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GEOLOGY AND ORE DEPOSITS OF THE BAYHORSE REGION CUSTER COUNTY, IDAHO

BY

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GEOLOGY AND ORE DEPOSITS OF THE BAYHORSE REGION, CUSTER COUNTY, IDAHO

By C. P. Ross

ABSTRACT

This report describes the geology and mineral resources of the Bayhorse quadrangle, much of the Custer quadrangle, and the area surrounding Round Valley, all in Custer County, and a small part of the Sawtooth quadrangle in Blaine and Custer Counties, Idaho. The region is underlain by a thick sequence of Paleozoic sedimentary rocks intruded on the west by the Idaho batholith and in large part overlain by Tertiary volcanic strata and associated sedimentary rocks. The Paleozoic rocks are divided into 14 formations, which appear to include representatives of each of the Paleozoic systems. The succession differs in several respects from that in any of the neighboring areas, but correlation is suggested with the formations of the Wood River region, immediately to the south, and also with the well-known formations of southeastern Idaho. The Tertiary strata are subdivided on the map to a greater extent than has heretofore been attempted in Idaho, seven map units being recognized.

The Paleozoic strata are complexly folded and have been broken by thrust and normal faults. There is reason to believe that the Idaho batholith had an active part in the deformation. The Tertiary strata are only gently folded. They are broken by several normal faults, mostly of small displacement. The present irregularities in distribution and thickness resulted largely from inequalities in the relief of the surface on which the Tertiary beds were laid down rather than from subsequent deformation.

Data obtained in the present investigations show that the Tertiary beds are of Oligocene or early Miocene age and that such beds are truncated by the surfaces of areas long recognized as remnants of an early partial peneplain. Two stages of Pleistocene glaciation are recognized and correlated with certain stream terraces.

The region includes the Bayhorse, Boulder, and East Fork mining districts. For purposes of description the metallic lodes are placed in four groups. One group comprises irregular replacement deposits in calcareous (mostly dolomitic) rocks containing galena, sphalerite, and minor amounts of other sulphides in a gangue consisting largely of partly silicified country rock and includes some promising lodes, several of which were formerly productive. Another group comprises lodes on shear zones in Paleozoic strata. Some of these differ from those of the first group mainly in the structural conditions guiding deposition. Other lodes, including those of several of the larger mines, have galena and locally tetrahedrite as the outstanding metallic minerals and siderite as the characteristic gangue mineral. A few of the lodes, notably the Livingston, are characterized by jamesonite and calcite. A third group occurs in granitic rock and is valuable principally for gold, although in places the deposits contain minable galena. One of the interesting features of the lodes of this group, most

of which have been little developed, is the presence of bismuth, a rare constituent in the lodes of central Idaho except the Tertiary lodes of the Boise Basin. The fourth group of lodes includes several varieties each of which has only a few representatives in the region and none of which have received much development. The most interesting of these are molybdenite lodes, copper deposits in breccias, and irregular arsenopyrite veins.

INTRODUCTION

LOCATION

The region here described lies in the upper drainage basin of the Salmon River, in south-central Idaho. It comprises the Bayhorse quadrangle; much of the Custer quadrangle, immediately to the west; Round Valley, to the north, in which Challis is situated; and a small part of the Sawtooth quadrangle, to the southwest. The region is mainly in southwestern Custer County but includes a small area in the northwestern part of Blaine County. Its location with reference to the rest of the State is shown in figure 1. For convenience it is here termed the "Bayhorse region."

The Bayhorse, Boulder Creek, and East Fork mining districts are included within this region. As the principal mines are valuable mainly for lead and silver, economic conditions since 1929 have caused most of them to suspend operations. Nevertheless the region is among the more promising in south-central Idaho[1] and, when the general economic situation improves, should again become active. In addition to lead-silver ores the region contains deposits of zinc, gold, copper, molybdenum, and other metals, most of which have as yet received comparatively little attention.

SCOPE

The present report includes the results of several interrelated studies carried out by different parties, all under the direction of the writer, and constituting parts of an investigation of the geology of south-central Idaho conducted in cooperation with the Idaho Bureau of Mines and Geology.

The writer's work in the area included on plate 1 began in 1924, but the field work on the present project was done in the summers of 1927 to 1930, with brief subsequent visits. Figure 2 shows the areas covered by the different parties engaged in the work. In area 1 the topography was mapped concomitantly with the geology. In areas 2, 3, and 4 and most of area 7 the geology was mapped in detail. In area 5, which was studied mainly in order to aid in elucidating stratigraphic problems encountered in the Bayhorse quadrangle, the geology was mapped in less detail, in part because of deficiencies in the topographic base. In area 6 the mapping was based on reconnaissance trips made at various times. The mines and prospects in

[1] Ross, C. P., A graphic history of metal mining in Idaho: U. S. Geol. Survey Bull. 821, pp. 6, 8, 1930.

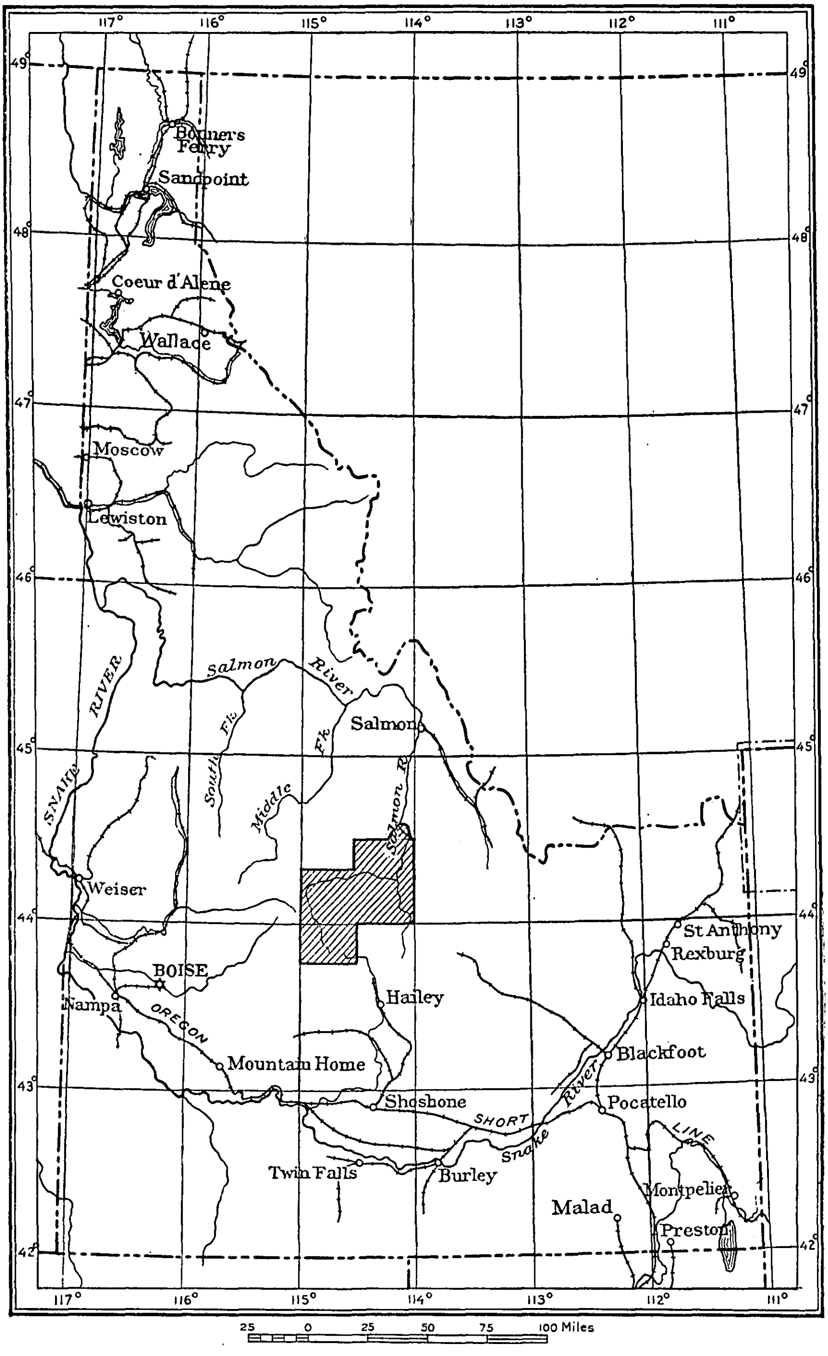

FIGURE 1.—Index map of Idaho showing location of the Bayhorse region (shaded area).

area 2 and the few prospects in areas 3 and 4 were studied as thoroughly as circumstances permitted. In area 5 the Livingston is the only one of the larger mines that was sufficiently accessible for adequate examination. Available data on mines in area 7 and near Bonanza have already been published [2] and are not repeated in this

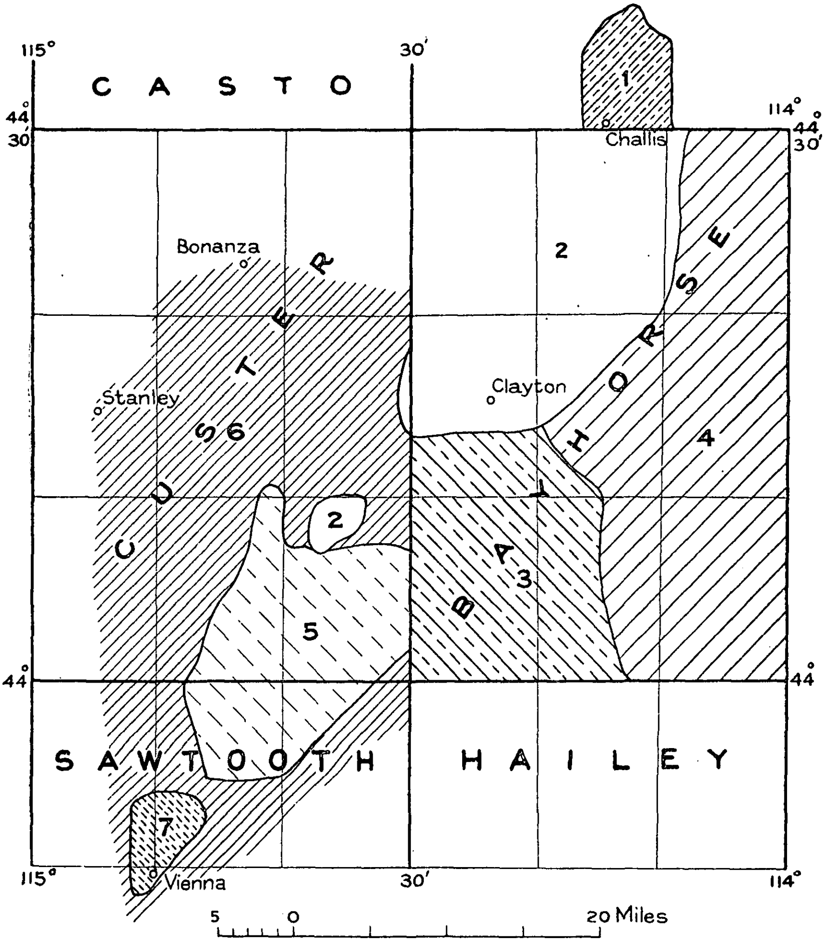

FIGURE 2.—Index map showing areas mapped by each of the parties that participated in the study of the Bayhorse region. 1, C. P. Ross and assistants, 1927, 1928; 2, C. P. Ross, R. R. LeClercq, and W. D. Mark, 1928; 3, T. H. Hite, Jr., and E. Slate, with assistance from C. P. Ross, 1929; 4, T. H. Hite, Jr., and W. Carpenter, with assistance from C. P. Ross, 1930; 5, C. P. Ross and S. S. Philbrick, 1930; 6, C. P. Ross and assistants, 1924-30 (reconnaissance); 7, C. P. Ross and C. H. Behre, Jr., 1926.

report. These areas are included on plate 1 only because they help to complete the picture of the structural conditions in the region.

[2] Ross, C. P., The Vienna district, Blaine County, Idaho: Idaho Bur. Mines and Geology Pamph. 21, 1927; Ore deposits in Tertiary lava in the Salmon River Mountains, Idaho: Idaho Bur. Mines and Geology Pamph. 25, pp. 3, 13, 14, 18, 1927.

ACKNOWLEDGMENTS

Throughout the investigation progress was facilitated by the hearty cooperation of the local mining men, Forest Service officers, and others. Much credit is due to T. H. Hite, Jr., of the Idaho Bureau of Mines and Geology, whose conscientious work has made possible greater subdivision of the Tertiary volcanic rocks than has heretofore been attempted in Idaho. His work and the writer's were especially furthered by the assistance and hospitality of the Leuzinger family. The writer's work in the Custer and Sawtooth quadrangles in 1930 was expedited by exceptionally efficient management of the pack train by Marion Peel. Stratigraphic concepts were expanded and strengthened as a result of field and office studies of the pre-Carboniferous fossils in and near the Bayhorse region by Edwin Kirk, of the Carboniferous fossils by G. H. Girty and David White, and of the Tertiary plant remains in the Bayhorse region and near Salmon, Lemhi County, by R. W. Brown.

EARLIER WORK

The Bayhorse and East Fork districts have been described in comprehensive reconnaissance reports by Umpleby,[3] which have been drawn upon freely in the present paper, especially for historical and other data regarding the mines. In addition, valuable information is contained in the annual reports of the Idaho State mine inspector and the annual volumes of Mineral Resources of the United States. Attention should be called to two short articles by Bell [4] dealing with mines in the Bayhorse district and to one by Stewart [5] describing the Livingston mine, of which he was manager at the time.

HISTORY

The Bayhorse region was early visited by fur trappers, but settlement did not begin until about 1877, when the Riverview and other lodes in the Bayhorse district were located. Many of the lodes in the East Fork district were found in 1880, and the Livingston mine in the Boulder Creek district in 1882. The first and most productive period of mining in the Bayhorse district was from 1877 through 1898. Smelters were built in 1880 at Bayhorse and Clayton and were intermittently operated until 1897 and 1902 respectively. The smelter at Clayton was reopened in 1912 but did not operate long. The total

[3] Umpleby, J. B., Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, pp. 9–26, 1913; Ore deposits in the Sawtooth quadrangle, Blaine and Custer Counties. Idaho: U. S. Geol. Survey Bull. 580, pp. 244–246, 1915.

[4] Bell, R. N., The deepest mine in Idaho, the Ramshorn at Bay Horse: Mines and Minerals, vol. 21, pp. 174–176, 1900: An outline of Idaho geology and of the principal ore deposits of Lemhi and Custer Counties, Idaho: Internat. Min. Cong. Proc. 4th sess., pp. 64–80, 1901.

[5] Stewart, J. B., The Livingston mine, Custer County, Idaho: Mining and Metallurgy, vol. 7, pp. 223–224, 1926.

production of the district during this period is estimated by Umpleby [6] at $10,000,000, of which roughly $6,900,000 was from silver, $2,700,000 from lead, and $650,000 from copper. The lead-silver deposits in Germania Basin and some in other parts of the East Fork district were productive from 1880 to 1887. Accurate data, particularly as to the production from the southern part of this district, are lacking, but the total may not have exceeded $500,000. Most of the ore was shipped by pack train to Galena and Ketchum, on the Big Wood River. Little more than prospecting was done in the Boulder Creek district in the early days, but there is record [7] of 48 small lots of ore shipped from that district, mainly by pack train, to the smelter at Clayton. These shipments amounted to 240.9 tons, containing 58.36 ounces of gold, 21,907.6 ounces of silver, and 194.185 pounds of lead.

The Bayhorse district had a brief revival in activity initiated when the smelter at Clayton was reopened in 1912. Renewed development in the period from 1920 to 1925, however, resulted in considerable production. At no time since its discovery has the district been entirely inactive. The production from 1906 through 1927, according to the records of the United States Bureau of Mines, was about $2,500,000. Over 50 deposits are known, but the average number of producers from 1910 to 1929 was about five. Since 1929 the general depression in the mining industry has greatly reduced the production from the district.

The production from the East Fork district since 1890 has been extremely small, but prospecting has persisted, and a recent revival of interest in the gold deposits in Washington Basin has been reported.

In the Boulder Creek district comparatively extensive development began in 1922, and the main ore body in the Livingston mine was discovered in 1925. Production began promptly and continued until 1929, but the mine has been shut down since 1930. The interest aroused by this notable discovery stimulated prospecting. Although several lodes similar to the Livingston and some containing molybdenum and other metals are now known, none have yet received much development.

TOPOGRAPHY

The Bayhorse region is in the mountainous country of south-central Idaho. As shown on plate 1, it comprises parts of several ranges, most of which are not sharply delimited. Most of the region is tributary to the Salmon River, although it includes small parts of the drainage basins of the Big Lost and Big Wood Rivers.

The main Salmon River flows first north, then east, then north again diagonally across the region. Above its junction with Valley

[6] Umpleby, J. B., Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull 539, p. 56, 1913.

[7] Bell, R. N., 21st annual report of the mining industry of Idaho, for the year 1919, pp. 78, 79, 1920.

Creek near the scattered settlement of Stanley it flows in the wide alluvium-floored depression of Stanley Basin. At Stanley it turns eastward and flows in a steep-sided valley that widens somewhat downstream. Near its junction with its East Fork the river swings northward, and its valley opens somewhat. A short distance below its confluence with Birch Creek it debouches into the comparatively broad expanse of Round Valley, but immediately to the north its valley is again constricted.

West of Stanley Basin several of the numerous short tributaries of the Salmon have lakes in their lower reaches. Below Stanley the Yankee Fork is much the largest tributary from the north. On the opposite side of the Salmon River is one of the larger tributaries, Warm Spring Creek, which enters at Robinson Bar, formerly a placer camp and now a summer resort. In its middle reaches it flows through a slightly swampy flat known as "The Meadows." The East Fork joins the Salmon River from the south 22 miles below Robinson Bar. This stream and its major tributary, Germania Creek, flow for the most part through country of only moderate relief.

Farther east is a second Warm Spring Creek, a small stream, ephemeral for much of its length, that drains a broad depression made up of flats interspersed with groups of hills. Much of the water comes from lukewarm springs that issue a short distance north of Grand View Canyon, near the middle of the valley.

The southeast corner of the region is tributary to the Big Lost River. Only a small part of the margin of the broad valley occupied by this stream is included in the area shown on plate 1. The Big Lost River flows southward to the Snake River Plain, where it sinks from view.

The mountains north of the Salmon River and west of Round Valley form the southeastern part of the Salmon River Mountains. A few of the peaks within the part here geologically mapped exceed 9,500 feet in altitude above the sea, and several of those farther north are materially over 10,000 feet. The Salmon River at the base of the range flows at altitudes but little over 5,000 feet.

The extremely rugged and serrate mountains west of Stanley Basin constitute the Sawtooth Range. This range has several peaks over 10,600 feet high, and the part of it bordering Stanley Basin has more definite trend and limits than most of the other mountain masses in central Idaho.

In the area east of Stanley Basin, south of the Salmon River, and west of the eastern Warm Spring Creek there is an aggregation of mountains that as a unit is not named. These mountains are considered by many to form the most easterly part of the Sawtooth Mountains, a group that includes not only the range of that name but many of the neighboring mountain masses. The highest part of this unnamed unit consists of the White Cloud Peaks, which extend southward from the vicinity of Robinson Bar between the western Warm Spring Creek and Slate Creek to the head of Germania Creek. Castle Peak, the highest of the group, is 11,820 feet above sea level, and several of the others are well over 10,000 feet. Between the White Cloud Peaks and Stanley Basin is a confused mass of mountains several of which reach altitudes of 9,000 feet and more. East of the peaks the country has somewhat the appearance of a greatly dissected plateau with flat summits rising 7,500 feet and more above sea level. A few peaks exceed 8,500 feet. The plateau contains numerous amphitheaterlike basins at the heads of minor streams. Along the south border of the region altitudes increase. They culminate in Bowery Peak, 10,915 feet above sea level. The elongate interrupted ridge of northwest trend with Lone Pine Peak as its highest point (9,660 feet) forms the east border of this mountain mass. In the northeastern part of the Bayhorse region, beyond the flats drained by the eastern Warm Spring Creek, is part of the Pahsimeroi Mountains. In and near T. 11 N., R. 21 E., mostly outside of the area mapped, a transverse range forms a link between the Pahsimeroi Mountains and the mountains just described.

The highest point in the Pahsimeroi Mountains within the area mapped is 9,677 feet above sea level, and the flat at its base is but little more than 6,000 feet. The Pahsimeroi Mountains constitute the northern part of the Lost River Range, which, a short distance to the southeast, is crowned by Mount Borah (12,655 feet), believed to be the highest peak in Idaho.

STRATIGRAPHY AND PETROLOGY

GENERAL FEATURES

The geology of this part of Idaho has long been known in reconnaissance fashion, but comparatively detailed data for any part of it have become available only recently, with the result that concepts on many points are undergoing modification. As the Paleozoic shore lines fluctuated through this region,[8] variations in stratigraphy are so frequent and so marked as to complicate correlation. The table below summarizes the interrelations between the formations of the Bayhorse region, the Wood River region,[9] immediately to the south, and southeastern Idaho. The detailed data assembled by Mansfield[10] for southeastern Idaho permit correlation between the Paleozoic section

[8] Ross, C. P., Correlation and interpretation of Paleozoic stratigraphy in south-central Idaho: Geol. Soc. America Bull., vol. 45, pp. 937-1000, 1934.

[9] Umpleby, J. B., Westgate, L. G., and Ross, C. P., Geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814, pp. 9-61, 1930.

[10] Mansfield, G. R., Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, pp. 48-52, 1927.

there and the well-known sections in Utah and other neighboring States.

The Paleozoic section in the Bayhorse quadrangle resembles that in southeastern Idaho more closely than that in the Wood River region; the similarity is so striking that three of the formation names in use in southeastern Idaho are here adopted to designate the corresponding strata in the Bayhorse quadrangle.

The Wood River formation of this part of Idaho appears to be so nearly equivalent to the Wells formation of southeastern Idaho that if the formation in and near the Bayhorse quadrangle were unnamed it should be called Wells. However, the strata here are coextensive with the Wood River formation of the Hailey quadrangle, where the name has long been in use, so that change at this time is undesirable. The Milligen formation of the Bayhorse and Hailey quadrangles and vicinity has no counterpart in southeastern Idaho. This formation is largely of Mississippian age but, as now mapped, may include older strata in some localities.

As a result of the present study it is now possible to trace the deformed Paleozoic strata along much of the eastern border of the Idaho batholith. The result shows such intimate relations between the deformed strata and the intrusive mass as to suggest close genetic association. Intricate folding and faulting mark the Paleozoic strata. One of the most striking features of the deformation is the fact that the largest anticline is flat-topped and overturned on both sides for much of its length. Tertiary deformation also occurred, but the faults of this age are less dominant than they are farther north.

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Stratigraphic correlation between the Bayhorse region, the Wood River region, and southeastern Idaho

Bayhorse region				Wood River region [1]	Southeastern Idaho [2]	Age [3]
Age	Formation	Character	Thickness (feet)			
Recent.	Landslides.	Coarse and fine detritus.		Landslides.	Landslides.	Recent.
Recent and Pleistocene.	Alluvium.	Sand, silt, and gravel.	0 to possibly several hundred.	Alluvium.	Alluvium.	
Wisconsin.	Late glacial deposits.	Sand and gravel.	Locally several score.	Late glacial deposits.	Lake beds; older alluvium; travertine.	Pleistocene.
Nebraskan (?).	Early glacial deposits.	Gravel.	Locally scores to hundreds.	Early glacial deposits.		
				Quaternary basalt.		
					Salt Lake formation.	Pliocene (?).
Early Miocene or late Oligocene.	Challis volcanics.	Germer tuffaceous member, with Yankee Fork rhyolite member in part interbedded with and in part overlying it, and basalt and basic andesite interbedded with and locally displacing it.	0 to several thousand.	Miocene (?) lava, subdivided into rhyolite, augite andesite, basalt, latite and hornblende andesite, with interbedded tuffaceous beds.		
		Latite-andesite member (where present, forms the lower part of the formation).	0 to several thousand.			
					Wasatch formation.	Eocene.
					Mesozoic formations.	
Permian (?).	Casto volcanics.	Altered flows and pyroclastic rocks; generally andesitic.	Only a fragment remains in the Bayhorse region, but 2,000-4,000 feet farther north.		Phosphoria formation.	Permian.
Pennsylvanian.	Wood River formation.	Impure quartzite, argillaceous and calcareous, and some limestone. A little conglomerate near the base.	8,000±	Wood River formation.	Wells formation.	Pennsylvanian.

Upper Mississippian.	Brazer limestone.	Generally dolomitic, rather massive; some chert. Local conglomerate.	2,000+	Milligen formation (includes argillaceous rocks of Brazer age; may include some Devonian).	Brazer limestone.	Mississippian.
Mississippian and older (?).	Milligen formation.	Argillite and argillaceous quartzite with impure dolomitic beds. Local beds of coarse grit to fine conglomerate. Most of the formation is characterized by much carbonaceous matter.	3,000±		Madison limestone.	
Upper Devonian.	Grand View dolomite.	Moderately dark well-bedded dolomite, in part quartzitic.	1,250		Threeforks limestone.	Upper Devonian.
Middle Devonian.	Jefferson dolomite.	Dark dolomitic limestone.	1,150		Jefferson limestone.	Middle Devonian.
Middle Silurian.	Laketown dolomite.	Moderately light colored dolomite. Locally a quartzite member thick enough to be mapped separately.	2,500±		Laketown dolomite.	Silurian (Niagaran fossils).
	Trail Creek formation.	Brownish-gray calcareous argillite; some quartzite.	Neither top nor bottom exposed. Probably several hundred feet.	Trail Creek formation.		
Upper Ordovician.	Saturday Mountain formation.	Dark massive dolomite interbedded with argillite and shaly dolomite, in part carbonaceous.	3,000±	Phi Kappa formation.	Fish Haven dolomite	Upper Ordovician.
Middle (?) Ordovician.	Kinnikinic quartzite.	Massive light-colored quartzite with local lenses of dolomite and dolomitic shale, separately mapped. Some conglomerate.	3,500±			
Lower Ordovician.	Ramshorn slate.	Dark thin-banded slate predominates in most places, with argillite and argillaceous quartzite locally, mainly in the south.	2,000	Early Lower Ordovician rocks (Beekmantown).	Swan Peak quartzite. Garden City limestone (Beekmantown).	Lower Ordovician.
Cambrian (?).	Bayhorse dolomite.	Generally massive thick-bedded dolomite, in part oolitic.	1,000+		St. Charles limestone.	Upper Cambrian.
	Garden Creek phyllite.	Intensely sheared and metamorphosed argillaceous rock.	Base not exposed. At least several hundred.		Nounan limestone, Bloomington formation, Blacksmith limestone, Ute limestone. Langston limestone.	Middle Cambrian.
					Brigham quartzite.	Lower Cambrian.
				East Fork and Hyndman formations (Algonkian?).		

[1] U. S. Geol. Survey Bull. 814, 1930. [2] U. S. Geol. Survey Prof. Paper 152, 1928. [3] This column relates to both the Wood River region and southeastern Idaho.

CAMBRIAN (?) ROCKS

GARDEN CREEK PHYLLITE

Distribution.—The Garden Creek phyllite was named [11] from Garden Creek, which flows through Challis. The formation constitutes the walls of the inner gorge of that creek about 9 miles above its mouth and extends up the sides of its valley and across the ridge into Daugherty Gulch, on the north. It is also exposed along Bayhorse Creek near the town of Bayhorse but has not been recognized in any other part of the region.

Character.—The formation is composed exclusively of a dark-gray or nearly black phyllite with abundant silvery sericite on cleavage surfaces. Some of the phyllite is slightly calcareous. Bedding is represented by thin crenulated bands visible only on close inspection. The rock is soft and weathers so readily that satisfactory exposures are rare except locally, as in the inner gorge of Garden Creek. It breaks into small smooth flakes and slivers that form masses of mobile talus.

The phyllite is much contorted and commonly steeply inclined. As the base of the formation is nowhere exposed its thickness is indeterminate, but plate 1 shows that the beds aggregate at least several hundred feet. The local crumpling and poor exposures characteristic of the phyllite make its relations to the overlying Bayhorse dolomite difficult to determine. In general, as the map indicates, there is little discordance in attitude between the two formations along the contact.

Age.—The Garden Creek phyllite has yielded no fossils and is tentatively referred to the Cambrian, mainly on the basis of its stratigraphic relations. It is clearly the only rock of the area at the base of the local succession and is overlain by the Bayhorse dolomite, which is separated from the Ramshorn slate (Lower Ordovician) by an unconformity. These facts show that the phyllite is at least as old as Cambrian. The rock is more argillaceous than most of those assigned to the Belt series in neighboring areas. It most nearly resembles and may perhaps be equivalent to the schist in the Loon Creek district,[12] regarded as of pre-Cambrian age. The phyllite is, however, less thoroughly foliated than the schist and does not appear to be separated from the overlying beds by so distinct an unconformity.

BAYHORSE DOLOMITE

Distribution.—The Bayhorse dolomite was so designated [13] because the best and most complete exposures of it are in the vicinity of the old

[11] Ross, C. P., Correlation and interpretation of Paleozoic stratigraphy in south-central Idaho: Geol Soc. America Bull., vol. 45, p. 941, 1934.

[12] Ross, C. P., Geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, pp. 22–23, 1935.

[13] Ross, C. P., Correlation and interpretation of Paleozoic stratigraphy in south-central Idaho: Geol. Soc. America Bull., vol. 45, p. 941, 1934.

town of Bayhorse, on Bayhorse Creek. The formation crops out at intervals along the crest and east flank of the major anticline in the region. It is extensively exposed in the vicinity of Daugherty and Garden Creeks, appears again along Bayhorse Creek, and crops out in smaller areas farther south, the last outcrop in that direction being on Sink Creek, a little more than 12 miles south of the most northerly known exposure. Like the Garden Creek phyllite, just described, the Bayhorse dolomite has not been recognized outside of the Bayhorse quadrangle. All the Paleozoic rocks disappear beneath the Challis volcanics close to the northern border of the quadrangle.

