been metamorphosed at several places near a monzonite stock, with the development of such characteristic contact minerals as garnet, epidote, chlorite, vesuvianite, tremolite, specularite, and magnetite. In one locality, on the southern slope of Henderson Mountain, marble containing much magnetite and chlorite has been formed. The shaly limestone of the Gros Ventre is a much better host for contact minerals than the purer limestone of the Gallatin. Selective action is especially notable at the Daisy mine, on Henderson Mountain, where the two rocks occur side by side. Here the Gros Ventre rocks have been completely changed to the contact minerals mentioned above, whereas the Gallatin has been but slightly affected, if at all.

More than 20 species of Middle Cambrian fossils were obtained by Walcott[19] from the strata overlying the Flathead quartzite and

[19] Walcott, C. D., The geology of the Yellowstone National Park: U. S. Geol. Survey Mon. 32, pt. 2, p. 440, 1899.

underlying the Gallatin limestone in the Yellowstone National Park, which compose the beds later named Gros Ventre formation by Blackwelder. These fossils are listed below:

Haguia sphaerica Walcott.
Obolus (Lingulepis) acuminatus var. meeki Walcott.
Iphidea sculptilis Meek.
Acrotreta gemma Billings.
Platyceras primordialis Hall?
Hyolithes primordialis (Hall).
Agnostus bidens Meek.
Agnostus interstrictus White.
Agnostus tumidosus Hall and Whitfield.
Ptychoparia penfieldi Walcott.
Ptychoparia antiquata (Salter).
Crepicephalus texanus (Shumard).
Ptychoparia (Lonchocephalus) hamulus? Owen.
Ptychoparia (Lonchocephalus) wisconsensis Owen.
Ptychoparia? diademata (Hall).
Liostracus parvus Walcott.
Solenopleura? weedi.
Zacanthoides sp.?
Bathyuriscus? sp.?
Arionellus sp.?
Ptychoparia sp.?
Iphidea sp.?

GALLATIN FORMATION

The Gallatin formation is classified by the United States Geological Survey as of Upper and Middle Cambrian age. It carries characteristic Upper Cambrian fossils in its upper part and contains representatives of beds to the north that carry Middle Cambrian fossils. In the New World district it consists of two distinct members, the lower member a massive oölitic limestone 130 to 150 feet thick, and the upper member, 250 to 300 feet thick, consisting of alternating beds of limestone and shale.

The lower member of the Gallatin is chiefly a massive gray oölitic limestone, very low in magnesia (see p. 38), commonly weathering in dark-colored cliffs. (See pl. 7, *A*.) The base of this member is a medium-bedded gray limestone which is locally rather sandy but more commonly is shaly and grades up into the massive oölitic limestone. This massive bed is nearly uniform from top to bottom and contains trilobite and brachiopod remains at many horizons. Its average thickness is a little over 100 feet. The limestone crops out as a cliff a few hundred feet above Soda Butte Creek and is also present on Miller Mountain and in the upper basin of the Stillwater River. Large xenoliths of the Gallatin are present on Red Mountain and Henderson Mountain. The massive lower limestone is little affected by contact metamorphism but is the favorite horizon for ore deposits of the vein and replacement type and contains the most promising lead-silver-zinc ores of the district. Locally it is known as the "Republic reef."

Resting on the cliff-forming member just described is a persistent bed of shale about 30 feet thick. Above this thin beds of limestone, flat-pebble conglomerate, and shale alternate for 200 feet. Some of the limestone has a marked columnar aspect when weathered, as shown in Plate 7, *C*. This is the result of a concentric texture suggesting the former presence of *Cryptozoon*. The individual beds range in thickness from a few inches to 10 feet; their average thickness is less than 5 feet. This upper shale member is affected by contact action at the north end of Red Mountain and strongly resembles metamorphosed upper Gros Ventre beds. Its areal distribution coincides with that of the lower member of the Gallatin.

A typical section of the formation is given below:

Section of Gallatin formation on north flank of Republic Mountains, 1,800 feet S. 30° W. of Republic smelter

	Feet
Tertiary tuff.	
Bighorn dolomite; black fetid limestone, base of the Bighorn	2
Gallatin formation:	
Hard calcareous gray shale; pyrite nodules locally, many limestone lenses; contains beds of limestone conglomerate 1 to 2 feet thick, pebbles small and fairly well rounded; weathers brown. The uppermost bed 15 feet thick; weathers as a low cliff	48
Massive dense gray limestone; weathers with concentric marks suggestive of *Cryptozoon*	4
Thin-bedded shale and limestone, in beds less than 1 foot thick	75
Massive coarse-grained dark-gray limestone, speckled with brown, forming low cliff	8
Medium-bedded limestone and shale, with a few layers of flat limestone pebble conglomerate. Individual beds are from 1 foot to 2½ feet thick. The shale is green and calcareous and contains many elliptical limestone nodules. Much of the limestone weathers with a mottled surface but is dense blue-black on a fresh break	50
Thin-bedded green shale and limestone and flat-pebble conglomerate; average thickness about 1 inch, maximum thickness 6 inches. Limestone much less abundant than conglomerate	18
Dense dark-gray limestone, breaking with a conchoidal fracture, weathering in a markedly columnar fashion. (See pl. 7, *C*)	12
Green fissile shale containing a few thin layers of limestone	30

	Feet
Gallatin formation—Continued.	
Massive gray limestone, cliff; rock is blue-gray medium-grained limestone, remarkably uniform but locally oölitic in texture and near the base composed largely of trilobite fragments. The weathered surface has a characteristic dark mottled appearance. Medium bedded at base	135
Gros Ventre formation: Flat-pebble conglomerate, flat limestone pebbles as much as 4 inches long and 0.3 inch thick in a limestone matrix	1

Walcott[20] collected characteristic Upper Cambrian fossils from the upper part of the Gallatin limestone in the Yellowstone Park, and these are listed below.

Billingsella coloradoensis (Shumard).
Obolus (Lingulella) desideratus Walcott.
Dicellomus nanus (Meek and Hayden).
Orthis? remnicha Winchell.
Orthis? sandbergi Winchell.
Ptychoparia (Euloma?) affinis Walcott.
Ptychoparia llanoensis? Walcott.
Arionellus levis Walcott.
Ptychoparia sp.?

ORDOVICIAN SYSTEM

BIGHORN DOLOMITE

The rocks heretofore included in the Jefferson limestone in Yellowstone Park have been found to include both Ordovician and Devonian sediments. Peale[21] originally defined the formation in the Jefferson Mountains of Montana and gave its age as Devonian. A few years later Weed[22] described the Jefferson of the Yellowstone Park as Silurian, but after an exhaustive study by Kindle[23] the formation was shown to be Devonian, chiefly Middle Devonian but also including some Lower Devonian. According to more recent unpublished studies of Edward Kirk the Jefferson limestone is wholly of Middle Devonian age, and the Lower Devonian is, so far as known, absent in the Rocky Mountain region. The discovery by the writer in the New World mining district of Ordovician fossils in the beds overlying the Gallatin, previously included in the Jefferson, proves the presence of the Bighorn dolomite in this area.

About 3½ miles northwest of Cooke, on the north side of the steep divide that separates the Stillwater River from Sheep Creek, there is an excellent section of the post-Cambrian Paleozoic rocks. In the

[20] Op. cit., p. 441.
[21] Peale, A. C., The Paleozoic section of the vicinity of Three Forks, Mont.: U. S. Geol. Survey Bull. 110, pp. 25, 27, 1893.
[22] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Yellowstone National Park folio (No. 30), 1896.
[23] Kindle, E. M., The fauna and stratigraphy of the Jefferson limestone in the northern Rocky Mountain region: Bull. Am. Paleontology, No. 20, pp. 4, 23–24, 1908.

beds overlying the Gallatin formation here the writer found a few fossils which Prof. A. A. Stoyanow has kindly identified. They include *Platystrophia lynx* Eichwald, *Halysites catenulatus* Linnaeus, *Raphistoma* sp.?, and *Orthoceras* sp.? This fauna is pronounced by Kirk to indicate the western facies of the latest Upper Ordovician or Richmond fauna, which is characteristic of the Bighorn dolomite. A marked lithologic change also occurs 175 feet above the base of the rocks previously included in the Jefferson, and at this horizon *Atrypa reticularis* Linnaeus was discovered. The chocolate-brown fetid limestone carrying this post-Ordovician fossil is believed to be the base of the true Jefferson limestone. Near by, in beds lithologically resembling the Bighorn of the New World district, Tomlinson [24] has found the following fossils:

Receptaculites oweni Hall.
Lichenaria cf. L. typa Winchell and Schuchert.
Columnaria alveolata Goldfuss.
Halysites gracilis Hall.
Streptolasma corniculum Hall.
Zygospira sp.?
Clinoceras sp.?

The rocks ascribed to the Ordovician in the New World district are lithologically similar to the Bighorn dolomite of Wyoming. The meager fauna found indicates that the age is the same, and accordingly the Ordovician beds in the region near Cooke are designated Bighorn dolomite.

The lower limestone member of the Bighorn forms a bold cliff on the south side of Silver Mountain, high above Soda Butte Creek. (See pl. 8, *B*.) It girdles Miller Mountain as a dark cliff just below the lava and can be seen at many points on Woody and Republic Mountains, where the hills of a pre-Tertiary topography are exposed beneath a great thickness of volcanic rocks. Good sections of the entire formation can be made on the north side of the Sheep Creek divide and on Woody Mountain 2,000 feet southeast of the Irma mine.

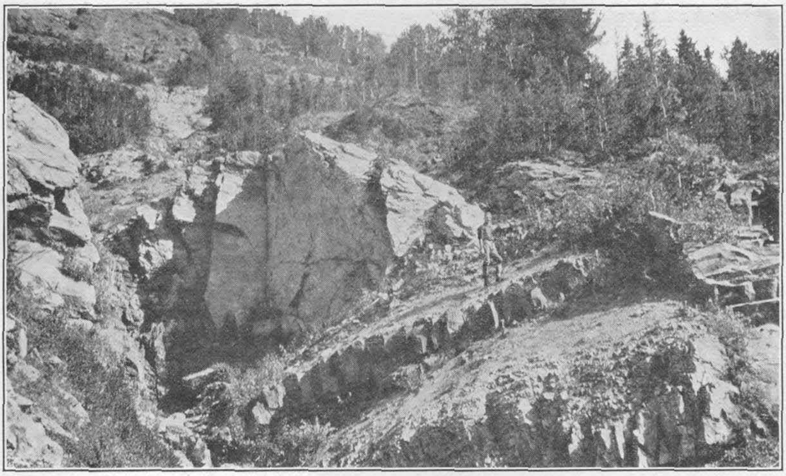
The thickness of the Bighorn rocks in the district is commonly about 175 feet, but locally the upper part of the Bighorn is missing and the Jefferson limestone is separated from the Gallatin by only 50 feet of the dark-colored Bighorn limestone. The basal bed of the Bighorn is a dark fetid-smelling limestone. About 40 feet above the Cambrian-Ordovician contact is a gray limestone carrying large nodules of black chert. Above this horizon the formation lacks the fetid odor which Hague [25] mentions as characteristic of the

[24] Tomlinson, C. W., op. cit., p. 130.
[25] Hague, Arnold, U. S. Geol. Survey Geol. Atlas, Yellowstone National Park folio (No. 30), 1896.

Jefferson limestone. Medium or thin-bedded gray limestone 35 feet thick rests on the cherty member and is overlain by a dense white crackled limestone whose weathered surface has a distinctly soapy texture and feeling. This member is a good horizon marker, and its appearance is well shown in Plate 8, *A*. The massive rough-surfaced buff dolomite shown in Plate 8, *C*, intervenes between the bed just described and a thin-bedded whitish limestone of shaly texture. The 35-foot layer of massive buff dolomite overlying the shaly limestone forms the top of the Bighorn formation and is covered by rocks of Devonian age. A vertical section is given below:

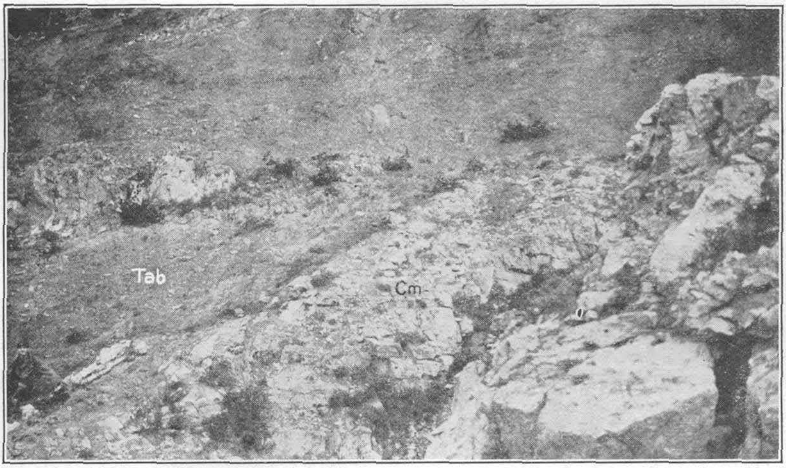
Section of Bighorn dolomite on north side of Sheep Creek-Stillwater River divide 3½ miles northwest of Cooke

	Feet
Jefferson limestone: Chocolate-brown fetid-smelling granular limestone	10
Bighorn dolomite:	
Rough-surface massive dolomite, weathering buff; fresh surface medium grained, light colored but blotched with gray	35
Thin-bedded, somewhat shaly whitish limestone; contains many thin layers of darker color; fossiliferous	25
Massive dolomite, weathering dark buff with rough, reticulated surface; rather coarse grained; contains some chert and many calcite nodules	15
White crackled limestone; weathers with a dull-white smooth, soapy-feeling surface; fresh surface white and dense	20
Brecciated limestone, massive; weathers gray; fresh surface shows light-gray fine-grained matrix containing dark blue-gray, irregularly rounded fragments	5
Massive banded limestone; bands of dark blue-gray fine-grained limestone alternate with bands of light blue-gray; the bands range from half an inch to 1 inch in thickness	10
Thin-bedded earthy-textured light-gray limestone, weathers back in slope	5
Massive limestone; weathers light gray to buff with rough, irregularly pitted surface; on fresh fracture the surface is brownish gray and has a somewhat brecciated appearance	10
Massive dark-gray dolomitic limestone, containing an abundance of black chert nodules 2 to 5 inches in diameter	10
Massive dolomitic limestone; weathers with rough dark bluish-gray deeply pitted surface; fetid smelling on fresh fracture and showing medium-grained dark-buff dolomitic patches in a finer-grained dark brownish-gray matrix; fossiliferous; covered by talus	25
Gallatin limestone (float)	10



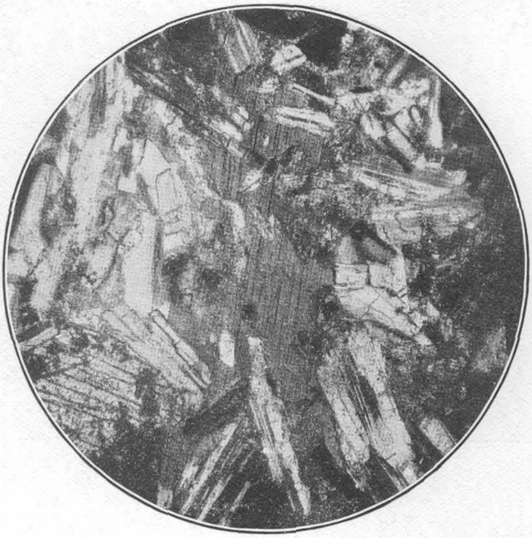
A. WOODY MOUNTAIN, MONT.

The cliff is the brown sandy limestone member of the Threeforks formation, and the man is standing on a sill of Pliocene basalt that is an offshoot from the dike seen on the right



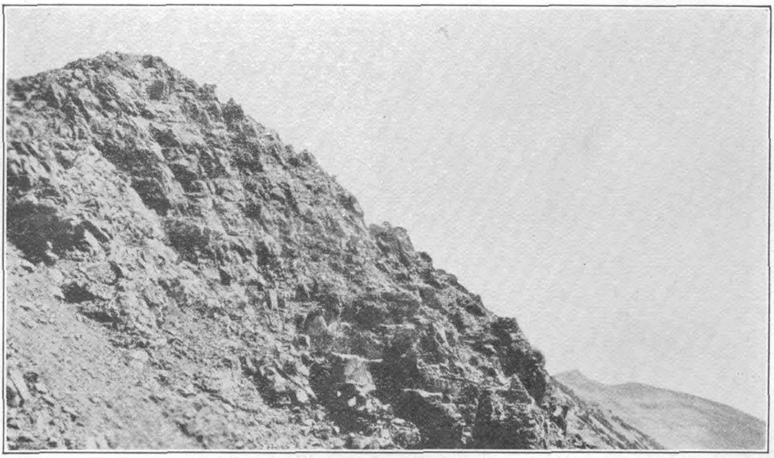
B. UNCONFORMITY BETWEEN MADISON LIMESTONE (Cm) AND EOCENE EARLY ACIDIC BRECCIA (Tab), WEST SIDE OF WOODY MOUNTAIN

The picture clearly indicates the rugged character of the early Tertiary topography upon which the volcanic tuffs and breccias were deposited



A. POIKILITIC INTERGROWTH OF BIOTITE AND LABRADORITE IN BIOTITE GABBRO

Specimen from prospect on Miller Creek 200 yards east of bench mark at Cooke



B. HORIZONTAL SHEETING DEVELOPED IN THE BIOTITE GABBRO FORMING THE TOP OF SCOTCH BONNET MOUNTAIN, MONT.

DEVONIAN SYSTEM

JEFFERSON LIMESTONE

In the foregoing discussion of the Ordovician rocks reasons were given for subdividing the formation previously mapped as Jefferson limestone in the Yellowstone National Park. The beds ascribed to the Jefferson in the New World district measure only 125 feet thick at the head of the Stillwater River and consist largely of dark-colored fetid-smelling limestone. In the southwestern part of the district the Jefferson is thicker, and there is apparently a marked erosional unconformity between it and the underlying Bighorn dolomite.

Jefferson beds are well exposed on the west side of Woody Mountain 2,000 feet southeast of the Irma mine, on the northeast face of Republic Mountain at an altitude of about 9,000 feet, and on the north and south slopes of the Sheep Creek-Stillwater River divide a few miles northwest of Cooke.

The base of the Jefferson is a massive 10-foot layer of chocolate-brown finely granular limestone, having a strong fetid odor on fresh fracture. It grades upward into thin-layered gray limestone and buff shale. Exposures of the contrasting lamination of limestone and calcareous shale present a peculiar woody appearance that is easily recognized. These beds are overlain by a 25-foot bed of dense gray limestone carrying many fossils, principally cup corals. The remainder of the Jefferson is a dark-brown medium to fine grained evil-smelling limestone. A generalized section is given below.

Generalized section of Jefferson limestone in the New World district

	Feet
Threeforks formation: Purple limestone.	
Jefferson limestone:	
Massive limestone; weathers dark gray; fresh surface is brown to brownish black and fine to medium grained and has a strong fetid odor. This member grades downward into the next	65
Fossiliferous limestone weathering pearl-gray; fresh surface is fetid smelling, dense, and dark-brownish gray; some chert occurs here	25
Thin-layered fine-grained gray limestone and buff limy shale; grades downward into massive brownish-gray limestone; fetid odor	20
Massive limestone; weathers dark gray, with deeply pitted surface; a fresh surface is fetid smelling, has a peppery appearance, and is brownish gray to chocolate-brown; chert nodules are common; locally the base has a peculiar penciled appearance caused by many platelike segregations and light-colored crystals about one-sixteenth of an inch thick and from one-fourth to three-fourths of an inch long	10

The fauna characterizing the Jefferson includes *Atrypa missouriensis* Miller and *Spirifer engelmanni* Meek. As explained on page 24, the Jefferson fauna is assigned to the Middle Devonian by Edwin Kirk.

THREEFORKS FORMATION

The Threeforks formation, of Upper Devonian age, is found on Woody and Republic Mountains and on the Sheep Creek divide at the localities where there are good exposures of Jefferson beds, as described on page 27. It consists of about 100 feet of shale and limestone. The rocks are not carbonaceous and lack the fetid odor so characteristic of the underlying Jefferson. The lowest member is a fine-grained purple limestone 6 feet thick, weathering light pink. It is overlain by 15 feet of gray limestone containing a few thin beds of gray shale. A massive fine-grained layer of light-gray limestone, 5 feet thick, stands above the shaly bed. It is blotched with purple and contains stringers of calcite. About 10 feet of purple shale and shaly limestone overlie this massive bed. The rocks just described seldom crop out, commonly weathering back in smooth slopes. In contrast with these rocks, the massive light-brown sandy limestone 35 feet above the base of the Threeforks stands out nearly everywhere as a low cliff 15 to 20 feet high. (See pl. 9, *A*.) The weathering of this bed is distinctive, as its surface becomes smoothly granular or knobby and is crossed by innumerable fine lines at various angles. It underlies about 50 feet of bright-red and green fissile shale and thin-bedded purple limestone. The limestone becomes more and more abundant as the overlying Madison (Mississippian) beds are approached.

It is difficult to locate the exact contact between the Madison limestone and the Threeforks formation. The break between Devonian and Mississippian sedimentation was apparently slight, and the bed considered to be the uppermost Threeforks member shows no evidence of unconformity with the Madison limestone above it. It consists of a light-gray limestone about 10 feet thick which has a general purplish cast on the weathered surface and shows a few bright-pink blotches several feet in length. These stains may be derived from the many lenses of red chert which it contains.

Some of the Upper Devonian fossils found in the neighboring region have been described by Girty[26] and Raymond.[27]

CARBONIFEROUS SYSTEM

Thick beds of Mississippian limestone occur in the country near the New World district, but only a thin basal representative is found here. The Pennsylvanian and Permian are entirely lacking.

[26] Girty, G. H., Geology of the Yellowstone National Park: U. S. Geol. Survey Mon. 32, pt. 2, pp. 479–482, 496–507, 1896.

[27] Raymond, P. E., On the occurrence in the Rocky Mountains of an Upper Devonian fauna with *Clymenia*: Am. Jour. Sci., 4th ser., vol. 23, pp. 120–121, 1907.

MADISON LIMESTONE

The Madison limestone can be seen at the localities previously described as exposing good sections of the Jefferson limestone. The thickness of the Madison in surrounding regions reaches 1,500 feet, but in the New World district a tenth of this figure is the maximum observed. Its contact with the underlying Threeforks formation is not sharp. The base of the Madison, as nearly as can be ascertained, consists of a medium-bedded dark-gray limestone which has a slight fetid odor. It weathers light gray, is much jointed, and contains many thin calcite stringers. The limestone becomes massive a short distance above its base and is highly fossiliferous. At the few localities near Cooke where it occurs it stands out as light-colored cliffs strongly contrasting with the dark lavas that cap them. The marked unconformity between the Madison and the Tertiary lavas is shown in Plate 9, *B*.

An abundant Mississippian fauna containing 79 species has been identified by Girty [28] from the Madison limestone of the Yellowstone National Park.

CENOZOIC ROCKS

TERTIARY SYSTEM

No Mesozoic rocks exist in the New World district, and Tertiary volcanic rocks lie unconformably upon the Paleozoic sediments. The Tertiary lavas of the district are readily correlated with similar rocks in the Yellowstone National Park. Two sets of extrusive rocks, both containing interlayered tuffs and tuffaceous sediments, and a variety of intrusive rocks occur within the New World district. The age of all the igneous rocks other than the pre-Cambrian discussed on pages 16 and 17 is believed to be Tertiary. Some of the salient features of the igneous geology are discussed under "Regional geology" on pages 8 to 10, but a brief summary showing the age relations of the important rock families is given below.

Pliocene: Basalt dikes and sills.
Miocene:
- Syenite stocks.
- Intrusive breccia (pyroclastic facies of the monzonite porphyry).
- Monzonitic intrusive rocks, including quartz monzonite, granodiorite, monzonite, and diorite families; usually porphyritic, in part fine grained, rarely coarse grained.
- Early basic breccia (augite andesite breccias, tuffs, and basalt flows). Cut by andesite dikes.
- Gabbro stocks.

Eocene: Early acidic breccia (augite and hornblende andesite breccias, tuffs, and basalt flows). Cut by hornblende andesite dikes.

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[28] Op. cit., pp. 484–496, 507–578.

EFFUSIVE ROCKS

Two periods of extrusive activity are represented. The evidence of the first, in Eocene time, is nearly obliterated, and only a small remnant of the early volcanic material is present. The activity of the second period resulted in the formation of the Miocene tuffs and breccias that now cap Miller Mountain, as well as the neighboring peaks farther to the south and west. These rocks have been extensively indurated near the large bodies of intrusive monzonite.

Early acidic breccia.—The early acidic breccia is of Eocene age, and Hague [29] believed that it should be correlated with the Fort Union formation. Hewett [30] has later evidence indicating that its age is more probably Wasatch. It consists chiefly of light-colored hornblende andesite, latite, and dacite fragments of variable size, rudely stratified and interbedded with andesite flows. The thickness of this breccia on Miller Mountain is not more than 150 to 200 feet, but it probably once covered the whole region to a much greater depth, as it reaches a thickness of 2,000 feet on Republic Mountain. This great variation in thickness is traceable to the long interval of quiet that followed the accumulation of the volcanic beds, for during this time most of the Eocene breccia disappeared under the attack of erosion. The vents from which the early acidic breccia came are not known.

Some dikes of hornblende andesite cut the early acidic breccia but are older than the early basic breccia.

Early basic breccia.—The early basic breccia is of Miocene age and has a maximum thickness of 2,000 feet in this region. It forms the steep upper flanks of Miller and Silver Mountains and weathers in dark-brown precipitous slopes, giving a somber-colored wall-like appearance to the mountains which it caps. It consists of andesite flows, basalt flows, and basic tuffs and breccias.

An abundant fossil flora was found in the lower part of the early basic breccia by Hague and his associates near the junction of the Lamar River and Soda Butte Creek. This material was correlated by Knowlton with the auriferous gravels of California,[31] which were then believed to be of late Miocene age. Accordingly, the many events recorded in the formations older than the Pliocene Tower Creek conglomerate were supposed to have been crowded into late Miocene time. During this interval at least 5,000 feet of early basic breccia slowly accumulated in the Yellowstone Park and was capped by the early basalt flows; both of these formations were intruded by

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[29] Hague, Arnold, The age of the igneous rocks in the Yellowstone National Park: Am. Jour. Sci., 4th ser., vol. 1, p. 450, 1896.

[30] Hewett, D. F., Geology and coal and oil resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, p. 62, 1926.

[31] Hague, Arnold, The geology of the Yellowstone National Park: U. S. Geol. Survey Mon. 32, pt. 2, p. 790, 1899.

stocks and dikes (the Sunlight intrusives) and then subjected to severe erosion. During the period of degradation the early basic breccia was completely removed in many places before a second stage of volcanic activity began. A thick mantle of the late acidic breccia was spread over the region and was soon covered with other volcanic formations—the late basic breccia, the late basalt flows, and the late andesite flows. The end of this period of volcanic activity was marked by the intrusion of many stocks and dikes, such as the Ishawooa intrusives, the Sherman diorite, and the Electric Peak intrusives. Subsequent to these events the Tower Creek conglomerate was deposited. Its age is well established by the bones of a Pliocene horse which it contained.

It was difficult to reconcile the length of time suggested by the events summarized above with the time interval apparently established by Knowlton, but no other course was open until recently. In 1926 Knowlton stated that the auriferous gravels of California probably indicate a much longer time interval than was formerly supposed and probably represent a phase of sedimentation extending from the upper Eocene well into and possibly through the Miocene, although the localities most frequently mentioned still fall within the Miocene.[32] This is equivalent to withdrawing the auriferous gravels from the late Miocene, and as a consequence the contemporaneous flora of Lamar Valley in the Yellowstone National Park becomes merely Miocene, instead of late Miocene. This shift in age makes it possible to assign ample time for the volcanic events that occurred after the burial of the Lamar flora and prior to the deposition of the Pliocene conglomerate on Tower Creek. It seems probable to the writer that the early acidic breccia, the early basalts, and the Sunlight intrusives represent early Miocene time, and that the erosion which followed occurred during the middle Miocene.

It is plausible to assume that the upper Miocene was ushered in by the volcanic activity that caused the formation of the late acidic breccia, the late basic breccia, the andesite flows, and the late basalt flows and ended with the intrusion of the Ishawooa intrusives, the Sherman Peak diorite, and the Electric Peak intrusives.

The predominant rock of the early basic breccia in the Cooke district is an augite andesite, but hornblende-augite andesite and basalt are common, and the breccia also contains fragments of the early acidic breccias and of the sedimentary formations. Large angular fragments of limestone, quartzite, and granite have been noted by the writer at the head of Sheep Creek. The breccia is rudely bedded and of subaerial origin. Its former thickness was probably very great. The materials of which it is composed may have come from

[32] Knowlton, F. H., Flora of the Latah formation of Spokane, Wash., and Coeur d'Alene, Idaho: U. S. Geol. Survey Prof. Paper 140, p. 19, 1926.

the Crandall volcano, 15 miles to the south, where, according to an estimate by Iddings,[33] this lava was formerly 13,000 feet in thickness. The amount remaining in this district thus represents only a part of Miocene volcanic activity. This lava rests unconformably upon the Paleozoic sediments of the region.

A few dikes of augite andesite occur in the district, and as none of them cut rocks younger than the early basic breccia, they are believed to be the intrusive representatives of this epoch of volcanic activity.

INTRUSIVE ROCKS

The Tertiary intrusive rocks range in composition from gabbro to granite. As indicated in the table on page 29 they have been subdivided into four groups, exclusive of the andesites described briefly above, and have been mapped as gabbro, monzonite and related rocks, syenite, and basalt. This subdivision is made primarily on the basis of age relation, and though the composition of all the rocks in a group is very similar, the textural varieties may include coarse-grained rocks, porphyries, and felsites. Only a few of the many intrusive rocks in the lavas are mapped, as the time required for detailed work was not available. From the work of Hague [34] it seems probable that basalt is the only intrusive rock of post-Miocene age near Cooke and that all the other cross-breaking rocks represent a period of intense volcanism in the Miocene.

GABBRO

Distribution, form, and age.—Gabbro has a scanty distribution compared with that of the monzonite family but is well represented at a number of localities. A large mass of biotite gabbro crops out north of Cooke, in the hill locally known as Fairview, and Scotch Bonnet Mountain is almost wholly composed of similar rock. On the south side of Henderson Mountain there is an area of about 50 acres made up of gabbro. North of Goose Lake a conspicuous outcrop of coarse-grained gabbro runs from the Copper King mine across the Glacier Divide and out of the district.

The gabbro usually occurs in the form of a stock, less commonly in dikes, and a few sills have been mapped, which were believed to be its finer-grained facies.

The mass of gabbro that makes up Scotch Bonnet Mountain is a uniform, medium-grained rock lacking any evidence suggestive of movement during its crystallization. The pronounced horizontal sheeting near the top of the mountain shown in Plate 10, *B*, may indicate solidification under a horizontal roof. The presence of

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[33] Iddings, J. P., U. S. Geol. Survey Mon. 32, pt. 2, p. 236, 1899.
[34] Hague, Arnold, U. S. Geol. Survey Mon. 32, pt. 2, pp. 1–59, 1899.

highly silicified xenoliths of Gros Ventre limestone lends support to this supposition. From the evidence at hand it seems improbable that this body was a volcanic pipe.

Study of the large irregular basic intrusive mass north of Goose Lake leads to a different conclusion. There the rock is very coarse grained and seamed with basic pegmatites, but near the contact of the gabbro and granite a porphyritic border facies exists. Phenocrysts 2 inches across are common in a medium-grained groundmass. The horizontal sheeting noted at Scotch Bonnet Mountain is not evident here. It is quite possible that the intrusive mass represents an ancient volcanic conduit.

Gabbro cutting sedimentary rock was observed in only a few places, but upon the crest of Scotch Bonnet Mountain some xenoliths of metamorphosed Cambrian limestone were found. The Cambrian sediments in contact with the gabbro on the top of Scotch Bonnet Mountain are only slightly metamorphosed. Epidotization and silicification have occurred, but it may be safely said that the gabbro exercised only a feeble contact action on the rocks which it invaded.

The gabbro is intruded by monzonite dikes, so that its age is later than Cambrian and earlier than the monzonite. The earliest known post-Cambrian volcanic activity in this part of Montana occurred in the Livingston epoch (Upper Cretaceous and Eocene), and the postgabbro monzonite is probably late Miocene. Thus there is little doubt that the gabbro is of Tertiary age. It seems reasonable to correlate the gabbro intrusion with one of the periods of volcanic and intrusive activity in the Yellowstone National Park. In composition the gabbro corresponds most closely with the early basic breccia, and so the suggestion is put forward that the gabbro is the intrusive representative of Hague's early basic breccia and should be considered Miocene, possibly early Miocene. (See discussion of early basic breccia on p. 30.)

Lithologic character.—Most of the gabbro consists essentially of labradorite, biotite, augite, and magnetite. In a few thin sections of the rock olivine was observed, and in some others quartz and orthoclase are present as accessory minerals. A characteristic but unusual feature of much of the gabbro is the poikilitic intergrowth of labradorite and brown biotite, which gives it a diabasic appearance. (See pl. 10, *A*.) In hand specimens it is commonly a very dark medium-grained granitoid, slightly diabasic rock in which small flecks of biotite may be seen. The amount of biotite present is variable, and some specimens are nearly free from this mineral. The basic intrusive mass near Goose Lake contains practically no megascopic biotite, except in pegmatitic dikes and seams. Magnetite is much more abundant here than in the intrusive bodies of a similar character farther south.

The basic intrusive rocks are usually much fresher in appearance than the monzonite, and the gabbro has suffered little hydrothermal alteration except near monzonitic rocks and along its contacts with other rocks, where it is in places heavily chloritized and sericitized.

About 40 per cent of the rock is composed of labradorite, which is present in interlocking laths from 0.3 to 1 centimeter in length but mostly about 0.5 centimeter. In the larger crystals zonal growth is common, the zones invariably being less basic at the margins. A few crystals in contact with balsam were observed to have the same index as balsam at their margins and a much higher index at their centers. This indicates that some of the plagioclase crystals consist of a labradorite core and oligoclase shell. Albite, Carlsbad, and pericline twinning are common. Much of the feldspar was earlier than the augite, which contains small inclusions of labradorite.

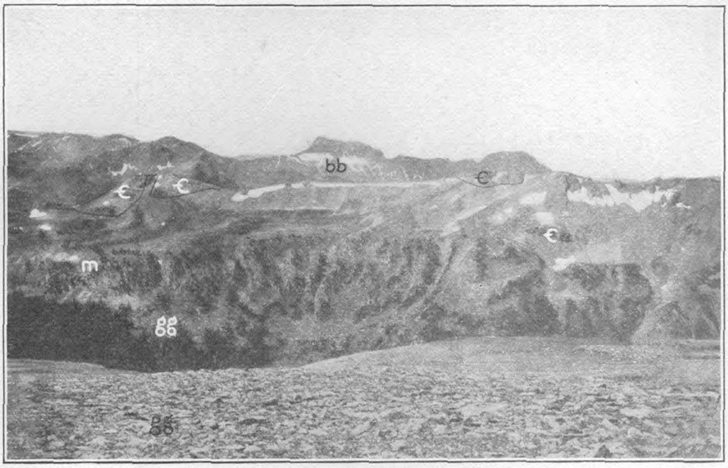
It is probable that two generations of pyroxene are represented, as a few small crystals of augite were observed in some of the larger crystals of plagioclase. The augite shows zonal growth, and in much of it three cleavages are visible. Two distinct types of crystals were noticed. In one the crystals of augite were large and nearly euhedral; in the other the crystals were small and subhedral to anhedral. Augite makes up about 15 per cent of the fresh rock.

The amount of biotite varies greatly but may make up 20 per cent of the thin section. The large grains are remarkable for the poikilitic intergrowth with the labradorite, which gives the rock a diabasic appearance.

Hornblende occurs in euhedral to subhedral crystals that vary greatly in size. The small crystals commonly occur in the interstitial spaces between the large feldspar laths. Hornblende is a minor constituent, as a rule not making more than 3 or 4 per cent of the fresh specimen. Magnetite is an abundant accessory mineral.

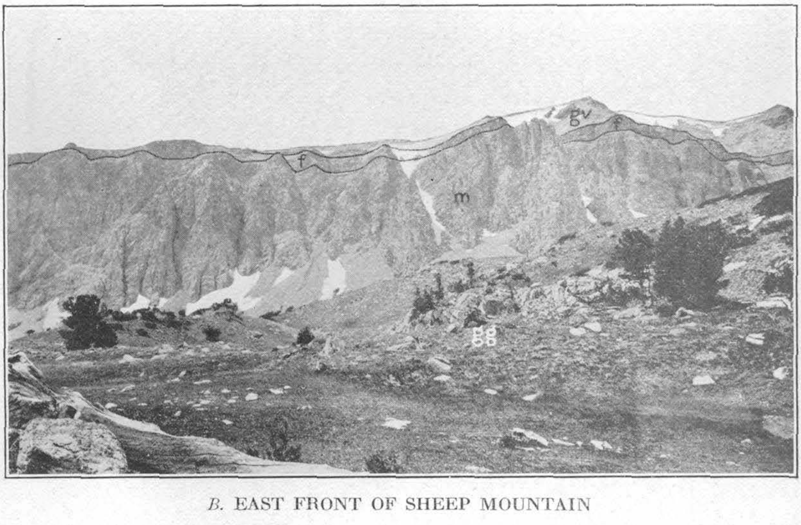
Some of the thin sections show small amounts of quartz, orthoclase, and albite, which are usually interstitial between labradorite laths. In one section a distinct fragment of granite which measured only 1 by 1.5 centimeters was noticed. At the contact of the fragment and the gabbro carbonate, talc, hornblende, and chlorite were developed. The specimen from which this slide was made appeared to be fresh unaltered rock, and the rest of the slide shows little evidence of alteration by hydrothermal action. This suggests that other crystals of quartz, orthoclase, and albite may be small fragments derived from the acidic rocks intruded by the gabbro.

The probable order of crystallization in the gabbro is as follows: The earliest minerals to crystallize were magnetite and apatite. These were followed by a part of the augite (the euhedral crystals). Plagioclase then crystallized, and later the remaining augite and the biotite. Quartz, albite, orthoclase, and hornblende formed still later.



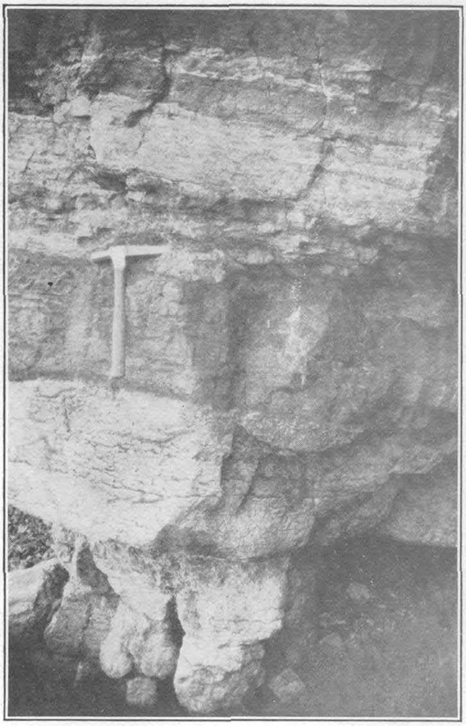
A. HENDERSON MOUNTAIN, LOOKING SOUTHWEST FROM SHEEP MOUNTAIN, MONT.

The valley floor is carved in Goose Creek granite (gg); the lower cliff is Miocene monzonite porphyry (m); the bedded rocks, which are easily distinguished, are xenoliths of the Cambrian Gros Ventre formation (Є) engulfed in the Tertiary monzonite; the rocks at the sky line are Miocene early basic breccia (bb)



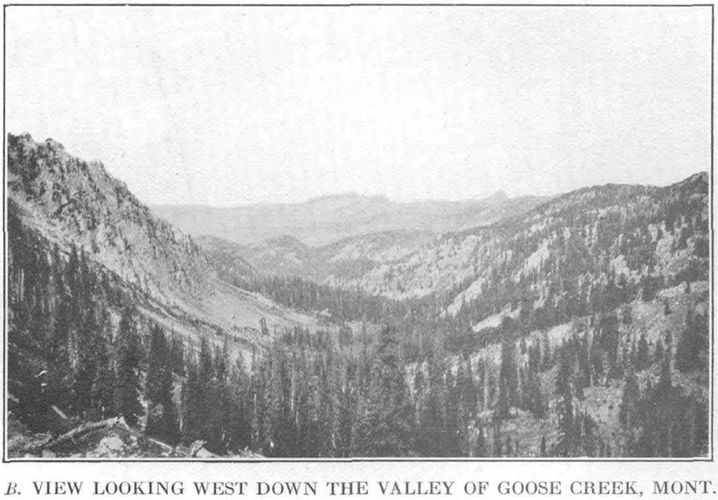
B. EAST FRONT OF SHEEP MOUNTAIN

The cliff consists of latite and monzonite porphyry sills capped by Flathead quartzite and Gros Ventre shales. gg, Archean Goose Creek granite; m, Miocene monzonite and latite porphyry; f, Flathead quartzite; gv, Gros Ventre shale



A. DIFFERENTIAL METAMORPHISM OF GROS VENTRE LIMESTONE ON EAST SIDE OF HENDERSON MOUNTAIN, MONT.

The hammer marks an epidotized and garnetized layer of impure limestone, and the white pure limestone beneath lacks any contact-metamorphic minerals



B. VIEW LOOKING WEST DOWN THE VALLEY OF GOOSE CREEK, MONT.

The U-shaped valley is a characteristic result of recent valley glaciation

The common alteration products of the above-named minerals may be noticed in most of the slides. The feldspar is altered to kaolin and carbonate, and the ferromagnesian minerals to green biotite, chlorite, hornblende, leucoxene, serpentine, carbonate, and talc. Characteristic pseudomorphs after olivine were observed. The olivine is now represented by an intimate intergrowth of serpentine and talc, but this was not abundant in any of the slides that were examined, and no fresh olivine was observed.

MONZONITE AND ALLIED ROCKS

Distribution, form, and age.—Most of the nonbasaltic intrusive rocks south of Soda Butte Creek are allied to the monzonite family. They strongly resemble basic andesite or andesite porphyry but contain sufficient potash to show their relation to the basic monzonite porphyry of Henderson Mountain. The thick sill south of Cooke, which causes Woody Creek to form Hayden Falls, is an example of this slightly potassic type of andesite porphyry. This sill is cut by dikes of the typical acidic monzonite porphyry.

Henderson Mountain and Red Mountain are composed chiefly of monzonite porphyry, and these rocks continue along the eastern slope of the Stillwater Valley to the northwest, as may be seen from the map. The conspicuous cliff on the eastern and southern sides of Sheep Mountain (shown in pl. 11, *B*) is made up of sills of latite porphyry and monzonite porphyry. The lower eastern slope of Miller Mountain and the southern slope of Crown Butte consist largely of monzonite porphyry sills which extend in a continuous belt around the head of Miller Creek to the main mass of Henderson Mountain.

The monzonitic rocks occur in a variety of forms. The earliest and most basic representatives of this group appeared in thick sills in the region of Miller, Henderson, and Sheep Mountains. Not long after the intrusion of these sills a great body of porphyritic monzonite broke through the sills and the Paleozoic sediments in the form of a stock, though some of this mass was also thrust out between the sediments as sills. At the same time dikes, sills, and small irregular pipe-like masses (known locally as "porphyry blowouts") were intruded in the surrounding region. A period of hydrothermal alteration and metallization immediately followed, and the igneous masses that had just broken through the earth's crust served as guides for the heated emanations rising from below. Intense alteration of the porphyritic monzonite stock and some of the sills and dikes resulted; all the earlier rocks were affected locally, but usually the action was less intense on the older intrusive rocks. Igneous activity waned after the events just recorded, and some hornblende-biotite monzonite dikes are the last intrusions belonging to the monzonite epoch.

Near the north end of Sheep Mountain gabbro is cut by many dikes of typical andesine monzonite. This rock forms thick sills in the south half of the same mountain, and the sills are cut by an albite-quartz "monzonite" dike. Porphyritic albite-quartz "monzonite"—that is, porphyritic soda granite—makes up the greater portion of Henderson Mountain and crops out extensively in the Miller Creek Basin and to a less extent at Goose Lake. It has invaded the Miocene basic breccia on Miller Mountain. Sills of oligoclase monzonite are present on the southern slope of Henderson Mountain and are believed to be older than the albite-quartz monzonite (granite porphyry). Dikes of hornblende-biotite monzonite cut all the other monzonites.

Henderson Mountain has the appearance of a laccolith which has been deeply eroded on two sides. The laccolith lies on a floor of pre-Cambrian granite and beneath early Paleozoic sediments. As illustrated in Plate 11, *A*, the contact of the albite-quartz monzonite and the granite is almost horizontal in the valley of Clark Fork of the Yellowstone, giving the monzonite the appearance of a thick sill. On the Adit claim a tunnel has been driven westward into Henderson Mountain for about 2,000 feet, starting 150 feet below this horizontal contact. About 600 feet from the entrance the granite is cut vertically by the albite-quartz monzonite. A short distance farther in a monzonite appears which is remarkable for the large number of granite, quartzite, and limestone fragments included in it. These fragments show great variations in size and metamorphism. This intrusion breccia is very erratic in its appearance, and at places the tunnel runs for several hundred feet through fresh monzonite entirely lacking inclusions. Shaly limestone may be seen in all stages of change from fresh rock to strongly pyritized, epidotized, and garnetized masses. Many of the quartzite and granite fragments are mineralized but do not show contact minerals. Similar intrusion breccias crop out at a number of points on Henderson Mountain, particularly at the Homestake tunnel, at the Daisy mine tunnel, and a short distance south of Bull of the Woods Pass. It seems evident that the large monzonite mass penetrated by the Gold Dust tunnel must be considered a portion of the mass which is in part stocklike and in part has spread out under the overlying sediments at the contact of the granite and Paleozoic strata. The mass is aptly termed a laccolithic stock.

Hague [35] distinguished two periods of pronounced intrusive activity in the Yellowstone National Park. The first immediately followed the volcanic activity represented by the early basic breccia and the late basalt and is typified by the augite syenites of the Sun-

[35] Hague, Arnold, U. S. Geol. Survey Mon. 32, pt. 1 (unpublished), Chapter X; atlas to accompany U. S. Geol. Survey Mon. 32, 1904.

light intrusives. The second period of intrusive activity followed the formation of the late acidic and basic breccia and gave rise to the diorite and granite porphyries mapped by Hague as the Ishawooa intrusives, the Sherman diorite, and the Electric Peak intrusives. The composition of this group of rocks corresponds closely to that of the monzonites and allied rocks of the New World district, and the two groups of intrusives are probably contemporaneous. If this correlation is correct, the intrusion of the monzonites probably took place near the end of the Miocene epoch. (See discussion of the probable age of the Ishawooa intrusives on p. 31.)

Lithologic character.—As most of the monzonitic rocks are greatly altered, the following description is only approximate. Most of the monzonite is porphyritic. Large phenocrysts of orthoclase are surrounded by smaller interlocking laths of plagioclase, which range from andesine to albite. It is quite possible that hydrothermal solutions have contributed sodium to the rock and caused the formation of albite from more calcic feldspars. The amount of quartz present is variable, but the rocks that consolidated early, which make up the bulk of those exposed, contain more than the later dike rocks. Hornblende and biotite are the most abundant ferromagnesian minerals, and augite is rare. Apatite is a common accessory mineral. Small amounts of zircon and magnetite are present.

A light-colored quartz monzonite or soda granite porphyry makes up the greatest portion of the laccolithic stock of Henderson Mountain. In hand specimens large pink phenocrysts of orthoclase as much as half an inch in diameter are easily distinguished from a matrix of plagioclase crystals which are sericitized and have a chalky appearance. Hornblende and biotite are present, but they are commonly altered to chlorite and are indistinguishable in the hand specimen. In finer-grained varieties of this rock the groundmass is gray-green and contains small phenocrysts of albite, orthoclase, biotite, and hornblende. The early sills are much darker in color than the later acidic varieties of monzonite. These rocks are in many places so thoroughly altered that their identification is impossible without the aid of a microscope.

Orthoclase is present in small anhedral grains and in large euhedral phenocrysts. In some of these larger grains zonal growth and Carlsbad twinning can be noted, as well as perthitic intergrowth with albite. The orthoclase is usually much less altered than the plagioclase in the same slide and rarely makes up more than 15 per cent of the thin section.

The most abundant plagioclase is a sodic oligoclase close to albite in composition, and it may make up 60 to 70 per cent of a thin section. It commonly occurs in small interlocking subhedral laths about 0.15 centimeter long, some of which show a trachytic texture;

here and there large phenocrysts, which may be over 1 centimeter in length, are present. Carlsbad and albite twinning are common; pericline twinning less so. Pericline and Carlsbad twinning are better developed in the large crystals than in the smaller grains of the groundmass, and there is a strong tendency for these larger crystals to form in aggregates of three or more. The albite phenocrysts are usually much smaller than those of orthoclase in the same slide.

Oligoclase occurs in euhedral and subhedral crystals which range in size from 0.05 to 0.2 centimeter. In many of these grains albite twinning is very poorly developed. Large phenocrysts of oligoclase were not observed.

Quartz, where present, is usually in the form of large heavily corroded phenocrysts that contain liquid and gas inclusions. Small grains of quartz were also noted in the groundmass, but in many sections it is questionable whether this quartz is secondary or primary. A micrographic texture is shown by quartz and albite in the groundmass of specimens representing the central portion of the Henderson Mountain stock, and it is believed that this quartz is primary. Quartz rarely makes up more than 10 per cent of a thin section.

Green hornblende and brown biotite seem to be primary minerals in the monzonites. Some of the hornblende is twinned. These minerals are usually present in euhedral crystals which are now altered more or less completely to green biotite, chlorite, iron oxides, leucoxene, and carbonate.

The order of crystallization in the monzonitic rocks is essentially the normal order. The earliest minerals to crystallize were the accessories, apatite, magnetite, and zircon. These were followed by the ferromagnesian minerals, augite, hornblende, and biotite. The feldspars formed next, orthoclase frequently earlier than the plagioclase; quartz appeared in part earlier than the plagioclase, but was also contemporaneous with it or later.