Character.—The greater part of the formation is composed of thick-bedded dolomite that tends to form prominent cliffs. Many of the beds are crowded with nearly black oval chert masses, commonly less than half a centimeter in maximum diameter. Locally the bodies are larger and more irregular. The dolomite in many of the beds is light creamy gray when fresh but weathers readily to a rusty buff. Some of it is sufficiently calcareous to effervesce feebly with cold acid. In a few places the dolomite is nearly black and instead of the chert masses is studded with white bodies of slightly greater average size. Each of these bodies consists of a single crystal grain of dolomite, commonly with a rim of finer-grained carbonate, at least in part calcite. In these beds, noted especially near Cold Spring Creek above Bayhorse, the mass of the rock is mainly dolomitic, but small calcite grains are scattered through it. Both in this variety and in the more common one with chert masses the average diameter of the grains in the groundmass is about 0.05 millimeter. Some beds are cherty, and some lenses, especially those near the top of the formation, are argillaceous. In a few places, notably on the west flank of the anticline on Garden Creek, there is dolomitic breccia or poorly rounded conglomerate. Lenses of white vein quartz are common in the dolomite along this creek. The dolomite on the east flank of the anticline north of Garden Creek is locally interbedded with quartzite containing fragments of dolomite. Some such beds are as much as 100 feet thick, are somewhat shaly, and have fucoid markings.

The formation was extensively eroded prior to the deposition of the overlying beds. Locally along Daugherty Gulch it was entirely removed. The greatest exposed thickness is along Bayhorse Creek, where the overlying conglomerate, so abundant farther north, is absent. In the cliffs immediately north of the town of Bayhorse about 1,000 feet of the Bayhorse dolomite is exposed, with Garden Creek phyllite below and Ramshorn slate above. Local contortion, here and elsewhere, has rendered accurate measurement impossible. On the east flank of the anticline near Garden Creek the thickness cannot be much less than 1,000 feet, although there the overlying conglomerate indicates that the dolomite has been eroded.

Age.—No diagnostic fossils have been found in the Bayhorse dolomite, although some of the larger concretionary masses so common in it have forms suggestive of algae or kindred organisms. The fucoid markings on quartzite beds resemble those locally abundant in the Kinnikinic quartzite. The formation is unconformable below slate of Lower Ordovician age and is lithologically quite unlike any known member of the Belt series. For these reasons the dolomite is tentatively regarded as of Cambrian age.

ORDOVICIAN ROCKS

RAMSHORN SLATE

Distribution.—The Ramshorn slate was first distinguished in the valley of Bayhorse Creek, where it constitutes the country rock of the Ramshorn mine, for which the formation was named.[14] It is exposed over a greater area than any of the other Paleozoic units. It extends in a band 2 to 5 miles wide from Mill Creek on the northern border of the Bayhorse quadrangle southward past Clayton, a distance of about 20 miles. From Clayton all the way to the southern boundary smaller isolated outcrops of it emerge at intervals through the cover of Challis volcanics. The overlying volcanic rocks prevent direct determination of the relations of the slate to the Paleozoic formations of the Wood River region.

Character.—The main mass of the formation is composed almost exclusively of a thin-banded argillaceous rock with well-developed slaty cleavage cutting the banding at high angles. Locally, especially near Daugherty Gulch, there is conglomerate at the base of the formation, and a few of the beds are more quartzitic or more calcareous than the average. In the isolated exposures farther south the proportion of quartzitic and locally carbonaceous material is somewhat greater, and the slaty cleavage is less perfectly developed.

The basal conglomerate is exposed only in the vicinity of Daugherty Gulch and Garden Creek and in a small area on upper Rattlesnake Creek. In and near the area of intensely brecciated rock near Potaman Peak, especially near the head of Corral Creek, there is some conglomerate.

Most of the conglomerate is composed almost exclusively of fairly well rounded pebbles of vein quartz and quartzite with maximum diameters rarely in excess of 3 inches, in a siliceous matrix. Interbedded with it locally are shaly quartzite without pebbles and scattered lenses of slate, all too small to be distinguished on plate 1. Some of the beds of conglomerate and quartzite are reticulated with

[14] Ross, C. P., Correlation and interpretation of Paleozoic stratigraphy in south-central Idaho: Geol. Soc. America Bull., vol. 45, p. 945, 1934.

quartz veins. The maximum thickness of conglomerate along Garden Creek somewhat exceeds 500 feet.[14a]

The pebbles of the conglomerate are so well worn and so dominantly composed of quartz as to indicate that the land from which they came had long been exposed to denudation.

Most of the slate that constitutes the major component of the formation is a dark-green to purplish rock with conspicuous bands commonly about a quarter of an inch wide. Locally it is lightened in color by calcareous material or darkened by carbonaceous matter. Nearly everywhere in the northern part of the region slaty cleavage is well developed. Plate 2, *A*, shows conspicuous, steeply inclined slaty cleavage planes cutting gently inclined, less clearly visible bedding planes. Except that weathering has emphasized both cleavage and bedding in the outcrop pictured, it is typical of much of the Ramshorn slate north of the Salmon River.

Most of the slate consists largely of quartz, in grains rarely more than a few hundredths of a millimeter in diameter, and fine aggregates of chlorite, serpentine, biotite, and other micaceous minerals. In several places igneous metamorphism has produced chiastolite, a variety of andalusite ($Al_2O_3.SiO_2$). On both sides of Juliette Creek and locally near the Ramshorn mine the slate has been metamorphosed into a coarse-grained gray to black rock that on weathered surfaces is studded with andalusite crystals.

Most of the Ramshorn slate in the isolated exposures farther south differs from that in the larger masses north of the Salmon River mainly in being in part more quartzitic and in part more carbonaceous, especially at one horizon, and having less perfect slaty cleavage. The more highly carbonaceous beds, which are especially plentiful along lower Pine Creek and at the head of Jimmy Smith Lake, unlike most other members of the formation, tend to part along the bedding, a condition that has permitted the discovery of fossils in them.

Locally some beds are distinctly more calcareous or quartzitic than the average. Limestone lenses are conspicuous only along Kinnikinic Creek, especially close to the contact with the Kinnikinic quartzite of Poverty Flat. Quartzitic beds are more widespread. In some places, notably near the Skylark mine, near upper Bayhorse Creek, and south of Potaman Peak, there are beds that closely resemble typical Kinnikinic quartzite.

The Ramshorn slate is everywhere contorted, although rarely so intensely crenulated as the Garden Creek phyllite. It is clear from the map and structure sections (pl. 1) that the average thickness is

[14a] According to G. R. Mansfield, the quartzitic and conglomeratic material at the base of the Ramshorn slate on Garden Creek is lithologically so similar to parts of the Brigham quartzite that a question is raised as to whether the lower part of the Ramshorn slate, as here described, may not be of Cambrian age.

more than 2,000 feet. Umpleby[15] estimates that the slate along Bayhorse Creek has a thickness of more than 4,000 feet. This figure, based on a supposed average dip of only 35°, is probably too great.

The isolated exposure of Paleozoic beds nearly 4 miles above the mouth of Herd Creek has been mapped with some hesitation as Ramshorn slate (pl. 1). It resembles almost equally well some varieties of the calcareous units in the Kinnikinic quartzite. The widespread cover of Challis volcanics prevents determination of its relations to other Paleozoic strata. The exposure comprises sandy and calcareous shale grading upward into calcareous quartzite overlain by more massive quartzite. The predominant color is light gray, in part bleached almost white. Several hundred, possibly as much as 1,000 feet of beds appear to be present in the small exposure, but the beds are so much contorted and broken as to preclude any attempt at measurement.

Age.—The fossils, found wherever the Ramshorn slate is carbonaceous and parts parallel to the bedding so as to reveal them, show conclusively that these portions of the formation are Lower Ordovician. Unfortunately the more extensive masses of the formation in the northern part of the Bayhorse quadrangle have yielded no fossils, doubtless because it is rarely possible to inspect bedding planes for graptolites. These strata, however, are clearly much older than the fossiliferous Upper Ordovician Saturday Mountain formation, as they are separated from it by the thick Kinnikinic quartzite. On the basis of these facts and of the close lithologic resemblances throughout the formation, all the strata here grouped in the Ramshorn slate are confidently regarded as Lower Ordovician.

The following list gives the determinations by Edwin Kirk of fossils collected from this formation. All came from exposures in the southwestern part of the Bayhorse quadrangle. The numbers assigned to the lots are those of the permanent early Paleozoic locality records of the United States Geological Survey.

2462. Talus along road, along the East Fork of the Salmon River, half a mile west of mouth of Lake Creek:

Caryocaris sp.

2461. Talus slope on the east flank of Pine Creek, 1 mile above the creek mouth:

Caryocaris sp.
Goniograptus sp.

2458. Outcrop on east slope of Pine Creek just above locality 2461:

Caryocaris sp.
Sponge spicules.
Poorly preserved graptolite fragments, doubtfully referable to *Didymograptus*.

[15] Umpleby, J. B., Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, p. 20, 1913.

2464, 2465. Outcrop on east slope of Pine Creek, three-quarters of a mile above its mouth:

Caryocaris sp.

2459. Talus on east side of Pine Creek a mile above its mouth:

Poorly preserved graptolites.

2463. West slope of East Pass Creek just above point where the stream swings eastward:

A few fragmentary graptolites probably referable to *Monograptus*.

Most of these lots Mr. Kirk referred to the Lower Ordovician (lower Deepkill horizon). Lot 2459 he originally referred doubtfully to the Normanskill, but he later visited this locality personally and satisfied himself that the fossils here were of the same age as the others along Pine Creek, listed above. The single collection of fragmentary graptolites from East Pass Creek (2463) he referred doubtfully to the Silurian. Although it is conceivable that representatives of the Trail Creek formation of the Wood River region [16] are present here, the lithology of the beds and their field relations make it seem more logical to group this exposure, like the others here described, with the Ramshorn slate, a decision with which Mr. Kirk is in accord.

KINNIKINIC QUARTZITE

Distribution.—The Kinnikinic quartzite was named [17] for its excellent exposures along Kinnikinic Creek, which reaches the Salmon River at Clayton. The largest exposed mass of this quartzite, with its intercalated calcareous beds, occupies much of the area between Kinnikinic and Squaw Creeks and continues across the Salmon River as far south as Potaman Peak. Other masses flank and crown the major anticline at intervals along its course northward to the point where it finally disappears beneath the cover of Challis volcanics, close to the northern border of the Bayhorse quadrangle. Still other remnants of the formation emerge through this cover in the northeast corner of the quadrangle and on the flanks of Round Valley. Similar beds crop out at intervals along the Salmon River as far as the border of the Pahsimeroi Valley, a distance of 10 miles downstream beyond the most northerly point shown on plate 1.

Character.—Most of the Kinnikinic quartzite is well bedded and nearly pure, but shaly partings and subordinate amounts of somewhat shaly beds are common. The prevalent color of the fresh quartzite is nearly white, but in most exposures some or all of the beds have a distinctive lavender cast, which is useful in recognizing isolated outcrops of the formation. Many exposures are stained brick red, largely through the oxidation of flakes of specularite of hydrothermal origin, which are commonly disseminated sparsely

[16] Umpleby, J. B., Westgate, L. G., and Ross, C. P., Geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814, pp. 23-24, 1930.

[17] Ross, C. P., Correlation and interpretation of Paleozoic stratigraphy in south-central Idaho: Geol. Soc. America Bull., vol. 45, p. 947, 1934.

through the quartzite and quartz veinlets. The rock is composed essentially of a mosaic of detrital quartz grains 0.1 to 0.5 millimeter in diameter and slightly enlarged by deposition of secondary silica. These grains are set in a siliceous cement containing sericite.

The more argillaceous beds are generally also calcareous. They are on the average finer-grained than the quartzite and contain dolomite, sericite, graphite, chlorite, and epidote in varying proportions. In several places, mainly in the vicinity of Clayton, the formation contains irregularly lenticular aggregates of impure magnesian limestone and argillaceous beds that are large enough to be mapped separately on plate 1. Conglomerate was noted in the Kinnikinic quartzite only in the vicinity of Little Bayhorse Lake, near the head of Bayhorse Creek.

The Kinnikinic quartzite is everywhere contorted. In many exposures the effects of crenulation are surprisingly intricate for a rock of this character. On the slope flanking the Salmon River on the east below the mouth of Bayhorse Creek contorted beds with an average dip of fully 20° are exposed through a vertical range of 2,400 feet. The river cuts almost directly across an anticline in this formation west of Clayton. The west side of the fold is almost vertical near the river and has a width of 4,000 feet at the base of the exposure in the canyon. These data indicate that the Kinnikinic quartzite is about 3,500 feet thick, or possibly somewhat more, a thickness that accords well with those indicated by the structure sections representing other parts of the region (pl. 1).

Age.—Bedding surfaces in the quartzite show fucoid markings in many places. Such markings are especially plentiful in the hills east of Round Valley. The limestone intercalated in the formation near the mouth of Kinnikinic Creek contains small calcareous algae. These organic remains, the only fossils known in the formation, are not accurately identifiable. As the formation lies below the Saturday Mountain formation (Upper Ordovician) and above the Ramshorn slate (lowest Ordovician) with approximate concordance in attitude, it is doubtless of Lower or Middle Ordovician age. It is possible that the Kinnikinic quartzite may be correlated approximately with the similar but thinner Swan Peak quartzite (Lower Ordovician) of Utah and southeastern Idaho.[18] This point is more fully discussed in a report on south-central Idaho now in preparation.

SATURDAY MOUNTAIN FORMATION

Distribution.—The Saturday Mountain formation was named [19] for Saturday Mountain Ridge, which lies west of lower Squaw Creek,

[18] Mansfield, G. R., Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, pp. 57–58, 1927.

[19] Ross, C. P., Correlation and interpretation of Paleozoic stratography in south-central Idaho: Geol. Soc. America Bull., vol. 45, p. 952, 1934.

near the middle of the western boundary of the Bayhorse quadrangle. The formation crops out on both sides of lower Squaw Creek from a point above the Red Bird mine to the mouth of the creek. It is exposed also in small areas along the lower courses of French and Sullivan Creeks and occupies a narrow band in the north-central part of T. 12 N., R. 19 E.

Character.—The Saturday Mountain formation is composed dominantly of more or less shaly dolomite, much of which contains enough carbonaceous matter to be black or nearly black on fresh fracture. Locally the strata are composed of shale with little or no dolomitic material. The rock is commonly bleached surficially to a dirty buff and in some places is stained rusty brown. The bleaching results largely from the action of water on the dolomitic material and hence is least conspicuous in the more argillaceous beds. The argillaceous beds are banded and tend to break in thin slabs, parallel to the bedding. Some beds contain rounded pebbles of quartzite about 0.1 millimeter in diameter, but in most of the argillaceous beds the component quartz grains are only about 0.02 millimeter in diameter. In a few places, especially in the Red Bird mine, ripple marks are well preserved on the surfaces of shaly beds. In and near this mine also are local lenses of exceptionally carbonaceous calcareous shale. A sample from such a bed on the ninth level of the Red Bird mine, analyzed by Charles Milton, of the United States Geological Survey, yielded 21.3 percent of graphite. Along the road on the east side of lower Squaw Creek the talus slopes are composed of very thin fragments of shale. In general the Saturday Mountain beds in this part of the region are distinguished from the overlying Milligen formation by a sufficiently greater proportion of calcareous beds to make them as a whole decidedly more massive and by a lower average content of carbon. Also the carbonate in calcareous Milligen beds is dominantly calcite instead of dolomite.

In T. 12 N., R. 19 E., the more argillaceous beds are absent, and the formation is composed of somewhat thin-bedded rusty dolomitic limestone, which is lighter-colored than much of the rock along Squaw Creek, in part because it is more exposed to weathering. The strata are distinguished from the Laketown dolomite, which here overlies them, by a more rusty appearance and a greater tendency to weather into slabs.

In both localities, but particularly in the more shaly beds near Squaw Creek, the Saturday Mountain formation, which is weaker than most of those previously described, is intricately deformed, and locally its thickness is exaggerated because of close folding. There is probably an unconformity at the top of the formation, which may account in part for the variations in thickness. Such an unconformity is suggested by discordance in attitude of the beds on each side of the upper boundary in T. 12 N., R. 19 E., and appears to be required near Squaw Creek to explain the absence of several formations which, in the eastern part of the quadrangle, represent the time interval between the Saturday Mountain formation (Upper Ordovician) and the Milligen formation (mainly Mississippian).

The main haulage tunnel in the Red Bird mine traverses a part of the formation roughly at right angles to the strike, and its inner end is probably not far from the base of the Kinnikinic quartzite. Although there is considerable variation in attitude and some minor faulting, no evidence of repetition of beds was found. The section tabulated below reads from the portal inward, in descending stratigraphic order.

Stratigraphic succession in the main haulage tunnel, Red Bird mine

[Measured by R. R. LeClercq and W. D. Mark]

	Feet
Thin-bedded calcareous shale, carbonaceous; some graphite films	280
Fine-banded shaly limestone	130
Banded limestone	20
Indistinctly banded limestone	90
Massive fine-grained limestone, fractured, and cut by minor slips	160
Banded, somewhat coarser limestone	10
Massive fine-grained limestone, sparingly fossiliferous	100
Banded shaly limestone	90
Massive fine-grained limestone	180
	1,060

It is probable that the beds in the Red Bird tunnel represent not more than a third of the whole formation in this locality. Sections drawn across the formation as mapped in plate 1 indicate a gross thickness of 5,000 feet. This is certainly exaggerated by crumpling and close folding. It is concluded that the formation may have here a thickness of about 3,000 feet, an estimate that may be in error by as much as 30 percent. The Saturday Mountain strata in T. 12 N., R. 19 E., are obviously much thinner, probably little more than 300 feet.

Age.—Cook and Ehlers [20] found in the strata along Squaw Creek here assigned to the Saturday Mountain formation poorly preserved specimens of a coral which they said "suggests very much the late Richmond species *Columnaria* (*Palaeophyllum*) *stokesi* (Edwards and Haime)." They found this coral in dark-gray finely crystalline dolomite near the Red Bird mine, on the east side of Squaw Creek, and also at the Saturday Mountain mine, west of Squaw Creek, near its mouth. Its tentative age assignment is confirmed by the data summarized below.

[20] Cook, C. W., and Ehlers, G. M., A possible occurrence of the Richmond formation in the vicinity of Clayton, Idaho: Michigan Acad. Sci. Papers, vol. 7, pp. 51–53, 1927.

Fossils were collected in the present study from dolomitic beds at several places and at different horizons within the formation and also from a somewhat carbonaceous shale near the mouth of Bruno Creek. The shale beds are probably near the middle of the formation. Determination of the graptolites from the shale was made by Rudolf Ruedemann. The other fossils were determined by Edwin Kirk, and the age assignment is his. In the lists below the serial numbers are those of the permanent locality records of the United States Geological Survey.

2610. Dolomite near the base of the Saturday Mountain formation on the south side of the Salmon River just below Sullivan Hot Springs. Collected August 5, 1930, by Edwin Kirk and C. P. Ross:

Streptelasma sp.
Zygospira recurvirostris Hall.
Dalmanella sp.
Rhynchotrema cf. *R. argenturbica* (White).
Dinorthis cf. *D. subquadrata* (Hall).

2506, 2238. Dolomitic argillite from the upper part of the Saturday Mountain formation on the crest of the ridge north of Bruno Creek overlooking the Red Bird mine. Collections made in 1928 by W. D. Mark and in 1930 by C. P. Ross:

Rhynchotrema sp.
Pleutomaria sp.

2240. 1 mile west of the mouth of Bruno Creek. Collected June 29, 1928, by W. D. Mark:

Crinoid columnals.

2241. Near 2240 and collected at the same time by W. D. Mark:

Plectambonites sp.
Rhynchotrema sp.

2243. Half a mile up Bruno Creek on the north side of road. Collected June 27, 29, 1928, by W. D. Mark:

Streptelasma sp.
Plectambonites sp.
Rhynchotrema sp.
Zygospira sp.

2244. Half a mile west of mouth of Bruno Creek. Collected June 29, 1928, by W. D. Mark:

Streptelasma sp.

2245. Collected June 27, 1928, by W. D. Mark:

Palaeophyllum sp.

2519. Mouth of Bruno Creek, north side. Collected August 5, 1930, by C. P. Ross and Edwin Kirk:

Glossograptus quadrimucronatus var. *spinigerus* Lapworth.
Climacograptus antiquus Lapworth.
Climacograptus antiquus var. *lineatus* Elles and Wood.
Dicellograptus gurleyi Lapworth.
Dicranograptus spirifer Lapworth.
Dicranograptus n. sp.
Diplograptus acutus Lapworth.
Amplexus sp.

Kirk states that the fossils listed above, except the last lot, represent a fauna of Upper Ordovician age that is widespread in the surrounding region. The horizon is equivalent to the Fish Haven dolomite of Utah and southeastern Idaho and the upper portion of the Bighorn dolomite of Wyoming. The graptolites in lot 2519 are derived Normanskill types and by themselves would be determined as of an earlier age than that shown by the fauna in the dolomitic beds with which the graptolite shale is interbedded. Thus the fossils of the Saturday Mountain formation in the vicinity of Squaw Creek constitute one of the rare assemblages in which it is possible to check the age of a graptolite fauna by means of a different fauna.

SILURIAN ROCKS

TRAIL CREEK FORMATION

Distribution.—The Trail Creek formation is named from an exposure along the upper course of Trail Creek in the Hailey quadrangle.[21] It was found nowhere else in that area, and in the Bayhorse region rock of this kind has been identified only in a few exposures extending a little over half a mile along Malm Gulch, in the north-central part of the Bayhorse quadrangle.

The slight lateral extent of the Trail Creek formation wherever recognized both here and farther south may have resulted to some degree from deposition in small depressions. Erosion shortly after it was laid down may also have been a factor.

Character.—Most of the rock in the outcrops along Malm Gulch is a brownish-gray calcareous argillite that breaks in thin slabs parallel to the bedding. The calcite grains are 0.02 to 0.05 millimeter wide and are interspersed with abundant somewhat larger subangular detrital grains of quartz and plagioclase. There are small chert lenses parallel to the bedding and small amounts of organic matter, muscovite, and apatite, also numerous veinlets and some aggregates of calcite several inches wide. On the northeast side of the gulch are a few outcrops of nearly white quartzite resembling that interbedded with the Laketown dolomite. The quartzite overlies a part, at least, of the argillaceous beds. It is not distinguished on the map.

Age.—Graptolites are widely but sparsely distributed through the argillite. According to Edwin Kirk most of them appear to be *Monograptus*, indicating that the beds are essentially equivalent in age to the Trail Creek strata of the Hailey quadrangle. The more diversified fossil fauna at the type locality of the formation led to approximate correlation with the Niagaran of the eastern United States. According to Kirk the Trail Creek formation is somewhat older than the Laketown dolomite, to which are assigned the other Silurian strata in the Bayhorse region. However, the presence in the Laketown of quartzite similar to some of that on Malm Gulch raises

[21] Umpleby, J. B., Westgate, L. G., and Ross, C. P., Geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814, pp. 23–24, 1930.

a question as to whether the strata at that locality may not be equivalent to some of the lower beds here included in the Laketown. The quartzite in the Laketown contains few argillaceous members suitable for the preservation of graptolites, and none have been found in it.

LAKETOWN DOLOMITE

Distribution.—The name "Laketown dolomite", originally given to strata in Utah and southeastern Idaho,[22] is here assigned to a formation in the Bayhorse region that is strikingly similar in lithology and fossil content. The principal exposure of this formation is in the ridge crowned by Lone Pine Peak, which extends from sec. 35, T. 13 N., R. 19 E., to sec. 18, T. 11 N., R. 20 E. Several smaller masses emerge through the cover of Germer beds in the area between this ridge and the East Fork of the Salmon River. Others crop out along Devils Canyon and in the northeast corner of the Bayhorse quadrangle.

Character.—Most of this formation consists of moderately thick bedded bluish-gray dolomitic limestone, much of which weathers rusty. Some beds are stained brick red by iron oxides. Chert nodules are commonly present but nowhere abundant. Some of the dolomite is somewhat sandy, and locally there are shaly beds. At several horizons are intercalated beds of quartzite, uniformly light slate gray to white, which weather readily into small, somewhat slabby fragments. Outcrops of the quartzite are rare except where thin beds are intercalated in the more resistant dolomite. All quartzite masses of sufficient size are distinguished on plate 1, but there are many quartzite lenses too small to map. Such lenses evidently occur at irregular intervals throughout the formation. In the isolated exposures of Laketown strata the proportions and relative distribution of the quartzite vary markedly.

None of the exposures include the total thickness of the formation. The nearest approach to it is along the ridge crowned by Lone Pine Peak, where fully 2,500 feet of dolomite with some intercalated quartzite is underlain by nearly 1,000 feet of quartzite and overlain by almost as great a thickness of similar rock. In the small exposure in the northeast corner of the quadrangle the aggregate thickness of the Laketown (here capped by Jefferson dolomite) is more than 3,000 feet, but it is made up of a rapid alternation of quartzite and dolomite. Although lithology and fossil content show that this exposure belongs to the same formation as the strata on Lone Pine Peak, the succession is strikingly different. In the ridge south of Devils Canyon somewhat more than 2,000 feet of the Laketown dolomite is exposed. As all the strata here are overturned, the steeply inclined Laketown beds seem to overlie the Devonian beds stratigraphically above them. Close to the canyon lenses of quartzite, represented in generalized fashion on

[22] Mansfield, G. R., op. cit. (Prof. Paper 152), pp. 58-59.

plate 1, decrease the amount of dolomite, but the aggregate exposed thickness of Silurian beds remains much the same. From these various observations it may be assumed that the average thickness of the formation is well over 3,000 feet, with dolomite commonly making up the larger part of this total. Probably the quartzite, which is locally abundant, occurs in lenticular bodies that are individually of small areal extent and irregular distribution.

Age.—Most exposures of the dolomitic part of the formation contain organic remains, but the quartzite has yielded no fossils. In a few places the fossils in the dolomite are so abundant and so well preserved that they can be determined with certainty as a Laketown fauna, but in most of the outcrops the fossils are sparse and fragmentary. In these the presence of moderately large crinoid stems is the most characteristic feature. The following lists record fossil collections from widely scattered exposures of the formation determined by Edwin Kirk, who visited several of the more fossiliferous outcrops and made some of the collections personally.

2242, 2251, 2252. 1 mile northwest of Lone Pine Peak, altitude 8,700 feet. Collected by C. P. Ross and R. R. LeClercq:

Amplexus sp.
Favosites sp.
Coenites sp.
Heliolites cf. *H. interstinctus* (Linnaeus).

2237. About three-quarters of a mile farther northwest, altitude 7,900 feet. Collected by R. R. LeClercq:

Syringopora?

2246, 2236. Ridge crest in sec. 10, T. 12 N., R. 19 E., altitude 8,200 feet. Collected by R. R. LeClercq:

Large crinoid columnals.
Fragment of coral, suggesting *Favosites*.

2230. Ridge north of Lone Pine Peak, just beyond the saddle, altitude 7,750 feet. Collected by C. P. Ross:

Large crinoid columnals.
Small fragments of what appears to be *Favosites*.

2224, 2515. Spar Canyon, a mile above its junction with the valley of the East Fork of the Salmon River. Collected by C. P. Ross and T. H. Hite:

Large crinoid columnals.

2523. Benchmark, altitude 7,565 feet, on ridge west of Bradshaw Basin. Collected by Edwin Kirk and C. P. Ross:

Syringopora sp.
Amplexus sp.
Alveolites sp.
Halysites catenularia (Linnaeus).
Heliolites 2 sp.
Diphyphyllum sp.
Striatopora sp.
Cladopora sp.
Conchidium sp.

2521. A short distance north of locality 2523. Collected by Edwin Kirk:
Syringopora sp.
Conchidium sp.

2510. Head of Bradshaw Gulch, altitude 6,800 feet. Collected by C. P. Ross:
Cyathophyllum sp.
Cladopora sp.
Plectatrypa? sp.

2512. Close to 2510. Collected by C. P. Ross:
Conchidium? sp.

2507. On ridge just above locality 2510, altitude 7,530 feet. Collected by C. P. Ross:
Cyathophyllum sp.
Conchidium sp.

2514. Isolated exposure near Hole in Rock Creek, altitude 6,500 feet. Collected by T. H. Hite:
Cyathophyllum sp.
Plectatrypa sp.

According to Edwin Kirk these collections, together with his own field observations, show clearly that the formation is essentially equivalent in age to the Laketown dolomite of the type locality. A single collection is at variance with this conclusion and apparently records the presence of a fault block of dolomite containing a fossil fauna essentially different from any known elsewhere in the region. Mr. Kirk determined the following fossils from this collection and states that they are diagnostic of the Threeforks formation of the Upper Devonian:

2248. Thin-banded limestone at head of Bradshaw Gulch, altitude 7,300 feet. Collected by C. P. Ross and W. D. Mark:
Syringopora sp.
Cyathophyllum sp.
Cyrtina sp.
Spirifer whitneyi Hall.

In an attempt to check this point collection 2510 was made in nearly the same place as 2248, and 2521, 2512, and 2507 were gathered in neighboring outcrops. These collections are regarded by Kirk as definitely Silurian, so that the Devonian mass indicated by 2248 must be very small.

DEVONIAN ROCKS

JEFFERSON DOLOMITE

Distribution.—The strata here designated "Jefferson dolomite" are very similar in nearly all respects to the Jefferson limestone of Montana, so that the use of the name appears clearly justified. In most previous descriptions of beds assigned to the Jefferson the rock is stated to be magnesian limestone, so that the fact that in this region it is a dolomite is not indicative of much if any lithologic variation. This formation is best exposed in Grand View Canyon along State Highway 27. It also forms a band along the ridge on both sides of Devils Canyon. The formation crops out in small masses in the northeast corner of the Bayhorse quadrangle and in and near Little Bradshaw Basin, in the central part of the quadrangle.