Contact metamorphism of adjacent rocks.—The monzonite mass has exerted pronounced contact action on the upper shaly limestones of the Gros Ventre formation. At the Daisy and Homestake mines, and on the Magnet, Longstreet, Sucker, and Bismarck claims contact-metamorphic minerals are particularly well developed. Epidote and specularite are most abundant, but in addition pyrite, chalcopyrite, chlorite, actinolite, andradite (garnet), magnetite, vesuvianite, muscovite, and quartz were formed. The massive lower limestone of the Gallatin formation, which is extremely pure, is very little affected by contact metamorphism. Samples of this member average 54.30 per cent of CaO, 0.57 per cent of MgO, and 2 per cent of Al_2O_3, SiO_2, etc. At the Daisy mine, where it is adjacent to the highly altered Gros Ventre beds, the abrupt change from the garnetized shaly limestone to the fresh unaltered oölitic limestone of the Gallatin is particularly striking. Differences of composition within the Gros Ventre also cause selective contact metamorphism, as shown in Plate 12, *A*.

SYENITE

Distribution, form, and age.—Rock of the syenite type has only a meager distribution, but because of its economic importance it is briefly described. Probably it represents one of the last stages of differentiation of the monzonite magma and was formed at the end of the Miocene epoch. (See p. 37.)

Syenite is found near Goose Lake and is best developed at the Copper King mine and in the region north of the Goose Lake tourist camp, where it occurs in dikes, sills, and a small stock. Its field relations to the gabbro and monzonite are difficult to make out, but it is believed to be younger than the gabbro and monzonite occurring in this vicinity. Flat-lying pegmatitic bodies consisting almost wholly of albite are very common in the monzonite of this region and are probably derived from the same source as the syenite.

Lithologic character.—The syenite consists essentially of orthoclase and albite, with accessory quartz, biotite, hornblende, magnetite, chalcopyrite, and muscovite. It is cut by small dikes or veins of a pegmatitic rock. Many of these seams when followed for a little distance are found to grade into the rocks that at other places make up their walls. Muscovite, biotite, chalcopyrite, and orthoclase are well developed in this pegmatitic phase, and crystals of biotite 2 inches in diameter were found. A description of the chalcopyrite syenite which forms the ore body of the Copper King mine is given in the section on ore deposits.

Microscopic features.—In many slides nearly the whole thin section is made up of albite and orthoclase, which are commonly intergrown as perthite. Microcline is abundant in some sections but totally lacking in others. The feldspars show no sericitization or hydrothermal alteration and are very little kaolinized. Quartz, hornblende, mica, chalcopyrite, and a second generation of feldspar occur in veinlets crossing the perthite grains and also as irregular seams bordering large crystals. In some slides chalcopyrite is so abundant as to be classed as an essential mineral.

BASALT

Distribution, form, and age.—Dikes and sills of basalt, believed to be of late Tertiary age, are present in the region south of Soda Butte Creek. They cut all the rocks older than the unconsolidated material of Quaternary age and are nowhere hydrothermally altered. In composition and appearance they correspond to the basalts mapped as Pliocene by Hague.[36]

Lithologic character.—These rocks are black, dense basalt or basalt porphyry, very fresh in appearance and locally weathering in relief. As these basalts have a partly glassy groundmass, it seems evident that they cooled more quickly than the earlier dikes and sills, which are entirely crystalline. This suggests a fairly thin and cool cover at the time of the intrusion.

Of the feldspars, labradorite predominates, but some andesine was observed. The plagioclase is later than the ferromagnesian minerals and occurs as subhedral trachytic laths. Augite is abundant. It is commonly twinned and occurs in small euhedral crystals included in the plagioclase phenocrysts and also as larger, later subhedral phenocrysts. The feldspar and augite are very fresh. Olivine is present in small to medium-sized euhedral crystals and was one of the earliest minerals to form. In several of the thin sections it is altered to serpentine and talc. Magnetite and apatite are common accessory minerals.

QUATERNARY SYSTEM

The topography of the region has been greatly modified by the action of ice during Quaternary time, and glacial deposits are abundant. Glaciers still exist in the Goose Lake area, and it is probable that the large valley glaciers were numerous a comparatively short time ago. Morainal deposits are abundant, although in many places covered by landslides. Striated pebbles are found in gravel far up the slopes of the mountains in the southern part of the district, and glacial scratches may be seen at many places on the polished surface of the pre-Cambrian granite.

Numerous cirques and hanging valleys are present, but the steep U-shaped valleys originally cut in the bedrock have been greatly modified in the southwestern part of the district by the slumping of the soft volcanic rocks on the upper slopes. The Stillwater Valley was the gathering ground of at least five glaciers, which headed in a series of cirques extending from Sunset Peak to Crown Butte. These ice streams must have fed a large valley glacier extending far to the north in the Stillwater Canyon. (See pl. 12, *B*.) The steep ridges of many of the mountains are probably due, in large part, to the rasplike action of the ice which plucked the rock from each side. Granite and quartz pebbles have been found on the crests of high mountains, thousands of feet above the valleys where these formations are now exposed. If these pebbles were carried to their

[36] Hague, Arnold, atlas to accompany U. S. Geol. Survey Mon. 32, 1904.

present resting place by glaciers, as seems probable, the entire region must at one time have been submerged under a veritable sea of ice.

Grasshopper Glacier, shown in Plate 13, is at the head of Rosebud Creek, 1 mile northeast of Goose Lake. This glacier is of peculiar interest, as it contains a great quantity of insect remains. Grasshoppers are embedded in the ice from top to bottom and are so well preserved that birds and fish feed eagerly upon their bodies as the ice releases them. The eastern part of the district and the granite country in general show evidence of the former action of a large sheet of ice in the knob and kettle topography, glacial striations, and numerous small lakes.

Glaciers have oversteepened the walls of many of the valleys, and as the lava which caps many of the mountains weathers very readily, heavy rainstorms frequently cause landslides of the mud-flow and avalanche type. During the summer of 1922 the writer witnessed a mud flow on Republic Mountain which started far up in Republic Basin and carried large boulders down to Soda Butte Creek. In the stream valley the slope which the landslide moved across was very gentle, yet the material carried ranged in size from fine silt to boulders 8 feet in diameter. As such action has been going on for long periods of time, much of the material on the lower slopes of the mountains is of this character. Huge masses of rock may be noted that must have slid from their former resting places to their present sites on a surface lubricated by mud. A large portion of the southern slope of Miller Mountain has moved in just this manner. It may be classed as a superficial fault or a landslide of enormous dimensions. It has been indicated on the geologic map as a fault.

The retreating glaciers probably contributed most of the deeper unconsolidated material present in the valleys, but nearly all of the mantle rock now exposed is thought to be the result of landslides. The streams have reworked these materials locally, but extensive alluvial deposits do not occur.

Talus breccias cemented by limonite cover many acres near the headwaters of Clark Fork of the Yellowstone. Large pyritic deposits occur near by, and both surface water and ground water move from the sulphides to the breccia, where deposition of iron hydroxide is going on actively. The formation of this compound may be readily explained by the solution and precipitation of iron during the oxidation of the pyritic ores. The oxidation of pyrite yields ferrous sulphate and sulphuric acid; hydrolysis and further oxidation ultimately yield ferric hydroxide (limonite).[37]

[37] Emmons, W. H., The enrichment of ore deposits: U. S. Geol. Survey Bull. 625, pp. 106, 452, 1917.

STRUCTURE

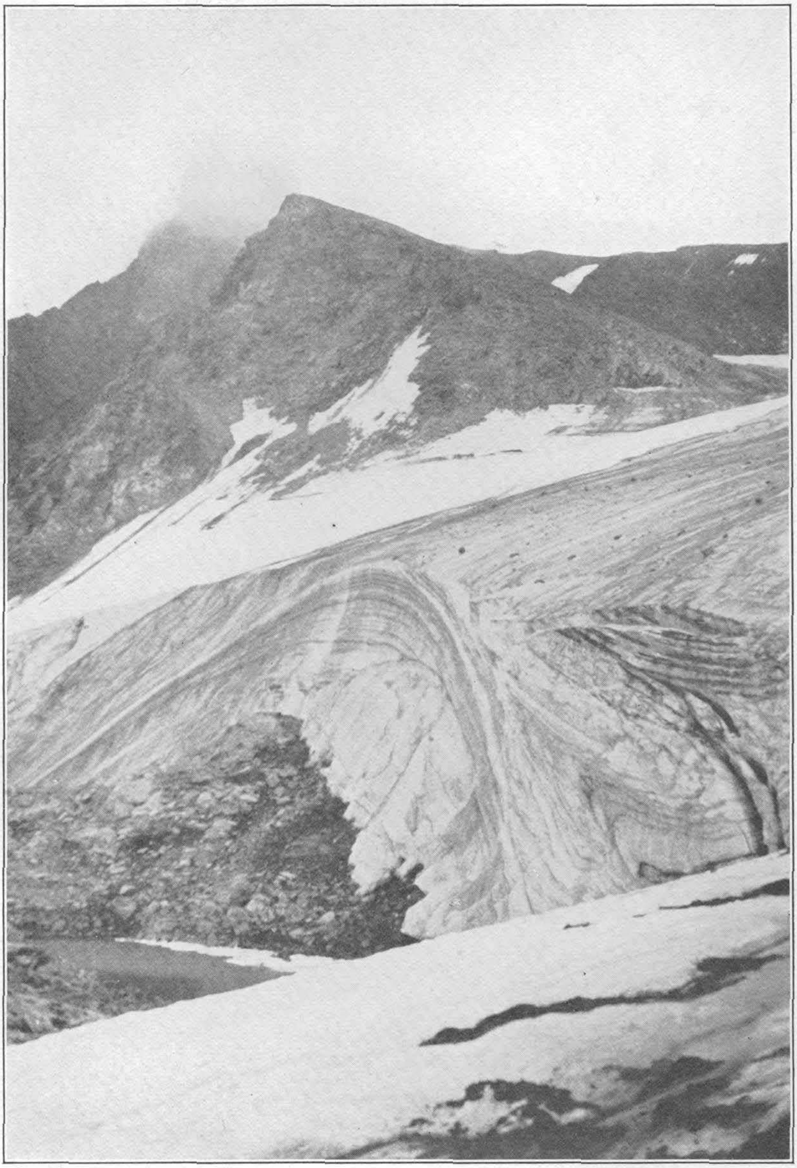
General features.—The district owes its major structure to its situation on the Beartooth-Snowy Mountain anticline. Formerly Paleozoic and Mesozoic sediments extended far to the east and covered the broad anticlinal uplift, but in the center of the arch erosion has cut through these beds and exposed wide areas of ancient crystalline rocks. The line of contact between the Paleozoic sediments and the pre-Cambrian crystalline complex runs through the New World district. The areal distribution of the sediments is largely influenced by the prevailing southwest dip due to their position on the southwestern limb of the great anticline; thus the greatest thickness of the sediments and lavas is in the southwestern part of the region, and pre-Cambrian granite is exposed in the northeastern part.

The sedimentary deposits consist of an essentially conformable series of Paleozoic beds whose thickness reaches a maximum of about 2,000 feet in Meridian Mountain. A great unconformity exists between these sediments and the volcanic rocks of Tertiary age that cap them. Although the topography was not as rough at the time the lavas were poured out as it is at present, considerable differences in altitude existed. The lavas have a present maximum thickness of 2,000 feet in the southwestern part of the region mapped but were formerly much thicker.

Veins and faults.—At about the line where erosion has now exposed the contact of the Cambrian and pre-Cambrian a number of Tertiary igneous rocks were intruded. Plugs, stocks, dikes, and sills are present. Close to the stocks are veins that roughly parallel the contact. These veins fill fissures which may have been formed as a result of contraction due to subsidence and cooling of the adjacent masses of igneous rocks. Veins of this type are present near Scotch Bonnet Mountain.

Dikes and veins follow all the fracture systems discussed below and are displaced by faults trending N. 30° E. and N. 20° W.

Faulting probably occurred throughout Tertiary time, and although a chronologic order is given for the systems of faults, late movements along many of these fractures have masked the earlier age relations to some degree. Faulting probably reached its maximum during the period of intrusion of the igneous rocks, but some movement took place both before and after this period. Nearly all the veins in the district follow fault planes or fractures paralleling one of the fault systems described below. Postmineral movement has taken place in many of the deposits, indicating that fracturing extended over a long period. As far as possible the direction of movement for each fault system and its amount, laterally and vertically, have been determined. In some of the classes discussed below there is so pronounced a uni-

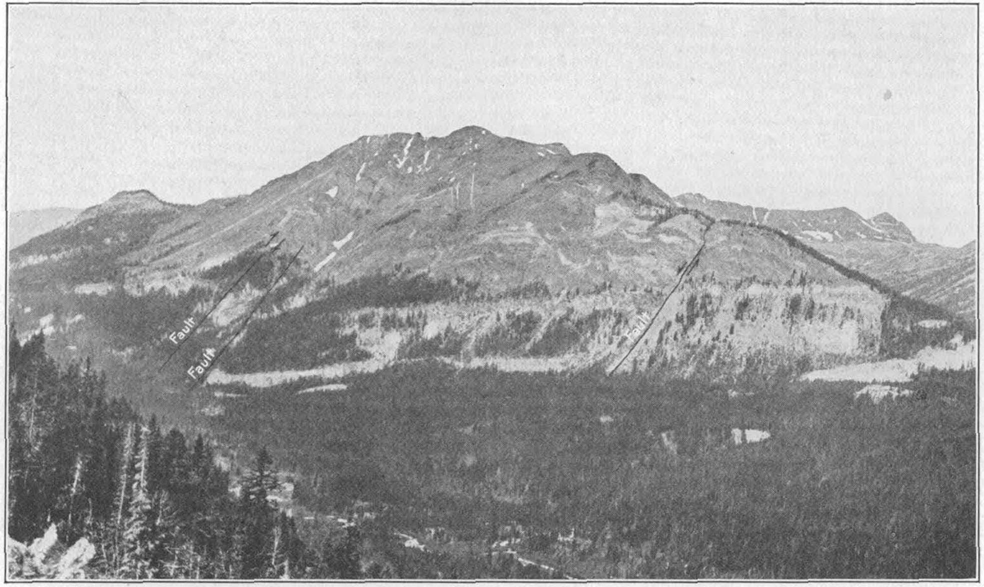


ICE FRONT OF GRASSHOPPER GLACIER, MONT.

Shows contorted laminae caused by differential movement in the ice

CROWN BUTTE, MONT.

A strong fault striking N. 20° W. with a throw of 180 feet is indicated. €gv, Gros Ventre formation; €gl, lower limestone member of the Gallatin formation; €c, upper part of Gallatin formation; Ob, Bighorn dolomite; Tbb, Miocene early basic breccia



A. SILVER MOUNTAIN FROM REPUBLIC MOUNTAIN, MONT.

Soda Butte Creek in foreground. The lower cliff is formed by the massive lower limestone member of the Gallatin formation, and the upper cliff is formed by the Bighorn dolomite. The Miocene early basic breccia overlies this dolomite and forms the crest of the mountain. A fault and a fault zone striking N. 20° W. are shown

B. DETAIL OF FAULT ZONE SHOWN ON LEFT IN *A*

Crushed and dragged Gros Ventre rocks on left and highly altered monzonite quartz porphyry on right formity that it is possible to indicate with considerable success the direction in which to search for the displaced segment of a vein. The systems of faults, in their probable order of age from the earliest to the latest, are as follows: (1) East-west; (2) N. 20° W. and N. 55° E.; and (3) N. 30° E. The general relations are indicated in Figure 3.

Many of the east-west faults have throws of more than 100 feet. The maximum displacement measured in the district along these faults was 255 feet. Reverse and normal faults are both known, but the fault planes usually dip north at high angles, and the down-

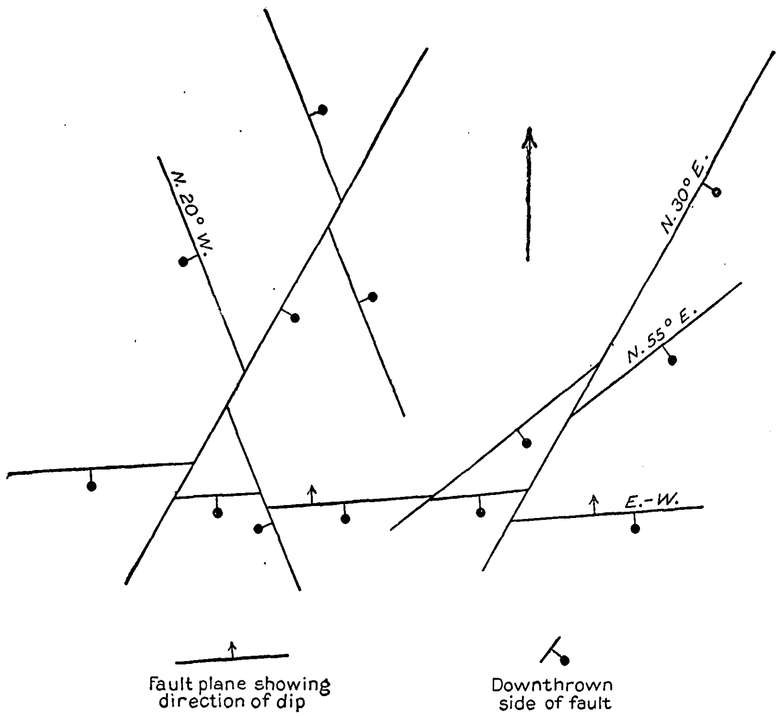


FIGURE 3.—Relations of fault systems in New World mining district

thrown side is nearly everywhere south of the fault line. No data were obtained on the amount of lateral movement in these faults.

The N. 20° W. faults are more common than any others and include both reverse and normal faults, as illustrated by Plates 14 and 15. Normal faults are more numerous, and although the downthrow may be either to the west or to the east of the fault plane, about 70 per cent of them have downthrows on the west. The amount of vertical movement generally measures less than 100 feet, and the maximum observed was 180 feet. Although the vertical component of the movement is the greatest, a lateral component is noticeable at many places. Where observations could be made the data indicated that the east wall had moved southeastward relative to the west wall. This component ranged from a few inches to several feet.

The N. 55° E. faults are rare and were nowhere observed to cut the N. 20° W. system. Their downthrown side is almost invariably on the southeast of the fault plane. The amount of displacement varies, and the maximum observed is 75 feet. No data are at hand on the lateral movement of this series of faults.

The N. 30° E. mineralized faults displace faults of the other systems. Lateral movement is more noticeable in this system than in any other. The downthrown side is generally to the southeast, and this side in all the faults observed has moved southwestward in relation to the upthrown side. The lateral displacement is commonly about 30 feet. The vertical movement varies greatly, and the maximum observed was about 100 feet. Many veins in the other series of fractures are displaced by N. 30° E. faults, indicating postmineral movement, but nevertheless veins striking N. 30° E. are common and apparently belong to the same period of mineralization as the veins that follow the older fractures. This premineral and postmineral faulting indicates that fracturing took place at intervals over a longer period of time than that covered by mineralization.

Cross sections.—The cross sections shown in Plate 1 are generalized, as it is not possible on a scale of 1:36,000 to give all the details that would be desirable, but these sections show the important features of the geologic structure of the district.

HISTORY OF MINING

Rumors of the existence of rich lead, silver, and gold deposits were reported as early as 1868, but no claims were located until 1870. In 1869 four trappers, Adam Miller, J. H. Moore, Bart Henderson, and James Gurley, were robbed of their horses by Indians who had discovered and looted their cache on Cache Creek. The four men narrowly escaped death and fled north up Cache Creek and crossed the divide that separates its headwaters from Republic Creek. They discovered the manganese-stained outcrop on the property which was later developed as the Republic mine, panned a small amount of gold from the streams, and pushed on to the Crow Agency at Columbus, where they reported the region as a very promising one. The following summer mining and placer claims were staked on Miller and Republic Mountains. Although this district was then part of the Crow Indian Reservation, a furnace of the Mexican type was built in 1875, and lead ore from Miller Mountain was smelted. The amount of base bullion produced is difficult to estimate, as the records were destroyed by a raiding party of the Nez Perce Indians in 1878, and the lead of the furnace was stolen, presumably to be converted into shot.

In 1880 George Houston bonded the Republic property to Jay Cooke, then a Northern Pacific contractor, and named the town Cooke City in his honor; this name was later shortened to Cooke by postal authorities. After an initial payment of $5,000 Cooke was unable to take up his bond, and the property reverted to its former owners.

On April 13, 1882, when the district was cut off from the Crow Indian Reservation and thrown open for settlement, Jack Allen set out from Bozeman, Mont., with the first 4-horse team to be driven into Cooke, building his road as he came. From this time on freighting was carried on by teams instead of pack horses, and during the next few years the district developed rapidly. In the summer of 1882 the Republic, Greeley, Houston, and New World claims were purchased from F. D. Peese, George Houston, and James Deevings by Lieut. George O. Eaton, later surveyor general of Montana. Eaton sold a half interest in these claims to Sturgiss & Lane, bankers, of Cheyenne, Wyo.

The Cooke City or Republic smelter was built by these men in 1883 and was put into operation in 1884 on the complex lead-silver-zinc ores of the district. As there was no coal or coke available charcoal was used, which at that time was obtained locally for 16 cents a bushel, or about $1.20 a hundredweight.

Clarence King, of the United States Geological Survey, who knew Sturgiss & Lane by reason of a mutual interest in cattle, recommended the services of Reuben Rickard as general superintendent of the Republic mine. Accordingly he was engaged as manager in 1884 and supervised the early trials of the smelter. The first run in 1883 had shown that the complex ores from the Republic mine contained too much antimony, arsenic, and zinc to be smelted without roasting. Heap roasting was unsuccessfully tried, and so in 1885 a roasting furnace was constructed and in the fall of 1886 the smelter was again put into operation. Smelting was successfully carried on by mixing the nearly pure lead-silver ores of Miller Mountain with the complex ores of Republic Mountain, and several hundred tons of lead was produced in that year. Owing to the high freight rates Rickard believed that shipping base bullion from Cooke would prove unprofitable and advised his employers that a desilverizing plant should be erected. He intended to ship the silver and hold the lead, hoping to accumulate enough to bring a railroad into the district. Owing to financial stringencies the owners were unable to supply the funds for this project, and Rickard resigned. Operations were then abandoned, and the mine was not reopened until 20 years later.

With the closing of the Republic mine and smelter the activity in the district practically ceased for many years, although some lead-silver ores from the Morning Star, Bunker Hill, and Black Warrior claims were smelted in the "Mexican furnace." About 1888 rich gold ore was found in the Daisy and Homestake claims, on Henderson Mountain, and several carloads were shipped. A few years later a small stamp mill was built on the claim, but this had only a short run, and no ore has been treated there since.

The Alice E. property, on the southern flank of Henderson Mountain, contained oxidized gold ore averaging about $14 in gold to the ton. A cyanide mill, erected in 1893, ran successfully for two years, and $35,000 in gold was recovered before the fall of 1894, when the oxidized ore was exhausted. As the sulphide ore remaining could not be cyanided profitably, the mine was closed, and no attempt has ever been made to reopen it.

In 1904 copper ore was discovered at Goose Lake, and the Copper King Mining & Development Co. was organized. This company built a road from Cooke to the mine and carried on operations actively until the financial panic of 1907. A 60-foot shaft and an open cut were made, and a fair tonnage of high-grade chalcopyrite ore was exposed, but little if any ore was shipped, and the mine has been inactive for 15 years.

In 1906 the Buffalo-Montana Co., organized by R. I. McKay and his associates, bought the Republic mine and operated it in a desultory way for a number of years, but the property finally went into the hands of a receiver. McKay was appointed receiver and as such continued to operate the mine intermittently, but apparently with little success. In the summer of 1918 W. D. Marlow leased the property and worked it for two years. The mine reverted to the old company in 1920; since that time it has remained idle, and in 1925 the property was in litigation.

G. L. Tanzer organized the Precious Metals Co. in 1904 and ever since has been a leading figure in the promotion of Cooke mining property. The Precious Metals Co. was succeeded by the New World Mining, Milling & Producing Co., which in 1912 was superseded by the Western Smelting & Power Co. These organizations have all been interested in the copper-gold deposits in Henderson Mountain. The Western Smelting & Power Co. completed a 250-kilowatt power plant on Clark Fork of the Yellowstone River about 4 miles from Cooke in 1915. Work on a 350-ton copper smelter 3 miles from Cooke was then started and was practically completed in 1921, although it had not begun operations in 1925. When the smelter neared completion an 1,100-foot adit was started on the Gold Dust claim, now known as the Adit. This adit was expected to tap at depth the ore body exposed in the Homestake claim, 700 feet higher on Henderson Mountain. In the fall of 1923 an aerial tramway was started to connect this adit (then 1,600 feet long) with the smelter. By the fall of 1925 the tramway was practically complete and the adit had reached a length of 2,100 feet but had not struck the ore body earlier estimated to be 1,100 feet from the entrance. The Western Smelting & Power Co. owns many claims in the district, but nearly all of its development work has been done on the Adit claim. Up to 1925 no ore had been piled, shipped, or smelted.

In 1905 G. R. Allison became interested in the possibilities of Cooke and raised sufficient capital to build the lead smelter that stands about half a mile east of the town. He searched unsuccessfully for ore in the vicinity of the smelter and after it was completed bought some copper ore from Henderson Mountain claims. As the smelter was built for lead, his effort to run it on copper ore was disastrous, and within a few days after starting operations the melt is said to have "frozen" in the crucible. The smelter discontinued operations and so far as could be learned was never reopened. With the failure of the smelter and near-by prospects Allison was unable to continue operations in the district, and the property has stood untouched since 1912.

C. R. Tuttle visited the district about 1906 and is reported to have raised a large sum for the exploitation of several prospects but was unsuccessful in developing any paying property.

In 1923 the Mohawk Mining Co. sank a shaft at the foot of Woody Mountain, in a galena-sphalerite vein which had a good content of silver. Some of the ore shows wire silver, and many specimens assay over 300 ounces to the ton. Little work has been done here since, however.

Active development work has been going on since 1920 in the Irma mine, southeast of the Republic mine and about a mile south of Cooke. Adits driven in from Republic Creek have disclosed ore of good grade, and in 1925 the company had sunk a 225-foot shaft close to the intersection of two fractures, where it hoped to find a good body of galena. This company shipped several carloads of lead-silver ore in 1922, 1923, 1924, and 1925.

The Tredennick Development Co. has a group of claims on Scotch Bonnet Mountain, where pyritic copper ore of good grade is exposed in a shallow adit. In 1925 an adit was being driven at a lower level to explore for this ore body at greater depth.

The Glengarry Mining Co. is engaged in developing some copper-gold property on Scotch Bonnet Mountain. An adit about 2,300 feet long driven into the base of the mountain failed to discover copper ore in depth, and the ore exposed in the upper workings is now being blocked out. A small pyritic copper smelter is planned, if sufficient tonnage is proved.

PRODUCTION

It is impossible to say how much lead-silver ore was produced in the early history of the district, but records of the Republic smelter show that in 1886 approximately 4,000 tons of ore was treated, from which 735,000 pounds of lead, 62,300 ounces of silver, and 438 ounces of gold were recovered. The prices were as follows: Gold, $20 an ounce; silver, $1 an ounce; lead, 4.6 cents a pound. The value of the metals produced in this one year was therefore about $104,870.

No records can be found of the ore produced between 1886 and 1901, but it is probable that ore to the value of about $55,000 was mined and shipped, the principal contributions coming from the Alice E., Homestake, and Daisy mines. (See pp. 61, 62, and 70.) From 1901 to 1923, according to C. N. Gerry, of the United States Bureau of Mines, the production from the New World district amounted to 1,213 short tons and had a value of $56,943. This would indicate a total production from Cooke of about $215,000. The details are given in the following table:

Metals produced in the New World district, 1901–1923

Year	Ore sold or treated (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Total value
1901	40	44.51	10			$926
1902	3	1.50	54		100	59
1906	18	10.84	71	3,316		911
1907	200	2.32	6,160		130,000	11,004
1910	152	12.23	2,132		148,488	7,938
1911	45	1.96	237		29,866	1,511
1912	101	45.52	311			
1917	45	6.44	746		32,076	3,506
1918	76	28.15	1,829		43,168	5,476
1919	86	33.06	3,111	251	58,985	7,340
1920	292	9.49	10,623	1,461	95,680	9,698
1922	38	2.10	1,165		33,962	3,076
1923	117	1.50	3,943	182	31,529	5,498

The chief producers in the last 20 years are included in the following list, which will also give an idea of the time of production and the amount:

New World Mining & Development Co., 18 tons of crude ore in 1906.
Hudson & Boulder mine, 200 tons of crude ore in 1907.
Big Blue mine, 152 tons of crude ore in 1910.
Cooke City Smelting Co., one shipment in 1911.
Clean-up of old mill, 100 tons in 1912.
St. Elmo & Cuba Consolidated mines, one shipment in 1917.
Yellowstone Mining Co., 133 tons of crude ore in 1917, 1918, and 1919.
Old Republic Leasing & Exploration Co., 290 tons of crude ore in 1919 and 1920.
Irma mine, 135 tons of crude ore in 1922 and 1923.
Morning Star mine, one shipment in 1922.

ORE DEPOSITS

GENERAL FEATURES

Many types of ore deposits are found in the New World mining district. The mineralization of this area is believed to have been accomplished wholly in Tertiary time, for although ores are found in pre-Cambrian granite, their characteristic features place them with the veins that cut the Tertiary rocks near by.

The syenite of Goose Lake and the monzonite porphyry of Henderson Mountain are separate centers of mineralization. A rude zonal arrangement of ores can be distinguished around the Henderson Mountain stock, which is the larger of these two. (See pl. 16.) On this mountain contact-metamorphic gold-copper deposits have been developed. Here too and in the immediately adjacent region are deposits of low-grade pyritic gold ore, in irregular masses or veins. Copper-lead deposits are predominant in a belt girdling the pyritic copper zone, but the segment in the granite country to the east contains very few mineral deposits except close to the larger intrusive bodies. Copper and lead deposits carrying some zinc can be found in the Cambrian sediments which in large part form the crest of Sheep Mountain. At greater distances from the metamorphic aureole the complex lead-silver-zinc ores appear. It is in these ores that the most promising prospects of the district are located. Veins belonging to this group occur in Woody Mountain, Republic Mountain, and the upper basin of the Stillwater River. In most places the massive basal limestone member of the Gallatin formation is the horizon for deposits of this type. Sideritic calcite veins containing silver are found at a slightly greater distance from the intrusive body than the complex ores just mentioned and probably represent the transition to the barren carbonate veins that appear at some places. Veins of this type are present on Woody Mountain and in the Stillwater Basin. Wherever a vein crosses limestone replacement deposits may be present; most of the complex lead-silver ores occur where veins cross a bed of Gallatin limestone.

The Goose Lake center shows mineralization of a different character from that near the Henderson Mountain stock. The region north of Goose Lake is cut by a series of intrusive rocks which range progressively from a basic gabbro through granodiorite into a syenite. The acidic rocks cut the more basic ones, showing that there was a progressive change of magmas from basic to acidic. These rocks occur in the form of stocks, dikes, and irregular intrusive bodies. A chalcopyrite segregated deposit occurs in the syenite, and at a little distance from the syenite mass galena-sphalerite veins crop out. The gangue of these veins is made up of quartz, thus differing from the manganiferous ankerite and sideritic calcite gangues of the veins to the south. There are also some veins containing practically no lead or zinc and consisting almost wholly of quartz with coarse comb structure, carrying small quantities of gold and as much as 25 ounces of silver to the ton. This region has not been as thoroughly prospected as the country near Henderson Mountain and may increase in importance as the country is more fully investigated.

CLASSIFICATION

With the exception of the Copper King and some small surficial deposits, all the ores in the New World district were formed originally by the agency of hot fluids emanating from a magmatic source. After erosion had removed the overlying rocks, cold surface solutions began to concentrate some of the ores in the zone of enrichment. Unfortunately for the miners, the great Pleistocene sheets of ice scoured most of the enriched rock from the region. In certain localities, however, remnants of the zone of enrichment still exist and contain ores of comparatively high grade.

The ores are grouped below primarily according to genesis, but as it is helpful to describe together deposits that are mineralogically alike, the genetic classification contains secondary subdivisions of a descriptive character.

Classification of ores in the New World district

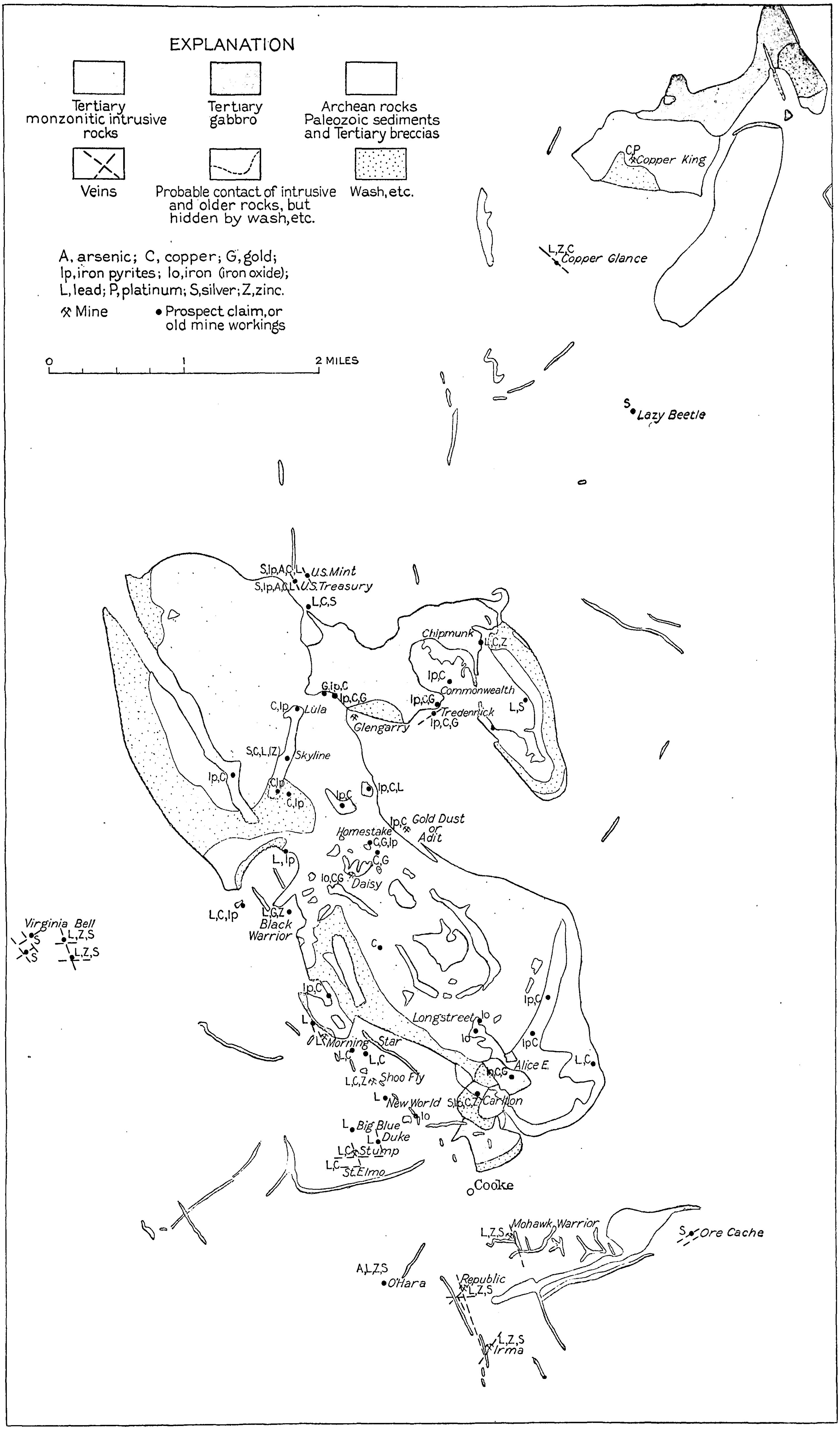
1. Deposit due to magmatic segregation: Copper-platinum deposit.
2. Contact-metamorphic deposits: Copper-lead-gold deposits.
3. High-temperature veins: Pyritic-copper deposits; gold-quartz deposits.
4. Moderate-temperature veins: Copper-lead deposits; lead-silver deposits; complex lead-zinc-silver ores; carbonate-silver veins.
5. Surficial deposits: Gold placers, bog copper, and bog iron ore.

DEPOSIT DUE TO MAGMATIC SEGREGATION

The only deposit formed by magmatic segregation in the district is found at the Copper King property north of Goose Lake. It is in a perthitic syenite, and 98 per cent of the gangue is composed of orthoclase and albite. Chalcopyrite is almost the only sulphide present, but some platinum and a very small amount of silver and zinc occur with the copper. In addition to feldspar small amounts of biotite, muscovite, and apatite occur in the gangue. Since the area was glaciated weathering has been practically negligible, and the material at the surface consists of primary ore.

CONTACT-METAMORPHIC DEPOSITS

Ores of contact-metamorphic origin are known on Henderson Mountain, but the metamorphism was intense at only a few localities. The copper deposits of this type have so far proved disappointing,



MAP SHOWING LOCATION OF PRINCIPAL MINES IN NEW WORLD DISTRICT AND RELATION OF DEPOSITS TO INTRUSIVE ROCKS and up to 1925 no paying ore bodies had been developed. Rich gold ores of contact-metamorphic origin were worked in the late eighties, but none are exposed to-day. Specimens showing wire gold in galena were seen and are said to be typical of the rich ore. The gold-bearing galena occurred in irregular masses intermixed with typical contact-metamorphic minerals such as garnet and specularite and showed no depth relation to the surface. On this somewhat meager evidence the gold ores are regarded as primary.

The most common sulphide of the contact-metamorphic deposits is pyrite. Second in abundance is chalcopyrite. Some galena and blende are occasionally found, but are not economically important. Specularite is abundant at a number of localities, but, contrary to the opinion of many of the prospectors, it does not indicate the presence of copper ore. Magnetite is much less abundant than hematite and is found in quantity only in the south end of Henderson Mountain. The nonmetallic minerals consist largely of quartz, epidote, and ankerite, which are suggestive of mild metamorphic activity. Where metamorphism has been intense garnet and tremolite are also developed, and more rarely vesuvianite and muscovite.

During the replacement of limestone, which is the country rock of these deposits, iron, silica, manganese, sulphur, and copper have been added and carbon dioxide, calcium, and magnesium have been subtracted. These deposits are resistant to weathering, except where they are traversed by fracture zones. In such localities the rocks are kaolinized and heavily stained with iron and manganese oxides. Some gold is close to the surface and is believed to be secondary, as it is associated with manganese-stained quartz. Secondary copper of commercial importance is not known, although copper carbonates, as well as some secondary sulphides, have been observed in these deposits. The fresh ores are for the most part dense, homogeneous masses, although vugs lined with quartz and containing some gold are occasionally found.

HIGH-TEMPERATURE VEINS

Pyritic gold-copper deposits are very numerous in the district, and many of them have been mined. Up to 1923 little of the ore mined from them had yielded any profit, but this may be due largely to the lack of proper beneficiation. The deposits are found in the neighborhood of large intrusive masses, such as the gabbro of Scotch Bonnet Mountain or the monzonite stock of Henderson Mountain. Quartz is the most abundant gangue mineral. The wall rocks are in places intensely altered by hydrothermal action, with the development of sericite, chlorite, and other minerals. Pyrite forms the chief sulphide, and smaller quantities of chalcopyrite, galena, and zinc blende are associated with it. Silver is rarely present, and the gold content runs from $5 to $15 a ton in the better class of primary ore. The intensity of hydrothermal action, the character of the ore, and the close spatial relation to large intrusive bodies indicate the deep-seated conditions prevailing at the time of deposition. Where these ores are partly oxidized the copper and gold content is markedly greater, and typical secondary copper minerals have been developed. The completely oxidized portions of the pyritic gold ores can be profitably cyanided, but the tonnage of such ore is small, and cyanidation of the sulphides in the past has been utterly unsuccessful. No other method of treating the ore has been tried, and it may be that with the introduction of modern methods of milling and concentration these deposits will prove a source of revenue.

Some rich pockets of gold-bearing quartz have been discovered in a few places close to and within the large intrusive masses of monzonite. As these deposits were mined out rapidly, the writer has not seen any in the field. Specimens of the ore, however, show coarse comb quartz of a vuggy character, with a small amount of pyrite and free gold. These veins, from the nature of their gangue and their areal distribution, are thought to have been formed at high temperature under great pressure.

MODERATE-TEMPERATURE VEINS

Copper-lead deposits.—Copper-lead veins containing little zinc are found in Miller Mountain and to a less extent in Sheep and Red Mountains and north of Scotch Bonnet Mountain. Most of these deposits appear small, but it is difficult to judge of their extent because of the meager development work. These veins were an important source of silver and lead in the early days of the camp and supplied much of the zinc-free ore that was used to run the Republic smelter during the fall of 1886.

The gangue minerals consist of manganiferous ankerite and a small amount of fine-grained quartz. Sericite and chlorite are developed to some extent in the wall rocks, but hydrothermal alteration is not as extensive as in the deposits that have already been described. Characteristic ore from veins in this group contains an abundance of coarse-grained galena and a small amount of chalcopyrite. Arsenopyrite is found locally. Zinc blende and tetrahedrite occur locally but usually in small amounts. Pyrite is of subordinate importance, and the amount present varies greatly.

These veins are typical fissure fillings, and extensive replacement of the wall rock occurs at very few places, even where they cut the pure, massive, lower limestone of the Gallatin formation.

Enrichment has made but little progress in the veins belonging to this class that were visited by the writer. Copper carbonates and superficial coatings of lead carbonate and lead sulphate may be noted at many places, but the primary ore is much more abundant than the secondary ore. Thin streaks of oxidized material along fractures may be found to depths of 50 to 100 feet, and they have a much higher content of silver than the unoxidized ore. None of the prospects have been worked for silver alone, however.

Lead-silver deposits.—Partly oxidized lead-silver ores, low in zinc, occur on the southern and southwestern flanks of Miller Mountain. Sulphides of lead and silver intermixed with cerusite made up the major portion of the zinc-free ore sought by the smelter in 1885–86 for admixture with the complex ore from the Republic mine. Most of the mines that supplied the demand have long been abandoned and caved, but information from men who mined the deposits of Miller Mountain suggests that the ore bodies were formed by replacement of Gallatin and Bighorn limestones. The ore was found either in nearly horizontal deposits or in nearly vertical pipelike masses. Cross sections of any ore body varied greatly, even in one deposit.

All the sedimentary rocks observed in Miller Mountain dip south or southwest. Postmineral movement has partly shattered the formations over large areas and greatly expedited the movement of meteoric water down the dip of the sediments into the valley of Soda Butte Creek. It is probable that large amounts of sphalerite and pyrite were removed through the active circulation of the ground water. Abundant lead carbonates and a low content of zinc would be expected in leached lead ores of this kind.

Complex lead-zinc-silver ores.—Deposits of lead-zinc-silver ore usually occur at some distance from the large intrusive masses and the mines now operating in the complex ores are south of Soda Butte Creek on Republic Mountain and Woody Mountain. Some promising prospects of the same class were seen in the Stillwater Basin. Large ore bodies have been developed at the Republic mine, and it is probable that there are other extensive deposits of this class. As there are no concentrating mills in the district, the present shippers send only their high-grade ores to market, either throwing away lower-grade lead ores and mixed lead-zinc ores or piling them for future use.

The complex ores are chiefly medium to fine grained replacement deposits in the lower limestone of the Gallatin formation, where the bed is cut by mineralized fissures. The fine-grained phases of the ore are in many places dense, siliceous, and zincky, but the coarser-grained ore commonly consists of friable fractured masses of galena, high in silver and lead and low in zinc. The most abundant gangue mineral is a carbonate (manganiferous ankerite), but fine-grained quartz is present in varying quantities. Galena and blende are by far the most plentiful of the sulphides. Chalcopyrite, pyrite, and silver are present in small amounts.

Some of the complex lead-silver-zinc ore bodies have been extensively enriched, and the black manganese-stained outcrops that form the characteristic gossan in such deposits are prominent in many localities. Cerusite and anglesite are abundant in the upper portion of the secondary zone, giving way in depth to galena, zinc blende, and secondary silver antimonides, such as pyrargyrite and polybasite. Native silver is encountered at several places some distance from the surface and is the deepest of the secondary ore minerals.

Texturally the ore bodies of this class are for the most part very friable, and their loose texture has been a great aid to the enrichment, which is prominent at the Republic and Irma mines.

Carbonate silver veins.—Veins consisting almost wholly of sideritic calcite containing small amounts of manganese and magnesium are found near Woody and Silver Mountains and in the Stillwater Basin and probably represent the outermost zone in which metalliferous deposits occur. A little silicification has occurred. The carbonate is much higher in iron than the gangues found in deposits of the preceding classes and resembles coarse-grained siderite.

Very small amounts of sulphides are present in these veins. A little pyrite has been noted but may be of supergene origin. Galena and blende are generally absent. The veins assay as much as 5 ounces to the ton in silver at the surface, and this metal may be present as the carbonate. Many of the veins are strong and well defined and may be traced for considerable distances.

Either brown or black manganese oxides are formed on weathering. Thiel,[38] who has made an exhaustive study of the conditions of deposition of secondary manganese oxides, reached the conclusion that the brown manganese oxide is the first secondary mineral to be formed and may indicate the upper portion of a vein. The darker oxide indicates downward migration of manganese.

The veins of this class have been little worked. It would be of great practical and theoretical interest to know the change in tenor of the vein with increasing depth, but no data are available on this point.

SURFICIAL DEPOSITS

Some small deposits of bog iron, bog copper, and placer gold occur in this district but are of minor economic importance. They are discussed in detail on pages 85 and 86.

[38] Thiel, G. A., The manganese minerals: Econ. Geology, vol. 19, p. 131, 1924.

MINERALOGY

In the following table the occurrence and relative abundance of the economically important minerals are summarized. The three groups of deposits listed are (1) contact-metamorphic deposits; (2) high-temperature deposits, including the pyritic copper lodes, the gold quartz veins, and a deposit formed by magmatic segregation; (3) moderate-temperature deposits, including copper-lead lodes, the complex lead-zinc-silver group, and carbonate silver veins.

Ore and gangue minerals of the New World mining district

[A, Abundant; D, dominant; S, sparingly present; R, rare; p, primary; s, secondary (supergene)]

Mineral	Contact-metamorphic	High temperature	Moderate temperature	Comments
Actinolite	Sp			
Ankerite	Rp	Sp	Dp	
Anglesite			Ss	At Morning Star mine.
Argentite			Sp, Ss	
Arsenopyrite		Sp	Sp	
Azurite	Rs	Rs	Rs	
Biotite		Rp		
Bornite	Ss	Rp, Ss	Rs	
Boulangerite			Sp	Abundant near Goose Lake.
Calamine			Rs	
Calcite	Rp	Rp	Rp, Rs	
Cerusite			Ss	
Chalcopyrite	Ap	Ap	Sp, Ss	
Chalcocite	Rs	Ss	Ss	
Chlorite	Sp			
Covellite			Rs	
Cuprite			Rs	
Dolomite	Rp	Rp	Rp	
Epidote	Dp			
Freibergite			Sp	
Galena	Sp	Sp	Ap	
Garnet	Ap			
Gold	Rp	Rp		
Gypsum			Ss	
Limonite	As	As	As	
Magnetite	Ap	Sp		Longstreet claim.
Malachite	Ss	Ss	Ss	
Marcasite			Ss	
Platinum	Pp			At Copper King mine.
Polybasite			Ss, ?p	
Proustite			Ss	
Pyrargyrite			Ss	
Pyrite	Ap	Dp		
Quartz	Ap	Dp	Ap, Ss	
Silver			Rs	
Specularite	Dp	Rp		
Smithsonite				Not observed but probably present.
Sphalerite	Rp	Rp	Ap	
Tetrahedrite			Sp	
Vesuvianite	Rp			

GENESIS

Paragenesis.—The paragenesis indicated for the ores related to the Henderson Mountain stock is as follows:

1. Quartz, sericite, magnetite, hematite.
2. Pyrite.
3. Chalcopyrite, arsenopyrite.
4. Small amounts of sphalerite.
5. Galena, freibergite, tetrahedrite.
6. Sphalerite.
7. Argentite and small amounts of galena and blende.
8. Ankerite and small amounts of quartz.

The minerals of group 1 are nearly contemporaneous. The pyrite is earlier than the major part of the chalcopyrite, which was the second sulphide to form. A very small amount of the chalcopyrite is contemporaneous with the pyrite, but most of it appeared at a much later stage. Where arsenopyrite is present its relation to chalcopyrite is obscure, but it is easily seen that pyrite is earlier than the arsenopyrite, whereas the galena is distinctly later. Galena, the third sulphide to be deposited in noteworthy amounts, closely followed the chalcopyrite. Next the bulk of the sphalerite was deposited. Later a second generation of galena appeared and in most places was followed by or contemporaneous with a second generation of sphalerite. Argentite was probably deposited with the second generation of galena. Some tetrahedrite and freibergite are later than the first generation of sphalerite and earlier than the second.

In the ore deposits south of Soda Butte Creek evidence is found of two stages in the period of mineralization. A reversal of the usual order of deposition is obvious, for veinlets of quartz and arsenopyrite cut all the other hypogene minerals. These facts suggest another wave of metallization or a mingling of the first solutions with those from a different source. The usual order of paragenesis given above holds for the first period of mineralization but is masked by the effects of the second period.

Only two deposits of any economic importance are now known that are related to the intrusive rocks at Goose Lake; one of these is due to magmatic segregation, and the other is a lode deposit formed at moderate temperature and pressures. (See pp. 59 and 72.) The paragenesis indicated for these deposits is chalcopyrite, quartz, pyrite, sphalerite, galena, antimonides (boulangerite), and carbonates.

Source.—All the field evidence in the New World district points to a magmatic source for the ores. The age of the ores (their formation closely followed the intrusion of the monzonite), the intensity of hydrothermal action on the monzonite porphyry of Henderson Mountain, the rude zonal arrangement of ores about the Henderson Mountain stock, the common occurrence of ore deposits close to other intrusions of this nature, and the lack of spatial and age relationship between other kinds of igneous rock and the ore deposits—all suggest a genetic relation between the metallization of the district and the magma from which the monzonitic intrusions were derived.