Character.—The Jefferson dolomite is distinguished from all other rocks in the region by its color, dark bluish gray, and in most outcrops by the abundance of a characteristic digitate form of *Favosites.* Commonly these features are so characteristic that the Jefferson beds can be identified with confidence even in small isolated outcrops. The lower part of the formation, however, locally includes light-colored beds distinguishable from the Laketown dolomite only by their fossil content. Such beds are particularly conspicuous on the crest of the hill south of Tub Spring, near the Spar Canyon road (fossil collection 2513), and in the isolated outcrops on the west side of Warm Spring Creek in and near sec. 10, T. 12 N., R. 20 E. The latter outcrops are particularly puzzling, as alteration by hot-spring water, which still issues in abundance, has obscured their lithologic character, and the only fossils found in them are fish remains. The fossils (2517), according to Kirk, are Devonian but not necessarily Jefferson in age. The beds in these outcrops are represented on plate 1 as Jefferson because their position with reference to the Devonian beds in Grand View Canyon makes such an assignment the most probable one.

The Jefferson dolomite in Grand View Canyon, as ascertained by plane-table traverse, has a thickness of 1,150 feet. Although the base is not exposed here, the total thickness is greater than in any other exposure in the surrounding region, and it is probable that nearly the whole of the formation is represented. Here, as elsewhere in the Bayhorse quadrangle, the beds are distinctly dolomitic, little if any calcite being present. In typical material the maximum index of refraction is a little more than 1.67. The upper 205 feet is dominantly massive dark-colored dolomite with abundant corals and some chert nodules. Some beds are coarsely sandy. The remaining 945 feet consists of dark blue-gray massive beds of dolomite with partings a few inches to 15 feet apart and averaging 1 to 3 feet in thickness. Most of the beds show laminations a fraction of an inch thick. There are a few thin light-colored beds.

The only other locality in the Bayhorse region in which the major part of the Jefferson dolomite is exposed is in the ridges on both sides of Devils Canyon. Here both the underlying and overlying formations are also present. The strata referred to the Jefferson consist of the typical dark-colored dolomite almost free from light-colored beds and locally with abundant *Favosites.* The thickness appears to be slightly less than 1,000 feet, but local contortion interferes with accurate measurement.

Age.—These strata are correlated with the Jefferson limestone, of Middle Devonian age, mainly on the basis of a field examination by

Edwin Kirk of the exposures in Grand View Canyon. The following lists give determinations by Mr. Kirk of fossil collections from this and other localities:

2247. Grand View Canyon. Lower part of Jefferson dolomite. Collected by C. P. Ross and W. D. Mark:
Favosites cf. *F. limitaris* Rominger.
Cladopora sp.
Diphyphyllum sp.

2525. Grand View Canyon. Lower third of Jefferson dolomite. Collected by Edwin Kirk:
Stromatopora sp.
Cladopora sp.
Favosites cf. *F. limitaris* Rominger.
Coenites sp.

2524. Grand View Canyon. Middle portion of Jefferson dolomite. Collected by Edwin Kirk.:
Syringopora sp.
Diphyphyllum sp.
Aulopora sp.
Cyathophyllum sp.

2517. Isolated outcrop below Grand View Canyon (p. 26). Collected by T. H. Hite, Jr., and C. P. Ross:
Fragments of fish plates.

2513. Hill south of Tub Spring, altitude 7,500 feet. Collected by T. H. Hite, Jr.:
Cyathophyllum sp.
Atrypa reticularis Linnaeus.

2516. South flank of hill south of Tub Spring, altitude 7,300 feet. Collected by T. H. Hite:
Stromatopora sp.
Cladopora? sp.
Atrypa reticularis Linnaeus.

300 feet south of locality 2516. Collected by T. H. Hite, Jr.:
Cladopora? sp.

2509. 500 feet south of locality 2516. Collected by T. H. Hite, Jr.:
Cyathophyllum sp.

2511. Sec. 10, T. 13 N., R. 20 E., altitude 7,350 feet. Collected by T. H. Hite, Jr.:
Indeterminable corals.
Atrypa reticularis Linnaeus.

GRAND VIEW DOLOMITE

Distribution.—The Jefferson dolomite is overlain by another formation somewhat different from any heretofore mapped in Idaho. It has been named the "Grand View dolomite" [23] from its excellent exposures in Grand View Canyon, where it was first recognized. The formation is also exposed on both sides of Devils Canyon, and there are small masses of it in and near sec. 18, T. 13 N., R. 21 E., and sec. 17, T. 11 N., R. 20 E.

The absence of both Devonian formations from the western part of the Bayhorse region and apparently the whole of the Wood River

[23] Ross, C. P., Correlation and interpretation of Paleozoic stratigraphy in south-central Idaho: Geol. Soc. America Bull., vol. 45, p. 963, 1934.

region, immediately to the south, doubtless resulted to some extent from post-Devonian erosion, but it may also be due in some measure to persistence of the land mass that appears to have occupied those areas in late Silurian and early Devonian time.

Character.—The results of plane-table measurement of the Grand View dolomite beds in the type locality are tabulated below. Assignment of beds in other localities to this formation is based on similarity in lithology and stratigraphic relations to the beds in Grand View Canyon. The section given below represents slightly less than the total thickness of the formation, the contact with the overlying Milligen formation being obscured by alluvium and Germer strata. The contact of the Grand View dolomite with the underlying Jefferson is marked by slight irregularity and abrupt change in lithology, but there is no appreciable angular discordance.

Section of Grand View dolomite in Grand View Canyon

	Feet
Mainly dolomite, in part dark. Some thin beds of quartzite and shale	177
Sandy dolomite	81
Beds somewhat less sandy than most of unit above	34
Mainly rusty-yellow sandy dolomitic beds. Light-colored nearly pure dolomitic limestone makes up somewhat less than 10 percent of the total. There are a few beds of gray quartzite which weather rusty yellow	276
In this unit about 30 percent of the beds are dark but not quite as dark as Jefferson. The remainder are rusty sandy dolomitic limestone	99
The proportion of dark Jefferson-like beds decreases rapidly. In the upper half of this unit more than half of the beds are rusty sandy dolomitic limestone. There are a few sandstone beds. Partings between beds are commonly 1 to 2 feet apart. Some beds are platy	380
Mainly coarse-grained dolomitic limestone, weathering rough; lighter-colored than the underlying Jefferson but with a few beds similar to it. Few beds of coarse sandy limestone, weathering rusty	123
	1, 170

Age.—Edwin Kirk, who has examined the exposures of this formation in Grand View Canyon, noted the presence in it of

indistinct traces of a small *Cladopora?*, such as is abundant in the upper part of the Middle Devonian and less abundant in the Upper Devonian of the Great Basin. These fossils are not in themselves diagnostic. They accord, however, with the belief, based on character and stratigraphic relations, that the Grand View dolomite is of either Upper or Middle Devonian age but post-Jefferson.

Data afforded by exposures in Elbow Canyon, in the Lost River Mountains west of Mackay, tend to support such an assignment.

This locality was examined by Umpleby and Girty [24] and has since been visited by Kirk. The dark Jefferson beds, here 700 feet thick, are overlain by about 650 feet of lighter-colored beds, of which the lower 200 feet especially is lithologically like the beds in Grand View Canyon. In the middle of the sequence in Elbow Canyon is a 350-foot bed of calcareous shale. Above this shale Umpleby and Girty obtained fossils which Kindle assigned to the Upper Devonian. He stated that he was "inclined to regard it as a calcareous facies of the Threeforks shale fauna, although it is not a typical fauna of this horizon."

MISSISSIPPIAN ROCKS

MILLIGEN FORMATION

Distribution.—The Milligen formation, originally distinguished in the Wood River region,[25] retains its salient characteristics in the Bayhorse region. Intervening masses of Challis volcanics render it impossible to trace the formation directly from one region to the other, but in most places similarity in lithology and in stratigraphic relations renders correlation easy. These factors are supported by scanty paleobotanic evidence and by the comparison of the heavy minerals with those of nearby formations (pp. 39–43).

Exposures of the Milligen formation extend, with interruptions, from Pole Creek near the head of the Salmon River, in the Sawtooth quadrangle, somewhat east of north across the White Cloud Peaks, in the Custer quadrangle. They reach the Salmon River again at the mouth of Slate Creek. The north side of the river valley from a point near Peach Creek eastward to Saturday Mountain is mainly underlain by this formation. It crops out at intervals along the south side of the valley as far east as French Creek. Masses of it emerge through the Challis volcanics on the upper reaches of Thompson and Bruno Creeks, nearly 5 miles north of the Salmon River, but it is not known to appear anywhere farther north.

In the eastern part of the Bayhorse quadrangle typical Milligen beds crop out in a small area in and near sec. 36, T. 9 N., R. 20 E. The Milligen appears again in the southeast corner of T. 11 N., R. 20 E. Another mass is exposed in and near Crane Basin, above Devils Canyon. Some of the beds in the eastern part of the Bayhorse quadrangle are coarser than those characteristic of the formation in most places, and some question remains as to correlation. (See pp. 30, 38.)

Character.—The greater part of the Milligen formation is a black carbonaceous argillite. Much of it is moderately soft and cleaves in thin plates parallel to the bedding. Some of the argillite beds are

[24] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, p. 26, 1917.

[25] Umpleby, J. B., Westgate, L. G., and Ross, C. P., Geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814, pp. 24–29, 1930.

somewhat calcareous, and others are sandy. Many of the harder beds are so fine-grained as to appear flinty, and it is only in exceptional beds that the average diameter of the grains is much more than 0.02 millimeter. The high content of carbonaceous matter is one of the most characteristic features of most exposures of the formation where not too much metamorphosed. Impure coal beds, such as locally characterize the formation in the Wood River region,[26] are not known in the Bayhorse region, but in several places cleavage plates of the argillite glisten with abundant graphite, and the mining of lodes in these rocks is hampered by a larger amount of gas than is given off by any of the other Paleozoic rocks of the region. Highly carbonaceous beds are particularly abundant on the northern slopes of Saturday Mountain and along nearby branches of Bruno Creek. Some of these might be termed very impure coal.

Locally intercalated beds of dark, commonly impure quartzite and limestone make up a small fraction of the total thickness of an exposure. Calcareous beds in this formation are particularly conspicuous in the area between Bay and Little Boulder Creeks, in the eastern part of the Custer quadrangle. The normally gray to black limestone has here been whitened through igneous metamorphism.

In the general vicinity of the quartz monzonite masses in the Custer quadrangle the Milligen has undergone widespread igneous metamorphism, although in most places the changes in characteristics are much less evident than in the overlying Wood River beds in the same vicinity. Metamorphism has locally bleached the Milligen strata and developed such minerals as chiastolite and diopside in it.

The Milligen strata in T. 11 N., R. 20 E., and near Grand View Canyon differ from those elsewhere in that grit, quartzite, and conglomerate are interbedded with the typical shaly beds. These coarser clastic beds are especially abundant close to the base of the formation. Most of the conglomerate is in thin beds in the grit near Grand View Canyon, but even here argillaceous and more or less calcareous beds are plentiful. Grit with a little conglomerate is abundant in secs. 15 and 16, T. 11 N., R. 20 E., and interfingers with shaly beds on the south. Some grit also occurs near Broken Wagon Creek. In sec. 2, T. 8 N., R. 20 E., sandy limestone and argillite are the principal rocks. Between this place and Pecks Canyon argillite like that characteristic of much of the Milligen in its type locality is abundant. The contact with the Brazer limestone, to the north, is obscure and apparently gradational.

The Milligen formation appears to record deposition in marine water so situated as to be relatively free from currents. A great deal of organic material mingled with the mud and sand that consolidated to form the greater part of the formation. Certainly part and possibly

[26] Umpleby, J. B., Westgate, L. G., and Ross, C. P., op. cit. (Bull. 814), pp. 26, 113–114.

most of the carbonaceous matter in these beds is derived from plants, as animal remains are almost unknown in either the Bayhorse or the Wood River region. In some places, especially in the Wood River region, organic matter is so highly concentrated as to suggest the rafting out of plant debris from sluggish rivers. So far there is no evidence that such concentration of carbonaceous material arose from burial of growing plants. The few recognizable plant fragments found (pp. 32–33) belong to land forms that have obviously undergone maceration and transportation. This is one of the principal ways in which conditions during Milligen time appear to have differed from those under which the Pennsylvanian coal beds of commercial importance elsewhere were formed.[27] Doubtless marine plants and animals mingled with the material carried in from the land, but it is certain that conditions were such that few organisms possessing shells or other readily preserved hard parts lived in the water. Pure limestone beds are exceptional, but calcareous material is so widespread and abundant as to indicate that marine rather than continental conditions prevailed.

In the eastern part of the Bayhorse region there were at times currents powerful enough to permit transportation of grit and gravel, which may in part be fluviatile. If some of the Milligen formation of this part of the region is the time equivalent of the Brazer limestone and interfingers with it, as appears probable, the coarse beds in the Milligen here can hardly have been derived from land to the east. The Brazer is widespread and thick east of the Bayhorse region and indicates clearer and presumably deeper water than that in which most of the Milligen was laid down. On this assumption the land of that time should have lain farther west. During the deposition of the Brazer limestone gravel was intercalated in it, at least at one horizon. Consequently, whatever its relative position, land can hardly have been far away. Inasmuch as Milligen strata underlie Brazer beds along the eastern border of the Bayhorse quadrangle and Brazer beds are unknown west of R. 20 E., either here or in neighboring regions, it is probable that the sea became deeper or at least less foul toward the east in late Mississippian time.

The Milligen formation varies materially from place to place, contains no beds suitable for use as general horizon markers, and in this region is intricately deformed and commonly occurs in isolated masses. Consequently no reliable estimate of its thickness can be made. In the Wood River region similar difficulties were encountered, but a thickness of 3,000 feet was assigned to it as the best approximation possible; in the Bayhorse region the thickness is probably fully as great.

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[27] White, David, Environmental conditions of deposition of coal: Am. Inst. Min. Met. Eng Trans., vol. 71, pp. 3-23, 1925.

Age.—The Milligen formation cannot be dated with precision, but consideration of all available information leads to the conclusion that it is Mississippian and locally equivalent in age to the Brazer limestone. It is possible that in different localities the formation includes beds ranging in age through the entire Mississippian epoch and conceivably even extending back into the Devonian.

In the Wood River region the Milligen underlies the Wood River formation (Pennsylvanian). Locally the two appear to be essentially conformable, although elsewhere some evidence of unconformity exists. Hence the upper part of the formation would appear to be not older than upper Mississippian. No rocks of definite Devonian age are known in that region, and faulting prevents determination of the relations between the Milligen and older formations there. The possibility that the basal Milligen may be as old as Devonian receives some support from the fact that a conglomeratic bed yielded fragments of fossils of probable Jefferson age. These, however, may have been pebbles derived from an older formation. The coaly beds locally prominent in the Milligen of the Wood River region suggest that the parts of the formation in which they occur are not older than Carboniferous.

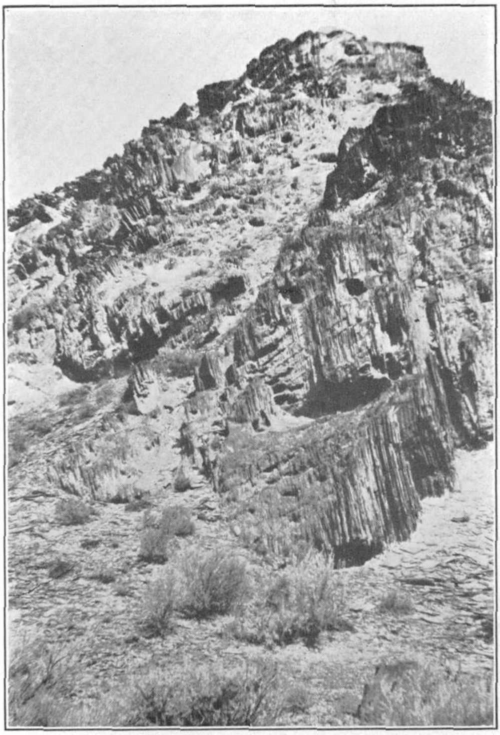
The exposures of the Milligen formation in the Sawtooth and Custer quadrangles, mapped during the present investigation, yield little additional information. The strata underlie the Wood River formation (Pennsylvanian) and overlie the Saturday Mountain formation (Upper Ordovician). Neither contact shows appreciable angular discordance.

Along the eastern border of the Bayhorse quadrangle the possible range in age is less. In Crane Basin the Milligen formation overlies the Grand View limestone (Upper Devonian) and underlies the Brazer limestone (upper Mississippian). The Brazer does not appear on plate 1 but is abundantly exposed immediately east of the area mapped. Farther south the Milligen underlies the Brazer, with older beds not exposed.

In several places in the Custer, Sawtooth, and Bayhorse quadrangles small amounts of plant fragments are preserved in the Carboniferous strata. The best of the scanty collections, all from the eastern part of the Bayhorse quadrange, were examined by David White, who made the following comments:

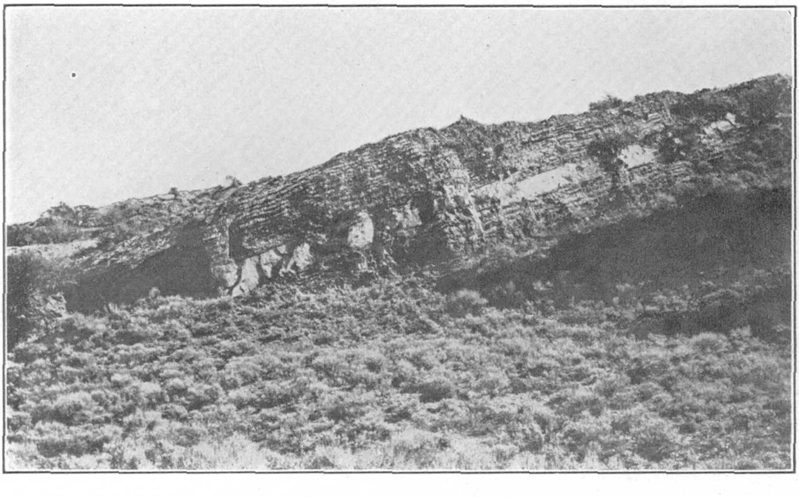
The collections are all very small and consist almost entirely of sandy material in which were buried very fragmentary parts of fossil plants that have been ground up by wave action. None of the fragments are specifically determinable.

BH85, station 75, Pinto Creek, barometer 7350; collected by C. P. Ross and T. H. Hite, Jr. The collection consists of mashed and ground debris embracing fragments, including possibly leaves, of *Asterophyllites*, of Pottsville aspect, one fragment probably representing a stem of *Sphenophyllum* and one a lepidophytic leaf that may have belonged to *Sigillaria*. The aspect of the material suggests either the upper part of the lower Carboniferous or the Pottsville group.



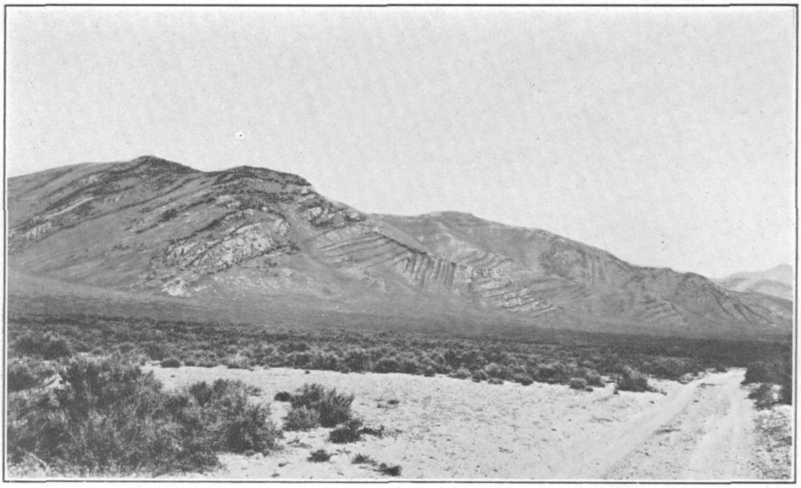
A. OUTCROP OF RAMSHORN SLATE AT THE MOUTH OF WOOD CREEK.

The conspicuous steep planes along which the rock parts are slaty cleavage. Less prominent planes dipping more gently in the opposite direction are bedding.



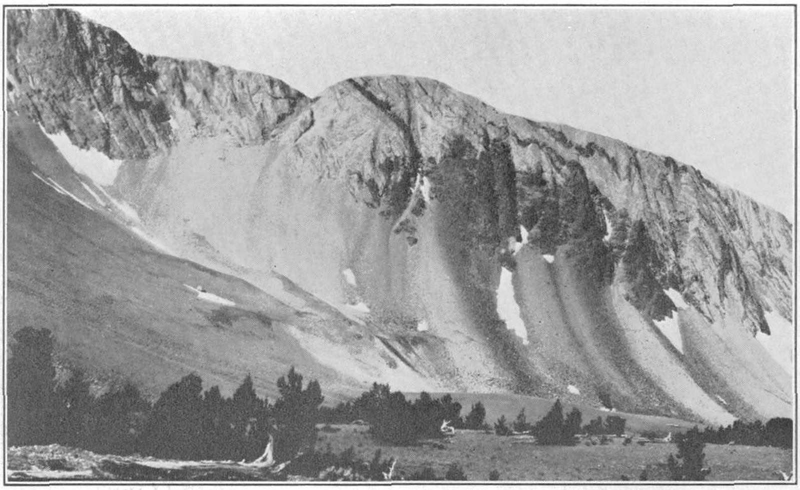
B. BRAZER LIMESTONE WITH CHERT BANDS ALONG BROKEN WAGON CREEK.

Photograph by T. H. Hite, Jr.



A. DISTURBED BRAZER LIMESTONE ALONG THE CUT-OFF ROAD BETWEEN PECKS CANYON AND THE MACKAY HIGHWAY.

Photograph by T. H. Hite, Jr.



B. DARK QUARTZ DIORITE INTRUDING LIGHT-COLORED WOOD RIVER BEDS WITH APOPHYSES ALONG THE BEDDING, ABOUT A MILE WEST OF CALKINS LAKE.

Looking south.

BH19, station 75, Pinto Creek; collected by T. H. Hite, Jr. Broken and indeterminable stems. One fragment probably represents a stem of *Annularia*, and one may be a leaf of a lepidophyte.

BH88, station 259, barometer 8200, north end of Crane Basin; collected by T. H. Hite, Jr. The collection contains a calamarian fructification, probably *Palaeostachya;* a fragment of *Sphenophyllum* leaf; a fragment of fern stem, possibly referable to the structural genus *Dictyoxylon;* and a fragment of *Sphenophyllum* stem.

BH78, station 225, barometer 8150 to 8350, eastern slope of Sage Creek, Bayhorse quadrangle; collected by T. H. Hite, Jr. Water-worn and macerated fragments, mostly comminuted, including one possibly belonging to a *Lepidodendron* and another piece that may be a fern stem.

BH87, station 258, barometer 9650 to 9677, Pahsimeroi Mountains south of Devils Canyon and Crane Basin; T. H. Hite, Jr., collector. This collection contains a fragment of leaf, probably lepidophytic, suggesting Pennsylvanian age; a defoliated fragment of spinous stem not generically determinable; a triturated fragment including parts of leaves probably belonging to *Lepidodendron* or *Sigillaria;* part of a fern stem stripped of pinnules and indeterminable; a fragment suggesting *Sphenophyllum;* and another fragment that may be a twig of *Lepidodendron* or *Walchia.*

Lots BH88 and BH87 are from typical Milligen beds, which here have Devonian strata below and Brazer limestone above them. BH85 and BH19 are from the beds of doubtful age on Pinto Creek mentioned above. BH78 is from conglomerate intercalated in the Brazer limestone on Sage Creek, in the Bayhorse quadrangle, probably several hundred feet stratigraphically above the point where typical Milligen strata dip under the Brazer limestone. In addition to the collections studied by Dr. White, a single similar plant fragment was found in the Milligen formation on Grand Prize Creek, in the Sawtooth quadrangle, and one of microscopic dimensions was noted in a specimen of Milligen shale from the Apex mine, on Squaw Creek, in the Custer quadrangle.

In the above-mentioned lots no genera identifiable with certainty are characteristic of the older Pennsylvanian or the upper Mississippian. It is fairly certain, however, that the material belongs either to the upper part of the Mississippian or to the Pottsville group (lower Pennsylvanian). All the fragments generically recognizable, including those tentatively identified, as an ensemble are suggestive of lower Pennsylvanian age.

These plant fragments from widely scattered localities appear to establish with reasonable certainty the Carboniferous age of the containing beds but are not sufficiently diagnostic to be of value for closer correlation.

BRAZER LIMESTONE

Distribution.—Along the eastern border of the Bayhorse quadrangle between Pecks Canyon and Big Antelope Flat are limestone beds which on the basis of lithology and faunal content are confidently correlated with the Brazer limestone of southeastern Idaho and northern Utah.[28] Within the area mapped such beds cover only about 40 square miles, but in the Lost River Range, to the east, and in the White Knob Mountains, near Mackay, they are widely exposed.[29]

Character.—Much the greater part of the formation is composed of magnesian limestone. Most beds are moderately dark gray, but some are nearly white, and others are almost black. Chert nodules and bands and lenses that are nearly black on fresh fracture are commonly present and are most abundant in the lower part of the formation. Locally there are black partly brecciated chert lenses of sufficient size to be mapped separately. Here and there, as shown in plate 2, *B*, narrow bands of chert are closely spaced in the limestone. Some of the chert appears to have formed around fossils as nuclei of replacement. Most of the limestone is massive and exhibits well-defined beds commonly over a foot thick. Locally the rock is seamed with white calcite. Minor amounts of thin-bedded more or less shaly limestone and thin laminated shaly and sandy partings are common. On upper Broken Wagon Creek the lowest part of the formation is composed largely of gray, brownish, and bluish beds of shaly and sandy limestone that grade upward into and are interbedded with the more massive and pure limestone characteristic of most of the formation.

East of Sage Creek is a band of conglomerate composed largely of limestone pebbles that ranges in thickness from a few feet to 200 feet or more.

The more massive conglomerate is composed of pebbles of chert, quartzite, and limestone rarely more than an inch in diameter and generally well rounded and sorted. Such material forms beds 4 to 8 feet thick interleaved with quartzitic sandstone, grit, and shaly limestone.

The Brazer limestone within the Bayhorse quadrangle is crenulated and has many minor structural irregularities as is shown to some extent by the variations in attitude recorded on plate 1 and illustrated in plate 3, *A*. With due allowance for this fact, the total exposed thickness must be fully 2,000 feet, and the top is not reached. Umpleby [30] estimates that the similar beds in the Lost River Range may have an aggregate thickness of more than 6,000 feet. He observed in several localities partial sections of 1,000 to 4,000 feet of beds. As shown in section 5, plate 1, the conglomerate near Sage Creek appears to be about 1,500 feet stratigraphically above the base of the formation.

Age.—Fossils are widespread in the Brazer limestone, but in only a few localities are they sufficiently diversified and well preserved

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[28] Mansfield, G. R., op. cit. (Prof. Paper 152), pp. 63–71.

[29] Ross, C. P., Geology and ore deposits of the Seafoam, Alder Creek, Little Smoky, and Willow Creek mining districts, Custer and Camas Counties, Idaho: Idaho Bur. Mines and Geology Pamph. 33, pp. 10–13, 1930. Also later unpublished data.

[30] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, p. 27, 1917.

for satisfactory determination. Collections from numerous localities both in the Bayhorse quadrangle and in neighboring areas all testify, according to G. H. Girty, to the fact that the beds are of upper Mississippian (Brazer) age. The Madison, so abundant farther east, is not represented in any of the collections and appears to be entirely absent from this part of Idaho, unless the lower part of the Milligen may locally be its age equivalent. The conglomerate near Sage Creek is evidently intraformational and does not record a stratigraphic break. Fossils collected from limestone immediately above it, although poorly preserved and fragmentary, are regarded by Girty as of Brazer age, as is better-preserved material from beds both stratigraphically above and below this horizon.

The following lists record Girty's determinations of fossils from the Brazer limestone in the Bayhorse quadrange. The numbers given are those assigned for the permanent record of the United States Geological Survey.

6734. Along road at summit at head of Road Creek; collected June 18, 1929, by C. P. Ross:

Tabulipora sp.
Fenestella sp.
Cystodictya aff. *C. lineata* Ulrich.
Productus (*Pustula*) aff. *P. indianensis* Hall.
Productus sp.
Composita? sp.

6735. Willow Creek Summit, on State Highway 27; collected July 16, 1929, by C. P. Ross and V. E. Scheid:

Cup corals.
Fistulipora sp.
Batostomella? sp.
Anisotrypa? sp.
Fenestella sp.
Rhombopora sp.
Cystodictya sp.
Productus (*Productus*) aff. *P. burlingtonensis* Hall.
Productus (*Productus*) *scitulus* Meek and Worthen.
Productus sp.
Productus (*Echinoconchus*) aff. *P. alternatus* Norwood and Pratten.
Productus (*Pustula*) aff. *P. blairi* Miller.
Camarotoechia aff. *C. mutata* Hall.
Dielasma sp.
Girtyella turgida Hall?
Spirifer bifurcatus Hall?
Spiriferina spinosa Norwood and Pratten?
Composita aff. *C. levis* Miller.
Cleiothyridina hirsuta Hall.
Eumetria verneuiliana Hall.
Aviculipecten sp.
Conocardium sp.
Griffithides sp.
Paraparachites sp.

6756. Lower Sage Creek, northeast of road; collected July 16, 1929, by C. P. Ross and V. E. Scheid:

Cup corals.
Tabulipora sp.
Batostomella sp.
Fenestella several sp.
Polypora several sp.
Cystodictya aff. *C. lineata* Ulrich.
Chonetes aff. *C. illinoisensis* Worthen.
Productus (*Productus*) *brazerianus* Girty.
Productus (*Productus*) *scitulus* Meek and Worthen?
Productus (*Pustula*) aff. *P. subsulcatus* Girty.
Camarophoria? sp.
Cleiothyridina hirsuta Hall.
Sphenotus sp.

6742. Crane Basin, immediately east of the Bayhorse quadrangle; collected July 3, 1929, by V. E. Scheid:

Cup corals.
Crinoidal fragments.
Fistulipora sp.
Anisotrypa sp.
Schizophoria? sp.
Productus (*Linoproductus*) *ovatus* Hall.
Cleiothyridina hirsuta Hall.
Euomphalus sp.

7097. Near Road Canyon triangulation station, in sec. 32, T. 10 N., R. 21 E.; collected by T. H. Hite, Jr.:

Cheilotrypa? sp.
Cystodictya? sp.
Productus (*Productus*) *brazerianus* Girty.
Productus (*Productus*) aff. *P. burlingtonensis* Hall.
Recticularia sp.
Composita sp.
Cleiothyridina aff. *C. sublamellosa* Hall.
Euomphalus aff. *E. planidorsatus* Meek and Worthen.
Euomphalus sp.
Loxonema? sp.