Character of the mineralizing solutions.—The probable character of the mineralizing solutions is indicated by the replacements that have been made. As each replacement means the loss of some constituents from the solutions and the addition of others, the change in the character of the moving solutions must be taken into account.

The monzonite porphyry has been altered to sericite and quartz, indicating the addition of potash and some silica to the rock and of calcium and sodium to the solutions.

In the near-by contact-metamorphic deposits limestone beds are replaced principally by epidote, quartz, and oxides of iron; to a less extent by sulphides of copper, iron, lead, and zinc. The replacement of limestone by these substances involves the loss from the solutions of ferrous and ferric iron, sulphur, silica, and some copper and manganese and the gain of calcium and magnesium carbonates. Although the epidote is not confined to the shaly beds, it is far more abundant in these than in the beds lacking alumina. This would indicate that little addition of subtraction was involved in the formation of these deposits but rather a recrystallization of the constituents of the rock.

In the region surrounding the metamorphic zone pyritic gold deposits are common. In these deposits sericitization and silicification were common, and where limy beds were encountered the metallizing solutions exchanged large amounts of iron, sulphur, potash, and silica and small amounts of copper and gold for calcium and magnesium carbonates. Evidence of a decreasing silica concentration and an increasing content of the carbonates in the outward-moving solutions may be adduced also from the fact that silicification was early and more intense close to the stock than at greater distances, while, conversely, the carbonates become more abundant in the gangue as greater distance from the stock is attained. It is worthy of note that the veins in the pre-Cambrian rocks near Henderson Mountain have a much more siliceous gangue than the veins in the Flathead, Gros Ventre, and Gallatin formations a corresponding distance the other side of the mountain.

Copper and lead are well developed in the zone immediately outside of the pyritic copper deposits; farther away we find sphalerite, galena, antimonides, arsenides, and silver minerals in a gangue of manganiferous ankerite and fine-grained quartz. Replacement of limestone was common in this outer zone, showing that the magmatic solutions were still able to exchange sulphides and silica for calcium carbonate.

From the considerations above set forth it seems probable that the mineralizing solutions had high concentrations of iron, potash, silica, sulphur, and, to a much less extent, lead. Copper, zinc, and manganese were present in moderate amounts, but gold, silver, arsenic, and antimony made up only a small percentage of the solutes. The calcium and magnesium carbonates that were deposited may have been derived wholly from the dolomitic limestone replaced by the solutions.

FUTURE OF THE DISTRICT

In view of the conditions prevailing in the New World district in 1922 to 1925, there seems little likelihood of railway transportation becoming available for many years. It is safest to assume that dependence must be placed on such carriers as automobile trucks and teams. This type of transportation makes freighting from Cooke to Gardiner cost about $20 a ton and prohibits the shipping of any but high-grade ore. According to Mr. L. H. Brooks, of the Irma mines, ore must be worth $40 a ton in order to be mined at profit. The zinc in the mixed lead-zinc ores is heavily penalized, and the value of the silver and lead must be correspondingly higher to enable such ore to pay its way.

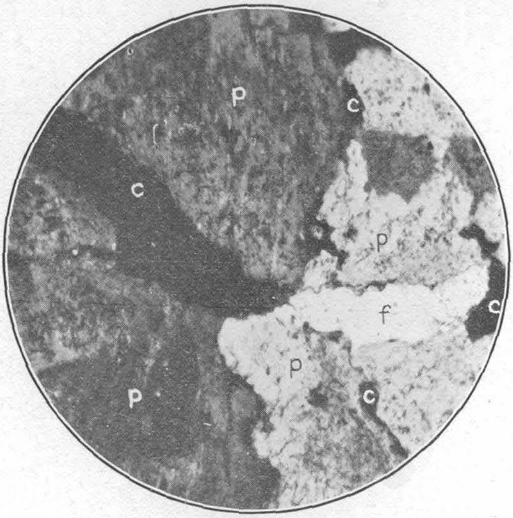
No mills for the concentration of lead-zinc ores have ever been built within the district. As galena-sphalerite ores are by far the most abundant, it is a surprising fact that four smelters have been built before the construction of any mills. Owing to the high cost of transportation, it seems highly advisable that only concentrates should be shipped, and it is improbable that the district will develop until steps to produce them have been taken.

The concentration of the pyritic copper ores would be a relatively easy matter, as the ore minerals consist primarily of chalcopyrite and pyrite, which may be separated by flotation with no great difficulty. In the coarse-grained lead-zinc ores the galena could easily be separated from the associated blende by ordinary tabling methods or by flotation.

The fine-grained lead-zinc deposits formed by the replacement of limestone in the outer zone of mineralization present a more difficult problem. These deposits, which contain considerable silver, seem to be the largest in the district, and the future of the camp appears to depend on the development of a method for their mining and treatment. A microscopic study of the fine-grained ores shows that the intimate intergrowth of sphalerite and galena would necessitate extremely fine grinding before mechanical separation would be possible. (See pl. 23, *B*.)

The problem of the complex ores is in a fair way of being solved at present, and there is little question but that some time in the future these intimate mixtures will be amenable to treatment. Selective flotation is now the only mechanical means by which these ores could be separated. Of the chemical processes electrolytic deposition, the sulphatizing roasts as developed by Coolbaugh, or the brine leaching of galena as practiced in Missouri offer the most promising possibilities of beneficiation.

It is probable that a substantial production of lead and zinc could be maintained for a number of years from these deposits. It is



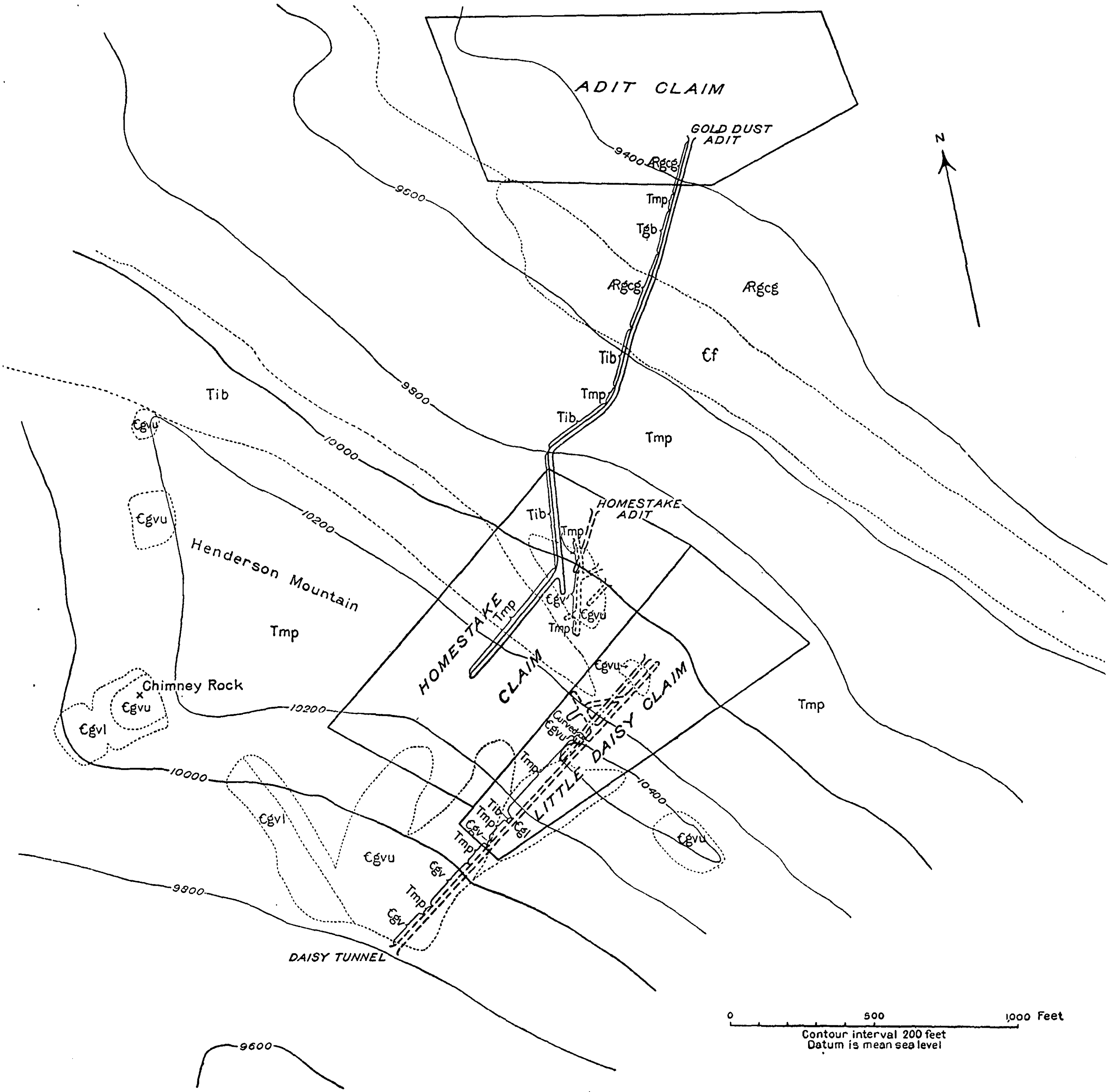
A. LATE FELDSPAR AND CHALCOPYRITE VEINLET CROSSING PERTHITE

p, Perthite; f, late feldspar; c, chalcopyrite. Enlarged 75 diameters

B. LATE NEEDLES OF MUSCOVITE PENETRATING CHALCOPYRITE

c, Chalcopyrite; s, muscovite. Enlarged 75 diameters

PHOTOMICROGRAPHS OF ORE FROM COPPER KING MINE, NEW WORLD DISTRICT



MINE MAP OF HOMESTAKE PROPERTY, NEW WORLD DISTRICT

ARgcg, Archean Goose Creek granite; Cf, Flathead quartzite; Cgv, Gros Ventre formation; Cgvl, lower member of Gros Ventre formation; Cgvu, upper member of Gros Ventre formation; Cgl, lower member of Gallatin formation; Tmp, Miocene monzonite porphyry; Tib, Tertiary intrusive breccia; Tgb, Tertiary gabbro unlikely that the pyritic copper deposits will ever be as valuable as the lead, silver, and zinc ores, but by shipping only concentrates the copper deposits might be worked at a profit. Where gold or silver are present in large quantities any of the ores may be mined and shipped with only hand sorting, but ores of this character are not abundant and would never form a source of large production for any length of time.

The smelting of ore at Cooke can not be economically justified under present conditions of high-priced coke and low known ore reserves. If a large tonnage of high-grade pyritic copper-gold ore is uncovered in which the pyrite can not be separated mechanically from the copper and gold, it might be advisable to smelt the ore at Cooke and ship out copper matte, but the deciding factor would be the cost of transportation.

MINES AND PROSPECTS

Owing to the nearly dormant state of mining at the time of the writer's visit, the workings of more than half of the mines and prospects were virtually inaccessible. A detailed report of such properties based on the scanty evidence available might be misleading, and unless a prospect of this sort must serve as an illustration of a certain type of deposit, only a brief description of it is given.

DEPOSIT DUE TO MAGMATIC SEGREGATION

COPPER KING MINE

The Copper King Mining Co. owns a group of patented claims at the head of Goose Lake (pl. 1), 7 miles north of Cooke, and the mine may be reached over a wagon road in a fair state of repair. Considerable exploratory work was done about 1906 by means of open cuts and pits, and many of these openings have exposed copper ore of good grade.

The two buildings on the property have been unused for many years but are kept in repair by the manager, F. C. Byrne, of Cooke. A shaft said to be 60 feet deep was filled with water at the time the property was visited.

The areal distribution of the rocks in this area is shown on Plate 1. No sedimentary rocks are present. The country rocks include pre-Cambrian granite, schist, and gneiss, and Tertiary intrusive gabbro, granodiorites, monzonite, syenite, and related rocks. A gabbro stock cuts the Archean granite 1,500 feet north of the mine and is intruded by both syenite and monzonite. East of the mine flat-lying sheets of pegmatitic syenite cut granodiorite. The Copper King ore body is in a coarse-grained syenite of considerable extent that locally carries good values in copper.

High-grade ore, running about 20 per cent of copper and 2.85 ounces of silver and as much as 0.1 ounce of platinum to the ton, may be seen in a trench about 75 feet long at the shaft house. The shaft is said to expose much leaner ore in depth, but little idea can be gained of the size and extent of the ore body without more prospecting of a systematic nature. From the evidence offered in the following paragraphs the deposit is thought to be a result of magmatic segregation. As segregated copper deposits in syenite are rarely very extensive and are usually rather irregular in shape, it seems advisable that the ore be blocked out by some such method as diamond drilling before an estimate of ore is made.

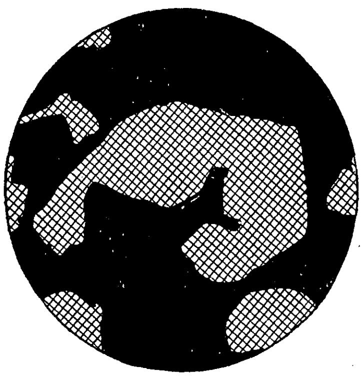


FIGURE 4.—Ore from Copper King mine, New World district. Orthoclase (white) corroded by chalcopyrite (black). Enlarged 74 diameters

The ore is made up essentially of chalcopyrite and a perthitic intergrowth of orthoclase and albite. Muscovite, biotite, apatite, and magnetite were noted as accessory minerals. Veinlets of muscovite, orthoclase, chalcopyrite, and apatite cut the perthite grains, but in place the contact appears to be gradational. The rock is fresh, and no evidence of hydrothermal alteration can be seen. The muscovite is medium grained, and as it does not resemble the sericite developed in a typical hot-water alteration, it is believed to be an original mineral of the segregation. Chalcopyrite surrounds and apparently corrodes the feldspars of the rock or crosses them in veinlets, which as a rule follow cleavage planes. Many of these veinlets show a second generation of feldspar contemporaneous with the chalcopyrite but later than the perthite grains traversed by the veins. (See pl. 17, *A*.) In the leaner parts of the rocks, where the chalcopyrite is sparingly represented, the orthoclase shows little tendency to develop euhedral shapes, but in the richer portions the texture resembles that of a porphyry, with a matrix of chalcopyrite and phenocrysts of orthoclase. Some of the feldspar grains are subhedral, but many show corrosion by the sulphide. The feldspar is not altered in any other way, and no reaction rims are present. Figure 4 illustrates the appearance of this corroded "porphyritic" ore. In many places muscovite crystals penetrate crystals of chalcopyrite, as shown in Plate 17, *B*, and this may be taken as an indication that the sulphide is earlier than the mica.[39]

[39] Tolman, C. F., and Rogers, A. F., A study of the magmatic sulphide ores, p. 30, Stanford University, Calif., 1916.

Although this criterion is not fully accepted by all geologists, it is believed by the writer that the muscovite in this ore is contemporaneous with or later than the sulphide. Minute bipyramids of chalcopyrite were observed in the interior of a grain of apatite; this suggests that the sulphide had started to crystallize before the phosphate. No pyrite was found in any of the specimens studied, and only very small amounts of magnetite and scattered stringers of sphalerite. The magnetite is clearly earlier than the chalcopyrite, and the sphalerite is contemporaneous with it or later. Grab samples of the ore from many of the open cuts and pits assay about 2.85 ounces of silver and as much as 0.1 ounce of platinum to the ton. No gold is present.

To summarize, (1) no hydrothermal alteration can be detected; (2) minerals associated with the ordinary hydrothermal deposits of this district, such as pyrite and ankerite, are lacking; (3) the minerals of the deposit are those which are typically developed in magmatic deposits; (4) the occurrence of platinum in small quantities is suggestive of the syngenetic character of the ore; (5) the subhedral crystals of orthoclase, lacking reaction rims, surrounded and partly resorbed by chalcopyrite, are difficult to explain by any other than this syngenetic hypothesis; (6) the penetration of chalcopyrite by muscovite indicates the early crystallization of the ore.

It is believed by the writer that the ore body of the Copper King mine marks the final stage in the differentiation of a basic magma and should be classed as a sulphide deposit formed at a late magmatic stage.

CONTACT-METAMORPHIC DEPOSITS

DAISY MINE

The Daisy mine, owned by the Western Smelting & Power Co., is on the southwestern slope of Henderson Mountain close to Daisy Pass, at an altitude of 9,600 feet. An excellent mountain road leads from Cooke to the property. This mine was originally opened on a gold deposit and produced some rich ore in 1888–1890 but has not been worked for many years. The buildings on the claim originally included a small stamp mill, boarding house, stable, and two cabins, but snow and marmots have taken a heavy toll from the once sturdy structures.

The Daisy is said to have 2,385 feet of workings distributed among three adits. (See pl. 18.) The long adit on the southwestern flank of Henderson Mountain, a short distance above the old stamp mill, is connected by a raise to an adit on the east side of the mountain. These drifts are partly accessible, but caving has rendered it impossible to explore more than 1,200 feet of the workings.

The mill adit was started in monzonite close to a large xenolith of Gros Ventre formation, and in this drift Gros Ventre and Gallatin beds alternate with monzonite. The lower limestone of the Gallatin is little affected by contact metamorphism, but the impure shaly limestone of the underlying Gros Ventre formation is in many places changed to masses of garnet, epidote, pyrite, and chalcopyrite. Other minerals which are less abundantly developed include chlorite, tremolite, vesuvianite, and quartz. The ore now exposed is of more value for the copper than for the gold and is one of the best examples in the district of a contact-metamorphic copper ore.

Thirteen carloads of gold ore averaging about $50 a ton are said to have been shipped to Omaha in 1888. According to the miners who worked here in that year, the ore was confined to the metamorphosed shaly limestone, where it occurred in irregular boulderlike masses. Wire gold was common and was invariably associated with galena. Two specimens said to be representative of this ore were examined by the writer and found to consist of white quartz needles from a quarter to half an inch long, dense red jaspery quartz, and crystals of resinous sphalerite and galena a quarter of an inch in diameter; wires and blebs of gold were conspicuous in the galena. This corroborates, in part, the tradition of the mine that "when the ore runs in lead it runs in gold." Very little pyrite, chalcopyrite, or magnetite was noted.

Typical polished specimens of the ore now exposed show an intimate intergrowth of sulphides, carbonate, quartz, and specular hematite. The hematite seems to be later than the quartz and probably earlier than the carbonate, which is a manganiferous ankerite. Brecciated crystals of pyrite are abundant and are penetrated by needles of hematite and blades of ankerite. Chalcopyrite is later than the pyrite and seems to be contemporaneous with or later than the hematite. No other ore minerals were found in any of the specimens from this claim.

HOMESTAKE CLAIM

The Homestake claim, owned by the Western Smelting & Power Co., lies on Henderson Mountain adjacent to the Daisy claim. (See pl. 18.) A secondary road runs from an adit on the east side of the mountain, at an altitude of 10,000 feet, to the main road to Cooke, as indicated on Plate 1. This claim has produced rich gold ore and some fair-grade copper ore of contact-metamorphic origin. According to Sam Mathers, the discoverer of the claim, a 30-ton carload of ore was shipped to Salt Lake City about 1887. The ore was sampled and assayed at the mine, and only rock carrying more than 3 ounces of gold to the ton or more than 18 per cent of copper was shipped. This shipment, which was the only one made from the mine, is said to have netted a little over $3,000.

There are three adits, two of which are connected by a raise. Some minor drifts and crosscuts open from the adits, but the total length of development work does not exceed 700 feet.

The lower adit (at an altitude of about 10,000 feet) penetrates monzonite porphyry for about 150 feet and after cutting a coarse intrusion breccia passes through a block of highly metamorphosed Gros Ventre limestone for about 50 feet. The remaining 25 feet of the adit exposes monzonite porphyry. Similar relations exist in the upper adits, though the limestone is exposed for greater distances, suggesting that the lower adit is near the base of the limestone block. The ore is practically confined to this metamorphosed limestone, but small amounts occur sporadically in the associated intrusion breccia. Thus the ore body is in no sense a vein, and there is little reason to expect a continuance of it in depth. This conclusion is supported by a failure to find similar ore in the long adit driven under the claim nearly 700 feet below. (See pl. 16.)

An intrusion breccia is visible on the surface as an iron and manganese stained outcrop running in a general north-south direction. Its width varies greatly, and at many places no sharp contact with the monzonite porphyry wall rock can be found. It consists of medium-grained monzonite porphyry containing mineralized fragments of limestone, shale, and quartzite. It probably owes its origin to the renewed movement of a partly cooled and pasty mass of monzonite magma containing slowly sinking fragments of the Cambrian sediments that were shattered by the first intrusion of the monzonite. The amount of ore disseminated through this mass was not ascertained but is unimpressive; the chief changes apparently consisted of replacement by pyrite and silica.

Although the rich ore shipped in 1887 carrying wire gold closely associated with galena is believed to be primary, some of the gold may be due to superficial enrichment. The abundance of manganese oxide along the outcrop of the intrusion breccia and the nature of the wall rock would favor enrichment in gold. Two specimens obtained from this claim show small flakes of free gold in a porous, earthy gangue made up of small nodules of carbonate, quartz, and kaolin.

The copper ore from the contact-metamorphosed limestone contains large euhedral crystals of pyrite in a matrix of chalcopyrite, hematite, quartz, and carbonate. Sphalerite and galena are present in minor amounts. The pyrite crystals range in size from microscopic grains to crystals half an inch in diameter. Pyrite was the earliest mineral to be formed and was followed by quartz. Specular hematite was deposited shortly after the silicification of the rock, and some chalcopyrite may be contemporaneous with it. As veinlets of chalcopyrite cut the hematite, some and probably most of the chalcopyrite is later than the iron oxide, but one section showed chalcopyrite replaced by carbonate and hematite. Chalcopyrite has commonly replaced pyrite. Galena is abundant in some specimens and usually occurs along the border of chalcopyrite grains. Small specks of another mineral are included in the grains of galena. The identification is not certain, but they are probably boulangerite, a lead antimonide.

GOLD DUST OR ADIT CLAIM

The Adit claim, known as the Gold Dust until 1925, is about 5 miles northeast of Cooke, on the southwest side of the valley of Clark Fork of the Yellowstone, at the base of Henderson Mountain. The claim is one of the many held by the Western Smelting & Power Co., and it is in the development of this prospect that the company's efforts have centered since its smelter neared completion in 1920. An aerial tramway 9,500 feet long connects the smelter with the portal of the adit, the altitude of which is about 9,200 feet. The equipment at the mine includes an electrically driven compressor, air drills, electric lights, ore bins, smithy, boarding house, and several cabins. Work was actively carried on through the summers of 1920 to 1925. The mountain has been penetrated about 2,000 feet by an adit, which the operators expect will soon reach the same ore body discovered in the Homestake claim, 700 feet above. (See pl. 18.)

The adit is chiefly in pre-Cambian granite for 600 feet from the entrance, but cuts a dike of monzonite porphyry and a 100-foot body of gabbro about 200 feet in. For 1,000 feet beyond the granite intrusion breccia makes up the bulk of the material exposed, but it is locally cut by monzonite masses free from inclusions. The intrusion breccia is very similar to that found on the Homestake claim, above (see p. 63,) and contains more or less altered fragments of sandstone, granite, limestone, and shale. The amount of mineralization in these fragments varies greatly, and shaly limestone in which epidote and pyrite were strongly developed occurs within a few feet of comparatively fresh limestone of similar composition. There seemed to be an increase in the intensity of mineralization about 1,500 feet from the portal, but 50 feet farther in the breccia disappears. From this point a fresh biotite monzonite porphyry extends for 60 feet and gives way abruptly to strongly sericitized monzonite prophyry, which forms the wall rock for the remaining 300 feet of the adit.

The mineralized specimens observed from this mine contained specular hematite, pyrite, ankerite, epidote, and quartz. The hematite has partly replaced the carbonate, but the age relations of the quartz and carbonate are uncertain. No chalcopyrite was found in any of the specimens collected by the writer, but some ore of different appearance said to come from this adit consisted of manganiferous ankerite, quartz, pyrite, and chalcopyrite. The euhedral crystals of pyrite were brecciated, and chalcopyrite and carbonate surround the fragments; the probable order of deposition was (1) quartz and pyrite, (2) carbonate, (3) chalcopyrite.

LONGSTREET PROSPECT

On the southern slope of Henderson Mountain, locally called Anderson Mountain, many claims have been staked on contact-metamorphosed limestone. The owners of these claims were not ascertained.

Copper sulphides are nearly absent from the deposits that have been explored. The limestones of the Gros Ventre formation have been strongly marmarized locally, and magnetite has been abundantly developed. Chlorite, garnet, hematite, tremolite, and other contact minerals are present, but the ore observed contains only a little gold and copper.

HIGH-TEMPERATURE DEPOSITS

PYRITIC COPPER DEPOSITS

GLENGARRY MINE

The Glengarry Mining Co. has several claims near the headwaters of Clark Fork of the Yellowstone. They include a large share of the ground between Red Mountain and Scotch Bonnet Mountain, and their exact location can be seen on Plate 16.

On Scotch Bonnet Mountain east of Lulu Pass, at an altitude of 9,800 feet, the company has three short adits and a winze. In the valley below, at an altitude of 9,450 feet, another adit has been driven N. 70° W. into the hill for about 2,300 feet, and the face is directly below Lulu Pass. The mine equipment includes a small tractor, sawmill, compressor, air drills, machine shop, and smithy. The buildings essential to the maintenance of a small force of men are located near the portal of the lower adit. Development work was proceeding rapidly in 1925, and several thousand tons of ore averaging about $9 to the ton in gold and a few per cent of copper had been blocked out. A communication received in December, 1925, stated that enough ore was believed to be in sight to justify the erection of a small pyritic copper smelter, the equipment for which was being hauled to the mine in spite of deep snow. The general relations in the upper levels are shown in Figure 5. The deposit exposed by the upper adits is intermediate in general character between contact-metamorphic copper deposits and pyritic copper veins. Although it lacks the contact minerals such as magnetite, hematite, and

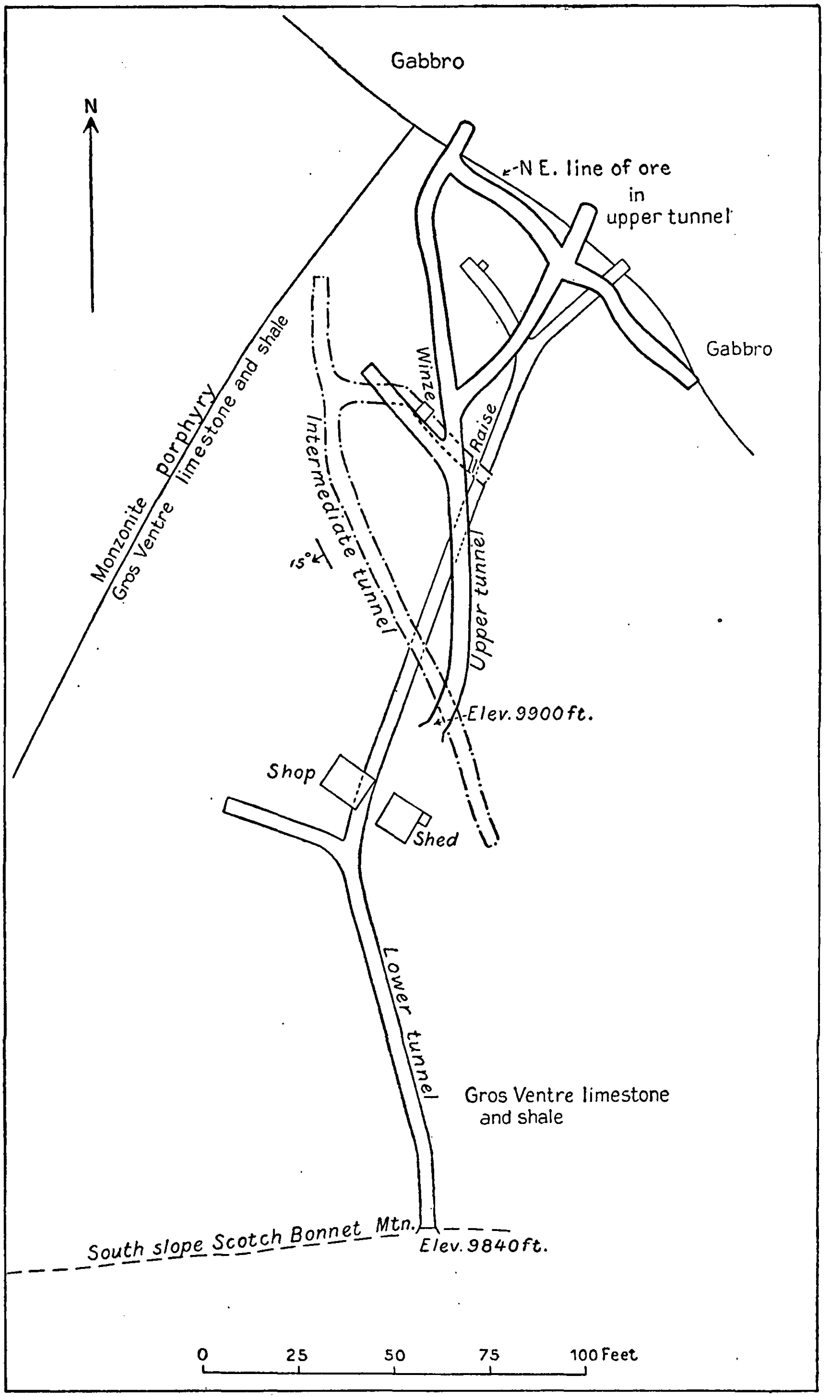
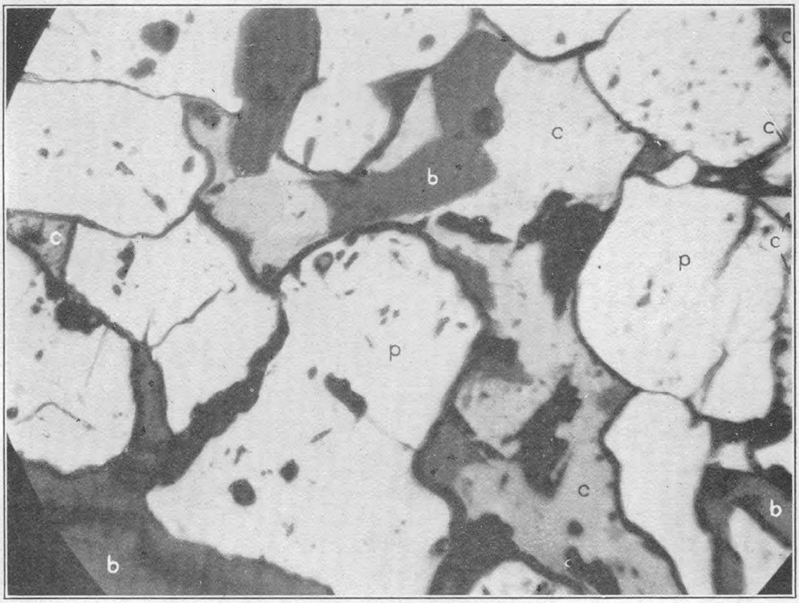
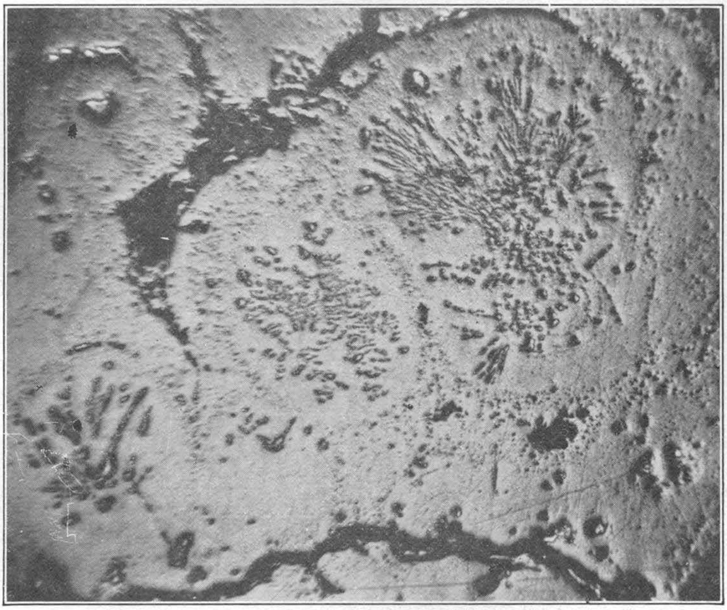


FIGURE 5.—Mine map of Glengarry property, New World district



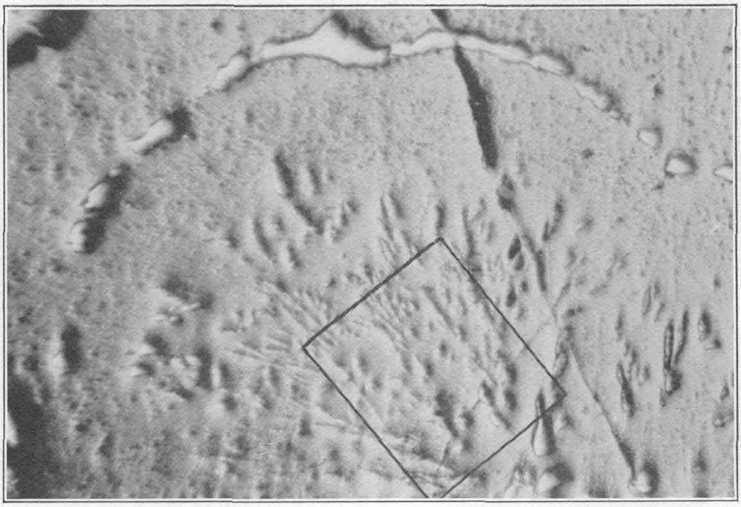
A. PHOTOMICROGRAPH OF PYRITIC COPPER ORE FROM GLENGARRY MINE, NEW WORLD DISTRICT

Brecciated pyrite grains (p) in a matrix of chalcopyrite (c), which is crossed by a veinlet of bornite (b). Enlarged 37½ diameters



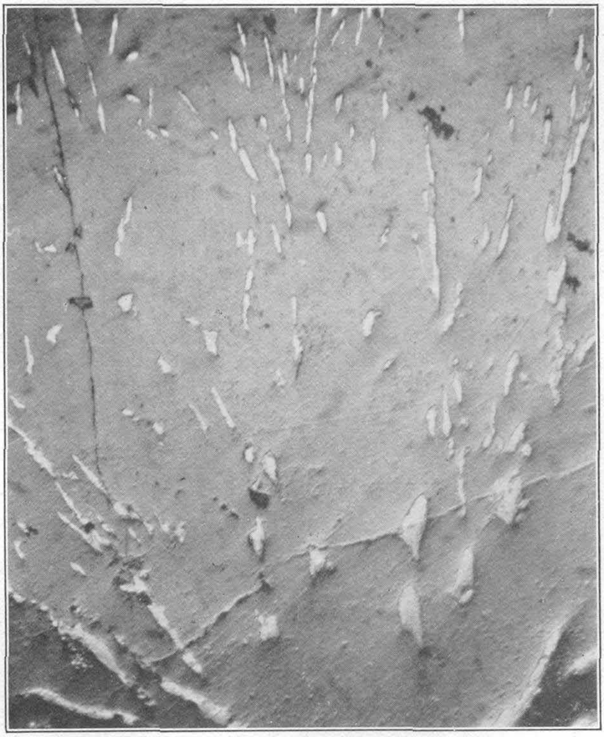
B. CONCENTRIC AND RADIAL TEXTURES IN ORE FROM THE REPUBLIC MINE, NEW WORLD DISTRICT

The gray mineral is sphalerite, and the very fine grained material giving it a colloform appearance is galena. (See pl. 20.) Enlarged 26 diameters



A. GALENA (GRAYISH WHITE) AND QUARTZ (DARK GRAY) IN SPHALERITE (GRAY)

The area shown in *B* is indicated by the rectangle. Enlarged 48 diameters



B. DETAILS OF THE RADIAL INTERGROWTH OF GALENA (WHITE) IN THE SPHALERITE (GRAY) SHOWN IN *A*

The many small speckled areas represent extremely fine grained galena. Quartz shows as dark-gray lines and spots. Enlarged 160 diameters

GALENA AND QUARTZ IN SPHALERITE

garnet and consists essentially of pyrite, chalcopyrite, and quartz, its occurrence in a limestone block at the edge of a large mass of monzonite strongly suggests the contact-metamorphic deposits. The gabbro of Scotch Bonnet Mountain forms the north wall of the deposit, and coarse-grained greatly altered monzonite porphyry roofs most of the limestone and makes an irregular boundary to the west. In the upper level some monzonite porphyry appears south of the limy shale, between the shale and the adit entrance. The limiting country rock to the east appears to be a felsitic variety of the monzonite porphyry—possibly a chilled border phase—which has been thoroughly silicified. The mineralized sediment probably represents a horizon well down in the Gros Ventre formation. The lowest of the recognizable sedimentary rock is an almost completely silicified shale. This is overlain by 30 feet of impure limestone which has been strongly silicified, heavily pyritized, and impregnated with moderate amounts of chalcopyrite and some gold.

Assays as high as $120 in gold to the ton are reported from the oxidized material at the surface, and some high assays have come from the sulphides in the limestone found in the intermediate level. The tenor of other pyritic copper ores of similar appearance in the district is seldom better than $10 in gold to the ton, and so it seems unwise, in advance of thorough exploration, to expect much high-grade rock here.

A microscopic study of the ores indicates a very simple relationship. Pyrite is by far the most abundant mineral and usually constitutes 80 to 90 per cent of a specimen. Neither galena nor zinc blende is present, and no gold was observed in any of the sections, but the ore examined ran only from $10 to $20 a ton in gold. The relations of the chalcopyrite and pyrite indicate that the pyrite was formed early as euhedral grains, which were brecciated and recemented by chalcopyrite. Enrichment has taken place to a small extent, and in some specimens chalcopyrite is being replaced by bornite and chalcocite. The relations are indicated in Plate 19, *A*.

A placer deposit of native copper near the lower Glengarry adit is described on page 85.

TREDENNICK CLAIMS

The Tredennick Development Co. has a group of claims on the southeast flank of Scotch Bonnet Mountain at altitudes ranging from 9,200 to 10,000 feet. Ore bins, tool shed, smithy, boarding house, and stables are located on a good wagon road to Cooke and close to the adits where work is now going forward.

In 1922 the company started an adit at an altitude of 9,460 feet with the object of reaching an ore body discovered in an upper adit at an altitude of 9,680 feet. (See fig. 6.) These workings contain

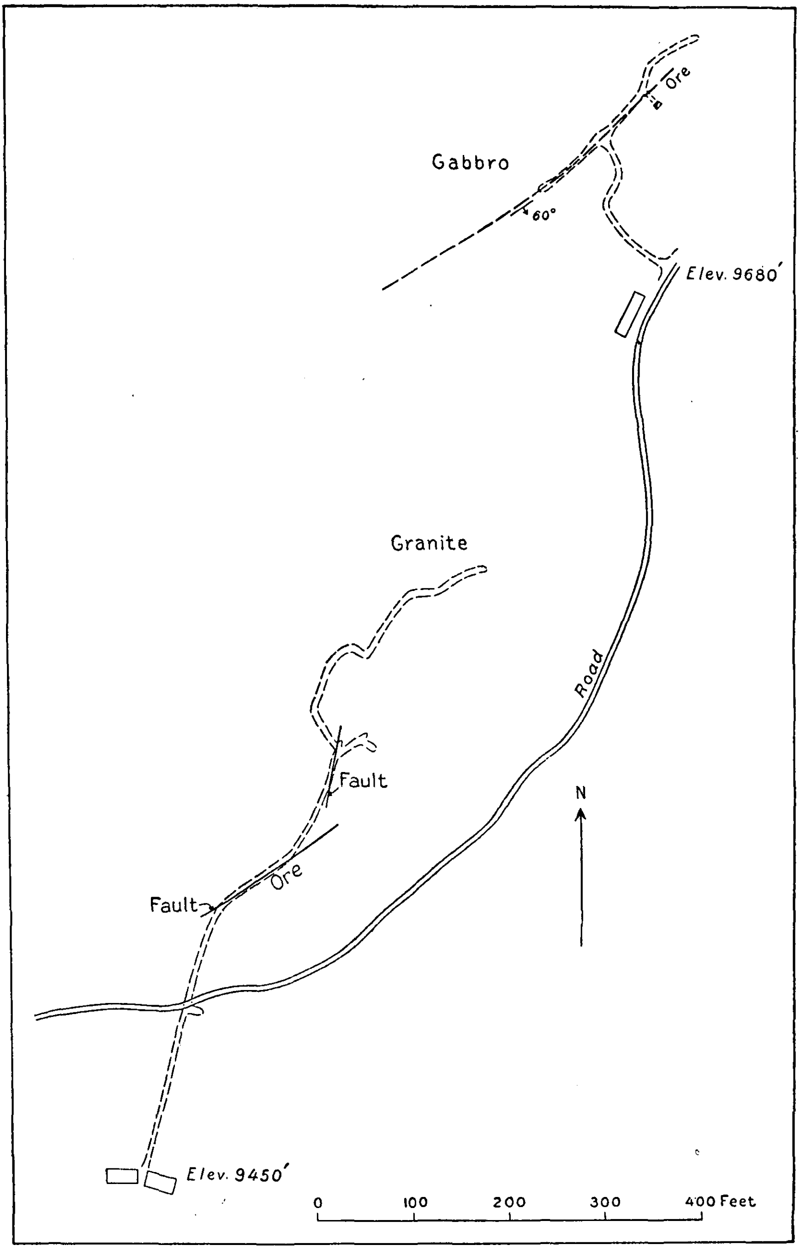


FIGURE 6.—Mine map of Tredennick property, New World district

about 1,200 feet of drifts, and the direction and relation of the upper to the lower adit may be seen from the accompanying mine map. In addition to the development work described above, there are several short prospect tunnels in the higher slopes of Scotch Bonnet Mountain.

The adit near the company boarding house (altitude 9,680 feet) discovered a deposit of chalcopyrite-pyrite ore at the contact of the Scotch Bonnet stock of gabbro with pre-Cambrian granite. A sheeted zone has been developed in the granite at this contact and is strongly mineralized. The width of the sheared zone ranges from a few to 30 feet, and the ore appears to be leaner in the narrower part of the zone. The ore is very similar to that found in the Glengarry workings, to the west. It is believed that the ore was formed in a contraction fissure, and small veins paralleling it may be found in the country rock near by, although their size decreases as distance from the gabbro stock increases.

The general strike of the sheeted zone is about N. 55° E., and the granite hanging wall dips southeast at a steep angle. The ore body as exposed in these workings is lenticular and increases from a thickness of 2 feet on the west to 30 feet on the east. This material is said to average about $10 a ton in gold, and the copper content varies between wide limits. As the upper workings are close to the surface the ore is somewhat oxidized, and this probably accounts for the changes in its tenor. The lower adit was started in granite, and in the fall of 1925 the face of the adit was still in this rock, about 150 feet from the presumable location of the ore. Two small knobs of gabbro were found in the lower tunnel about 250 feet from the entrance and are probably apophyses from the main stock to the north. Some small mineralized veins were penetrated striking parallel to the main ore body discovered in the upper adit. These veins contain pyrite, chalcopyrite, and minor amounts of galena and sphalerite.

Pyrite and chalcopyrite make up the bulk of the ore and have the same relations as in the Glengarry ores. (See p. 67.) Some isolated subhedral crystals of sphalerite (free from blebs of chalcopyrite) are earlier than chalcopyrite, as both sphalerite and pyrite grains are surrounded or partly bordered by chalcopyrite, which was presumably the third mineral to form. Carbonate (manganiferous ankerite) is later than the above minerals and crosses them in small veinlets. Galena is a minor constituent of the ores; it borders the other sulphides and crosses them in small veinlets and is distinctly a late mineral. All the minerals mentioned above are fractured and cut by tiny veinlets of chalcopyrite, carbonate, and quartz. This second-generation chalcopyrite is most abundantly represented in veinlets crossing the sphalerite, an association which suggests that the sphalerite precipitated the copper-iron sulphide from the quartz-carbonate solution more readily than pyrite or galena.

ALICE E. CLAIM

The Alice E. patented claim lies on the southern slope of Henderson Mountain less than a mile north of Cooke. The mine is only a few hundred yards from the main road to Daisy Pass and may be readily reached by wagons. The property has not been worked for 30 years, and the buildings still standing are in bad repair. They include an old cyanide mill and several cabins. Most of the work done was surface mining of the open-pit variety, and as the adits and the shaft on the claim were inaccessible during the writer's visits to the district little was seen of the underground development.

This claim, under the direction of George A. Packard, successfully cyanided gold ore in 1893–1895. According to Mr. Packard a little more than 2,500 tons of ore was treated, averaging about $14 to the ton in gold. A short distance from the surface pyritic gold-copper ore was encountered, but it proved so difficult to treat that mining was abandoned when the oxidized ore was exhausted.

The ore is in the Flathead quartzite close to a small body of intrusive gabbro and only a short distance from the main mass of the Henderson Mountain stock of monzonite porphyry. The cement and some of the quartz grains of the sandstone have been replaced by sericite and pyrite. Ore on the dumps indicated seams of pyrite 2 to 3 inches wide cutting across massive blocks of quartzite.

From the evidence just given the conclusion is drawn that the Alice E. belongs to the pyritic gold-copper deposits and that a moderate tonnage of $8 or $10 sulphide ore might be developed with a little exploration.

COMMONWEALTH CLAIM

The Commonwealth prospect, held by Gus Solomonson, of Cooke, is on the western slope of Sheep Mountain at the headwaters of the small stream that flows past the Tredennick Development Co.'s mine into Clark Fork of the Yellowstone. No buildings are present on the claim.

Two adits, at altitudes of 9,800 and 9,850 feet, have been driven about 175 feet on a narrow vein that strikes N. 30° E. The exposed ore is similar to that found in the Glengarry and Tredennick mines and has about the same tenor. The metallic content is reported to run as follows: Gold, 0.07 to 0.1 ounce to the ton; silver, 0.5 to 4.5 ounces to the ton; copper, 1 to 7.6 per cent. The vein crops out in the Flathead quartzite and consists of a seam of pyrite, quartz, and chalcopyrite 3 to 6 inches wide. The order of deposition, as revealed by mineralographic study, is as follows: (1) Pyrite, (2) chalcopyrite and quartz, (3) carbonate. A period of brecciation separated the deposition of pyrite from that of the other minerals.

LULA AND CONTACT CLAIMS

Two patented claims, the Lula and Contact, lie on the northern flank of Red Mountain. In 1925 they were owned by P. S. Branser, of Cooke, who had a cabin on his property at Lula Pass. According to the owner, between 400 and 500 feet of development work has been done, but as the workings have been allowed to cave the writer was unable to examine the mine. It is said that 20 tons of pyritic ore running $20 to the ton in gold and carrying a small amount of copper was shipped from the Contact claim to the Allison smelter in 1912. The ore is reported to have come from a fissure between monzonite porphyry and felsite.

Garnet, epidote, hematite, and pyrite occur in Gros Ventre and upper Gallatin beds on the Lula claim, but apparently contact-metamorphic ore deposits were not formed.

LAZY BEETLE CLAIM

The Lazy Beetle unpatented claim is on the road to Grasshopper Glacier, about 2 miles south of Goose Lake. The prospect was held in 1925 by F. C. Byrne, of Cooke, who had a cabin on the claim.

Exploration is being conducted on a vein 1 to 6 inches wide, striking N. 60° E. and dipping 40° S. The country rock is granite, and the vein is composed of coarse crystals of comb quartz containing small amounts of pyrite, chalcopyrite, and blende. No ore has been shipped, but grab samples assayed about 25 ounces to the ton in silver, 1.5 per cent of copper, and 2.8 per cent of zinc. This deposit probably belongs to the class which was formed at moderately high temperature and pressure.

Quartz was the first mineral formed and makes up most of the deposit; pyrite followed, and chalcopyrite was formed still later. Small crystals of zinc blende were observed, but their relations to the other ore minerals could not be made out. Silver-bearing minerals were not discovered under the microscope.

ELIZABETH CLAIM

The Elizabeth claim is in the valley of Goose Creek almost due north of Red Mountain, at an altitude of about 8,700 feet. There is no road to the claim, and the trail to the property is followed with difficulty. The vein which was followed is a high-temperature deposit containing silver, copper, and gold. The ore occurs in Archean granite near a small irregular monzonite plug. The ore minerals consist of chalcopyrite, argentite, and pyrite in a quartz gangue.

MODERATE-TEMPERATURE DEPOSITS

LEAD-COPPER DEPOSITS FORMED AT MODERATE TEMPERATURE AND PRESSURE

UNITED STATES TREASURY AND ADJOINING CLAIMS

Several lead-copper-silver prospects are located in or near the Goose Creek Canyon, about a mile north of Lulu Pass. They were held chiefly by Messrs. Byrne, Solomonson, Stintson, and Tredennick, of Cooke, in 1925. The mineralization of these claims is similar, and so a brief description of only one prospect is given.

In the United States Treasury claim, the ore dips 20° SW. and follows a shear zone within the pre-Cambrian granite, which is strongly sericitized near the vein. The ore is irregular and bunchy and consists of a number of thin sulphide seams in the shear zone. The thickness of these bands of ore is usually from a quarter of an inch to an inch, but the width of the mineralized zone ranges from a few inches to 7 or 8 feet. Galena, chalcopyrite, and arsenopyrite are the most abundant sulphides. The hydrothermal alteration of the walls and the abundance of arsenopyrite indicate formation at moderately high temperature and pressure.

The ore from these claims carries considerable silver, and a small quantity packed out in the eighties is said to have averaged over 300 ounces to the ton. In general, assays of 75 ounces to the ton in silver may be expected where galena and chalcopyrite are abundant, but no attempt was made to take channel samples and estimate the average value of the rock.

A large percentage of the ore consists of arsenopyrite and galena with some chalcopyrite and sphalerite in a quartz-carbonate gangue. The order of deposition was as follows: (1) Pyrite and quartz, (2) arsenopyrite; (3) chalcopyrite, galena, sphalerite, and pyrite; (4) manganiferous ankerite.