7096. Anderson Peak; collected by T. H. Hite, Jr.:

Triplophyllum sp.
Campophyllum? sp.
Lithostrotion sp.

7098. Near benchmark 8723, in sec. 25, T. 10 N., R. 20 E.; collected by T. H. Hite, Jr.:

Fistulipora sp.
Rhombopora sp.
Productus (*Productus*) *brazerianus* Girty.
Productus sp.
Composita? sp.

7095. Sec. 30, T. 10 N., R. 21 E.; collected by T. H. Hite, Jr., half a mile up old road from Road Creek road toward Anderson Peak:

Zaphrentis sp., perhaps *Z.* (*Cyathophyllum*) *multilamella* Hall.

PENNSYLVANIAN ROCKS

WOOD RIVER FORMATION

Distribution.—The term "Wood River formation" has been applied to the Pennsylvanian strata in the Wood River region.[31] Strata that are lithologically and stratigraphically similar are exposed on both sides of the south end of Stanley Basin, in the Sawtooth quadrangle, and are here correlated with the Wood River formation. They extend

[31] Umpleby, J. B., Westgate, L. G., and Ross, C. P., op. cit. (Bull. 814), p. 25.

northward through the Custer quadrangle to a point a short distance south of Bonanza. Isolated patches of these strata are exposed through the Challis volcanics on upper Bruno and Thompson Creeks. The small mass of somewhat similar beds along Pinto Creek, in the southeast corner of the Bayhorse quadrangle, forms the northern continuation of exposures in the Hailey quadrangle, immediately to the south.[32]

Character.—The Wood River formation in most exposures in the northern part of the Sawtooth quadrangle and the southern part of the Custer quadrangle is essentially identical in lithologic character with the beds in its type locality farther southeast. Close to some of the igneous contacts here and to an increasing extent farther north the strata have, however, undergone intense igneous metamorphism. This has so changed the appearance of the rocks that it is only by tracing them through the progressive changes that the more thoroughly altered strata can be recognized as belonging to the formation.

The less metamorphosed rocks are mainly quartzitic. They range in color from light gray to nearly black with increase in impurities, of which carbonaceous material is the principal coloring matter. Many are somewhat calcareous, and the more limy beds tend to weather rusty.

Limestone beds are distinctly subordinate in amount in the southern part of the region. It appears, however, that the more conspicuous metamorphism farther north resulted to some degree from an increase in easily replaceable limestone beds. In the moderately metamorphosed beds along lower Warm Spring Creek more or less impure limestone makes up the greater part of the formation. This was probably originally true also along upper Slate and Livingston Creeks, where the metamorphism is at its maximum. Although much of the quartzite is somewhat argillaceous, shaly material is nowhere abundant and is commonly confined to thin partings spaced several feet apart between the quartzitic beds. Nearly everywhere outcrops of this formation have a massive appearance and readily visible partings 2 to 5 feet apart. Finer banding and cross-bedding are, however, almost invariably perceptible on close inspection.

Conglomerate occurs in several localities at or near the base of the formation, but it is not as conspicuous or constant a feature as in the Wood River region. The more abundant pebbles are quartz and quartzite, but the matrix is somewhat more impure and the rock consequently less resistant to weathering than in that region. The larger masses of conglomerate are shown on plate 1. Thin beds of conglomerate or scattered pebbles in quartzite and limestone, although they cannot be shown on such a map as plate 1, serve to mark the horizon elsewhere distinguished by more massive conglomerate.

[32] Idem, pl. 1.

The outstanding feature of the metamorphism is the conversion of normally somber-colored beds into dazzling white rocks. This results in part from elimination of organic matter but mainly from the development of abundant white wollastonite and diopside. In the limestone beds not thoroughly replaced by silicates the recrystallization of the calcite has lightened the color of the rock.

In the southeastern part of the Bayhorse quadrangle the rocks along Pinto Creek comprise an alternating series of conglomerate, grit, and carbonaceous argillite, with grit somewhat the most abundant of the three. Individual beds range from a few inches to 15 feet in thickness. The pebbles in the conglomerate are well rounded, are rarely over an inch in diameter, and include chert, quartzite, and argillite. The grit varies markedly in size of grain. Some of the argillite and argillaceous grit has fairly well developed slaty cleavage.

These rocks constitute the northern continuation of strata mapped by Westgate [33] as the Wood River formation and are consequently so designated here. However, grit is more abundant than in other recognized exposures of the Wood River formation, and the grit and argillite along Pinto Creek differ little from the coarser beds in the strata north of Broken Wagon Creek whose stratigraphic relations prove them to belong to the Milligen formation. Thus it is quite possible that the strata on Pinto Creek and the related beds in the northeastern part of the Hailey quadrangle properly belong to the Milligen formation. On this assumption the Brazer limestone, which is absent in the Hailey quadrangle, must thin out completely in the short distance between Pecks Canyon and the northeastern part of the Hailey quadrangle.

Age.—The Wood River formation in its type locality contains fossils that definitely establish it as of Pennsylvanian age.[34] Although no fossils have been found in the beds referred to the Wood River within the Bayhorse region, the resemblances in lithology and stratigraphic relations are both so close that the correlation seems fully warranted. The failure to find fossils results in part from the greater metamorphism of the rocks. Most of the Wood River beds north of the township line that passes through Blackman Peak and some of those to the south are so metamorphosed that it is not likely that fossils would be preserved in them. Even in the less altered rocks of the Wood River region extensive areas of the formation yielded no recognizable fossils.

It should be borne in mind that the Wood River and Milligen formations are both composed largely of clastic beds, which over large areas have yielded no fossils. Both here and in their type localities farther south they have been mapped mainly on the basis of their lithologic

[33] Umpleby, J. B., Westgate, L. G., and Ross, C. P., Geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814, pl. 1, 1930.

[34] Umpleby, J. B., Westgate, L. G., and Ross, C. P., op. cit. (Bull. 814), pp. 33–34.

characteristics. Consequently each formation as mapped records similarity in conditions of sedimentation rather than in age. As is suggested by the foregoing descriptions, more complete data might show that the beds in different places vary materially in age and that in places the Milligen, Brazer, and Wood River strata interfinger with one another. The data summarized below in regard to the heavy minerals of detrital origin in the rocks supplement other information in indicating that the beds grouped in the Milligen and Wood River formations, at least in the western part of the Bayhorse region, are interrelated and differ from other beds in the region.

HEAVY MINERALS AS AIDS IN STRATIGRAPHIC CORRELATION

Inasmuch as many of the exposures of the Paleozoic beds contain no fossils, it is desirable to support the stratigraphic correlations based on lithologic character and general relations in any way possible. This is especially true regarding the metamorphosed rocks assigned to the Milligen and Wood River formations. Except for two small fragments of plants in supposed Milligen beds at widely separated localities these rocks have yielded no fossils. As of possible aid in the correlation a study was made of the heavy-mineral content of 7 specimens from supposed carboniferous beds and 26 specimens from other Paleozoic rocks, all from the Bayhorse region, 5 specimens from the Wood River formation in the southern part of the Hailey quadrangle, 2 from the Milligen formation in the Hailey quadrangle, and 6 from the pre-Cambrian Hoodoo and Yellowjacket formations in scattered areas north of the Bayhorse region. The available specimens were not originally collected for this purpose, and several of them were poorly adapted to it because of inadequate size, abundance of minerals formed by subsequent metamorphism, or other reasons. All the Paleozoic and pre-Cambrian sedimentary rocks of this part of Idaho are so thoroughly cemented and so largely recrystallized as to render separation of heavy-mineral concentrates from them difficult. The abundance of flaky carbonaceous and argillaceous matter interfered with clean separation and with determination of the minerals in the concentrates. All samples were thoroughly leached with hydrochloric acid, after grinding and sizing, in order to eliminate the carbonate generally present. Some of the separations were made by Miss Jewell Glass and the rest by Charles Milton, both of the United States Geological Survey, with the writer's assistance. Two or more separations were made from most of the specimens.

Heavy minerals of probable detrital origin in specimens from Bayhorse and nearby regions

Age	Formation	Garnet	Tremolite	Apatite	Epidote	Staurolite	Zoisite	Dark tourmaline	Hornblende	Augite	Rutile	Feldspar	Zircon	Titanite	Corundum
Pennsylvanian	Wood River formation (Custer quadrangle; southeastern Bayhorse quadrangle)	×	×	×											
	Wood River formation (southern part of Hailey quadrangle)	×	×		×			×							
Mississippian	Milligen formation (Custer and Bayhorse quadrangles)	×	×	×		×									
	Milligen formation (Hailey quadrangle)	×			×	×		×		×			×		
Devonian	Jefferson dolomite (Grand View Canyon)					×			×	×					
Silurian	Laketown dolomite							×	×				×		
Ordovician	Saturday Mountain formation (near Squaw Creek)					×	×	×		×	×	×	×		
	Kinnikinic quartzite (northern Bayhorse quadrangle)						×	×					×		
	Ramshorn slate (near Bayhorse)						×	×		×		×	×		
	Ramshorn slate (southern Bayhorse quadrangle)						×	×		×	×				
Cambrian (?)	Bayhorse dolomite (near Bayhorse)							×							
Pre-Cambrian	Hoodoo quartzite (Lemhi and Valley Counties)							×					×	×	
	Yellowjacket formation (Lemhi and Valley Counties)							×				×	×		×

The table summarizes the results of the microscopic examination of the concentrates. Only minerals of probable detrital origin are included. Many of those listed are so worn or so pitted as clearly to have that origin. Some or all of the tremolite and augite, part of the epidote minerals, and perhaps some of the apatite, staurolite, and feldspar, named in order of decreasing probability, may have formed during the metamorphism that has affected all the rocks. Feldspar is not strictly a heavy mineral, but as it has similar diagnostic value where it appears to be an original constituent of the sediments, it is included in the table. Minerals known to have crystallized after the sediments were deposited and indurated are omitted from the table. They include several micaceous minerals, graphite, diopside, wollastonite, pale tourmaline, andalusite (chiastolite), and others. Distinction was made in part on the basis of the amount of wear visible on the heavy-mineral grains and in part on the study of thin sections. Most of the metamorphic minerals are sufficiently abundant to be visible in thin section. Several specimens failed to yield recognizable heavy minerals other than micaceous and graphitic aggregates, and a few yielded clean or abundant concentrates. Most of the concentrates contained specks and small grains of opaque material, largely magnetite and pyrite. No account is taken in the table of the opaque matter, as it is widespread and doubtless largely crystallized in place in the rocks. Sufficient variation was found in the results of different separations from identical material to indicate that the proportional amounts of the different minerals in the concentrates cannot, in these analyses, be relied on as a diagnostic feature. It is not to be expected that the table includes all the detrital heavy minerals originally deposited in the sediments, but the results are sufficiently consistent to indicate that they have some diagnostic value.

Inspection of the table shows that the heavy-mineral assemblages in the Carboniferous rocks are on the whole obviously different from those in earlier formations. Material from the Carboniferous formations of the Hailey quadrangle differs somewhat from that assigned to these formations in the Bayhorse and Custer quadrangles but has much more resemblance to it than to the assemblages from any of the older Paleozoic rocks. The tourmaline in the Carboniferous rocks of the Hailey quadrangle is brown and distinctly different in appearance from the greenish to nearly black tourmaline of the older rocks. Presumably it is derived from a source that did not contribute to any of the rocks studied from localities outside the Hailey quadrangle. The same is true of the epidote in the Carboniferous rocks of the Hailey quadrangle. It is quite possible that the abundant fresh augite in Milligen limestone near the Little Wood River in the eastern part of the Hailey quadrangle is not detrital. Feldspar, both microcline and sodic plagioclase present in the same specimen, is excluded from the table because it is in sharply angular, almost perfectly fresh fragments that seem clearly to have crystallized in place. The zircon crystals found in both specimens of Milligen rocks from the Hailey quadrangle are unmistakably water-worn. They constitute the only exception, among the rocks examined, to the fact that in this part of Idaho detrital zircon is confined to rocks believed to be of pre-Carboniferous age. Staurolite, identified in three specimens of Milligen rocks, is also present in specimens from the Jefferson and Saturday Mountain formations.

The heavy-mineral assemblage in the Jefferson dolomite is distinctive in that it does not contain any of the minerals especially characteristic of either the Carboniferous or the Ordovician formations and does contain hornblende, probably detrital. The few heavy minerals found in the Laketown dolomite suggest greater affinity with the assemblages from the Ordovician rocks than with those from the Carboniferous formations. No heavy minerals were obtained from the Brazer limestone, but the material available for study was so scanty that this fact may have no significance. The Laketown and Brazer are sufficiently distinguished by lithology and fossil content.

The assemblages from the different Ordovician formations, although not identical, are obviously related. The dark tourmaline, certainly detrital, is especially characteristic of these beds. Similar tourmaline is also present in the Bayhorse dolomite, which yielded no other heavy minerals. The fact that only three heavy-mineral species are recorded from the Ramshorn slate in the southern part of the Bayhorse quadrangle is probably due to the fine grain of the rock and the pressure and contortion to which it has been subjected, which made separation of heavy minerals difficult.

The Hoodoo and Yellowjacket formations (pre-Cambrian) are represented in the present study only by small specimens from widely scattered localities near Yellowjacket and Forney, Lemhi County, and Edwardsburg, Valley County, which cannot be considered to represent adequately the heavy-mineral content of the two formations. The mineral assemblages obtained from them, however, differ distinctly from those in either the Carboniferous or the early Paleozoic groups and include two minerals not noted in any of the other specimens studied.

In summary, the data obtained accord with conclusions reached from other evidence and appear to justify the conclusion that a study of the heavy minerals, even in rocks as poorly adapted to such a study as these, yields results of distinct value in stratigraphic correlation. Conclusions as to the broader groupings of rock units suggested by the data in the table are regarded with confidence. The distinction between rocks assigned to the Carboniferous and those of greater age, which was the principal reason for undertaking the study, is especially clear. Close correlation, if possible at all in rocks of this character, would have to be based on an intensive study of more adequate, specially selected material than was available in the present study.

GRANITIC ROCKS AND RELATED INTRUSIONS

DISTRIBUTION AND CORRELATION

The principal body of granitic rock in the Bayhorse region is a part of the main mass of the Idaho batholith. This body, the greater part of which consists of calcic quartz monzonite, occupies almost the whole western half of the Custer quadrangle and projects some distance eastward from the middle of that quadrangle, especially in the vicinity of the Salmon River. The Idaho batholith also continues southward and is exposed over the greater part of the Sawtooth quadrangle as well as over a large area to the west and northwest. Near its margin in the southeastern part of the Custer quadrangle there are small dioritic bodies of two kinds, both within the main mass and in the sedimentary rocks nearby.

The two varieties of quartz dioritic rocks here are somewhat similar, both in character and in position with respect to the main intrusion, to calcic rocks on the borders of the Idaho batholith in many other localities.[35] The calcic rocks, wherever an age difference is evident, consolidated slightly before the main mass of the batholith. By analogy the quartz diorites of the Bayhorse region may be tentatively regarded as a little older than the quartz monzonite.

Here and there a few aplitic and lamprophyric dikes cut the granitic and sedimentary rocks. Such dikes are widely distributed but nowhere abundant or conspicuous.

East of the main batholith are several detached masses of quartz monzonite and similar rock that are tentatively regarded as related to the Idaho batholith. There can be little question that the stock which forms much of the higher parts of the White Cloud Peaks and the smaller masses south and southwest of it are so related. The small detached masses in the upper drainage basin of Thompson Creek are also confidently regarded as of this age. In both localities the rock is similar in essential characteristics to that of the Idaho batholith, and the position and structural relations of the isolated masses are such as to leave little doubt that they are offshoots of the main body, connected with it at comparatively small depth beneath the surface.

The small mass of granodiorite near Juliette Creek, in the northwestern part of the Bayhorse quadrangle, is likewise believed to be

[35] Ross, C. P., Geology and ore deposits of south-central Idaho: U. S. Geol. Survey Prof. Paper — (in preparation).

related to the Idaho batholith, although the greater intervening distance introduces some doubt. Petrographically, it is more like rocks commonly regarded as of that age than any others in Idaho. The contact between this rock and the Challis volcanics on the west is steep and abrupt, but there is no evidence of intrusion into or alteration of the volcanics.

Gabbroic rock crops out in numerous places in the northwestern part of the Bayhorse quadrangle. Most of such bodies are sill-like, but some of the larger ones are irregular. All are close to the contact between the Ramshorn slate and the Kinnikinic quartzite. Some, such as that at the head of Garden Creek, follow the contact. Most of the numerous bodies of gabbro near Clayton are in the argillite. The alteration in the gabbro is more complete than is common in rocks associated with the Idaho batholith. However, as the alteration is hydrothermal and may have been accomplished during the late stages of intrusive activity, it is not necessarily diagnostic as to age. The Pedrino and Sadle prospects, near Kinnikinic Creek, show that mineralization took place subsequent to intrusion and probably was related to the hydrothermal alteration of the gabbro. Consideration of these facts leads to the supposition that the gabbro is more or less closely related to the Idaho batholith, although direct evidence is lacking.

CHARACTER

QUARTZ MONZONITE

The parts of the main batholith and nearby outliers whose average composition is that of quartz monzonite are in general moderately coarse-grained, gray to pinkish, and, with local exceptions, not conspicuously porphyritic. In some places, such as lower Warm Spring Creek, in the Custer quadrangle, and Galena Creek, in the Sawtooth quadrangle, white to somewhat pinkish microcline phenocrysts, commonly over an inch long, are conspicuous. Much of the rock, except where very fine grained, has a faintly gneissic appearance caused by the roughly parallel arrangement of the biotite flakes, probably a result of flowage before final consolidation.

Under the microscope the quartz monzonite from different places is found to contain 20 to 40 percent of quartz, 30 to 45 percent of plagioclase (mainly oligoclase-andesine), 10 to rarely more than 40 percent of microcline, 5 to 15 percent of biotite, exceptionally a little hornblende, and minor amounts of titanite, apatite, and epidote. Myrmekitic intergrowths of quartz and plagioclase are common but nowhere abundant. Most of the microcline shows a little replacement by albite. Most of the plagioclase is zoned, and it varies slightly in composition in specimens from different localities. In the material examined the maximum observed indices of refraction in the plagioclase are about 1.54–1.55. The rock from all localities is fresh but contains a little sericite and chlorite. The hornblende, where present, is commonly more altered than most other constituents.

The feldspars, especially the plagioclase, tend to have imperfect crystal form. In most places the crystals range in length from 1 to 2 millimeters. Quartz tends to be interstitial and to show the effect of incipient crushing more than the other constituents. The biotite is in somewhat ragged flakes, rarely more than a millimeter long. In a few places, such as the vicinity of the Idahoan mine, the texture is different. Some plagioclase occurs in prisms ranging from 1 to more than 3 millimeters in length, but much of the rock is composed of interlocking grains of quartz and feldspar about 0.3 millimeter in average diameter. This rock is somewhat more altered than most.

The most silicic granitic rock examined during the present study is that in the small boss on one of the headwater tributaries of Pole Creek, in the northern part of the Sawtooth quadrangle. This rock contains about 30 percent of microcline, an equal amount of oligoclase-andesine, and almost as much quartz, together with some biotite and hornblende. In the Vienna district, still farther west, across the upper Salmon River, the rock is still more silicic, being a true granite with abundant quartz and microcline and subordinate amounts of andesine and biotite.[36]

GRANODIORITE

The small stock near Juliette Creek, in the northern part of the Bayhorse quadrangle, is on the whole somewhat more calcic than most of the other granitic rock in the region, although of variable composition. It is moderately coarse and even-grained, without perceptible gneissic texture or phenocrysts. The abundant biotite gives it a rather dark gray tone, but the feldspars are pinkish.

Much of the rock consists of 40 to 60 percent of sodic andesine, somewhat less than 10 percent of microcline, about 20 percent of quartz, and less than 15 percent of biotite; and the rock has a content of hornblende ranging from almost nothing up to about 10 percent. Minor constituents include magnetite, apatite, titanite, myrmekitic intergrowth of quartz and feldspar, and epidote. It thus has the composition of granodiorite. Locally, however, the rock contains only about 20 percent of plagioclase, 40 percent of microcline, 25 percent of quartz, 15 percent of biotite, and little or no hornblende. In this variety the plagioclase is distinctly more sodic than in that previously described, and the rock may be termed a granite. In both varieties the rock is more altered than most of the quartz monzonite. Farther west sericite is conspicuous in the potash

[36] Ross, C. P., The Vienna district, Blaine County, Idaho: Idaho Bur. Mines and Geology Pamph. 21, p. 6, 1927.

feldspar, which also, as in the quartz monzonite, contains albite. The biotite and especially the hornblende are chloritized. On the margins of the stock, especially on the north side, fine aplitic rock almost free from ferromagnesian constituents in part forms dikes cutting the Ramshorn slate and in part probably forms an outer border zone of the stock. Some of this rock in the vicinity of the Virginia Dare mine is rusty and contains quartz stringers.

QUARTZ DIORITE

Two kinds of quartz diorite have been recognized, both in the southeastern part of the Custer quadrangle. The more silicic of the two has been mapped only on the borders of Washington Basin, near the southern boundary of the Custer quadrangle, although small bodies of essentially similar rock that cannot be adequately represented on such a map as plate 1 are present in the quartz monzonite near Champion Lakes and elsewhere. The rock in and close to Washington Basin mapped as quartz diorite is of somewhat variable character and appearance. Some of it is little more calcic than the surrounding quartz monzonite, but most of the mass is dark-gray quartz diorite, in part rather coarse and porphyritic, in part somewhat finer and nonporphyritic. The dioritic rocks reach out in stringers into the Wood River beds surrounding the stock. The contacts between the different varieties of igneous rock are irregular and gradational.

The differences between the two varieties of the quartz diorite are mainly textural. Both consist in general of about 65 percent of zoned plagioclase of the average composition of sodic andesine, 13 percent of quartz, 12 percent of hornblende, 8 percent or less of biotite, 2 percent of potash feldspar, and minor quantities of titanite, apatite, epidote, calcite, and sericite. The ferromagnesian constituents are rather well formed, but the feldspars are less perfectly prismatic than in the quartz monzonite. In the finer variety the maximum length of grain is about a millimeter, whereas in the groundmass of the coarser variety the plagioclase grains are more than 3 millimeters long and the rounded plagioclase phenocrysts are about 10 millimeters in diameter.

The other kind of quartz diorite, which for the sake of distinction is termed "calcic quartz diorite" on plate 1, forms small irregular bodies and apophyses along the bedding of Wood River quartzite in the area between Calkins Lake and The Meadows, on Warm Spring Creek. The rock is darker gray than the quartz diorite of Washington Basin and looks black in contrast to the white metamorphosed sedimentary strata it invades. In some places the alternating bands of white sedimentary rock and nearly black igneous rock have the appearance, at a distance, of a conformable sedimentary sequence (pl. 3, *B*). Intrusion took place prior to the later folding and crumpling of the sedimentary strata.

The rock contains 50 to 60 percent of calcic andesine, in part perthitic, 15 to 20 percent of quartz, 15 to 20 percent of biotite, 15 percent or less of hornblende, and minor amounts of apatite, chlorite, calcite, and sericite. The texture is more like that of the quartz monzonite than that of the other quartz diorite, but the plagioclase is even more lath-shaped. Most grains are 1 to 2 millimeters long. Some of the rock contains rounded plagioclase phenocrysts about 10 millimeters in diameter. The quartz throughout is interstitial and was evidently one of the last minerals to consolidate.

GABBRO

The gabbro is a dark-greenish rock that has obviously undergone hydrothermal alteration. It is of variable texture but almost everywhere distinctly finer-grained than any of the intrusive rocks described above.

In most places this rock consists of an irregular aggregate of calcic plagioclase, chlorite, secondary quartz, and calcite. In some of it the plagioclase is in laths about a millimeter or less in length. Commonly the plagioclase is too much altered for precise determination. Exceptionally coarse fresh material from a locality near Ramshorn Mountain consists of feather-ended laths of bytownite about 2 millimeters long with abundant chloritized biotite and a small amount of uralitic hornblende partly replaced by biotite. The very calcic plagioclase indicates that the rock originally had a composition akin to that of gabbro. The hornblende, biotite, and chlorite probably represent successive steps in the hydrothermal alteration of the original pyroxene of the gabbro.

APLITIC ROCKS

Light-colored aplitic dike rocks are present in several places at the margins of the quartz monzonite bodies and in the nearby Paleozoic sedimentary rocks. Some of the dikes in the sedimentary rocks crop out at a considerable distance from exposures of quartz monzonite. The aplite exposed along the upper reaches of Grand Prize Creek, in the northern part of the Sawtooth quadrangle, is an example. Aplitic dikes, in part coarse-grained, are similarly situated with respect to the granodiorite of Juliette Creek. The aplite dikes are nowhere numerous or long.

Prospect holes in the aplitic rock on Grand Prize Creek show that both the aplite and the nearby sedimentary beds are somewhat mineralized. The aplite consists essentially of quartz, microcline, and sodic plagioclase, is sericitized, and contains some calcite and pyrite. The groundmass has a granular texture, and the average diameter of grain is about 0.05 millimeter. It is studded with quartz and feldspar phenocrysts about 0.1 millimeter in diameter.

At the Lucky Strike mine, on Fourth of July Creek, there is a somewhat more calcic dike whose original characteristics have been partly obscured by crushing but which is not much sericitized. Most of the groundmass is a granular aggregate of quartz and feldspar. The phenocrysts are about 0.5 to 1.0 millimeter long and consist of more or less chloritized biotite, oligoclase, and quartz. The minor constituents include epidote, sericite, apatite, and disseminated galena and pyrite.

Along the upper reaches of Champion and Fourth of July Creeks are several aplitic dikes. Most of them are somewhat coarser, less porphyritic, and much fresher than those described above. They are pink to nearly white and consist of microcline, quartz, oligoclase, and small amounts of biotite and hornblende.

Pink aplitic rocks near the granodiorite near Juliette Creek are noted on page 46. On Ramshorn Mountain, some distance to the east of the granodiorite stock, stringers of coarse, almost pegmatitic aplite cut the Ramshorn slate. These stringers consist essentially of quartz, microcline, and muscovite.

LAMPROPHYRE

Small, nearly black lamprophyre dikes are exposed in the Idahoan mine, in Germania Basin, along the borders of the batholith east of The Meadows, on Warm Spring Creek, and in other localities but are everywhere rare. Some of the dikes are as much as 8 feet wide, but most of them are small. Umpleby[37] noted a dike of this character in the Ramshorn mine.

All the lamprophyre dikes examined consist essentially of anorthite and augite more or less altered to serpentine. The groundmass is composed largely of feldspar laths 0.02 to 0.20 millimeter long, and the phenocrysts of augite as much as 1.5 millimeters long.

AGE

Analysis of the evidence available in 1928 led to the conclusion that the Idaho batholith is probably younger than Triassic and probably as old as Lower Cretaceous, at least as old as Cretaceous.[38] On this basis it appeared logical to regard this batholith as one of the products of widespread diastrophism, which occurred in the Cordilleran region near the end of the Jurassic period. These conclusions were based in part on the fact that the batholith is much older than the Challis volcanics, then regarded as Miocene (?). The fossils discussed on pages 65–68 indicate that the Challis volcanics are early Miocene or late Oligocene and thus put this concept on a firmer basis.

[37] Umpleby, J. B., op. cit. (Bull. 539), p. 24.

[38] Ross, C. P., Mesozoic and Tertiary granitic rocks in Idaho: Jour. Geology, vol. 36, no. 8, p. 692, 1928.

Structural features both in the Bayhorse region (pp. 80–82) and in surrounding areas [39] indicate that the deformation of the Paleozoic strata and the intrusion of the Idaho batholith are intimately related in age and genesis and that both may well have preceded similar occurrences farther east that are commonly regarded as having originated in the Laramide revolution, at about the beginning of the Tertiary period. In a forthcoming paper on south-central Idaho [40] this matter is discussed in all aspects.

CHALLIS VOLCANICS

The Tertiary volcanic strata in this part of Idaho are, as a whole, designated the "Challis volcanics." [41] This thick and widespread formation varies in character from place to place but has general characteristics sufficiently consistent to permit subdivision into units whose essential features can be recognized wherever found, even though their mutual relations and thicknesses vary in different localities. As subdivision was necessarily made on the basis of petrographic characteristics rather than age, the stratigraphic relations of the different units vary from place to place. Such variation results from irregularities in the order of eruption and from erosion between eruptions of both lava and tuff. Although local unconformities are common throughout the formation, especially in the soft tuff, no known evidence suggests a major time break. To certain of the more definitely distinguishable units are assigned geographic names, taken from localities in which they are especially well exposed. The larger and more variable units are designated by the names of the prevailing rock types therein.

In most localities in south-central Idaho by far the greater part of the formation consists of flows made up dominantly of latite and andesite with some intercalated beds of tuff, rhyolite, and basic flows. This aggregate may be termed the "latite-andesite member." In the Bayhorse region, especially in its southeastern part, this unit is less prominent than usual and in some localities is entirely absent.

Another unit composed essentially of tuff, tuffaceous sandstone, and subordinate amounts of conglomerate and shale is here named the "Germer tuffaceous member," after Germer Basin, in the north-central part of the Bayhorse quadrangle. It is exceptionally thick and fossiliferous in and near this basin. Here and in some other localities in this part of Idaho the Germer beds constitute the whole of the Challis volcanics, except for local intercalated flows. Where

[39] Ross, C. P., Some features of the Idaho batholith: 16th Internat. Geol. Cong. Rept., pp. 376-381, 1936; preprint, pp. 8-13, 1935.

[40] Ross, C. P., Geology and mineral resources of south-central Idaho: U. S. Geol. Survey Prof. Paper — (in preparation).

[41] Ross, C. P., The Seafoam mining district, Custer County, Idaho: Idaho Bur. Mines and Geology Pamph. 33, p. 2, 1930; Geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, pp. 46-53, 1935.

the latite-andesite member is present, as it is nearly everywhere, the Germer is interbedded with and overlies the flows. It thus constitutes the major unit in the upper part of the Challis volcanics. Wherever rock having the lithologic characteristics of the Germer member is distinguished on plate 1, it is shown in the map color assigned to the Germer, irrespective of its local stratigraphic relations.