SKYLINE CLAIM

The Skyline claim, formerly the Hudson & Boulder, lies on the western slope of Red Mountain. A good road to Cooke runs through the property. Several adits penetrate the mountains for short distances at altitudes ranging from 9,700 to 10,100 feet. The claim is held by the Yellowstone Mining Corporation.

Two different types of deposits were found on this claim. In the lower adits pyritic copper ore has been discovered; the upper adits disclosed copper-lead ore formed at moderate depths, containing little pyrite but reported to run well in gold.

A large xenolith or roof pendant made up of Gros Ventre beds and lower and upper Gallatin strata occupies most of the claim.

Some of the upper adits which discovered copper-lead ore started in monzonite but penetrated Gallatin limestone at a distance of a few hundred feet. Ore was found cutting the limestone in narrow veins. The pyritic copper ore in the lower adits occurs both in monzonite porphyry and in the Gros Ventre formation. As the workings were badly caved it was difficult to judge of the extent of the deposit. The veins are probably not large, if the ore lying on the dump may be used as a criterion.

The pyritic copper ore consists of large brecciated subhedral crystals of pyrite in a matrix of chalcopyrite and carbonate. The two sulphides are crossed by abundant veins of carbonate (manganiferous ankerite). A few small stringers and veinlets of galena cut the chalcopyrite and carbonate. Ore from the upper adits consists of carbonate, pyrite, chalcopyrite, galena, and sphalerite. The paragenesis in this ore seems to be as follows: Hypogene—(1) pyrite, (2) carbonate and chalcopyrite, (3) galena, (4) sphalerite; supergene—(1) chalcopyrite, (2) covellite, (3) cerusite.

MORNING STAR MINE

The Morning Star mine is on the eastern slope of Miller Mountain near its south end, at an altitude of 9,500 feet. A secondary road runs to the mine, and ore has been hauled over it as recently as 1922. The mine was then owned jointly by Adolph Whetzstein, of Butte, and Mrs. Samuel Brady, of Wilsall. Although this deposit was discovered and operated in the early history of the camp, it remained idle for many years, but during the summer of 1922 a small amount of work was done, and about a carload of ore netting $93 a ton in lead and silver was taken out by lessees. There are no buildings on the claim, and the developments consist of a lower adit, measuring about 500 feet in length, connected by a raise to a short upper adit. The material shipped in 1922 was coarse-grained galena carrying about an ounce of silver for every 20 pounds of lead. This ore contained little chalcopyrite and was free from pyrite and blende.

The 500-foot adit starts in the massive dark-colored lower limestone of the Bighorn dolomite, and about 150 feet from the portal it penetrates an irregular mass of monzonite dipping to the southwest at a low angle. The dark, fetid-smelling limestone appears again on the other side of this intrusive, and about 250 feet farther in the ore occurs as a nearly vertical seam from 2 to 4 feet in width striking N. 20° W. The material from the upper portion of this vein is strongly oxidized and consists of a comblike mass of cerusite and anglesite. It was not possible to observe the ore relations carefully, as the lessees caved the ore and drew it off through chutes as it was needed.

Polished sections of ore from the lower adit show coarse crystals of galena being replaced along cleavage planes by anglesite and cerusite. A few small flecks of argentite were observed on etching the sulphide with nitric acid.

COPPER GLANCE CLAIM

The Copper Glance claim, held by O. B. Hart, of Gardiner, lies on the southwestern shore of Goose Lake about 6 miles north of Cooke. A trail leads from the Copper King road to the prospect, half a mile away. Two adits have been driven close together in the pre-Cambrian granite, exposing a quartz-sulphide vein striking about N. 50° E. No post-Cambrian intrusive rocks were noted in the immediate vicinity. The vein, which crops out very inconspicuously if at all, is about 10 feet thick where the lower adit cuts it. No ore has been shipped, and indeed it is probable that concentration will be needed to provide ore of shipping grade.

Most of the gangue consists of quartz, but a small amount of carbonate is also present. The quartz is extremely friable, and the ore crumbles readily, differing from the usual quartz vein in this particular. This feature is probably due to movement after the formation of the vein. Many inclusions of granite penetrated by small veins of quartz indicate that the deposit might be regarded as a sheeted zone, rather than a single vein. Medium-grained galena and sphalerite are disseminated through the lead, but assays of the cuttings from four 20-inch drill holes—two on the hanging-wall and on the footwall side of the vein—gave the following results: Gold, 0.61 ounce to the ton, silver 1.62 ounces to the ton, lead 0.3 per cent. If this represents the average vein matter now exposed it seems advisable that more exploratory work be done, both on the strike and on the dip of the vein, before attempting to estimate the value of a deposit of this type.

Under the microscope the quartz is seen to be one of the earliest minerals to form, but it may be antedated by some pyrite. Coarse crystals of sphalerite were formed subsequent to the quartz and earlier than the other minerals. Coarse-grained galena is fairly abundant, and a considerable quantity of boulangerite (lead antimonide) penetrates it as minute stringers and veinlets. Some chalcopyrite is seen, apparently later than the minerals just described and clearly earlier than the carbonate and second generation of pyrite.

CARLTON CLAIM

The Carlton unpatented claim is on Miller Creek about three-quarters of a mile north of Cooke and was held jointly by Messrs. Solomonson and Burke, of Cooke, in 1925. Four adits have been driven with an aggregate length of about 400 feet, of which only a small part is still accessible.

This mine produced a high-grade silver ore in the early days of the camp, but no ore has been shipped from it for many years. According to Mr. Solomonson, 700 pounds of silver ore netting $375 was taken from the claim by Mr. Collins in 1887, and 18 tons of unknown tenor was shipped from it by the New World Mining & Development Co. in 1906. The main lode is a quartz-carbonate vein about 1 foot wide. It strikes N. 20° W. and dips 82° NE. A smaller vein striking N. 32° E. and dipping 43° NW. was also noted. The ore consists of argentiferous tetrahedrite, chalcopyrite, galena, sphalerite, and carbonate.

The earliest minerals to form were sphalerite, pyrite, and quartz. Argentiferous tetrahedrite was deposited next, and small veinlets of it may be seen traversing coarse crystals of pyrite and sphalerite. Brecciation occurred after the formation of these minerals, followed by the deposition of galena and carbonate. Small veinlets of chalcopyrite around carbonate grains indicate that it was the last mineral to be deposited. It is present in very minor amounts, and the bulk of the sulphide minerals consists of argentiferous tetrahedrite, sphalerite, and pyrite.

DUKE CLAIM

The Duke claim, formerly called the Street, is on the southern slope of Miller Mountain at an altitude of about 8,300 feet, half a mile northwest of Cooke. In 1925 it was held by Harry Stintson, of Cooke, who had built a substantial cabin on the property, driven two adits, and sunk a short shaft. The property was a fair producer of high-grade lead-silver ore prior to 1885, but no ore has been shipped from it for several years. The original workings are caved, and the drifts now open do not expose the ore body worked in the eighties. The ore taken from the mine in the early days, according to men who worked it, consisted of partly oxidized lead ore mined from a vein striking a little west of north. In the recent development work some small seams of ore have been noted which run in a northeasterly direction through the broken upper beds of the Gallatin formation, but no large ore body had been uncovered in 1925.

Specimens of ore show banded veins of quartz and galena in limestone. Galena was formed early; quartz and pyrite are contemporaneous with it or later. A very small amount of zinc blende is present and is clearly later than the other minerals.

STUMP MINE

The Stump mine, owned by the Yellowstone Mining Corporation, is on the southern slope of Miller Mountain at an altitude of about

8,200 feet, approximately three-quarters of a mile east of Cooke. In the early history of the camp the Stump mining property sent a large amount of high-grade zinc-free lead ore to the Republic smelter, but the mine has not been operated for many years. Three adits having a total length of about 800 feet and a shaft indicate that mining at one time was prosecuted actively, but many of the workings have been allowed to cave.

The upper adit, from which practically all the ore was taken, is in the basal massive limestone member of the Gallatin formation, but the lower workings are in the Gros Ventre formation. One of the former miners describes the ore body worked in the early eighties as a flat-lying pipelike mass of galena and cerusite about 2 feet in diameter striking a little north of west. The deposits still exposed are in nearly horizontal fractures which strike N. 80° W. and dip about 7° S. They are bedding-plane deposits and are very irregular in thickness. The seams exposed in 1923 were only 1 or 2 inches thick at a maximum, but some lumps of ore remaining in the dump are 10 inches in diameter. The ore in the mine appears to consist almost wholly of galena, pyrite, and a small amount of chalcopyrite.

The typical polished surface show about 65 per cent of galena, 15 per cent of chalcopyrite, 5 per cent of pyrite, and 1 or 2 per cent of zinc blende. The rest of the specimen is made up of carbonates and secondary minerals. Two generations of chalcopyrite were noted, the first associated with pyrite, in relations similar to those observed in the pyritic copper deposits close to the large monzonite intrusive masses. The brecciated pyrite is seamed by massive chalcopyrite. Galena is clearly later than these two minerals and is itself cut by small veinlets of sphalerite and chalcopyrite. The veinlets of sphalerite are seamed with minute stringers and blebs of chalcopyrite, which is later than the zinc blende. Although the chalcopyrite occurs in irregular dots and blebs replacing the galena, it is much more abundant in the zinc sulphide, and the fine-grained intergrowth of the two is a characteristic feature of the second generation of chalcopyrite, and nearly all late sphalerite has this appearance. Some of the galena seen was partly altered to cerusite, and a thin border of covellite was present between the galena and the carbonate. Chalcopyrite partly altered to covellite was also observed. Some specimens of this ore show chalcopyrite oxidized to cuprite and limonite. Small amounts of malachite are present also. Although covellite replaced chalcopyrite, it seems evident from the relations that sphalerite was more rapidly replaced than chalcopyrite, and this inference is in accord with the greater solubility of the zinc mineral. In addition to the occurrences just described, covellite was found in veinlets and rims in galena, bornite, and chalcopyrite.

The relations discussed above indicate the following paragenesis for these ores: A, Hypogene—(1) pyrite, (2) chalcopyrite, (3) galena, (4) sphalerite, (5) chalcopyrite; B, supergene—(6) cerusite, (7) bornite, (8) cuprite, limonite, malachite, and azurite.

SHOO FLY MINE

The Shoo Fly fraction was one of the principal sources of lead-silver ore in the seventies and eighties and produced ore variously estimated at 1,700 to 3,000 tons before it was abandoned. It is on the southern crest of Miller Mountain at an altitude of about 9,300 feet. A good road formerly existed between this mine and Cooke, but it has not been kept up for a number of years.

The ore occurred as a replacement deposit in the lower part of the Bighorn dolomite. The limestone near by is intruded by several dikes of monzonite porphyry, and irregular "plugs" or "blow-outs" of this rock occur in the vicinity. Mineralized rock may be seen along fissures, but the bulk of the ore is said to have come from one "chamber" in the limestone.

Galena is an abundant constituent of the ore, and moderate amounts of sphalerite and a little chalcopyrite are also present. This deposit suggests a transition from the lead-copper group to the complex lead-zinc group. The probable order of paragenesis in this deposit is (1) quartz, pyrite, and sphalerite, (2) pyrite and chalcopyrite, (3) galena, (4) sphalerite and chalcopyrite.

CHIPMUNK CLAIM

The Chipmunk claim, held by John Brown, of Logan, Mont., lies across the north end of Sheep Mountain. According to Mr. Brown an adit (now caved) 70 feet long on the east side of the mountain exposed a seam of ore 3 inches wide running $75 to the ton in lead and silver. A 200-foot adit on the west side has cut only small stringers of ore. The ore exposed on the eastern dump indicated the deposit to be of the galena-copper type, containing some zinc.

NEW WORLD CLAIM

The New World patented claim, owned by the Buffalo-Montana Mines Co., lies on the southwestern slope of Miller Mountain close to its crest. The mine is said to have produced about 2,000 tons of mixed sulphide and carbonate ore which carried about an ounce of gold to the ton. Very little zinc was present and the galena was very coarse grained. Most of the mining was done before 1886, but the claim was worked again for a short time in 1907. The ore is said to have occurred as a horizontal pipelike body of greatly varying dimensions. The average cross section of the ore was estimated at

7 by 7 feet, the maximum at 22 by 7 feet, and the minimum at 5 feet by 4 inches. The workings were caved when the writer visited the property but are reported to comprise about 700 feet of drifts in all.

BIG BLUE CLAIM

The Big Blue unpatented claim, held jointly by the Buffalo-Montana Mines Co. and Jerry McCarthy, of Bozeman, Mont., lies on the southern slope of Miller Mountain adjacent to the Duke claim. The amount of ore taken from the property in the eighties is unknown, but in 1910 Mr. Allison leased the claim and shipped 152 tons of ore. It is estimated that the ore shipped was made up largely of galena but that about one-fourth of it was lead carbonate. The workings are in the lower part of the Bighorn dolomite but were inaccessible when the writer visited the property.

COMPLEX LEAD-SILVER-ZINC GROUP

REPUBLIC MINE

The Republic mine is on the northeast side of Republic Mountain at an altitude of about 8,250 feet, three-quarters of a mile south of Cooke. It is the principal property of the Buffalo-Montana Mines Co. and has long been the subject of litigation. About 1,500 feet of adits have been driven, and a vein has been worked by open-cut methods for about 3,000 feet. An inaccessible shaft, reported to be 225 feet deep, does not connect with the main workings. A short adit at the base of the mountain, planned to provide a lower entry to the property, was started 1,700 feet from the vein but was driven only 200 feet. Tool house, ore bins, and two log cabins are present on the property, and the road leading to the Republic smelter at Cooke (owned by the same company) is in good repair.

The Republic mine has been the largest producer in the district, but a record of its production could not be obtained. A general idea of the ore taken out can be gained from the history of mining on pages 44 to 47 and from the figures given under production on page 48.

The ore occurs as replacement deposits in the Gallatin formation following four intersecting fissure systems. (See fig. 7.) The fissures strike N. 20° W., east-west, and N. 50° W., and mineralization has been most intense along the N. 20° W. and east-west systems. The deposits enlarge at the intersections of fractures, and the largest of the ore bodies have been developed at the intersection of the strongly mineralized east-west and N. 20° W. fissures.

The outcrops of mineralized limestone are heavily stained with black manganese oxide, and this material is characteristic of the outcrop of complex lead-silver-zinc deposits in this region. The

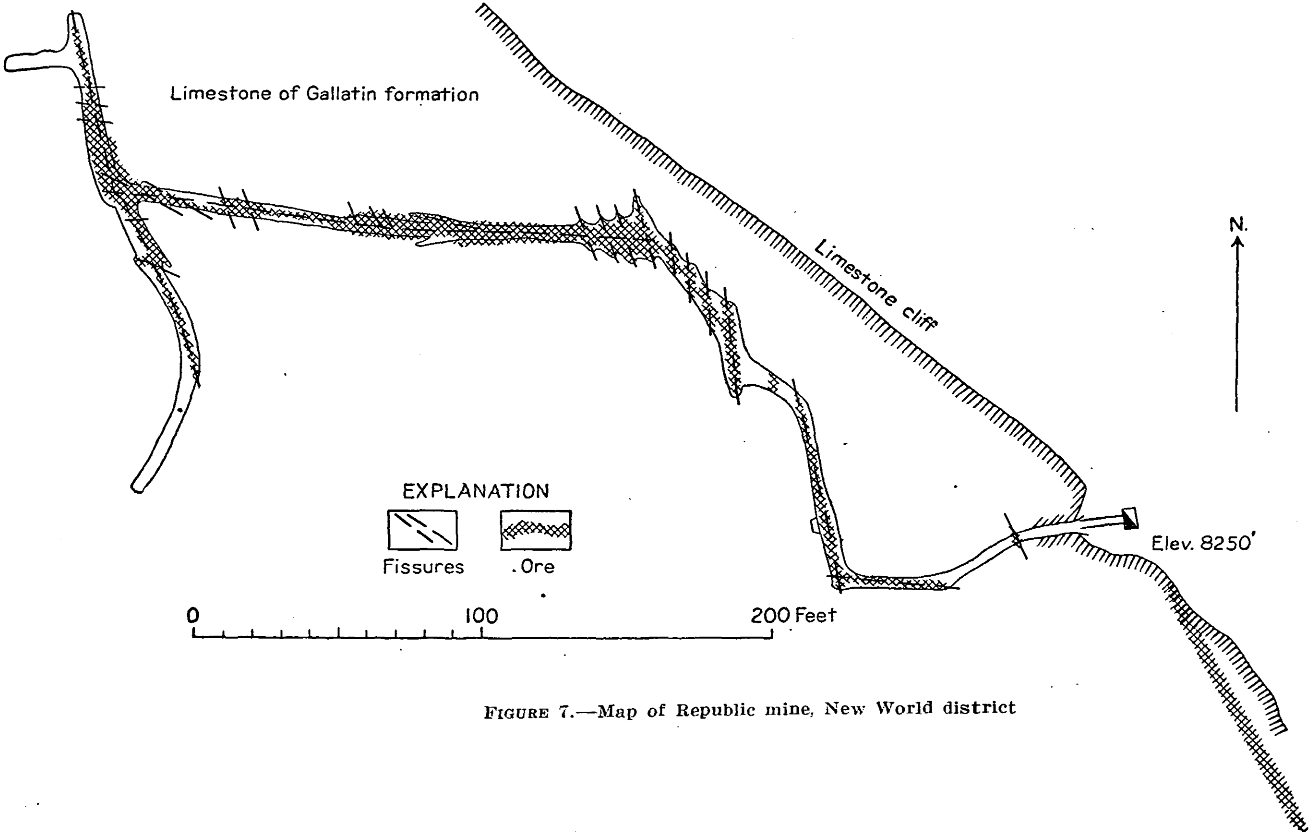


FIGURE 7.—Map of Republic mine, New World district

road from the Irma mine to the Republic mine parallels a fissure in which this gossan is well developed, with hardly a break in its continuity. The sulphide ores are encountered at a short distance from the entrance to the mine and, although stained with manganese oxide, contain only very small amounts of secondary ore minerals. A stope and a raise to the overlying shale near the southwest face of the principal workings expose a good section of the ore body. The material in the upper portion of the stope is thoroughly oxidized and consists of a loose granular mass of anglesite and cerusite, containing small nodules of galena which were cut by numerous proustite veinlets. Little sphalerite is found in this part of the ore body. The ore 20 feet deeper consists of sulphides with only subordinate quantities of anglesite and cerusite. The oxidized ore in some of the stopes is reported to have run as high as 1,000 ounces of silver to the ton.

The unoxidized sulphide ore ranges from medium-grained mixtures of iron, lead, zinc, arsenic, and copper sulphides to the extremely fine grained masses of galena, sphalerite, and quartz shown in Plate 23, *B*. The pink carbonate that makes up most of the gangue for the medium-grained sulphides is called manganiferous ankerite, as it contains manganese, magnesium, calcium, and iron. The occurrence of this ankerite was practically confined to the fissures, and it rarely made masses more than a foot wide. The sulphides were notably coarser grained in and close to the fissures than at some distance from them. Polished sections of the fine-grained lead-zinc ore from the mine clearly show the replacement of limestone. The limestone in which alteration is slight contains replacement veinlets and irregular masses of fine-grained galena and quartz. Where the metallization is more intense the galena is a little coarser grained, and sphalerite and pyrite appear. These minerals are intimately intergrown with one another, but galena and pyrite seem to have been formed earlier than the sphalerite. In limestone that has been completely replaced by fine-grained sulphides sphalerite is usually the predominant mineral with galena earlier and less abundant. The amount of quartz in the rock varies, and silicification seems to have preceded the main period of mineralization. The intimate intergrowth of quartz, sphalerite, and galena shown in the Irma ores (pl. 22) is duplicated in many of the polished sections of the Republic ore.

Open fractures an inch wide and vugs 2 to 3 inches wide are common. Recent movement has caused the opening of a few crevices to a width of as much as 6 inches, but as they are distinctly post-mineral they have no bearing on ore deposition. Pisolitic, nodular, and crustified ore is common in the openings along the ore fissures and usually shows a distinct rhythmic banding ("Liesegang rings") of sulphide and gangue minerals. These concentric textures are shown in Plates 19, *B*; 20; 22; 23, *A*; 24. Some nodules of this ore are made up of a small central core of galena surrounded by a thick shell of sphalerite, which in turn is surrounded by a ring of galena. This outer shell of galena may be bordered by a thick rim of manganiferous ankerite cut by thin radially arranged veinlets of both galena and sphalerite. If quartz is present it is either in the central core or in the outermost shell. In other types of ore, as illustrated in Plates 19, *B*, and 20, the sphalerite forms an embedding mass in which blebs and lines of galena radiate from many centers toward concentric galena borders. Boydell[40] believes that structure of this type indicates ore formation from colloidal solutions. According to this interpretation the early silicification of the limestone might have produced a gel-like mass of silica through which the metallizing fluids diffused. A zonal precipitation might result, giving rise to the structure observed. This supposition is supported by the experimental work of Watanabe.[41]

A specimen of ore taken some distance from the surface in the Republic mine showed a large mass of pyrite which was fractured and partly replaced by galena and sphalerite. Small veinlets of quartz and arsenopyrite cut these earlier minerals. Some limonite was formed at the expense of the pyrite, but the supergene action was very slight. The occurrence of the arsenopyrite in quartz veins is noteworthy, as this mineral is usually one of the earliest to form in sulphide deposits.

Nodules of ore obtained from the highest accessible portions of the ore body consisted essentially of galena and quartz, but some proustite, arsenopyrite, marcasite, and zinc blende were also present. The sphalerite seems to be a little later than the galena and quartz, and arsenopyrite cuts both sphalerite and galena. Many grains of proustite are associated with the quartz veinlets. The crustified ore shows pyrite and quartz inside of a thick shell of sphalerite, which in turn is generally bordered by galena. Outside of the galena a layer of ankerite containing small grains of galena and sphalerite is present. The crustified ore showed that pyrite and quartz were the first minerals to form, followed successively by galena, sphalerite, ankerite, and a second generation (supergene?) of quartz. Veinlets of lead carbonate penetrate these nodules and seem to replace the sulphides.

The probable order of mineral deposition in this deposit is as follows: A, Hypogene—(1) quartz and pyrite, (2) galena, (3) sphalerite, (4) manganiferous ankerite, (5) arsenopyrite and quartz, (6)

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[40] Boydell, H. C., Rôle of colloidal solutions in the formation of mineral deposits: Inst. Min. and Met., December, 1924.

[41] Watanabe, Manjiro, Zonal precipitation of ores from mixed solutions: Econ. Geology, vol. 19, pp. 497–504, 1924.

argentiferous galena, (7) sphalerite; B, supergene—(8) proustite, quartz, and marcasite, (9) pyrolusite, (10) psilomelane. It is probable that there is no real difference in age between Nos. 6 and 7 and that diffusion and zonal precipitation account for the relations observed in the nodular ores.

IRMA MINE

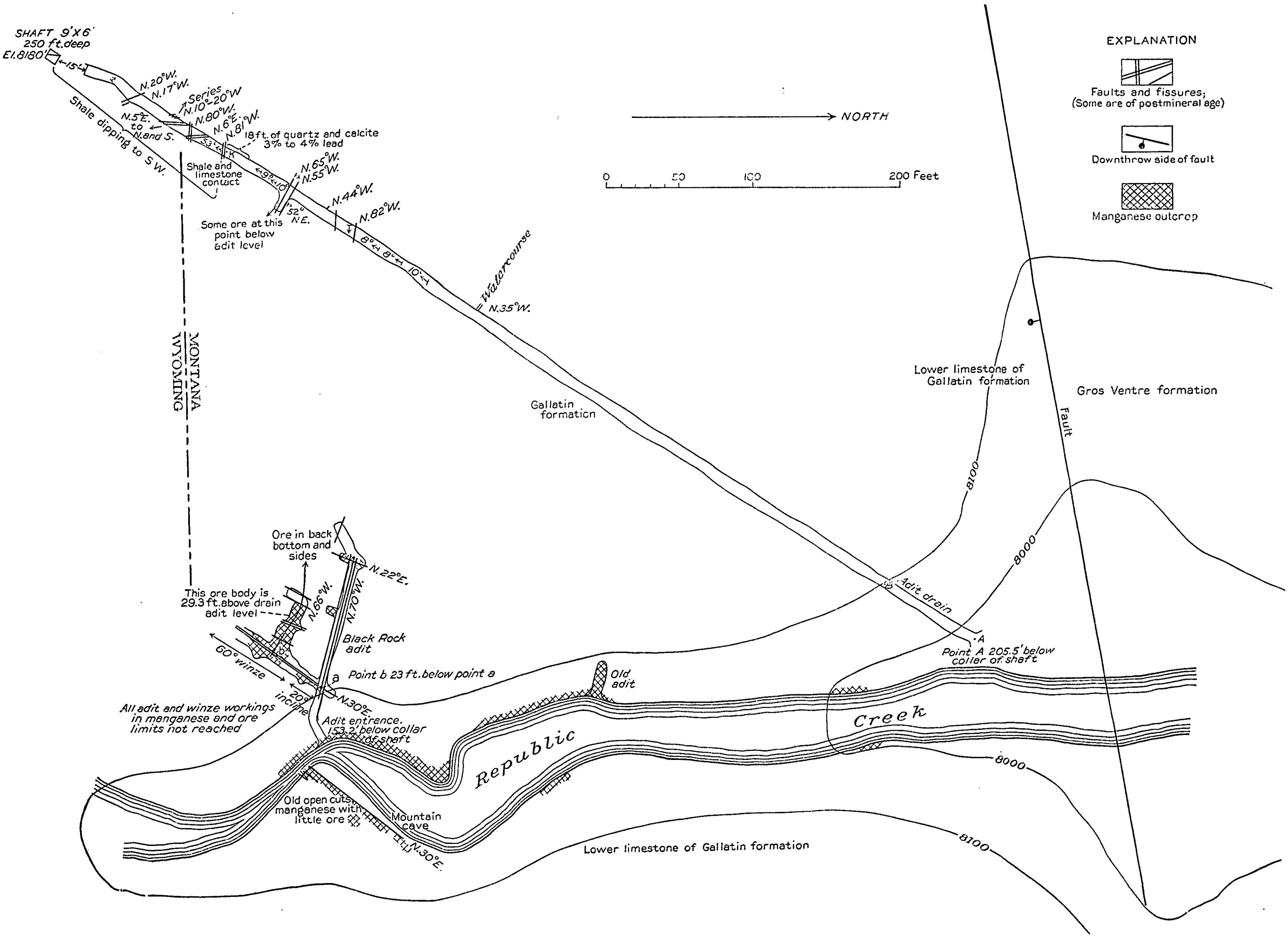
The Irma Mines (Inc.) hold a group of 14 claims on Republic Creek about a mile south of Cooke. Development work has proceeded steadily since 1920 under the supervision of L. H. Brooks, and in 1925 the mine workings included a shaft 250 feet deep, a drainage tunnel 740 feet long, and about 300 feet of drifts, crosscuts, and winzes opening from an adit. Seven buildings have been erected on a bench at an altitude of about 8,200 feet, or 100 feet above the stream. The mechanical equipment includes a sawmill, hoist, air compressor, gasoline storage tanks, tractor, air drills, and gas engine.