Basalt is commonly intercalated in the Germer tuffaceous member. Locally such flows, with related basic andesite, increase in thickness to such a degree as to constitute a large part of the Challis volcanics.

The flows of rhyolite are commonly so distinctive in appearance as to be readily distinguished from others. In the Casto quadrangle, which lies north of the Bayhorse region (see fig. 2), most of the rhyolitic flows were grouped in the Yankee Fork rhyolite member, at the top of the Challis volcanics.[42] In the Bayhorse region the corresponding flows are interbedded with the tuffaceous strata to a greater extent than farther north, and it has been possible to distinguish three varieties on the map. These represent differences in physical conditions at the time of eruption and probably also some variation in composition, but all the flows of the Yankee Fork member are so similar as to suggest a common magmatic source.

Travertine is associated with the volcanics in the southeastern part of T. 13 N., R. 19 E. Smaller bodies of similar material occur in sec. 25, T. 12 N., R. 18 E., and in and near sec. 6, T. 10 N., R. 19 E.

In most of the Bayhorse region distinction between the different members of the Challis volcanics was made in mapping, but in the area west of the Bayhorse quadrangle, especially near and north of Railroad Ridge, this was not done.

LATITE-ANDESITE MEMBER

DISTRIBUTION

The latite-andesite unit occupies much of T. 13 N., R. 19 E., and is extensively exposed in the northwest and southwest corners of the Bayhorse quadrangle. Small detached masses of similar rocks are distinguished in several other localities in this quadrangle, particularly in the general vicinity of Jerry Peak, in and near T. 9 N., R. 20 E. The member occupies nearly all of the eastern margin of the Custer quadrangle and that part of the Sawtooth quadrangle here mapped except the area between Boulder Creek and the Salmon River, which is occupied by other units of the Challis volcanics. The andesite and latite extend westward to the head of the Salmon River and, in eroded and faulted remnants, into the middle part of the Stanley Basin, farther north. To the north of the eastward-flowing part of the Salmon River they cover not only the areas geologically mapped on

[42] Ross, C. P., Geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, pp. 52-53, 1935.

plate 1 but also most of that part of the Custer quadrangle that lies farther north.

CHARACTER

The latite-andesite member is a diversified aggregate of flows, flow breccias, and some intercalated tuff. There is a wide range in appearance and composition among the many beds that compose the unit, but much the greater number are fine-grained, rather light-colored rocks studded with small phenocrysts, mostly feldspar, and are either latitic or andesitic in composition. On the whole the rocks of this member are somewhat more somber in color and more basic in composition than the corresponding beds in either the Custer or the Casto quadrangle.[43]

A few small flows of dark obsidian and dense spherulitic flows of rhyolite here and there in the upper parts of the sequence have been mapped with the latite-andesite member, but in the Bayhorse quadrangle they are nowhere abundant. The scattered tuff beds included in the member are also rhyolitic and in all respects resemble the tuff of the Germer member, with which they are closely allied.

Many of the flows of the latite-andesite member are of latitic composition. These are commonly, though by no means invariably, colored some shade of purple or lavender. The phenocrysts are generally 0.5 to 1.0 millimeter in length and make up 5 to 30 or rarely as much as 40 percent of the rock. Commonly more than half of the phenocrysts are oligoclase. In some of the flows quartz phenocrysts are almost as abundant as the feldspar, but in many they are nearly or quite absent. Biotite is the principal ferromagnesian constituent, but a little hornblende is present in several flows. The groundmass in some has a granular texture, in others trachytic. The component grains range from 0.02 to about 0.10 millimeter in length. The major constituent of the groundmass is alkali feldspar, which, as shown by analysis, is largely potassic. Quartz is probably present in the groundmass of most of the latitic rocks. For the most part the latitic rocks are conspicuously free from alteration. Analyses BH11 and BH36 in the table below are representative of these rocks.

Several of the flows are somewhat more basic than those just described. These may be termed "andesite", although, as shown by analysis BH1, made from a sample thought to be representative of such flows, they contain a considerable amount of potash. The phenocrysts have about the same range in size and number as those in the latite, although in some flows they are a little larger. In nearly all the andesite flows calcic oligoclase or sodic andesine is the most abundant constituent of the phenocrysts. Both hornblende and biotite are commonly present but together rarely make up as

[43] Ross, C. P., The geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, pp. 46-47, 1935.

much as 15 percent of the rock. The groundmass is composed mainly of plagioclase laths, commonly about 0.1 millimeter long, obscured by much coloring matter. These rocks are distinctly more altered by hydrothermal action than the latitic flows. In some the hornblende is entirely and the biotite partly broken down. The relatively high lime content of BH1 is largely calcite of secondary origin, and the ferromagnesian minerals in many of the andesitic flows are more or less completely replaced by calcite. Also part of the potash is in the form of secondary sericite.

Those andesitic flows that are characterized by the presence of augite vary markedly. For example, the augite andesite in the hills east of Beardsley Hot Springs is mottled buff and pinkish. The phenocrysts are as much as 2 millimeters in length and constitute about 30 percent of the rock. About two-thirds of them are andesine, and the remainder are mostly augite, in part serpentinized, and a little biotite. The groundmass is mainly andesine laths as much as 0.2 millimeter in length, clouded by dust and micaceous alteration products.

In contrast, the augite andesite on the north side of Bradbury Flat is a black rock with vitreous luster. The coarser phases of this rock have numerous resinous phenocrysts of calcic andesine as much as 2 millimeters in length and smaller inconspicuous phenocrysts of augite and biotite. Polygonal jointing is exceptionally well developed. Joint blocks of this rock have been utilized to construct a small irrigation dam in sec. 27, T. 13 N., R. 19 E. (See pl. 4, *A*.) The andesine phenocrysts make up about 25 percent of the rock, augite fully 10 percent, biotite less than 2 percent, and the remainder is a mat of andesine laths less than 0.02 millimeter in length and dark, nearly opaque dust. The rock is decidedly fresh. Its chemical composition is indicated by partial analysis M29, given below.

In some places, especially in the southern part of the Bayhorse quadrangle, more calcic augite andesite like that associated with the basalt is included in the latite-andesite member.

Partial analyses of rocks representative of the latite-andesite member of the Challis volcanics

[Analyzed in June 1932 by George Steiger, U. S. Geological Survey]

	BH11	BH36	BH1	M29
Silica (SiO_2)	67.26	63.54	53.53	62.35
Lime (CaO)	3.70	3.11	7.42	4.96
Soda (Na_2O)	4.02	3.34	2.62	3.44
Potash (K_2O)	3.44	5.16	3.94	2.74

BH11, latite, sec. 34, T. 9 N., R. 20 E.
BH36, latite, sec. 20, T. 8 N., R. 20 E.
BH1, andesite, sec. 24, T. 8 N., R. 19 E.
M29, augite andesite, sec. 27, T. 13 N., R. 19 E.

The thickness of individual flows varies greatly but on the average is greater than that of either the rhyolitic or basaltic lavas. Some flows are 300 feet or more thick.

The aggregate thickness of this unit varies greatly from place to place. Locally it is absent entirely, and elsewhere flows of this type are intercalated with other members of the formation. Where typically developed, however, the flows of this character commonly have large aggregate thicknesses. South of Challis the thickness of the unit is more than 3,000 feet. In the vicinity of Bowery Peak and also farther west near Germania Creek the total thickness is at least as great. The detached masses of lava of this character that rest with local erosional unconformity on basalt in the vicinity of Jerry Peak comprise four or five flows each 100 to 250 feet thick, with an aggregate thickness of 750 feet. In the vicinity of Mill Creek and upper Squaw Creek, in the northwestern part of the Bayhorse quadrangle, the thickness is about 1,500 feet. North of the Salmon River below Robinson Bar the thickness is little more than 1,000 feet, but here erosion has removed part of the unit. In the vicinity of Bonanza the Challis volcanics appear to occupy a depression carved in the older rocks, and near the old General Custer mine, east of the town, the latite-andesite unit aggregates at least 2,000 feet and probably materially more. Here as elsewhere increase in the thickness of the Germer tuffaceous unit is accompanied by decrease in the thickness of the latitic and andesitic flows. Where the flows have their maximum development the upper flows are evidently stratigraphically equivalent to the Germer beds.

GERMER TUFFACEOUS MEMBER

DISTRIBUTION

The Germer tuffaceous member of the Challis volcanics is especially well developed in Tps. 10 to 14 N., R. 19 E., and adjacent areas to the east and west. To the northwest it decreases in thickness and becomes interbedded with latite and andesite flows. In the area between the upper reaches of Bayhorse and Squaw Creeks more refined mapping would record the presence of more tuffaceous beds than are differentiated on plate 1, intricately interfingered with lava flows. Similarly, in the areas west of the Bayhorse quadrangle the latite-andesite unit includes local tuff beds individually so small that it would be difficult to distinguish them on the map. At about the latitude of Bonanza, however, the proportion of tuffaceous material increases. In much of the area between Bonanza and the ridge crowned by Mount Estes and Mount Jordan (north of the area geologically mapped on pl. 1) tuff constitutes the principal rock at higher altitudes. This area has been studied only in reconnaissance and consequently has not been included on the geologic map (pl. 1).

The only part of the Custer quadrangle geologically mapped on plate 1 in which tuffaceous beds of the Germer type are abundant is the area in and near unsurveyed T. 10 N., R. 16 E. In this area the available information is shown on plate 1, but boundaries of the members were not traced in the field.

CHARACTER

By far the greater part of the Germer beds in this region are medium- to fine-grained cream-buff and light-brown rocks composed dominantly of products of explosive volcanism. They accumulated in part directly from ash showers, with little or no subsequent sorting. A considerable proportion of the rock shows bedding and water sorting to a greater or less extent. Such rock contains, in addition to the volcanic material, a variable but commonly subordinate amount of quartz of detrital origin.

Much of the tuff that has been water-sorted is in beds a few inches to a few feet thick (pl. 5, *A*), but in many places bluffs exhibit tuff masses 1 foot to several score feet thick, with little or no bedding (pl. 5, *B*).

The most abundant variety of the unsorted tuff that shows little or no water-sorting is composed mainly of fragments of crystals of igneous minerals, commonly about a millimeter in maximum diameter, embedded in a matrix composed of grains many of which have diameters of only about 0.02 millimeter. Among the larger fragments more or less broken crystals of oligoclase are the most abundant. Some of these are almost or quite perfect in form, and nearly all are fresh. In addition there are quartz fragments, in part corroded, shreds of biotite, a little hornblende, and a few pieces of lava. Some of the smaller feldspar fragments are altered and may be potash feldspar, although here, as in the lavas, few grains of potash feldspar have been positively identified. The character of the groundmass has been in part obscured by silicification, but it appears to be made up largely of sharply angular bits of feldspar and quartz and flakes of mica.

In addition there are a few beds of tuff that are distinctly harder and denser than the average, although not perceptibly silicified. These, like the tuff just described, contain fragments of such minerals as feldspar, quartz, and mica, but the greater part of the rock is made up of delicate glass shards with sharp points that could not have survived much transportation in water. Some of the shards are 0.5 millimeter long, but the average length is about 0.1 millimeter.

Certain other beds, very similar to those described above in superficial appearance, are composed of pumice in which the glassy fragments ejected during an eruption were still so hot when they fell on the ground that they flowed and welded together into a mass of glassy material with exceedingly irregular and discontinuous banding. This rock contains a few microliths of feldspar and biotite, sparse crystals of sodic plagioclase and quartz, rarely much more than a millimeter long, and here and there somewhat larger fragments of feldspar.

In some of the tuffaceous beds, especially those close to lava flows, the original character is more or less completely obscured by silicification. Some of the smaller beds of this sort have become fine-grained and flintlike. In some, such as the beds on Bowery Peak, the groundmass is much altered and tends to merge into the larger fragments enclosed in it, but the general character of the rock is still discernible. The larger fragments, unlike many of the tuff beds, consist dominantly of lava of several kinds and include only a subordinate amount of crystal fragments.

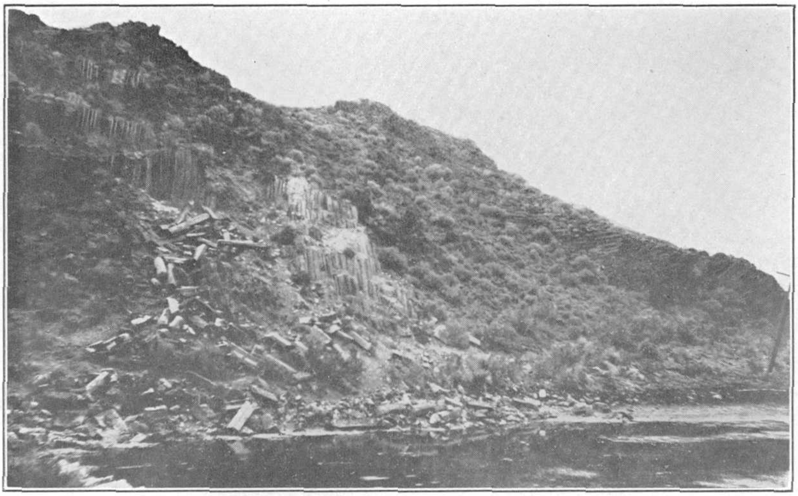
Thin bands of silt and clay occur locally but are rarely thick or abundant. In and near Germer Basin fine-grained material commonly occurs as lenses of slight lateral extent and rarely more than a few inches thick. The better-preserved plant remains are generally found in such rock. In a few places, notably in secs. 7 and 29, T. 12 N., R. 19 E., there are thin seams of impure lignite that locally rest on clay. The largest amount of argillaceous material observed in the Challis volcanics anywhere in the neighborhood of the Bayhorse region is along the road from Bonanza to Loon Creek in the saddle between Jordan and Mayfield Creeks. Here the road cuts expose tilted beds of rather dark gray laminated shale whose thickness surely exceeds 20 feet and is possibly several times this figure.

Conglomerate is a conspicuous constituent of the Germer unit in several localities. It is more abundant at and near the base but is by no means confined to this position. So far as it is practicable to do so this conglomerate is distinguished on plate 1, but there are numerous small exposures of massive conglomerate and of pebbles scattered through tuffaceous beds that are not shown on the map. Most of the conglomerate has a matrix essentially identical with the tuffaceous sandstone already described. Some of it, however, has a matrix composed mainly of grains of quartz and quartzite in a siliceous cement. In the former variety the pebbles generally include a considerable proportion of material derived from erosion of the Challis volcanics, although older rocks are commonly the more abundant. In those conglomerates cemented with silica, quartz and quartzitic rocks derived from the Paleozoic formations are by far the most abundant, and volcanic rocks are commonly so scarce as to be found only on close inspection. The pebbles are somewhat more perfectly rounded than in many of the beds with tuffaceous matrix. The best examples of the siliceous variety of conglomerate are in sec. 18, T. 9 N., R. 21 E., and along the ridge crest east of Pinto Creek. The numerous conglomerate beds west of the East Fork of Sage Creek have in part a siliceous cement but include much tuffaceous material. This fact and the small extent of many of the individual beds introduce so much difficulty into the mapping that the representation of these beds on plate 1 is necessarily much generalized, as is indicated by dashed contact lines. The smaller and finer-grained conglomerate beds in this vicinity are largely omitted on plate 1. A little of the siliceous conglomerate is present near the base of the Challis volcanics, both near East Pass Creek close to the southern border of the region and along Corral Creek north of Jimmy Smith Lake, but the beds are individually so small that they were not mapped. The deeper gulches in and near Germer Basin expose coarse and poorly sorted basal conglomerate, of which only the larger masses are indicated on plate 1. In secs. 8 and 9, T. 11 N., R. 20 E., and in and near sec. 23, T. 11 N., R. 19 E., the conglomerate has in part a siliceous and in part a tuffaceous matrix, and the arrangement of the pebbles is exceptionally heterogeneous. In the former of these two localities it is especially obvious that the deposit was laid down on a steep and irregular slope and constitutes part of an alluvial fan formed by a torrential stream.

The conglomerate along Malm Gulch in sec. 28, T. 12 N., R. 19 E., is likewise conspicuously heterogeneous and includes many large boulders (pl. 4, *B*). Some of the conglomerate beds have evidently been derived from distant sources. For example, that on the ridge crest in sec. 30, T. 11 N., R. 19 E., consists largely of rounded pebbles of several granitic rocks, although the nearest exposures of granitic rock are about 11 miles to the north, and the most probable source of the pebbles is nearly twice that distance to the west. The pebbles and boulders in the different beds of conglomerate range in diameter from about a quarter of an inch in some of the finer beds in the southeast corner of the region to several feet along Malm Gulch, though most of the pebbles range from 2 inches to 1 foot. The character and distribution of the conglomerate show that most of it was laid down in fairly rapid but for the most part small streams, some of which were subject to torrential flows. The difference between the beds cemented with silica and those in which tuff predominates is mainly in the character of the material available for erosion by the streams that formed them.

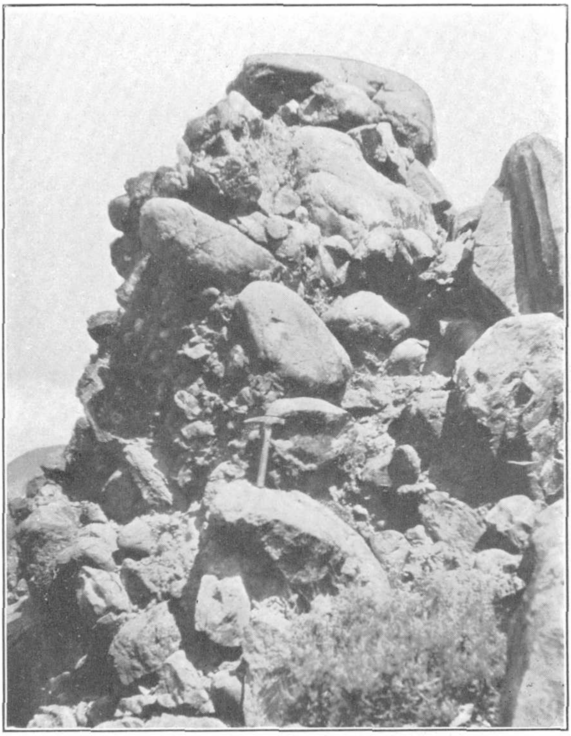
The total visible thickness of the member in Round Valley near Challis exceeds 1,000 feet, and the base is not exposed. In and near T. 11 N., R. 19 E., the tuffaceous deposits fill a basinlike area in which numerous preexisting hills are now being resurrected. This tuffaceous fill must have a maximum thickness of fully 2,000 feet.

In all directions outward from this area the tuffaceous material interleaves with the lava and tends to thin out. In consequence the tuffaceous member is rarely much more than 1,000 feet thick and

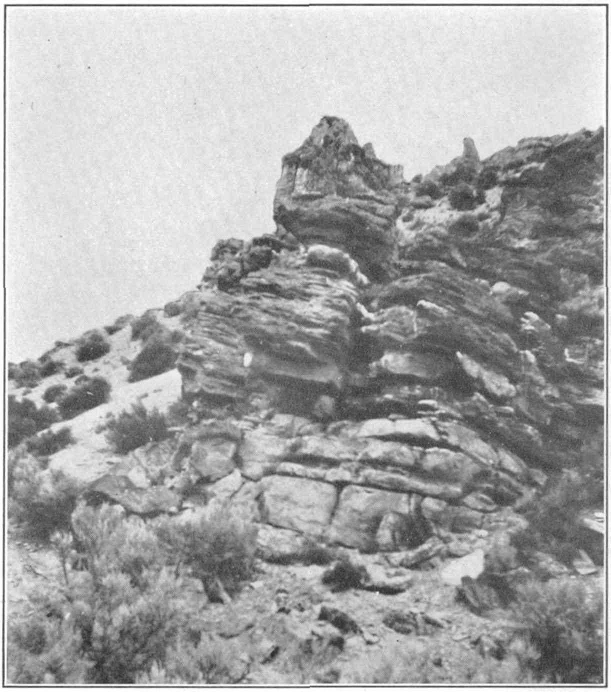


A. POLYGONAL JOINTED ANDESITE IN SEC. 27, T. 13 N., R. 19 E.

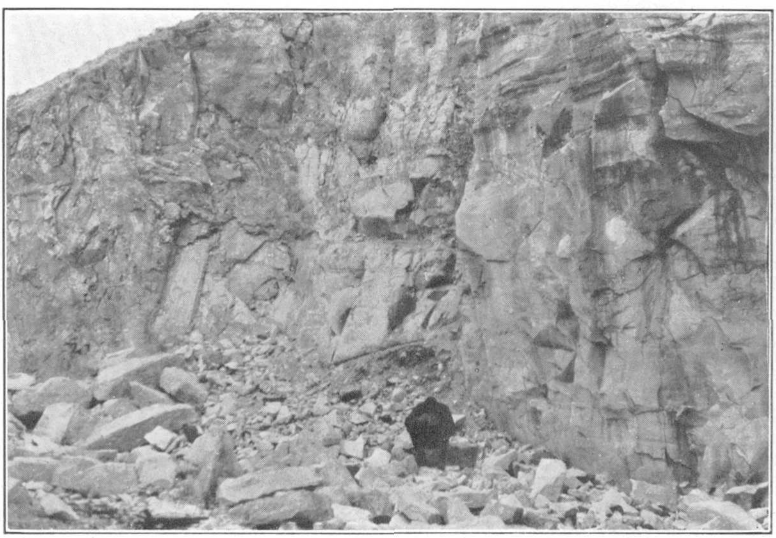
Used as masonry blocks to construct the dam for the small reservoir shown in the foreground.



B. COARSE CONGLOMERATE AT THE BASE OF THE GERMER MEMBER IN MALM GULCH.

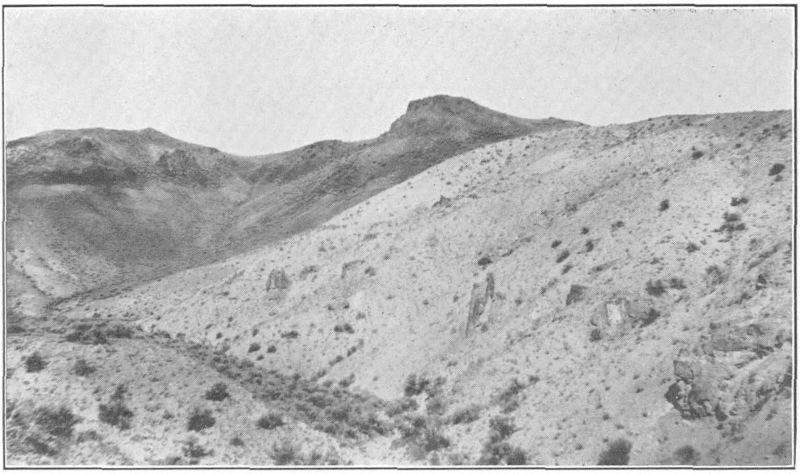


A. DISTINCTLY BEDDED GERMER BEDS ON BIRCH CREEK.

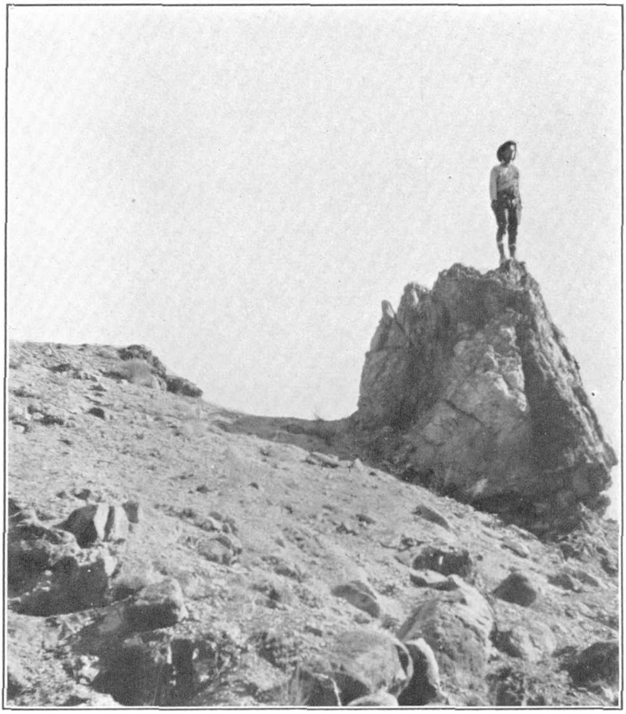


B. GERMER BEDS IN THE QUARRY AT CHALLIS.

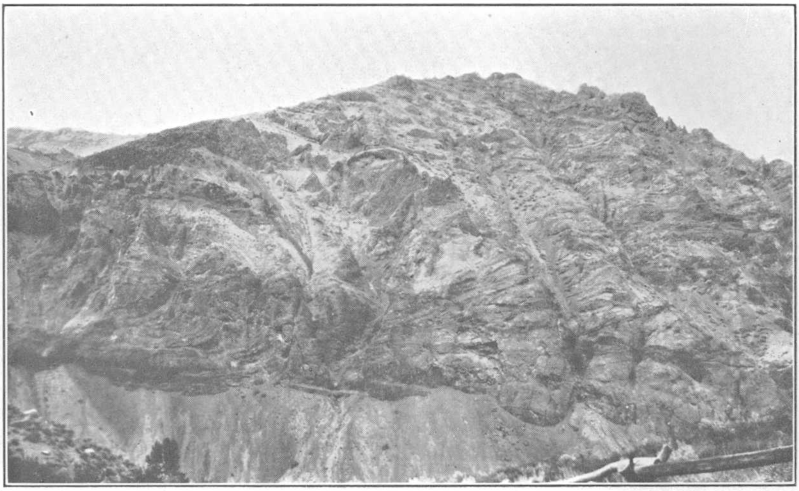
The tuff in the middle part of the quarry face shows almost no indication of bedding.



A. THE "FOSSIL FOREST" ON A FORK OF MALM GULCH.

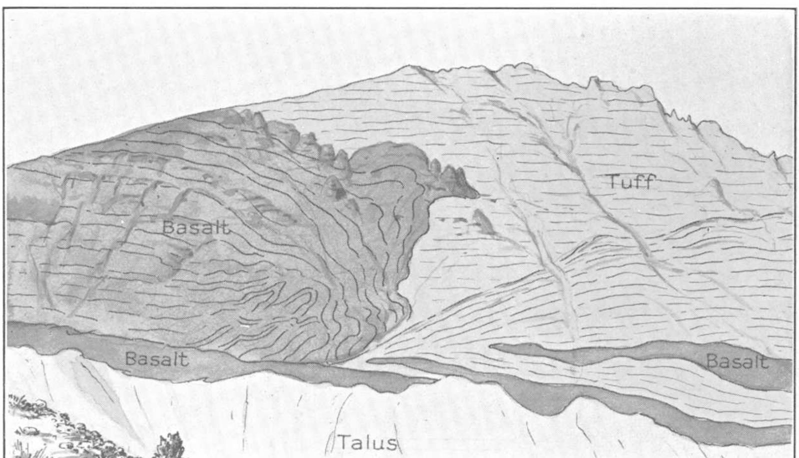


B. THE LARGEST STUMP IN THE "FOSSIL FOREST" WEST OF MALM GULCH.



A. IRREGULAR STRATIFICATION IN GERMER BEDS AND INTERSTRATIFIED BASALT ON THE WEST SIDE OF THE VALLEY OF THE EAST FORK OF THE SALMON RIVER

Crumpling in the basalt is especially evident to the left of the center View taken from the mouth of McDonald Creek.



B. KEY TO VIEW SHOWN IN *A*.

commonly less than 500 feet. In some places, such as much of the northwest quarter of the Bayhorse quadrangle, the member is represented only by detached and lenticular masses that have not been mapped.

Vegetable remains, mostly wood fragments, logs, stumps, and the leaves of trees, are widely distributed at several horizons in the tuffaceous beds. The thin intermittent seams of lignite are mostly too impure to be of value. The best exposures of such remains of ancient forests, particularly of fossilized tree stumps in the position of growth, are in T. 12 N., R. 19 E., especially in and close to the SW¼ sec. 28 (pl. 6, *A*). About half a dozen large stumps and logs are visible in this view, and others are hidden in the gulch. Had not alteration incident to burial so changed the wood as to cause it to resemble in color the rock around it, this area would have much the appearance of a modern woodland thoroughly devastated by a forest fire. Fire may indeed have played a part in the destruction of the ancient forest, but it can have been only an incidental factor.

Nearly all the tree trunks preserved are large, and some of them are giants far outranking any now growing in the region. That pictured in plate 6, *B*, especially, dwarfs the man standing on it and would make the largest trees in neighboring modern forests seem mere saplings by comparison. This stump is still in the position of growth and is considerably more than 10 feet in diameter at the base. Many other sequoia trees also grew here.

Much of the wood scattered widely over the surrounding area was rounded by running water before it was entombed in the ash, which later became rock. Not all the water was in rapid motion, for here and there in the rocks are dark layers that record the former presence of stagnant pools and marshy areas in which vegetable matter accumulated and was preserved as impure lignite. Attempts have been made to mine some of these lignitic layers for use as fuel, but the results have not been encouraging.

The forest was engulfed by ash similar to that in which it grew. Renewed volcanic outbursts covered the country with additional showers of ash. Subsequently the mantle of loose material thus deposited over the surface was in part concentrated in low places by the agency of rain, wind, and streams. Both processes were effective in destroying the forest.

Similar but smaller and more scattered stumps are exposed in secs. 16 and 17, T. 12 N., R. 19 E., and fragments of wood and leaves at many places and at numerous levels in the Germer beds record successive periods of forest growth during pauses in the volcanic eruptions.

The wood has all undergone alteration during its long burial. Infiltrating water carrying mineral matter in solution dissolved much of the organic material and left silica and other substances in its place. This substitution was accomplished so delicately that the woody structure is preserved in minute detail. The grain of the wood and the texture of the bark are almost identical today with those existing when the trees died, several million years ago. This slow process of exchange of mineral for organic matter is not yet complete. Many pieces of wood still contain notable amounts of their original constituents and are so soft that they can be crumpled in the fingers like rotten modern wood.

BASALT AND RELATED FLOWS

DISTRIBUTION

Basalt and locally interbedded calcic andesite are more abundant components of the Challis volcanics in the Bayhorse region than in any other region yet studied in south-central Idaho. Flows of such rock are intercalated in the Germer member almost everywhere that it is exposed. Both in and near T. 13 N., Rs. 20 and 21 E., and in most of the southern half of the Bayhorse quadrangle they thicken greatly and constitute the major component of the formation. With the exception of areas near French and Wickiup Creeks, where it covers much of the surface of the dissected plateau, basalt is exceptional in the part of the Bayhorse region west of 114°30′ west longitude.

CHARACTER

The basalt, which in this region is an unusually abundant component of the Challis volcanics, is commonly nearly black on fresh fracture, but some flows are brown or red. The greater part of most flows is massive and uniform in texture. Phenocrysts are commonly present but are rarely conspicuous. Vesicles are generally small, filled except in weathered outcrops, and absent in large portions of the rock. Veinlets and bunches of coarse calcite are locally common in basalt flows and in nearby Germer beds. Some of the flows associated with the basalt, expecially in the southern part of the Bayhorse quadrangle, are augite andesite, similar to that described above. Locally in this part of the region, however, flows of andesite and latite are intercalated in the basalt. Some of the dense purplish flows of andesitic appearance intercalated in this basalt prove, on microscopic study, to differ little in composition. Most of the basaltic flows are composed essentially of plagioclase and augite. The composition of the plagioclase varies somewhat in different flows, but it is commonly a somewhat sodic labradorite. Phenocrysts make up 5 to 30 but commonly about 20 percent of the rock. They vary in size in different places but are commonly about 1 millimeter and rarely as much as 3 millimeters long. In some flows augite, commonly somewhat altered, is the principal phenocrysts. In others plagioclase is as abundant as the augite or even somewhat more abundant. The plagioclase is zoned and is commonly surrounded by reaction rims. In a few of the flows small amounts of biotite or quartz or both are included in the phenocrysts. The groundmass in all the basaltic flows is composed of tiny plagioclase laths, rarely more than a few hundredths of a millimeter long, set in a nearly opaque red, brown, or black matrix.

As plate 1 shows, there is much variation in the stratigraphic relations of the basaltic flows. Over most of the region such lava is intercalated in the Germer tuffaceous beds and is somewhat more abundant in the upper part of that unit. Under these conditions there are rarely more than two or three flows at a given place. In the southern part of the Bayhorse quadrangle the basalt increases and the tuff decreases more or less proportionately. Such tuffaceous beds as exist here are, for the most part, lower stratigraphically than the basalt, thus preserving the same time relations as farther north. Locally, however, tuff is intercalated high in the basalt sequence. The basalt in places rests on the latite-andesite member, and elsewhere flows of intermediate composition are interbedded with basalt and tuff. Exceptionally, as in the area west of Jerry Peak, such flows cap the basalt.

The basalt flows, especially where interbedded with tuff, have many irregularities in detail. The lava flowed down over eroded slopes and locally filled hollows. In some places where such irregularities interfered with flow the partly congealed lava was rolled up and contorted as a result of pressure from the mass behind. The irregularity of stratification produced in these ways was increased by subsequent ash showers that conformed to the existing topography and in consequence locally assumed relatively steep original dips. The result of these different factors is that in some places the interbedded basalt and tuff look as if they had been greatly deformed by orogenic processes. Some of the best-exposed examples of such pseudo-deformation are found along the East Fork of the Salmon River, as illustrated in plate 7, *A*.

Individual basalt flows range in thickness from a few feet to over 100 feet. There are about 30 flows west of Zeigler Basin, in T. 10 N., R. 18 E., and at least 27 above Taylor Creek east of Bowery Peak. The maximum thickness of basalt in the Taylor Creek area is about 2,300 feet.

YANKEE FORK RHYOLITE MEMBER

DISTRIBUTION AND SUBDIVISION

In the Casto quadrangle the Yankee Fork member of the Challis volcanics constitutes a compact unit in which the proportion of interbedded tuff and other rock differing from the typical rhyolite is so small that it was not distinguished on the map.[44] In the Bayhorse region the tuffaceous beds form relatively a much more prominent and much thicker component of the Challis volcanics than in the Casto quadrangle and consequently are mapped and named separately. Flows corresponding in lithologic character to those in the Yankee Fork rhyolite member in the Casto quadrangle are here interbedded with and overlie tuff in several places, close to the top of the Challis volcanics. Although these rhyolitic flows are thus clearly to be correlated with the Yankee Fork rhyolite member in the Casto quadrangle, the isolation of relatively small masses of the rock, resulting in part from interbedding with tuff and in part from subsequent erosion, have permitted minor variations in character to be distinguished in mapping. Consequently three phases of the Yankee Fork rhyolite member are shown on plate 1. Representatives of all three of these phases exist within the masses of that member originally mapped in the Casto quadrangle. The phases distinguished in the Bayhorse quadrangle are (1) lithoidal rhyolite with smoky-quartz phenocrysts, (2) light lithoidal rhyolite, (3) dark glassy rhyolite. Discrimination in mapping was based entirely on petrographic character. In detail the stratigraphic relations of the flows belonging to the different phases vary in different localities.

The porphyritic lithoidal phase of the Yankee Fork rhyolite member is conspicuous on both sides of Round Valley near Challis and on the southwest rim of Little Bradshaw Basin. It occurs also in smaller masses in and near Sand Hollow and Joe Jump Basin and north of Jimmy Smith Lake. The light lithoidal phase is confined to Joe Jump Basin and to Railroad Ridge and other crests to the north, mainly in T. 10 N., R. 17 E. The dark glassy phase caps the Summit Rock ridge in the northwest corner of the Bayhorse quadrangle and also appears in unsurveyed sec. 6, T. 14 N., R. 20 E.

The crest of Railroad Ridge east of the mass of early Pleistocene glacial detritus and west of the boundary of the Custer quadrangle is composed mainly of rhyolitic flows of somewhat different appearance from any of the Yankee Fork flows. These are grouped with the latite-andesite member on plate 1 but might be separately mapped if desired. In other places, such as the vicinity of Jerry Peak, flows of rhyolitic composition are associated with the more calcic flows characteristic of the latite-andesite member.

Many of the individual Yankee Fork flows in this region, particularly those near Spar Canyon, are only about 25 feet thick and are necessarily somewhat exaggerated on plate 1. The mass west of Little Bradshaw Basin comprises several flows and is more than 100 feet thick. The Yankee Fork immediately north of Challis has a

[44] Ross, C. P., Geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, pl. 1, 1935.

maximum thickness of somewhat more than 300 feet, and some of the individual flows are fully 50 feet thick.

CHARACTER

Lithoidal rhyolite with smoky-quartz phenocrysts.—All the flows here included in the Yankee Fork rhyolite member are similar in composition, and all originally consolidated with a large amount of glass in the groundmass. The variety characterized by abundant phenocrysts of smoky quartz and a groundmass of stony rather than glassy appearance is here, as in the Casto quadrangle, the most abundant, the most widespread, and the most typical phase of the member. The other phases distinguished are merely variations of this type.

Some beds of the stony-textured rhyolite with smoky-quartz phenocrysts are nearly white, some bluish gray, and most have different shades of rather dark brown and red. Essentially all of the rock belonging to the stony-textured phase, however, has a distinctive tinge of violet. Weathering tends to lighten the color of the rock, but only intensely bleached material loses its violet tinge. The rock is studded with rounded quartz phenocrysts that, except where much weathered, are dull purplish black. Most of these are about a millimeter in diameter, but a considerable number are 2.5 millimeters or even more. In addition there are phenocrysts of glistening feldspar of about the same size. These are for the most part sodic oligoclase, but there are sporadic phenocrysts of feldspar that appear to be orthoclase, clouded with alteration products.

The phenocrysts commonly make up 25 percent or more of the rock, with the quartz distinctly more abundant than the feldspar. The groundmass was probably originally glass, as shown by its wavy flow lines and local spherulitic texture, but it is now recrystallized into an aggregate of quartz and feldspar, probably in large part orthoclase, in which the grains are commonly less than 0.02 millimeter in width.

Light-colored lithoidal rhyolite.—The other phase of the rhyolite that has a stony or lithoidal appearance is prevailingly lighter-colored and locally more brecciated than that just described. The quartz phenocrysts are not so smoky and are less conspicuous and relatively less abundant than in the other variety. Also the groundmass, as viewed under the microscope, although now devitrified, shows an abundance of exceedingly irregular flow lines and local spherulitic forms. On and near Railroad Ridge, in the Custer quadrangle, immediately west of one of the largest masses of this phase of the Yankee Fork mapped in the Bayhorse quadrangle, there are dark-colored rhyolitic flows in which spherulitic growths are so abundant and so coarse that they are conspicuous on inspection with the unaided eye. These flows are doubtless comparable to the spherulitic flows that were grouped with the undifferentiated Challis volcanics rather than with the Yankee Fork rhyolite member in the mapping of the Casto quadrangle,[45] to the north.

In the lithoidal rhyolite without smoky quartz many of the phenocrysts are less than 0.5 millimeter long, although some are as much as 2 millimeters. Many of the feldspar phenocrysts are irregular and merge into the groundmass. The phenocrysts constitute less than 10 percent of the rock. About half of them are quartz, and the rest are sodic oligoclase and orthoclase in about equal numbers. The fine devitrified groundmass is composed essentially of quartz and feldspar, but few grains are sufficiently large or well defined for accurate determination.

Dark glassy rhyolite.—The dark glassy phase of the rhyolite differs considerably in appearance from any previously described but is essentially similar to many of the beds included in the Yankee Fork member in the Casto quadrangle. Although such dark beds are less abundant along the upper reaches of the Yankee Fork than they are near Meyers Cove, it seems certain that the dark beds capping the ridge above Mill Creek, in the northwest corner of the Bayhorse quadrangle, represent the attenuated extension of the more abundant beds of the Yankee Fork member in its type locality.

Much of the dark rhyolite near Mill Creek and the similar flow east of Round Valley is nearly black rock with a distinctly glassy texture and luster and with abundant white-feldspar phenocrysts and smoky-quartz phenocrysts that are inconspicuous against the dark groundmass. Some of the groundmass is mottled with areas of pink feldspar. The proportion of phenocrysts ranges from almost nothing to nearly 25 percent of the whole. They range in maximum dimensions from less than 0.5 millimeter to more than 2 millimeters. Most of them are oligoclase, but there are some flakes of biotite and in places small rounded crystals of quartz. The groundmass is glass, mottled with small areas of incipient crystals and uniformly speckled with black dust.

A sample of the nearly black variety of this rhyolite from an exposure near Mill Creek was partly analyzed by George Steiger, of the United States Geological Survey, and found to contain 70.52 percent of silica (SiO_2), 1.07 percent of lime (CaO), 3.48 percent of soda (Na_2O), and 4.90 percent of potash (K_2O).

TRAVERTINE

DISTRIBUTION

Travertine covers parts of secs. 26, 27, 34, and 35, T. 13 N., R. 19 E. A much smaller mass crops out in sec. 25, T. 12 N., R. 18 E., and another near the present streamway in Spar Canyon in and west of sec. 6, T. 10 N., R. 19 E. This last-mentioned mass was formerly

[45] Ross, C. P., Geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, p. 47, 1935.

quarried for flux for the Clayton smelter. The large mass is clearly a component of the Challis volcanics. The others may be related to hot-spring action that persisted long after deposition of the Challis volcanics ceased. In some other places, notably at the springs in sec. 10, T. 12 N., R. 20 E., which discharge copious amounts of lukewarm water, recent films of calcareous matter coat the neighboring rocks.

CHARACTER

The main mass of travertine rests in part on the Laketown dolomite and in part on beds of the Challis volcanics of several different kinds. Fragments of each are included in the basal travertine beds. On the margins the travertine locally appears to be interbedded with and overlain by tuff. It is commonly yellowish white, though much of the material has a brownish stain. Most of the travertine is distinctly but somewhat irregularly bedded. The average attitude of this part is nearly horizontal, but some, especially near the west end, is distinctly inclined. Locally blocks are steeply tilted, presumably as a result of collapse occasioned by solution. Some of the travertine is a jumbled mass, in part banded but without definite bedding. All has in varying degree irregular cellular and concentric texture and numerous cavities and incrustations. Some of the more irregular finer banding doubtless resulted from successive coatings of the carbonate precipitated from films of water, but the beds several inches to over a foot in thickness, mostly horizontal, which make up the greater part of the deposit, suggest sedimentation in a lake, especially as the relations to underlying and bordering rocks, where they are not eroded away, show that the travertine formed in at least a partly enclosed basin.

As is shown by the two analyses listed below, the travertine is high in calcium carbonate and suitable in composition for lime or cement making, sugar refining, and similar purposes. The firmer and more massive parts would also serve for use as ornamental stone. It covers nearly a square mile, and much of it is more than 100 feet thick. The situation of the deposit is such that it could easily be quarried and shipped by trucks, if a suitable market were available.

Analyses of travertine from sec. 27, T. 13 N., R. 19 E.

[J. G. Fairchild, analyst]

	1	2		1	2
Lime (CaO)	52.90	51.78	Soluble silica (SiO_2)	0.05	Undet.
Magnesia (MgO)	1.43	1.63	Insoluble (dried at 118° C.)	2.18	2.47
Carbon dioxide (CO_2)	43.31	43.24			
Iron and aluminum oxides [(Al, Fe)$_2$O$_3$]	0	0	Total	99.99	99.12
			Calcium carbonate ($CaCO_3$)	94.99	92.99
Sulphur trioxide (SO_3)	.12	Undet.	Magnesium carbonate ($MgCO_3$)	2.18	2.23

Approximate analyses of insoluble constituents

[L. T. Richardson and J. G. Fairchild, analysts]

	1	2		1	2
Silica (SiO_2)	67	60	Calcium and magnesium oxides (CaO, MgO)	3(?)	0
Alumina (Al_2O_3)	9	11	Water and organic matter	10	23
Ferric oxide (Fe_2O_3)	6	3	Total	100	100
Alkalies (Na_2O+K_2O)	5	1			

NOTE.—The insoluble matter is in part clay containing less than 5 percent of organic matter.

The isolated mass in sec. 25, T. 12 N., R. 18 E., crops out over an area fully 500 feet long. It is in part covered on the margins with tuff, but the upper parts of the travertine, which have a much fresher appearance, conform roughly to the present surface of the ground, as if deposited by a comparatively modern spring. This material is honeycombed and channeled by the lukewarm water of a spring that issues on the slope a short distance above.

The third small mass of travertine is in Spar Canyon, and part of it floors a section of the modern channel about 600 feet long along which spring water flows. Similar material rests on tuff and Laketown dolomite well above the present spring outlet. All the material in this locality is porous banded calcareous tufa. The banding conforms to the surfaces on which precipitation took place.

It is probable that part or all of the tufa here and perhaps also in sec. 25, T. 12 N., R. 18 E., was formed by spring water since essentially the present topography came into existence, and hence it is much later than the Challis volcanics. These deposits resemble those in the valleys of Elkhorn, Milligen, and other creeks in the Hailey quadrangle.[46]

HOT SPRINGS

Hot springs similar to those which must have, at least in part, deposited the travertine above described are still active in the region, although very little solid matter is now being precipitated from them. The principal springs of this kind are the Beardsley Springs, near the southeast corner of sec. 23, T. 14 N., R. 19 E., on the east side of Round Valley; those for which the eastern Warm Spring Creek is named, which are in and near sec. 18, T. 12 N., R. 20 E., a short distance north of Grand View Canyon; the Sullivan Hot Spring, west of Clayton, in sec. 27, T. 11 N., R. 17 E.; the springs at Robinson Bar, at the mouth of the western Warm Spring Creek; and a group about a mile west of Sunbeam Dam, at the mouth of the Yankee Fork. At each except the second and last of these there is a resort hotel and swimming pool. At the first two the bleached rock with thin white coatings, mainly calcite, indicates that formerly warm water issued at more numerous and higher orifices than now. At both of these

[46] Umpleby, J. B., Westgate, L. G., and Ross, C. P., Geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814, p. 117, 1930.

localities the rocks are disturbed, and recent faulting may have occurred. The three analyses below illustrate the character of the water. The samples were all collected in the summer of 1925 by the writer.

Analyses of hot-spring water

[C. S. Howard, analyst. Parts per million]

	Beardsley Hot Springs	Robinson Bar	1 mile above Sunbeam Dam
Silica	30	87	84
Iron	.07	.05	.08
Calcium	48	3.0	3.6
Magnesium	10	.4	.7
Sodium and potassium	162	65	79
Carbonate	0	41	40
Bicarbonate	436	28	44
Sulphate	128	49	51
Chlorine	21	6.0	12
Nitrate	Tr.	Tr.	Tr.
Hardness (calculated)	161	9.1	12
Total solids	611	296	320

AGE OF THE CHALLIS VOLCANICS

It is clear that the Challis volcanics are much younger than the Idaho batholith and are older than the earliest Pleistocene glaciation in this region. Hence they are undoubtedly of Tertiary age. Closer dating depends on the interpretation of the fragmentary fossil record in the Germer beds, in the upper part of the formation.

Remains of plants, invertebrates, fish, and insects have been found in the Germer member at numerous localities in the Bayhorse quadrangle and in similar beds near Salmon and along the Lemhi Valley. The principal collections came from the west-central part of T. 12 N., R. 19 E., in the Bayhorse quadrangle; the G. W. Oliver coal mine, 3 miles west of Salmon; the Philip Rand house, in Salmon; and a place near the electric-power plant on the Lemhi River close to Salmon. R. W. Brown, of the United States Geological Survey, who collected much of the material, has made the identifications of plant remains listed below.

Bayhorse quadrangle:
- Equisetum sp.
- Pinus sp.
- Sequoia langsdorfii (Brongniart) Heer.
- Alnus carpinoides Lesquereux.
- Quercus sp.
- Ficus densifolia Knowlton.
- Hicoria antiquora (Newberry) Knowlton.
- Juglans sp.
- Salix sp.

Vicinity of Salmon: [47]

Osmunda sp.
Pteris silvicola C. C. Hall.
Sequoia langsdorfii (Brongniart) Heer.
Glyptostrobus sp.?
Typha lesquereuxi Cockerell.
Grass?
Salix californica Lesquereux.
Alnus carpinoides Lesquereux.
Alnus hollandiana Jennings.
Betula multinervis Jennings.
Banksia saffordi (Lesquereux) Berry.
Laurus similis Knowlton.
Umbellularia dayana (Knowlton) Berry.
Philadelphus bendirei (Knowlton) Chaney.
Amelanchier dignatus (Knowlton) Brown.
Chamaebatia prefoliolosa Brown.
Malus idahoensis Brown.
Acer osmonti Knowlton.
Ceanothus idahoensis Brown.
Rhamnus idahoensis Brown.
Cercidiphyllum crenatum (Unger) Brown.
Arctostaphylos cuneata Brown.
Fraxinus denticulata Heer.
Symphoricarpus salmonensis Brown.
Potentilla salmonensis Brown.

Brown interprets the fossil-plant evidence as follows:

The list of species from the Germer member in the Bayhorse quadrangle includes both fossil wood and leaves. The wood represents *Pinus* sp. and *Sequoia* sp. The latter was probably the tree that produced the *Sequoia langsdorfii* leaves. The leaves are more or less fragmentary, so for some a generic determination alone seems possible. *Ficus densifolia* is apparently identical with the original species described by Knowlton from the early Tertiary of the Yellowstone Park. *Hicoria antiquora* is a widespread early Tertiary species. *Alnus carpinoides* ranges into the Miocene. The general aspect of this collection indicates a probable upper Oligocene or lower Miocene age.

The collections from the vicinity of Salmon include 22 recognizable species. Of the recognizable species, 9 are new, leaving 13 on which to base arguments for correlation with other floras. It is apparent from an inspection of the complete list that the flora which these species represent lived within or at least in the neighborhood of a redwood forest. The plant-fossil records of Idaho reveal no redwood remains later than upper Miocene time. The present collection, therefore, must fall somewhere in the Tertiary prior to that limit. In brief, the evidence shows that the Salmon flora was intimately related to the Bridge Creek, Mascall, Payette, and Latah floras and to one 1½ miles northwest of Missoula, Mont., but it seems to resemble most closely, in number of identical species and in general ecologic aspect, the Bridge Creek and Missoula floras. Both these floras were originally assigned to the Oligocene, but the most recent opinion among paleontologists shifts them to the lower Miocene. The conclusion therefore seems warranted that the Salmon flora was a Miocene flora and probably occupied a chronologic position between the flora of Bridge Creek (upper Oligocene or lower Miocene) and the Latah flora (middle or upper Miocene).

[47] For descriptions of species credited to Brown in this list see Brown, R. W., Miocene leaves, fruits, and seeds from Idaho, Oregon, and Washington: Jour. Paleontology, vol. 9, no. 7, pp. 572–587, 1935.

Ashlee [48] has determined plants from tuff in the Thunder Mountain district, Valley County, as Oligocene. These tuffs are near the top of the local section of the Challis volcanics and are nearly analogous in position and character to the Germer tuffaceous beds in the Bayhorse quadrangle.

Brown's remarks indicate that the beds in both localities visited by him are older than the Latah and that those in the Bayhorse quadrangle may be somewhat older than those near Salmon. There still remains doubt as to the exact position in the geologic column of the beds in both localities. So far as the relations between the Challis volcanics and representatives of the Columbia River basalt have been determined they indicate that the Challis volcanics are the older. This accords with the paleobotanic data. The numerous time-consuming events believed to have taken place in south-central Idaho since the deposition of the Challis volcanics lead to the inference that that formation is old, possibly pre-Miocene.

The beds on Bridge Creek, Oreg., referred to by Brown, were first regarded as upper Eocene by Knowlton [49] and later assigned to the upper Oligocene by Chaney.[50] Jennings,[51] who described the plant remains from the beds near Missoula, referred to by Brown, accepts the concept of Oligocene age, which he says was held by Douglass, who made the collections. It appears to be well established that Douglass [52] was correct in regarding beds in many places in Montana from which he collected vertebrate fossils as of White River (Oligocene) age. One such locality is north of Dillon, about 60 miles east of Salmon.[53] Unfortunately no vertebrate fossils appear to have been described from the plant locality near Missoula, and the age of the beds there is thus left in doubt, especially as Miocene beds are known to exist in the general region. Chaney [54] has recently remarked, with reference to the Bridge Creek flora and that near Missoula: "It seems possible that both of these floras may be more accurately referred to the lower Miocene." Consideration of all aspects of the problem leads the writer to the opinion that the

[48] Carpenter, J. T., A tentative correlation of northwestern Tertiary strata: Northwest Sci., vol. 6, p. 59, June 1932.

[49] Knowlton, F. H., Fossil flora of the John Day Basin, Oreg.: U. S. Geol. Survey Bull. 204, pp. 103-105, 1902.

[50] Chaney, R. W., Geology and paleontology of the Crooked River Basin, with special reference to the Bridge Creek flora: Carnegie Inst. Washington Pub. 346, pp. 93-97, 1927.

[51] Jennings, O. E., Fossil plants from the beds of volcanic ash near Missoula, western Montana: Carnegie Mus. Mem., vol. 8, pp. 385-450, 1920.

[52] Douglass, Earl, The Neocene lake beds of western Montana and descriptions of some new vertebrates from the Loup Fork [thesis, Univ. Montana], 27 pp., 1899; Fossil Mammalia of the White River beds of Montana: Am. Philos. Soc. Trans., new ser., vol. 20, pp. 237-279, 1902; New vertebrates from the Montana Tertiary: Carnegie Mus. Annals, vol. 2, pp. 145-199, 1903; The Tertiary of Montana: Carnegie Mus. Mem., vol. 2, pp. 203-224, 1905; A geological reconnaissance in North Dakota, Montana, and Idaho: Carnegie Mus. Annals, vol. 5, pp. 271-288, 1909.

[53] Douglass, Earl, Some Oligocene lizards: Carnegie Mus. Annals, vol. 4, pp. 278-285, 1908.

[54] Chaney, R. W., The Goshen flora of west-central Oregon: Carnegie Inst. Washington Pub. 439, p. 61, 1933.

Challis volcanics are possibly, if not probably, of Oligocene age and that they can hardly be younger than early Miocene.

TERTIARY INTRUSIVE ROCKS

INTRUSIVE BASALT AND AUGITE ANDESITE

Small dikes and sills of basalt and augite andesite that cut the Challis volcanics in many places in the Bayhorse quadrangle are so nearly identical with the flows of such rocks that further description seems unnecessary. (See pp. 58–59.) Basaltic intrusions are especially abundant in T. 12 N., R. 19 E., although several crop out elsewhere. Most of the dikes mapped near the southern border of the Bayhorse quadrangle are augite andesite, although some are basalt, and there are probably some more silicic dikes in this part of the region.

BIOTITE ANDESITE DIKES

Several relatively persistent andesite dikes cut the quartz monzonite in the southern part of the White Cloud Peaks, in the Custer quadrangle. The principal phenocrysts are zoned plagioclase of the average composition of andesine, nearly 4 millimeters in maximum length, smaller and less abundant plates of fresh biotite, and a few prisms of intensely altered hornblende set in a groundmass of andesine that is in part granular and in part lath-shaped. Some laths are more than 0.1 millimeter long, but most of the grains are smaller than this.

AUGITE SYENITE

Irregular, in part sill-like masses of augite syenite cut the Germer beds in T. 11 N., Rs. 19 and 20 E. These are the largest and coarsest-grained of the intrusions in or apparently related to the Challis volcanics in the Bayhorse region.

The rock is faintly pinkish and liberally sprinkled with augite needles that tend to have a radial arrangement. About 80 percent of the rock is composed of sanidine clouded with alteration products; somewhat less than 15 percent is augite; and the other essential constituent is biotite. Calcite, chlorite, apatite, and serpentine are present in small amounts. The feldspar is in irregular grains rarely more than a millimeter long and about half as wide. Some of the narrow prisms are more than 2 millimeters long. Many of the biotite plates are nearly 2.5 millimeters long.

AGE OF TERTIARY INTRUSIVES

The basic dikes all cut the Challis volcanics and are obviously related to the flows of similar composition. Consequently, they must be of the same age as the Challis volcanics. The biotite andesite dikes do not show such direct association with the formation, but they are alined in approximate accord with a major fault that displaces some of the lava flows. This fact and the textural characteristics of the dikes show that they are more closely related to the Challis volcanics than to any of the older rocks, although probably intruded later than at least the greater part of the volcanic sequence.

The augite syenite is obviously at least as young as the Germer beds it cuts but is of different composition and coarser grain than any of the flows or other intrusions of Challis age in the region. No augite syenite is known elsewhere in this part of Idaho. The rock may be regarded as of Challis age or somewhat later.

QUATERNARY DEPOSITS

Partly and completely unconsolidated clastic deposits regarded as of Pleistocene and later age are plentiful in the Bayhorse region. The order of events that led to the deposition of these glacial and alluvial deposits was not everywhere identical, and the extent to which later events have obscured the record of earlier ones varies in different parts of the region. The deposits have been subdivided in mapping on the basis of their relations to the local topography, degree of consolidation, and character of material, listed in order of decreasing emphasis. Necessarily, on such a basis, precise equivalency cannot be established for all the deposits in a given subdivision. The origin and age of the different units are discussed on pages 91–99.

Early Pleistocene (Nebraskan?) deposits related to glaciation have already been reported from this region,[55] and the present study has served to increase somewhat the known extent of such deposits, which constitute one of the most definite and most easily delimited units of the Quaternary.

In numerous places there are gravel deposits, locally widespread and thick, which are obviously relatively old. These are grouped as the "older alluvium." There is less uniformity in age and origin in this group than in any of the others. It includes all the clastic deposits distinct from and for the most part younger than the early Pleistocene glacial deposits and, on the other hand, older than the alluvium bordering and closely associated with the present streams. The Wisconsin glacial deposits, most of which have been so reworked as to destroy their original form, are included with the older alluvium.

The unconsolidated and for the most part undissected alluvium bordering the present streamways is grouped as "younger alluvium." All the streams have flood plains floored by loose material subject to continual rearrangement. Commonly such material constitutes a narrow band which, along the perennial streams, is mostly covered with water. Hence distinction on plate 1 is impracticable. In Round Valley, however, there is a broad expanse of silt, sand, and gravel,

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[55] Ross, C. P., Early Pleistocene glaciation in Idaho: U. S. Geol. Survey Prof. Paper 158, pp. 123-128, 1929.

parts of which are annually inundated during floods. This is mapped as flood-plain alluvium.

Landslides and talus rivers are both common in this region and locally attain considerable size. Broken material that has slid more or less as a mass is mapped as landslides. Angular talus which has crept downhill along comparatively restricted courses is mapped as talus rivers. Obviously there are places where the material partakes of the characteristics of both landslide and talus river, and distinction has to be made on the basis of the apparent preponderance of one or the other. Talus that has accumulated without conspicuous creep and minor or incipient slides that are not topographically prominent are not mapped.

EARLY PLEISTOCENE GLACIAL DEPOSITS

Distribution.—The principal masses of material believed to have resulted from glaciation much earlier in the Pleistocene than the Wisconsin stage are on the ridges in the southeastern part of the Custer quadrangle and contiguous parts of the Bayhorse quadrangle between Germania Creek and Silver Rule Creek. Of these the largest and thickest are those crowning Railroad Ridge and the ridge between Boulder and Little Boulder Creeks. Remnants of similar material are mapped on the ridge southwest of The Meadows, on Warm Spring Creek, and on three of the ridges southwest of Chamberlain Creek and east of Washington Peak.

Character.—All these masses are composed of poorly sorted and poorly rounded gravel that ranges from coarse sand to boulders more than 10 feet long. Nearly all the gravel is composed of granitic rock like that in nearby exposures of the Idaho batholith and the stock in the southern part of the White Cloud Peaks. Near the base, fragments of the rock that locally underlies it are incorporated in the gravel, but even here they are subordinate in size and amount to the granitic rock. The material is sufficiently compacted, where undisturbed, to form slopes steeper than would be maintained in loose gravel, but it contains little or no cementing material. Weathering has roughened the surfaces of the granitic boulders sufficiently to destroy or obscure glacial grooves, but most of the boulders are firm and fairly fresh.