The initial exploration and subsequent development of ore were due to Mr. Brooks, who noted that the strike of the main Republic vein (N. 20° W.) would carry it through the property now held by the Irma Mines (Inc.). Ore was found on a fissure striking N. 30° E., and a shaft is being sunk near the point where it is thought that this fracture will intersect a continuation of the Republic vein. In 1925 the shaft had not reached the lower limestone of the Gallatin formation, where ore is expected. The relations are indicated in Plate 24.

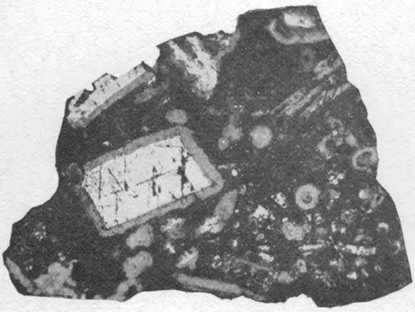
Several carloads of ore have been shipped, and the returns from 200 tons of ore show an average tenor as follows: Silver, 34½ ounces to the ton; lead, 12 per cent; zinc, 13 per cent. No mill has been built, and much zincky ore which might prove amenable to concentration is now thrown away.

The deposit is one of the complex lead-silver-zinc deposits formed at moderate depths. Ore has been discovered only in the lower Gallatin beds, a fact which indicates that the ore horizon is the same as at the Republic mine. The Gros Ventre, Gallatin, Bighorn, and Jefferson formations may be seen near the mine and usually dip about 15° SW. The beds are broken by many faults, and the ore found along the fissure striking N. 30° E. in the Black Rock workings shows a lateral displacement of about 20 feet, the northwest wall having moved north relative to the southeast wall. In the upper adit the limestone has been replaced in irregular bodies adjacent to fissures striking N. 30° E.

The ore consists of coarse to fine grained galena and sphalerite and contains small amounts of pyrite and quartz. Some native silver was observed, and although it is probably of supergene origin, the

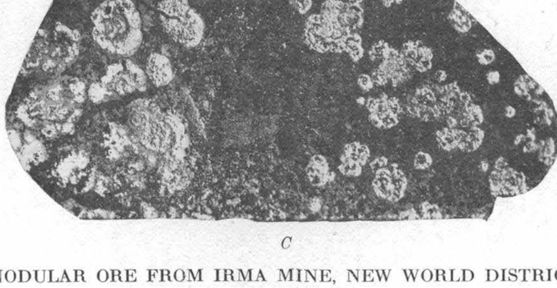


MAP OF IRMA MINE, NEW WORLD DISTRICT



A

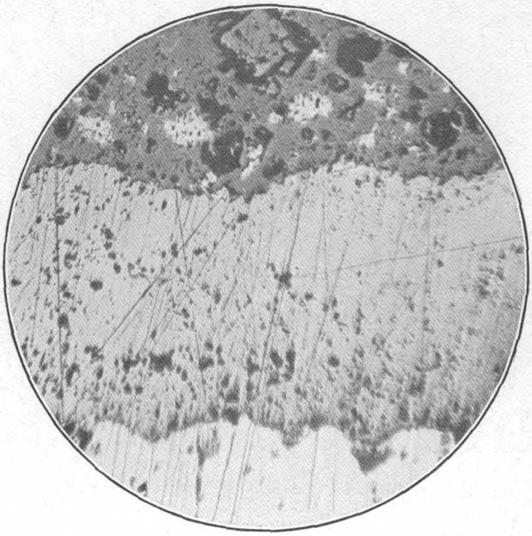
B



C

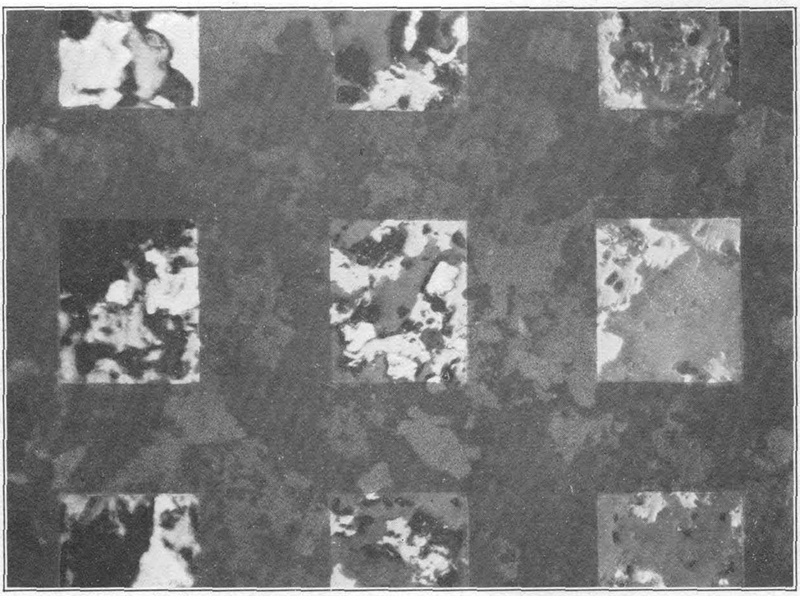
NODULAR ORE FROM IRMA MINE, NEW WORLD DISTRICT

Subhedral and rounded grains of galena (white) with peripheral coatings of sphalerite (gray) in jasperoid (dark gray)



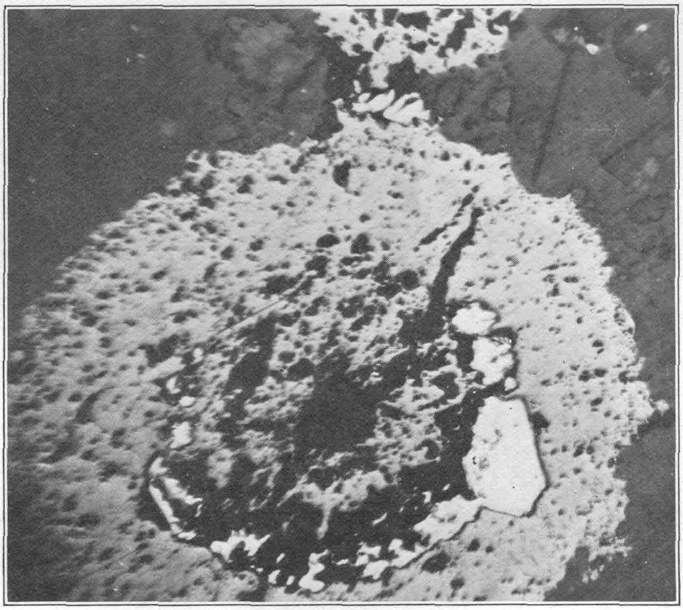
A. DETAIL OF SPHALERITE BORDER SHOWN IN PLATE 22, *A*

Note irregularity of border between sphalerite (gray) and galena (white) and the presence of small masses of sphalerite in the jasperoid (dark gray). The rhombic outline of an early carbonate grain now replaced by silica is clearly shown. Enlarged 85 diameters



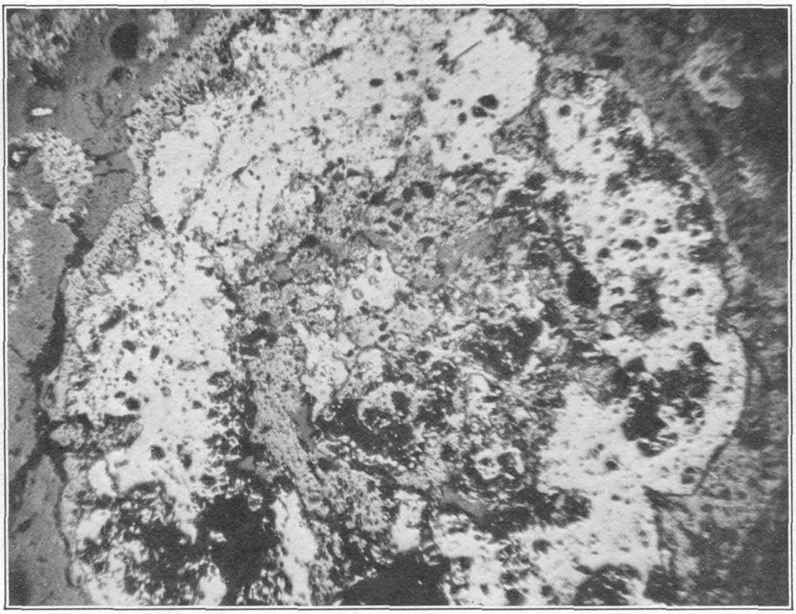
B. RELATION OF A 150-MESH SCREEN (INDICATED BY SHADOW) TO FINE-GRAINED LEAD-ZINC ORE FROM NEW WORLD DISTRICT

The small size of the individual grains of galena (white), sphalerite (gray), and gangue (dark gray) indicates that the ore would have to be crushed to a much smaller size than 150 mesh if each mineral is to be liberated in nearly pure particles. The grains in material coarser than 150 mesh would necessarily contain two or three substances. Enlarged about 150 diameters



A. A NODULE MADE UP OF MEDIUM-GRAINED SULPHIDES

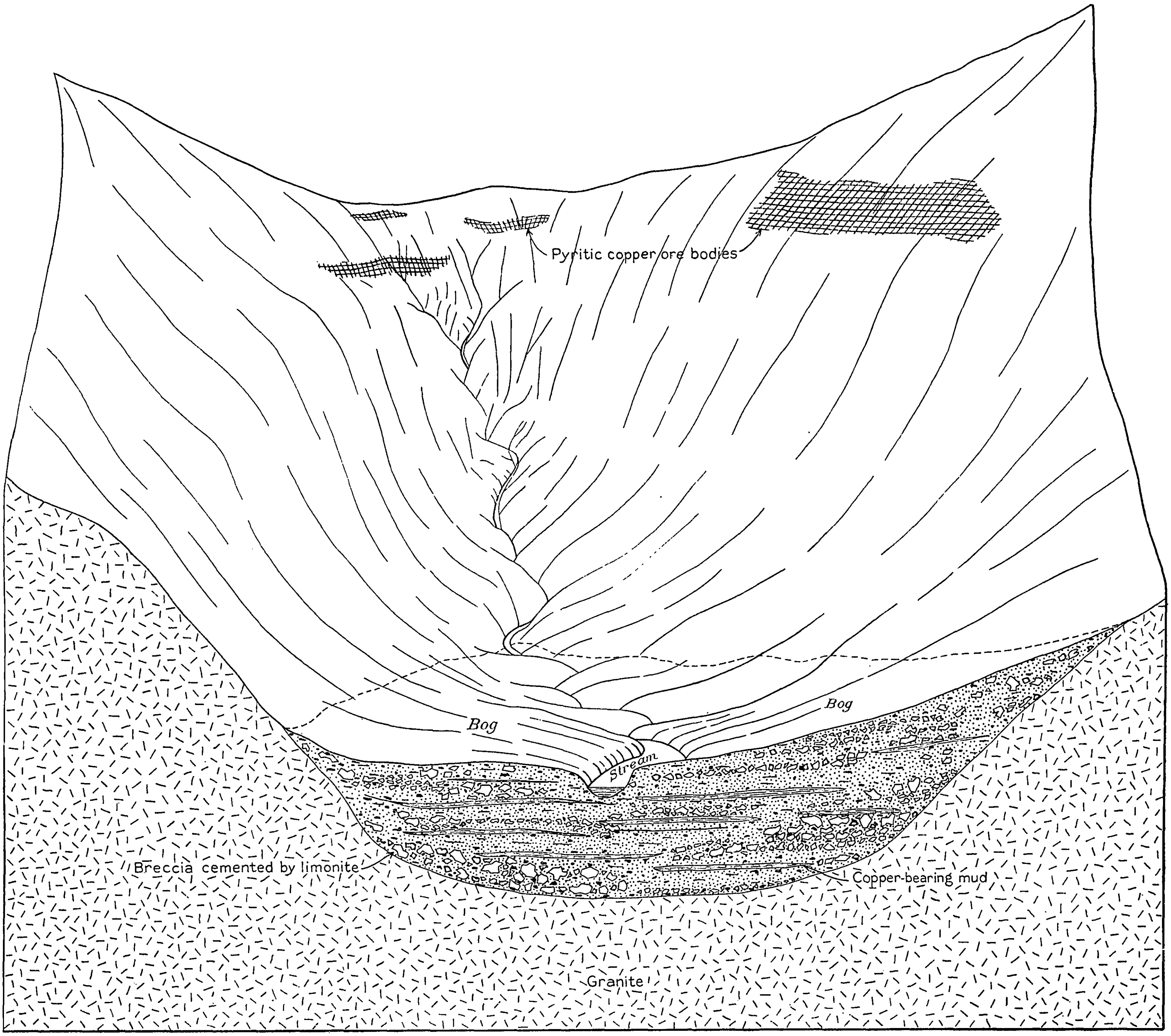
Consists of a core of sphalerite (gray), an intermediate shell of galena (white), and an outer shell of sphalerite. The sulphides are embedded in jasperoid, which has replaced a carbonate. Enlarged 48 diameters



B. A NODULE MADE UP OF FINE-GRAINED SULPHIDES AND QUARTZ

Consists of a core of fine-grained sphalerite (gray), galena (white), and quartz (dark gray), a thick intermediate shell of fine-grained galena with some fine-grained sphalerite, and a thin outer shell of sphalerite surrounded by jasperoid. Enlarged 48 diameters

SULPHIDE NODULES FROM IRMA MINE, NEW WORLD DISTRICT



FIELD RELATIONS OF BOG COPPER DEPOSIT IN NEW WORLD DISTRICT effects of oxidation and enrichment are inconspicuous in the material now exposed.

The limestone replacement deposits in the Irma mine are essentially similar in appearance to those in the Republic mine, above described. Some coarse-grained lead ore from a fissure has an unusual appearance in the hand specimen and is shown in Plate 22. It is evident from study of the polished surface that rhombs of carbonate have been replaced by chalcedonic quartz or jasperoid and that lead and zinc sulphides have been precipitated alternately around many nuclei in the jasperoid, giving the ore a characteristic appearance. This unusual type of ore has many variations, some of which are illustrated in Plates 23, *A*, and 24. A study of these ores leads to the conclusion that the minerals of the outer shells have replaced the inner shells or core to a very slight extent if at all. A very small amount of pyrite is present. These minerals are cut by polybasite and native silver. Some quartz and carbonate are later than the minerals above mentioned and cut across them. Cerusite has replaced galena along its cleavage and in places forms a narrow belt between the zinc blende and the lead sulphide. Some specimens of similar ore which are more oxidized show concentric grains of anglesite around galena nodules and anglesite veins cutting across the galena.

In general the order of deposition was (1) quartz, jasperoid, and pyrite; (2) galena, freibergite, sphalerite, quartz, and ankerite; (3) quartz, polybasite, chalcopyrite, and native silver, probably supergene. In a few specimens galena has replaced quartz, pyrite, and coarse-grained sphalerite, but this is rare.

MOHAWK WARRIOR MINE

The Mohawk Mining Co., of Miles City, Mont., holds several claims on Woody Creek about half a mile southeast of Cooke, at an altitude of 7,750 feet. In 1922–23 exploration went forward on a vein carrying considerable silver, but little work was done in 1924–25. The equipment includes four buildings, a hoist, a 25-horsepower gas engine, and an air compressor. A shaft has been sunk 110 feet and a drift driven from the bottom for 100 feet along a vein. A shallow adit 100 yards northwest of the shaft is in an andesite sill for its entire length of 200 feet, and no evidence of mineralization was observed in it. Ore has not been shipped from the mine, but the high content of silver which is present makes it an attractive prospect.

The collar of the shaft is in the lower shale of the Gros Ventre formation, but the drift at the base of the shaft is in the glauconitic upper sandstone of the Flathead quartzite, probably about 75 feet above the Cooke granite. The deposit exposed in the drift is a mineralized sheeted zone which strikes N. 20° W. and dips to the northeast at a high angle. The ore is found in numerous thin parallel veins across a space of 1 to 3 feet, but few individual seams attain a width of more than 4 inches. The vein material consists of quartz, coarse-grained galena, and "rosinjack" (sphalerite), with a minor amount of tetrahedrite and some secondary silver minerals. This is one of the few deposits in which native silver was frequently observed.

The deposit is in a glaciated valley, and the oxidized zone has probably been removed, for neither gossan nor oxidized ore is present. The occurrence of native silver and polybasite near the surface suggests a location close to the base of a secondary sulphide zone. The siliceous character of the gangue minerals and wall rock favor an extensive zone of enrichment, and solutions containing the silver salts could probably descend a considerable distance from the surface before precipitation occurred. Thus it seems possible that the enriched ore may continue some distance below the present workings even though they are now in the deeper part of the secondary sulphides.

The most persistent vein consists of banded quartz, sphalerite, and galena. From the hand specimen it is evident that quartz with a small amount of pyrite was deposited early. It was followed by galena and later by sphalerite. Small amounts of galena, quartz, and pyrite were then deposited, presumably near the end of the period of mineralization.

Under the microscope the polished surface corroborates the evidence of the hand specimen. The earliest minerals to form were quartz and subhedral grains of pyrite. On these minerals galena was precipitated in irregular masses and was followed by coarse-grained sphalerite nearly free from galena or other minerals. A slight brecciation of these earlier minerals preceded the precipitation of tetrahedrite and more galena. The deposition of the lead sulphide continued for some time after all the tetrahedrite had been precipitated, and this generation of galena contains small irregular masses of argentite, presumably contemporaneous. A small amount of manganiferous ankerite was deposited later, but the carbonate gangue in this deposit is of minor importance as compared with quartz. Polybasite and similar minerals were deposited either with the second generation of galena or later. The writer was unable to ascertain whether the polybasite was primary or secondary, but some pyrite, quartz, argentite, and native silver are distinctly later and are probably supergene, as they cut all the other minerals in irregular replacement deposits and minute veins.

A thin section of the wall rock shows a pyritized glauconitic sandstone, cut by veinlets composed chiefly of quartz and to a less extent of carbonate, galena, and sphalerite. The original cement of the sandstone has been changed in large part to iron sulphide. Some of the grains of quartz and glauconite are replaced by calcite, probably owing to the hydrothermal action of the mineralizing solutions.

VIRGINIA BELL AND JOSEPHINE CLAIMS

The Virginia Bell and Josephine claims lie in the upper Stillwater Basin half a mile northwest of the Sheep Creek divide. Neither claim has been worked for many years, but some high-grade silver ore was packed from the Josephine to the Republic smelter in 1886, according to Mr. Tredennick, who was then assistant superintendent of the smelter. The country rock is the lower limestone of the Gallatin formation, but the workings are shallow and badly caved, and little idea can be gained of the ore body worked in the eighties. Outcrops stained black with manganese and galena-sphalerite ore on the dumps suggest that the deposit is similar to those in Republic Mountain.

SURFICIAL DEPOSITS

BOG COPPER

The alluvium near the lower Glengarry adit carries spongy nuggets of native copper. Trenches several feet deep expose gravel and slope wash interbedded with a little black mud. Some of the gravel is clean, and some contains limonite, but no native copper has been found in it. The dark mud usually contains native copper but is nowhere iron stained. The copper-bearing layers do not make up more than 5 to 8 per cent of the section exposed in the cuts, but without systematic sampling no estimate should be made of the copper present.

The deposit rests in a recently glaciated valley and must be of very late origin. The copper-bearing mud contains blackened blades of grass, partly decomposed twigs, and other organic material which has now lost all form. Much of the water crossing the bog must first travel over outcrops of pyritic copper ore a short distance above. (See pl. 25.) The inevitable consequence is the oxidation of pyrite and chalcopyrite, with the attendant solution of copper as copper sulphate before this ground water reaches the bog. As the ore is confined to the black mud the conclusion is reached that metallic copper has been precipitated from these solutions by organic material. This conclusion is supported by experimental evidence. Some cultures made from this black soil developed bacteria capable of living in copper sulphate solutions containing 1 part of copper in 2,500. As most mine waters are much less strong [42] the bacteria were then

[42] Emmons, W. H., The enrichment of ore deposits: U. S. Geol. Survey Bull. 625, p. 97, 1917.

studied in solutions whose strength varied from 1:10,000 to 1:50,000. The copper was completely removed from the solution in a few months, and metallic copper was easily recognized under the microscope in the bacterial films.[43]

BOG IRON

Talus and gravel have been thoroughly cemented by iron hydroxide in many places near Red Mountain, and areas covering many acres may be found on its western and eastern flanks. The limonite has probably been formed by the hydrolysis of iron sulphate solutions. Owing to the admixed rock, the deposits are believed to be too impure to be of economic importance.

GOLD PLACERS

Placer deposits in this district are neither rich nor abundant. This fact may be explained in large part by the recent glaciation and consequent removal of preexisting stream gravel. In many of the valleys small deposits have been worked at intervals by different companies, but the amount of gold obtained from these placers is not known, though presumably small.

MISCELLANEOUS MINERAL RESOURCES

Limestone.—Black limestone has been quarried from the Gros Ventre formation on Republic and Woody Creeks and used for flux in the old Republic smelter, and some limestone from the lower massive limestone member of the Gallatin formation was also used. These rocks are said to have given excellent results in smelting.

At Trident, Mont., the Threeforks formation is quarried and used in the manufacture of Portland cement, and a large plant has been running successfully for a number of years. Near Cooke this bed is too impure to permit its use for cement or plaster; analyses of samples show 16.76 per cent of MgO, 26.52 per cent of CaO, and 16.8 per cent of impurities. Samples of the massive lower limestone of the Gallatin, however, show 0.57 per cent of MgO, 54.30 per cent of CaO, and 2 per cent of impurities, indicating an exceptionally pure limestone.

Clay.—The alluvial clay deposits of the district have been used in the manufacture of common brick and are very satisfactory for most purposes, but in the construction of the smelters a very high grade fire clay was needed for the manufacture of refractory bricks. Such a material was found in the Fire Clay claim, on the southern slope of Miller Mountain, and is the result of thorough decomposi-

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[43] Lovering, T. S., Organic precipitation of metallic copper: U. S. Geol. Survey Bull. 795, pp. 45–52, 1927.

tion of monzonite porphyry. Much of the quartz originally present has gone into solution and disappeared. Portions of the deposit do not yield clay of high enough grade to be used directly, but material of this quality can be utilized by washing it free of the residual quartz phenocrysts.

Iron.—There are no known deposits of iron ore in the district that are large enough to be worked economically as iron ore, but the hematite and magnetite in many of the contact-metamorphic deposits have furnished quantities of flux to the near-by smelters. It is possible that the limonite deposits on Red Mountain (see p. 86) could be used for a similar purpose, but these deposits are not extensive, and they contain large amounts of lime and silica, due to included rock fragments, which would have to be eliminated. The material could be easily quarried but seems to be of too low grade and too small in amount to be of commercial interest.

Building stone.—Limestone and sandstone have been quarried to a very small extent for dimension blocks. Most of the local buildings have been constructed of timber.

Water.—The region is well supplied with water, but there is not enough for the development of large electrical units close by. About 15 miles north of the district, at Mystic Lake, a large hydroelectric plant has been erected and may serve as a source of power at some future date. In most of the mines the level of ground water seems to be very high—in fact, it is much higher than the level to which enrichment extends. This indicates a comparatively recent elevation of the water table. Most of the water is of excellent quality and may be used freely, but on Henderson Mountain there are some springs which are rich in natural alum.