OLDER ALLUVIUM

Distribution.—Older alluvium covers large areas in Bradbury and Big and Little Antelope Flats, which together constitute the broad, relatively flat depression southwest of the northern part of the Pahsimeroi Mountains. Such material also forms the higher parts of the floor of the Big Lost River Valley, which crosses the southeast corner of the region here described.

There are numerous remnants of terraces on the steep slopes bordering the Salmon River, but some have little or no alluvium on them, and few have enough to be mapped. Patches of loosely cemented gravel cling to the canyon walls in sec. 32, T. 13 N., R. 19 E. A comparatively large mass lies in and near sec. 14, T. 11 N., R. 18 E. Another small mass rests in the bend of the canyon wall in sec. 20, T. 11 N., R. 17 E. Between this locality and Robinson Bar high-level gravel is conspicuous at intervals.

A high-level gravel-capped terrace borders the south side of the East Fork of the Salmon River in and on both sides of sec. 6, T. 9 N., R. 18 E. Two other terraces at different levels near the mouth of Herd Creek, about 4 miles to the east, are mapped, and several remnants of high-level gravel along the East Fork are too small to be shown on plate 1. The gravel in secs. 4 and 7, T. 9 N., R. 17 E., is terraced and has undoubtedly been sorted by the East Fork but is obviously so closely related to the early Pleistocene glacial deposits that it was mapped with them.

Character.—The deposits grouped as older alluvium differ materially in character and origin. In the flats in the eastern part of the Bayhorse quadrangle they include alluvial fans and valley fill into which the channels containing the younger alluvium have been incised. This material ranges from coarse gravel and boulders, mostly poorly rounded and sorted, to fine silt. Most of it contains a large proportion of gravel composed of the different rocks exposed in the nearby mountains. It is all compacted, and much of it is cemented, at least surficially, by caliche. Where streams have cut into it, steep walls, locally as much as 50 feet high, are maintained.

In Stanley Basin and the lower courses of the tributary valleys the older alluvium is mainly compacted and in places partly cemented coarse gravel, with sand in the interstices and locally intercalated beds of sand. Both gravel and sand are derived mainly from granitic rocks, even where, as on Fourth of July Creek, they are contiguous to other rocks. The area on Fourth of July Creek, one of the few whose boundaries were accurately traced, contains gravel more thoroughly cemented and more intricately dissected than most of the other gravel in the region. It may perhaps be older. The ridge south of the confluence of the Salmon River and Valley Creek is composed of gravel and sand more evenly bedded than most of that exposed in this part of the region. Most of the older gravel along the west side of Stanley Basin is probably of glacial origin, and those masses that lie in the mouths of the tributary valleys are in part moraines, in part outwash material. The lakes here are caused by morainal damming of the streams. The gravel deposits on the west side of Stanley Basin, both those forming the ends of interstream ridges and those in more or less definite moraines in the valleys, have a conspicuously greater cover of soil and vegetation than those on the east side. The shapes of the slopes and such exposures as were seen indicate little cementation.

In the upper reaches of the streams on the southwest side of the White Cloud Peaks and to a less extent on their northeast side there are accumulations of boulders and gravel more abundant and coarser than would be formed by normal erosion in valleys of this size. They are for the most part on the flanking slopes rather than in the valley bottoms, and in numerous places scattered boulders continue almost to the ridge crests. On the lower slopes and in hummocks on the valley flats this material is compacted but not noticeably cemented. It consists largely of cobbles and boulders a foot or more in maximum dimension, with interstitial sand. On the higher slopes the finer gravel and sand have been removed, and the boulders are strewn about. Irrespective of the character of the local bedrock all these deposits are composed dominantly of granitic rock.

YOUNGER ALLUVIUM

Distribution.—Material grouped as younger alluvium borders most of the larger stream channels throughout the region. It is almost or entirely absent along the minor tributaries and in those sections of the major streams that have been incised in narrow gorges.

Character.—These deposits are mainly gravel, sand, and silt of fluviatile origin, varying in coarseness and in the character of the component material in accordance with local conditions. They are somewhat compacted but scarcely cemented except locally and superficially. In the mountains they consist mainly of gravel. In the broader valley flats they include also much silt and sand, in part laid down in bodies of temporarily impounded water.

FLOOD-PLAIN ALLUVIUM

Distribution.—Flood-plain alluvium is mapped only in Round Valley in and near T. 14 N., R. 19 E., but all except the smallest streams are incised into the younger alluvium or bedrock and floored by flood-plain deposits too narrow for representation on plate 1.

Character.—In Round Valley these deposits consist mainly of silt intermixed and interbedded with sand and gravel. The river flows in a gravel-lined channel but in every flood continues to add to the accumulations of silt on each side. In the mountains the narrow flood plains are composed mainly of sand and gravel. In mapping the broader intermontane flats it is impracticable to make distinction between younger alluvium and flood-plain alluvium as the terms are here employed. In the flats west of the Pahsimeroi Mountains relatively little water flows at the surface most of the time, and the shifting channels do not form distinct flood plains. In Stanley Basin the Salmon River is incised into the younger alluvium, and flood-plain deposits are small and local.

STRUCTURE

The Paleozoic rocks of the Bayhorse region have been bent into fanlike and overturned folds and intruded by granitic rock of the Idaho batholith and its outliers. The intrusion and deformation are interrelated. The principal structural feature is a sinuous anticline which, although broken by a thrust fault near Clayton and locally obscured and partly covered by Challis volcanics, appears to continue from a point west of Challis southwestward and southward through the Bayhorse and Custer quadrangles and thence southeastward diagonally across the Hailey quadrangle. There are at least two other anticlines farther east. Within the region here discussed thrust faults have been recognized in several localities but are conspicuously less common than in the Hailey quadrangle, immediately to the south.

The Challis volcanics, which originally covered most of the area, have been flexed and broken by normal faults. The flexures are on the whole gentle, and the faults do not involve great displacement. Deformation and intrusion in these rocks are less intense than in the Casto quadrangle, to the northwest. No evidence has been found suggesting that the Challis volcanics fill structural depressions or that the larger topographic depressions now existing, with the possible exception of that west of the Pahsimeroi Mountains, are outlined by faults or have resulted primarily from faulting. Present irregularities in the distribution and thickness of the Challis volcanics are due largely to inequalities in the relief of the surface on which that formation was laid down.

DEFORMATION IN PALEOZOIC ROCKS

ANTICLINE IN PAHSIMEROI MOUNTAINS

The part of the Pahsimeroi Mountains within the Bayhorse quadrangle is composed mainly of the overturned eastern limb of an anticline in Paleozoic strata, whose axis, as shown in figure 3, lies immediately west of the mountains.

The Devonian rocks in the vicinity of Grand View Canyon constitute the only exposed part of the syncline west of the anticline unless the synclinal structure near Dry Creek in Tps. 10 and 11 N., R. 21 E., is also a part of it. It appears that the strata between Grand View Canyon and the Pahsimeroi Mountains are contorted and closely folded in some such way as is indicated in section 4, plate 1. If the close folding was supplemented by faulting, the evidence of it is obscured by the cover of Tertiary and later deposits. The structural relations of the scattered exposures of Paleozoic beds in and north of T. 13 N., Rs. 20 and 21 E., are not susceptible of interpretation with present data. Faults may exist here, but if so they do not appear to affect the Challis volcanics. The Kinnikinic quartzite in and near sec. 3, T. 13 N., R. 20 E., may be close to the core of the anticline. If so, the trend of the axis is more nearly north than it is in T. 12 N., R. 21 E. The conspicuous fault in and near T. 14 N.,

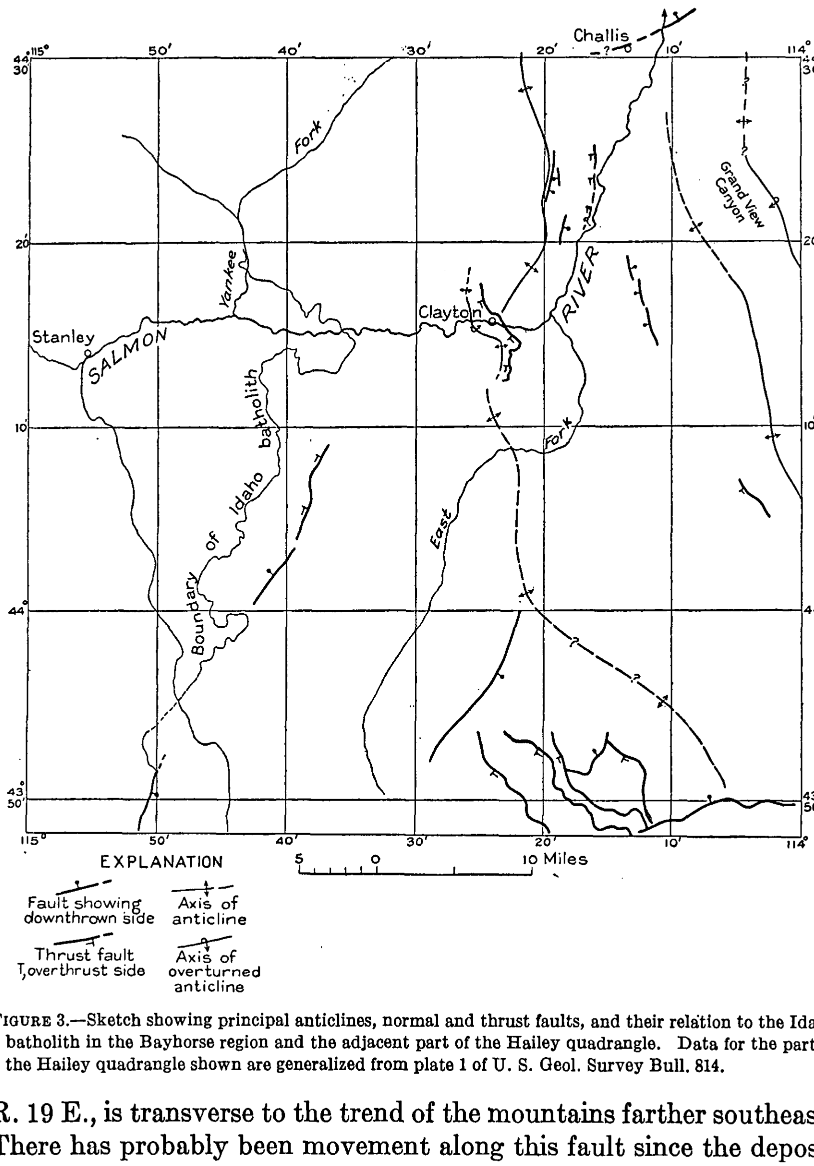

FIGURE 3.—Sketch showing principal anticlines, normal and thrust faults, and their relation to the Idaho batholith in the Bayhorse region and the adjacent part of the Hailey quadrangle. Data for the part of the Hailey quadrangle shown are generalized from plate 1 of U. S. Geol. Survey Bull. 814.

R. 19 E., is transverse to the trend of the mountains farther southeast. There has probably been movement along this fault since the deposition of the Challis volcanics, but the intricate contortion and minor thrust faulting in the Kinnikinic quartzite in the immediate vicinity suggest that the original break occurred during the deformation of the Paleozoic strata.

ANTICLINE NEAR LONE PINE PEAK

The axis of a second anticline is buried under the Tertiary and later beds along the old Challis-Mackay stage road, about as indicated in figure 3. The axis appears to the south near Broken Wagon Creek and continues through the hills surmounted by Anderson Peak. The prolongation of this anticline may lie in the White Knob Mountains, west of Mackay. This fold has been less tightly compressed and pushed upward to a less extent than the one east of it. Sections 4 and 5, plate 1, illustrate its open character. This anticline is broken by a thrust fault of small displacement along Sage Creek in T. 9 N., R. 20 E., and is modified by many crenulations and minor breaks (pl. 3, *A*). The syncline west of the above-described anticline is comparatively narrow and simple in its northern part, where it is fairly well exposed. Its axis passes through unsurveyed sec. 10, T. 12 N., R. 19 E. In T. 11 N., R. 19 E., the eastern part of T. 11 N., R. 18 E., and the southwestern part of T. 12 N., R. 19 E., the structure of the Paleozoic beds is largely concealed under the Challis volcanics, and farther south almost no Paleozoic rocks are exposed within the Bayhorse region. The syncline evidently continues in a general way, but it is complicated by minor anticlines and, at least in the central part of T. 11 N., R. 19 E., by normal faults that have had little if any effect on the overlying Challis beds.

ANTICLINE NEAR BAYHORSE AND CLAYTON

One of the largest and longest of the anticlines in this part of Idaho trends southward past Bayhorse and Clayton. After an interruption by thrusting near Clayton, it appears to continue across the East Fork of the Salmon River and swings southeastward across the Hailey quadrangle.

The northern part of the anticline in the western part of the Bayhorse quadrangle is the best exposed of the major structural units in the region. This part is wider, and as it exposes the oldest known rocks in the region it appears to have been lifted higher by the orogenic forces than any of the anticlines previously described. The fold is comparatively gentle, nearly flat on top, steep to overturned on both sides of the axis, and somewhat less steep farther out on the flanks. The axis of folding is, in general, considerably east of the middle of the anticline. These characteristics are especially well developed and well exposed along Bayhorse, Garden, and Daugherty Creeks in the northern part of the area. The conditions near Daugherty Creek are shown diagrammatically in section 1, plate 1. The anticline here and along Garden Creek is asymmetric, the easterly limb as a whole being distinctly the steeper. However, the resistant Bayhorse dolomite and overlying conglomerate in both limbs are steep and locally overturned. Farther north the anticline plunges sharply to the northwest and within a short distance disappears beneath the cover of Challis volcanics. In secs. 9 and 10, T. 13 N., R. 18 E., there is an outcrop of nearly flat-lying Bayhorse dolomite with a little conglomerate. It is not clear from the small exposures whether those rocks came into this position, so far east of most exposures of similar beds in this locality, through faulting or as part of a sharply overturned fold.

Along Bayhorse Creek farther south the fold has widened and is not quite so asymmetric. Part of its western limb is illustrated in figure 4.

The Ramshorn slate occupies a wide area along upper Bayhorse Creek because of repetition of beds by close folding, contortion, and possibly also local faulting. There is much disturbance in the pyrometamorphosed Ramshorn beds around the granodiorite near Juliette

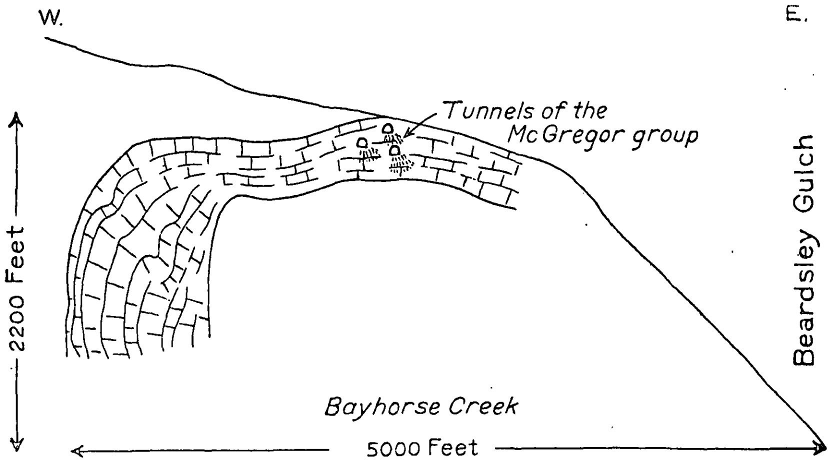

FIGURE 4.—Diagrammatic sketch of folding in the Bayhorse dolomite on the north side of Bayhorse Creek just west of Beardsley Gulch. Adapted from a drawing made from a point high on the south slope of the valley of Bayhorse Creek.

Creek and some tendency for them to conform in strike to the shape of the intrusion.

Farther downstream the east flank of the fold is somewhat more irregularly flexed. Locally, especially on the south side of the creek, it is sharply overturned to the east, and near such places the dolomite is brecciated. On the north side of Bayhorse Creek near Bayhorse there is a single large normal fault with downthrow to the west, but on the south side this has split into two faults dipping toward each other, with a block of Ramshorn slate dropped between them (sec. 2, pl. 1). All three have vertical displacements of fully 1,000 feet and large horizontal shifts.

Cross sections of part of the anticline are exposed also along Rattlesnake and Lyon Creeks. Here, as a result of infolding of Ramshorn slate, possibly aided by minor thrusting, the principal exposure of

Bayhorse dolomite is divided into two parallel bands linked together only along one branch of Lyon Creek. A short distance farther east the Ramshorn slate and Kinnikinic quartzite are separated by a normal fault with downthrow on the east, marked by slickensides and brecciation in the quartzite. The small amount of slate thus left between the quartzite and the Bayhorse dolomite suggests that the displacement on the fault may be large. It is possible that faulting extends farther both north and south than it can be mapped on available evidence. There is evidence of fracturing in the slate on the slope between Sink and Birch Creeks.

From a point west of Centennial Flats to Sink Creek along the east slope of the mountains the dolomite is probably nowhere far below the surface. It emerges through the slate at the Turtle and Mammoth mines, largely because the anticline in this stretch continues to have a steep flank, probably with a tendency to bulge eastward. The crest of the anticline is broader, and, so far as the evidence shows, no part of the western flank is as steep in this section as it is farther north. Along the Salmon River from sec. 6, T. 12 N., R. 19 E., to a point beyond the mouth of the East Fork there is much contortion and both normal and thrust faulting. The extreme crenulation in the resistant Kinnikinic quartzite here is illustrated on plate 8, *B*. The thrust fault in sec. 6, T. 12 N., R. 19 E., has been traced for only a mile but may continue along the river much farther. The anticline is interrupted near Clayton by a zone of thrust faulting that extends along lower Kinnikinic Creek, crosses the Salmon River, and passes around the east side of Potaman Peak. Along this zone Kinnikinic quartzite is bent and shoved over Ramshorn slate. Limestone lenses in the quartzite are intricately deformed and fractured. In the spur of the ridge above the old Ella mine the shattering of the limestone is well displayed, as is shown in figure 5 and plate 9, *B*. Disturbed strata related to the thrust occupy a zone nearly half a mile in horizontal width that includes several interrelated shear planes of irregular but on the whole steep westward dip. The principal planes of movement are shown on plate 1. Farther south the limestone is absent, and only a single plane of thrust can be traced. East and southeast of Potaman Peak a zone of brecciation borders the plane of thrust, which is here gently inclined. This zone consists mainly of a breccia of Kinnikinic quartzite with some intermingled fragments of silicified Ramshorn slate in a siliceous cement. Some of the fragments are large, but most are less than 3 inches in maximum dimension. In a few places slivers of slate override the breccia.

The mass of Kinnikinic quartzite immediately west of the thrust zone is bent into an anticline overturned to the west, as shown in section 3, plate 1. Both thrust and anticline are somewhat curved and tend to wrap around the larger fold that extends northward from

Clayton. It appears that the thrust and the anticline west of it are genetically related and together constitute a local interruption in the continuity of the major anticline. The asymmetry of the anticline above the fault may result in part from a backward canting of the mass as its lower part was dragged forward to the northeast by the thrust. Here, as is so common in the region to the south,[56] thrusting has caused younger rocks to rest on older rocks instead of the more usual reverse arrangement. This is a result of folding prior to thrusting, combined with the accidents of subsequent erosion.

The Paleozoic rocks bordering Squaw Creek are argillaceous in varying degree and hence less resistant than the Kinnikinic quartzite. In general they dip westward and northwestward, forming a continuation of the western flank of the anticline in the quartzite. In detail they are intricately crumpled. There is much close folding, and most of the folds are overturned toward the east. Minor fractures are present, but no faults of any magnitude have been discerned in this part of the region.

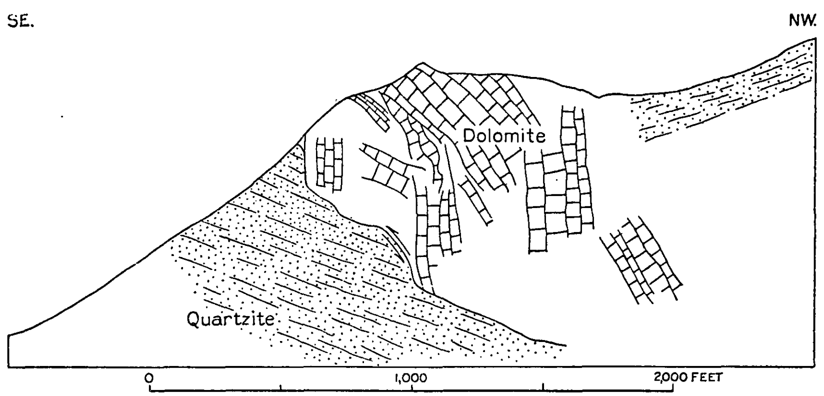

FIGURE 5.—Diagrammatic sketch of exposures on the west side of lower Kinnikinic Creek above the abandoned Ella mine.

South of the Salmon River west of Clayton interpretation of the structure of the Paleozoic rocks is hampered by the widespread cover of Challis volcanics. In a broad way it is evident that the major anticline that is well exposed from T. 13 N., R. 18 E., south to Clayton continues and eventually joins the principal anticline in the Hailey quadrangle.[57] The crest of this anticline appears to pass through the succession of outcrops of Ramshorn slate that extend from a point near Potaman Peak to East Pass Creek on the southern border of the Bayhorse quadrangle. The anticlinal structure is evident in several of these exposures, and as they represent the oldest rocks exposed in this part of the region it is to be expected that they should be in the core of the fold.

[56] Umpleby, J. B., Westgate, L. G., and Ross, C. P., Geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814, pp. 64–66, 1930.

[57] Umpleby, J. B., Westgate, L. G., and Ross, C. P., op. cit., p. 69.

DEFORMATION ALONG THE BORDER OF THE BATHOLITH

Farther west, mostly in the southern part of the Custer quadrangle, there is a belt of intricately deformed and metamorphosed Carboniferous rocks. These beds are closely folded and overturned both eastward and westward but mainly toward the east, as is indicated somewhat diagrammatically in section 6, plate 1. The complexity of the structure is illustrated in detail in plate 9, *A*, and figure 6. As each fold is of small dimensions in comparison with those previously described and none have been forced high enough to permit pre-Carboniferous rocks to be uncovered, it is probable that as a group they are simply crumples on the west flank of the long anti-

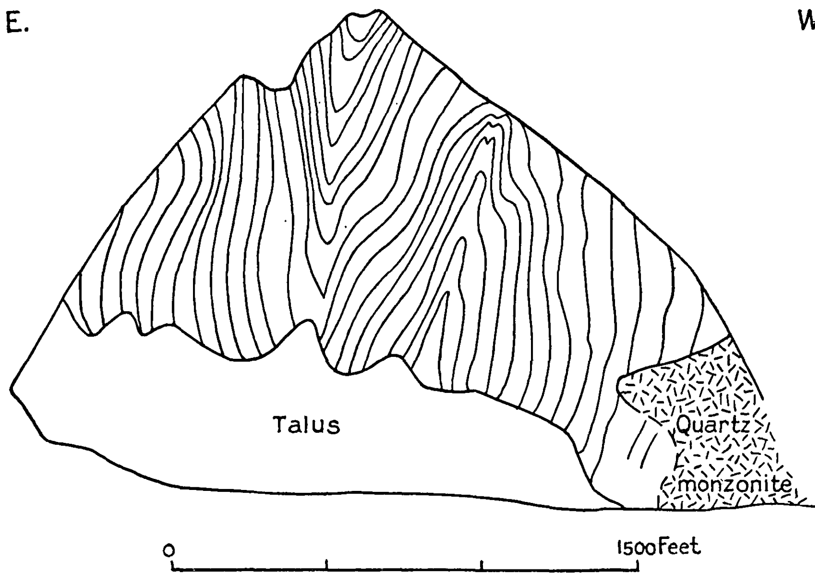

FIGURE 6.—Sketch of contorted Milligen beds on the north face of the mountain north of the peak 10,545 feet above sea level in the north-central part of the White Cloud Peaks.

cline previously described. As can be seen from plate 1, the strike of the beds in these minor folds accords closely with the shape of the nearby border of the Idaho batholith.

A thrust fault extends in essential continuity from upper Livingston Creek past Calkins Lake to a point just north of Blackman Peak. Near its south end several planes of shearing are visible. This fault is essentially parallel to the crumpled belt and, in part at least, resulted from failure along the crest of one of the tightly compressed folds, as is especially well shown in cirque walls from a point opposite Calkins Lake northward. There is a gap of more than 10 miles between the most northerly point at which this thrust has been recognized and the nearest known part of the thrust near Clayton. Much of the intervening distance is covered by Challis volcanics, and the two faults are probably closely related and may even form segments of a single zone of thrusting.

Southwest of the vicinity of Blackman Peak a normal fault continues for almost 5 miles with nearly the same trend as the thrust north of Blackman Peak. The normal fault is marked at short intervals by outcrops showing pronounced shearing and brecciation (pl. 10, *A*). It is nearly vertical, has the downthrow on the northwest, and involves the Challis volcanics. A similar fault, which, however, has the downthrow on the southeast, lies between Beaver and Smiley Creeks in the Vienna district.[58] This fault so closely alines with the one southwest of Blackman Peak as to suggest that both belong to the same zone of weakness. In view of the position of the zone with reference to the thrusts farther north it is possible that the normal faults are a reflection in mid-Tertiary time of fractures initiated during the earlier deformation.

RELATION BETWEEN DEFORMATION AND INTRUSION

The Paleozoic strata of the Bayhorse region were certainly deformed before they were cut by the Idaho batholith and related stocks, but much of the intricate crumpling and fracturing that now characterizes the structure originated during the intrusion and in close relation to it. The crenulations along the eastern margin of the main batholith, such as are illustrated in figure 6, and the tendency to doming around the stock on Juliette Creek seem clearly to be of this nature. The thrust fault that passes near Calkins Lake and Blackman Peak conforms closely to the west border of the stock immediately east of it. Conceivably there is a genetic relation between the thrusting and batholithic intrusion. Clapp [59] has shown that in Montana the granitic masses are closely associated with thrust faults and infers that the magma made way for itself by thrusting its upper confining walls apart. It may be significant in this connection that the thrust and shattered Paleozoic rocks near Clayton are directly opposite an eastward projection in the margin of the Idaho batholith and at a point where the folds in the Paleozoic strata change in trend.

The peculiar anticline with flat top and bulging sides that extends from a point west of Clayton northward past Garden Creek is so differently shaped from most anticlines as to require some special explanation. Such a shape could result if an open arch were further deformed by pressure so applied that the resultant effect was a pinching inward of both flanks, the top being held comparatively unchanged, as is indicated diagrammatically in plate 11. In this plate the sections are drawn so as to represent approximately the present valley of Bayhorse Creek.

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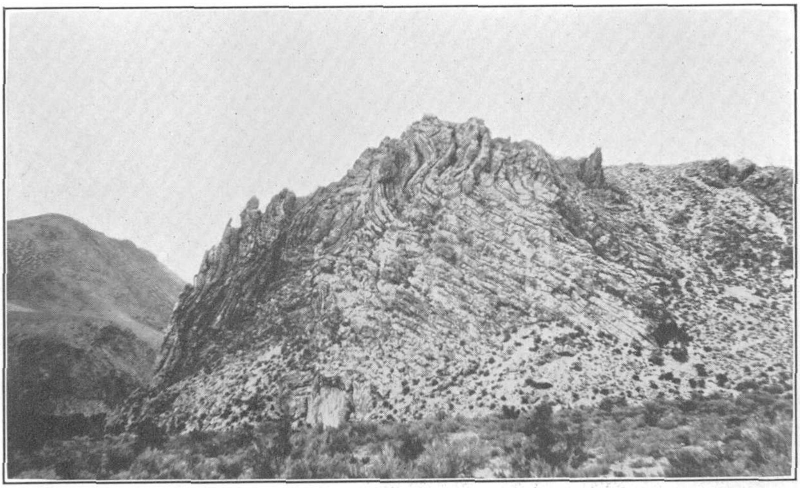
[58] Ross, C. P., The Vienna district, Blaine County, Idaho: Idaho Bur. Mines and Geology Pamph. 21, p. 7, 1927.

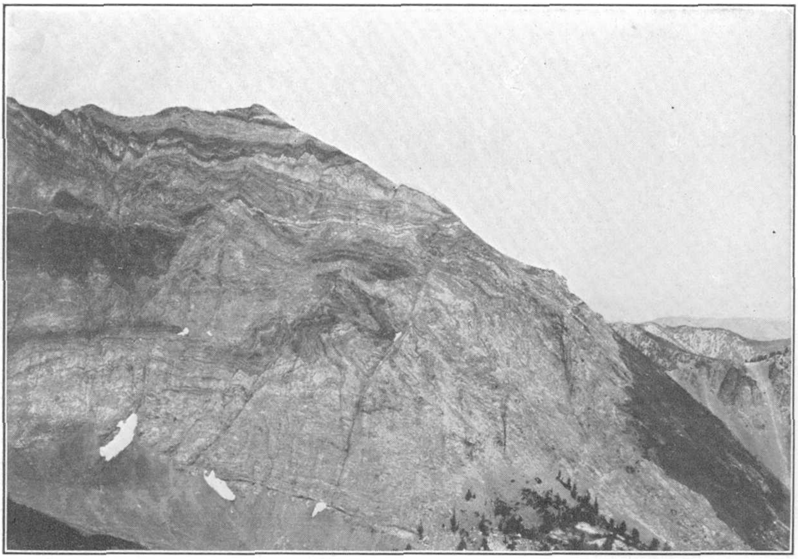
[59] Clapp, C. H., Geology of a portion of the Rocky Mountains of northwestern Montana: Montana Bur. Mines and Geology Mem. 4, pp. 28-30, 1932.

A WEST FLANK OF THE PAHSIMEROI MOUNTAINS.

Looking east from a point a mile southeast of Drake's ranch on Big Antelope Flat. Photograph by T. H. Hite, Jr.

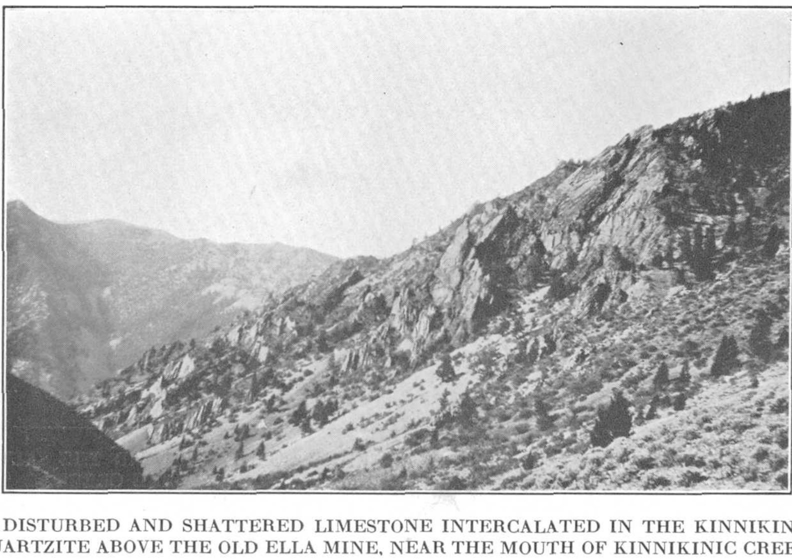


B. CONTORTED AND OVERTURNED KINNIKINIC QUARTZITE NEAR THE SALMON RIVER, NEARLY OPPOSITE THE MOUTH OF RATTLESNAKE CREEK.

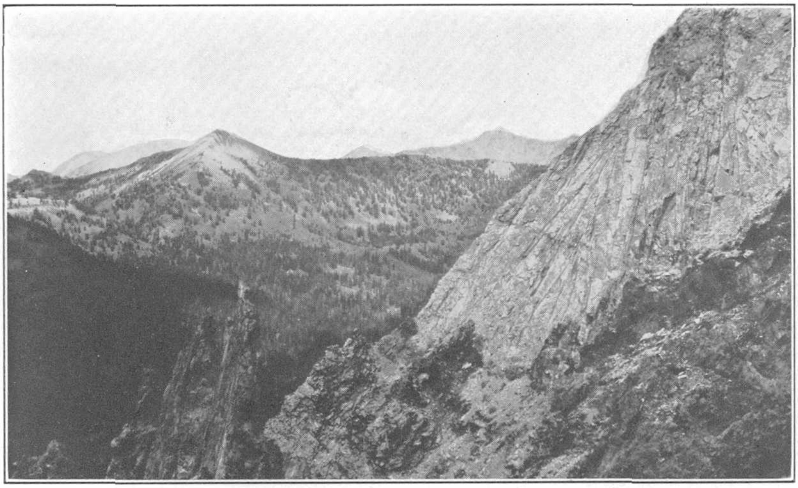


A. THE NORTHWESTERN PART OF THE "CHINESE WALL" AT THE HEAD OF LIVINGSTON CREEK.

Photograph by R. R. Le Clercq.

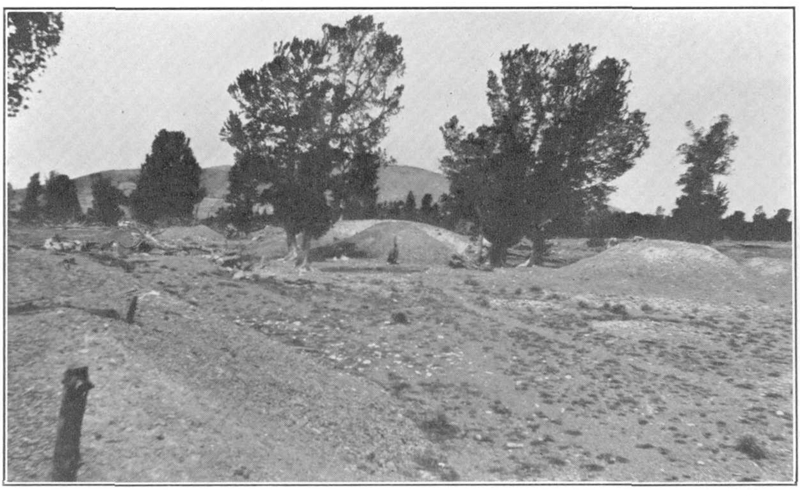


B. DISTURBED AND SHATTERED LIMESTONE INTERCALATED IN THE KINNIKINIC QUARTZITE ABOVE THE OLD ELLA MINE, NEAR THE MOUTH OF KINNIKINIC CREEK.



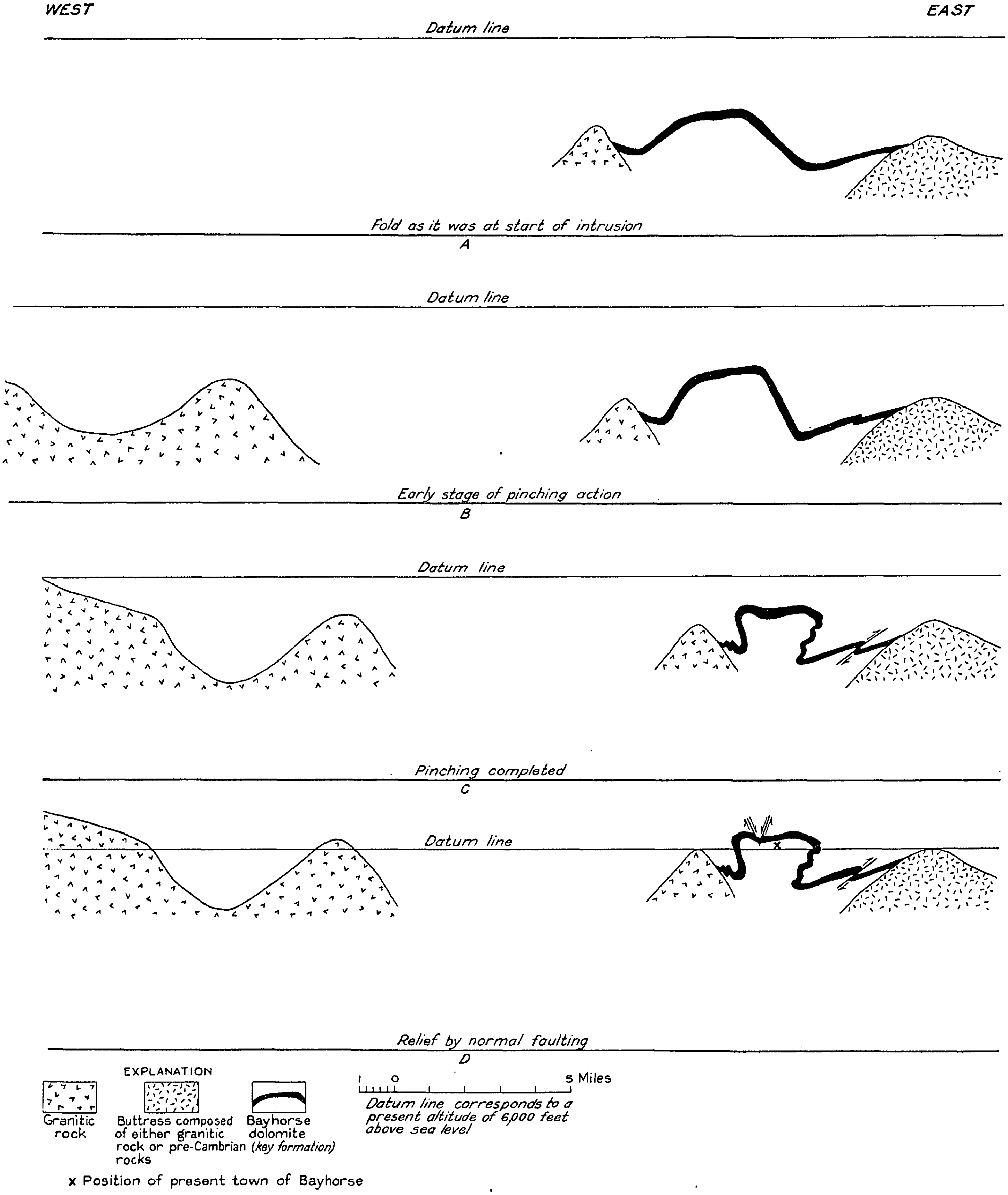
A. SHEETING ALONG FAULT BETWEEN THE CHALLIS VOLCANICS ON THE WEST (LEFT) AND THE WOOD RIVER FORMATION ON THE EAST (RIGHT).

Looking northeast on ridge crest north of the lowest of the Champion Lakes. Photograph by S. S. Philbrick.



B. GENERAL VIEW OF THE SURFACE OF POVERTY FLAT.

The mounds are dumps of the old Silver Bell mine.



DIAGRAMS ILLUSTRATING POSSIBLE MODE OF ORIGIN OF THE ANTICLINE THAT EXTENDS FROM CLAYTON NORTHWARD.

The localized pressure required would be furnished if the arch were caught between an invading body of magma on one side and a buttress of some sort on the other. The intrusion of the Idaho batholith may well have supplied the necessary conditions. As stated above, this large mass appears to have been intruded into previously folded strata with such force as to crumble them. Near the south end of the fold present exposures of the batholith are nearly 10 miles to the west. At the north end the distance is about 18 miles. Much of the intervening country is covered by the Challis volcanics, but two bosses of granitic rock crop out, one of them on Juliette Creek in an area of disturbed and pyrometamorphosed Ramshorn slate on the west flank of the fold. The postulated buttress on the east side of the fold is nowhere exposed, most of this area being blanketed by the Challis volcanics. It might well consist either of an elevation in the floor of pre-Cambrian rocks on which the Paleozoic strata must lie or more stocks of granitic rock intruded into the Paleozoic rock. If, as is common, such outlying stocks had been introduced before the main batholith reached its present level in the earth's crust, their role in the pinching in of the anticline would have been passive. If, on the other hand, they were being intruded at the time of deformation they may have contributed lateral pressure. Such active participation in the pinching process might be especially effective if the stock or stocks east of the arch had the tendency to lateral spreading that many stocks are believed to possess.[60] However, neither the main batholith [61] nor such well-exposed outliers as those in the Wood River region [62] appear to have the requisite shapes.

In plate 11 it is assumed that the eastern buttress, whatever its character, was present prior to the pinching and acted merely as a body sufficiently massive and resistant to be only slightly affected by the thrust exerted by the Idaho batholith. If the mass east of the arch also exerted lateral pressure the pinching effect would be intensified but, other than in details, not greatly changed from that indicated in the diagrams except that the margin of the mass would doubtless have moved westward as the magma rose instead of remaining in the same relative position, as indicated in plate 11.

Under the hypothesis here advanced the forces active during the intrusion of the Idaho batholith shifted the position of the preexisting fold and apparently even turned the fold, so that the axis of the resulting compound structure became roughly parallel to the border of the intrusive mass and hence assumed a trend sharply at variance with the average strike of folds in the Paleozoic strata farther east.

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[60] Chamberlin, R. T., and Link, T. A., The theory of laterally spreading batholiths: Jour. Geology, vol. 35, pp. 319-352, 1927.

[61] Ross, C. P., Mesozoic and Tertiary granitic rocks in Idaho: Jour. Geology, vol. 36, pp. 677-678, 1928.

[62] Umpleby, J. B., Westgate, L. G., and Ross, C. P., Geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814, pp. 43-53, 1930.

The shape of the gently flexed crest of the original arch, however, was modified only in detail. The crest was so situated as to escape the direct thrust of the advancing magma and was supported by the superincumbent strata, which may well have had an aggregate thickness of more than 20,000 feet. Removal of much of this load would permit the relief of stresses remaining along the crest of the anticline and might well result in normal faults such as those mapped on the crest and flank of the anticline.

The intricate deformation on both sides of the existing anticline, in sharp contrast to the gently undulating crest, accords with the probable results of such localized pressure as is required by the hypothesis above outlined. The contortion in the resistant Kinnikinic quartzite (pl. 8, *B*) on the east side of the anticline and the overthrusting in the same formation north of Bayhorse Creek are especially striking.

The fact that the oldest known rocks in the Bayhorse region are exposed only in the core of the peculiar anticline under discussion accords with the compound origin postulated. The strata here were twice folded and were so situated with respect to the batholith that they may well have had a maximum share in the regional uplift associated with its intrusion.

TERTIARY DEFORMATION

The Challis volcanics exhibit numerous local unconformities, especially where soft tuffaceous beds are abundant. In some places the angular discordance between neighboring strata is so sharp as to suggest that it results from deformation of some magnitude. Although it is quite possible that some crustal disturbance took place in the course of the accumulation of this great mass of volcanic material, there is no known evidence that any such movement was sufficient to interrupt deposition over any large area. Where the exposures are such as to give adequate data, it is clear that the local unconformities record merely erosion followed by deposition on the irregular and locally steep surface thus produced. In some places basalt flows thicken and thin and change in attitude from flat to inclinations of 10° and more, all within a single cliff exposure and obviously in response to the irregularities of the surface on which they were poured out. Especially striking examples of such flows are visible in the cliffs bordering the middle reaches of the East Fork of the Salmon River (pl. 7, *A*). Others are exposed in the vicinity of Malm and Bradshaw Gulches. The disconformities between the different andesitic and more silicic flows are less conspicuous and commonly less pronounced than those between basalt and tuff. The differences in attitude in the Challis volcanics are thus in large measure the result of differences in slope of the preceding surface. Slumping and landslides both during and subsequent to the accumulation of the beds have also been effective in producing heterogeneity of attitude. As a consequence, the general relations of the different units composing the formation to one another and to the older rocks are of greater value in studying the effects of deformation than observation of the strike and dip of the strata in individual outcrops.

The Challis flows and pyroclastic materials inundated the preexisting topography and tended to build up a nearly level surface. In a very general way the surface resulting at the end of volcanism may be conceived to have approximated a plain, possibly with a few ridges of older rock rising above it and with local irregularities of several kinds. The attitudes and mutual relations of the existing remnants of the uppermost beds show clearly that there has been deformation subsequent to the volcanism. Locally enough of the upper beds are exposed to permit the structure to be discerned with certainty. In Round Valley, for example, there is a shallow syncline with its western flank somewhat steeper than its eastern flank. Near Challis there are several closely spaced faults of small throw that approximately parallel the axis of the syncline. On the opposite side of the valley a fault that drops Germer beds on the northwest against Kinnikinic quartzite on the southeast is marked by a line of cliffs that have been traced for more than 2 miles. There is so much lateral variation in the Challis beds in this vicinity that the displacement of the fault cannot be directly measured, but it is obviously several hundred feet and may exceed 1,000 feet. The fault is essentially vertical and trends about N. 60° E., transverse to the trend of Round Valley. If it extends across the valley, the fault lies under the alluvium of Garden Creek and probably dies out in the vicinity of Klug Gulch. Such a concept is supported by the decided difference in the character of the volcanic strata on opposite sides of Garden Creek near Challis.

In the Casto quadrangle, immediately north of the region here discussed, there is evidence [63] that the Challis volcanics are flexed into a broad anticline that trends northwestward, is interrupted by large longitudinal faults, and has a Miocene granitic intrusion at its core. Figure 7 illustrates the probable relation between this structure and the deformation of comparable age in the Bayhorse region. All the existing patches of beds at or near the top of the Challis volcanics, as well as the highest parts of the masses of older rock now projecting through the volcanics, were first plotted. With these points as guides, contours were drawn approximately representing the surface of the Challis volcanics as it would have been subsequent to deformation if unmodified by erosion. In much of the eastern

[63] Ross, C. P., Geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, p. 77, 1935.

half of the region the different rhyolite flows and beds whose relations to the rhyolites are approximately known fix the position of the top of the formation with some accuracy. Farther west these key beds are absent.

One factor that must be taken into account is the fact that irregularities in the surface prior to deformation arising from variations

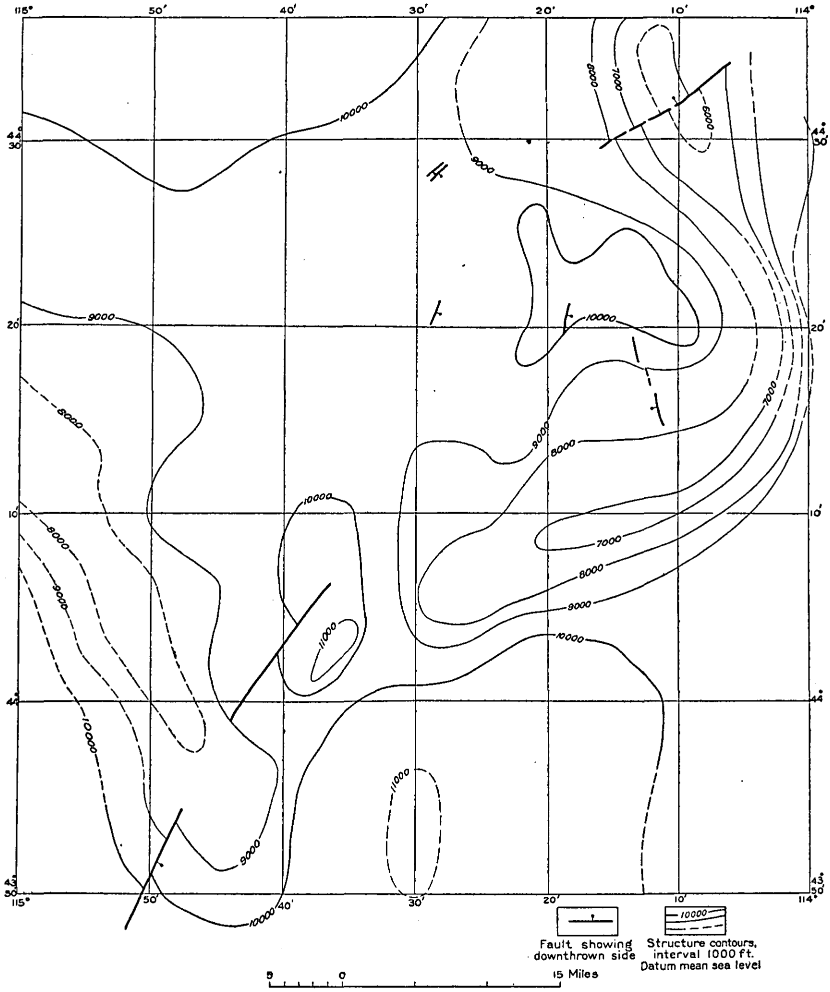

FIGURE 7.—Hypothetical shape of the surface of the Challis volcanics after deformation but without erosion. The effects of the associated erosion are not taken into account.

in deposition of the volcanics are necessarily reflected in the contour lines on figure 7, especially in localities where the Challis volcanics were originally thin.

Low hills in and near sec. 13, T. 12 N., R. 20 E., east of Grand View Canyon, are composed of the Yankee Fork rhyolite member resting in part directly on Jefferson dolomite and elsewhere separated from the dolomite by only a small amount of tuff. The present topographically low position of the upper member of the Challis volcanics is clearly due to the fact that less material was originally deposited here than in most other places.

Inasmuch as no Challis beds are known in or west of the northern part of the Sawtooth Range and remnants of the formation are comparatively scattered and thin for some distance east of that range, it is assumed that the Challis volcanics thin westward. Only a small part of the Sawtooth Range has yet been mapped in any detail, but reconnaissance studies show that north of the Vienna district both this range and the mountains for a long distance west of it are mainly underlain by the Idaho batholith. However, the gravel along the stream that feeds Alturas Lake contains pebbles of andesitic rocks interspersed with the predominant granitic pebbles. This suggests that somewhere in the higher part of the Sawtooth Range patches of Challis volcanics may exist.

The contour lines in figure 7 indicate that the Challis volcanics of the Bayhorse region are flexed into a large structural terrace with a broad, nearly flat top on the southeast flank of the anticline whose axis traverses the Casto quadrangle. This terrace is bordered by a depression, which passes southward from Round Valley through Big and Little Antelope Flats. In and just southeast of Round Valley this depression corresponds to a shallow syncline in the Challis volcanics, as is shown on plate 1.

Farther south the west front of the Pahsimeroi Mountains is straight and steep, and its spurs have a truncated appearance (pl. 8, *A*). This straight and steep front and the presence at its base of beds belonging to the upper part of the Challis volcanics suggest the possibility of faulting. The low position of the upper Challis beds, as noted above, results from the original deposition, and the facets on the spurs correspond approximately to the strike of the bedding planes in the Paleozoic rocks. These facts coupled with the data summarized below make it improbable that major faulting of post-Challis age occurred here.

From Big Antelope Flat the depression in the upper surface of the volcanics swings west into the southwest corner of the Bayhorse quadrangle. Farther west it is shallower, but its synclinal character is more clearly evident. It is bordered on the north by the upwarped and faulted Paleozoic strata surrounding the high southern part of the White Cloud Peaks. On the south is a dome centering in the intrusive masses in and near Glassford Peak, in the Hailey quadrangle.[64] Still farther west an apparent depression in the surface of the Challis volcanics corresponds in position to the present Stanley Basin.

[64] Umpleby, J. B., Westgate, L. G., and Ross, C. P., op. cit. (Bull. 814), pp. 57–60.

The basalt and tuff in and near the southern part of T. 13 N., R. 20 E., extend some distance west of the projection of the range front without any evidence of faulting and, although partly masked by alluvium, appear to connect with the similar beds on the west side of the valley without material structural disturbance. These facts show that no major fault affects the Challis volcanics at the base of the range in either T. 12 N., R. 21 E., or T. 13 N., R. 20 E. The scarplike front of the range here corresponds closely to the upturned bedding planes of the Paleozoic rocks and evidently resulted largely from control of erosion by these planes, in part before the Challis volcanics were laid down. If erosion was also aided by faulting such movements preceded the eruption of the volcanics and were doubtless incidental to the folding of the Paleozoic rocks.

No direct evidence has been found to support the suggestion [65] that the Stanley Basin resulted in part from a fault along the front of the Sawtooth Range. If faceted spurs exist here, they are concealed by the Pleistocene glacial material. The only recognized faults in this vicinity trend diagonally across the basin. The depression suggested in figure 7 may, like that near Grand View Canyon, have resulted mainly from original thinning of the Challis volcanics.

If figure 7 is approximately correct, it appears that essentially the entire Bayhorse region, with the possible exception of the highest peaks, was covered by the Challis volcanics. As the highest mountains in the central part of the Bayhorse quadrangle are either composed of Challis volcanics or have remnants of this formation high on their flanks, it is clear that few if any peaks here could have escaped. The northern part of the Pahsimeroi Mountains was covered, but there is as yet no proof that the volcanics extended over the higher peaks farther south. In the western part of the region the lava extended high on the flanks of the White Cloud Peaks and doubtless flowed across many of them. The higher pinnacles, such as Castle Peak, may well have escaped. There can be little doubt that the area west of the White Cloud Peaks to and including Stanley Basin was, for the most part, covered by the volcanics. The highest parts of the Sawtooth Range may have been above their reach.

The faults recognized at intervals along a line from the northwestern part of the Sawtooth quadrangle to the vicinity of Round Valley suggest that a northeasterly zone of fracture of Tertiary age extends diagonally across the middle of the Bayhorse region. Most of the known faults affecting the Challis strata are approximately parallel to those along this line. In the southern part of the Bayhorse quadrangle the trend averages about N. 30° E., whereas near the northern border it becomes about N. 65° E. A few of the faults, such as those

[65] Umpleby, J. B., and Livingston, D. C., A reconnaissance in south-central Idaho: Idaho Bur. Mines and Geology Bull. 3, p. 13, 1920.

north of Challis, trend N. 25°–30° W. In the eastern half of the region many of the ridge crests, especially those carved in Challis volcanics, trend approximately parallel to these northwesterly faults. This feature is sufficiently conspicuous to suggest that the development of the topography may have been controlled in some degree by structural weakness in this direction. It would thus appear that when the volcanics yielded to tensional stresses the greatest displacement took place along northeasterly lines, but the partings in the complementary direction were more closely spaced. Similar paired sets of lines of weakness are present both north[66] and south[67] of the Bayhorse region.

GEOMORPHOLOGY

PRE-CHALLIS SURFACE

In the Casto quadrangle[68] the character of the lower contact of the Challis volcanics shows that the surface on which they were laid down was nearly flat. Along the north side of the canyon of the Salmon River in the Custer quadrangle the surface is almost equally smooth but slopes gently northward. In several other places, such as east of Silver Rule Creek and north of Champion Creek, the pre-Challis topography was similarly gentle. There is abundant evidence, however, that over most of the Bayhorse region the slopes on which the volcanics were deposited were steep and locally even precipitous. The total relief was probably as great as that of the present topography. The base of the Challis volcanics under Round Valley must be materially less than 5,000 feet above sea level, whereas in several places in the mountains east of Stanley Basin it is more than 9,500 feet. In some places the surface was intricately dissected before burial. For example, in the hills east of Beardsley Hot Springs there is an area in which only a thin cover of tuff and basalt remains on the pre-Challis surface carved on Kinnikinic quartzite and related limestone and schist. Small, irregular knobs, commonly steep-sided, project here and there through the tuff. It is evident that the volcanic beds blanketed a surface whose details were intricate and unsystematically carved. The abundant gravel, in part exceedingly coarse, at the base of the Challis volcanics in many places supports the evidence of rugged topography at the time of volcanism.

The mutual relations of the Challis volcanics and the older rocks show clearly that the principal elevations on the pre-Challis surface correspond in position and are apparently parallel to the bedding in the larger masses of old rocks exposed at the present time. There was a broad high area east of Stanley Basin, crowned by mountains

[66] Ross, C. P., The geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, pp. 77–81, 1935.

[67] Umpleby, J. B., Westgate, L. G., and Ross, C. P., op. cit. (Bull. 814), pp. 71–73.

[68] Ross, C. P., Geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, pp. 83–84, 1935.

from which the White Cloud Peaks have since been carved. Another range, probably then as now partly flat-topped, extended from a point near the site of Clayton northward to the border of the Bayhorse region. The Pahsimeroi Mountains, the high areas crowned by Lone Pine and Anderson Peaks, and the Sawtooth Range are all resurrected elevations of pre-Challis time, possibly in part accentuated by subsequent deformation. The deepest valley appears to have extended west of north from the upper end of the site of Big Antelope Flat under the present Bradbury Flat and Round Valley. Its axis presumably passed west of the fills into which Grand View Canyon has since been cut. A broad depression, possibly as deep as that under the present Round Valley, had its center in or near T. 10 N., R. 19 E. Another depression, possibly not greatly different from the present one, may have occupied the site of Stanley Basin.

It is noteworthy that, almost without exception, both steep depositional surfaces and conglomerate at the base of the Challis volcanics are most abundant in the deeper ancient depressions. It is equally noticeable that both in the Casto quadrangle and in the region here described comparatively high areas of the old surface are relatively smooth and, for the most part, nearly flat, though several elevations, such as that on the site of the White Cloud Peaks, rose materially above this gentle topography. It is therefore evident that the parts of the pre-Challis surface now between 7,500 and 9,000 feet above the sea were much less dissected than those now between 5,000 and 6,500 feet. The contrast is so sharp and the areas of gentle topography are so broad as to indicate that the country had been brought at least to a mature stage of erosion and in a subsequent cycle had begun to be redissected before being covered by the Challis volcanics. The presence on the old surface of mountains in part controlled in trend by the structure of the component rocks shows that erosion of the earlier cycle was considerably short of perfect peneplanation.

A somewhat similar explanation has been offered by Umpleby.[69] He recognized the fact that locally the Tertiary lava and associated clastic beds were deposited in topographic depressions, but the incomplete information then available led him to assume that in and south of the Bayhorse region they were largely confined to deep valleys instead of being as widely distributed as they are now known to be. He supposed that the upland areas of slight relief that are conspicuous features of the landscape in some areas were remnants of an old erosion surface or peneplain of Eocene age, into which valleys had been eroded. The upland areas thus interpreted by him are, however, shown below to be remnants of what is here regarded as the post-Challis surface, cut in part across the surface of the volcanics.

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[69] Umpleby, J. B., Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, pp. 16–17, 24–25, 1913; Ore deposits in the Sawtooth quadrangle, Blaine and Custer Counties, Idaho: U. S. Geol. Survey Bull. 580, pp. 228–229, 1915.

POST-CHALLIS SURFACE

In the Casto quadrangle [70] there are remnants of a postmature erosion surface later than the deformation of the Challis volcanics. This surface is surmounted in many places by peaks and ridges. A surface in all essential respects comparable to and correlative with this can be traced over the Bayhorse region. At or a short distance below the highest elevations in each locality there are areas of flat or gently rolling topography that are conspicuous in contrast to the rugged slopes around them. Similar features exist in all parts of the region, irrespective of the character or structure of the underlying rocks. The independence of these features is most clearly evident where the surface is carved on the much deformed Paleozoic strata. For example, the ridge surmounted by Lone Pine Peak, altitude 9,660 feet, composed of Laketown dolomite, has gently rolling topography between 8,500 and 9,000 feet above sea level. In the White Cloud Peaks there are numerous nearly flat ridge crests and other upland areas at altitudes near and above 9,000 feet. Most of these are doubtless remnants of the post-Challis surface, but glaciation has been so active here as to hamper interpretation. The largest of such upland areas in this vicinity is Railroad Ridge, carved in part across rhyolitic and tuffaceous beds of the Challis volcanics and in part across argillaceous and calcareous Milligen strata. The original surface of this ridge, below its cover of Nebraskan(?) glacial material, ranges in altitude from about 9,000 to more than 10,000 feet. Farther west areas in the northeast quarter of T. 9 N., R. 14 E., at altitudes just below 9,000 feet and within the area underlain by the Idaho batholith, and the ridges east of the Aztec mine and south of The Meadows, carved across diverse rocks, are among the most conspicuous upland areas of gentle topography. North of the Salmon River in the Custer quadrangle there are numerous flat-topped ridges at altitudes ranging from 8,500 to 9,500 feet above the sea. Some of these are developed on nearly undisturbed Challis strata, but in parts of this area the volcanic rocks are tilted as much as 30°. There can be little doubt that the nearly flat upland areas here correspond in general to the erosion surface under discussion. Umpleby [71] noted the abundance of nearly flat ridge crests at accordant altitudes in the Yankee Fork mining district, which has Bonanza in its southern part. As he believed that the only extensive old erosion surface in the region was of Eocene age, he supposed that this accordance resulted from the deposition of the tuff, which is here an abundant constituent of the Challis volcanics, in a body of water whose surface accorded essentially with that of the postulated Eocene peneplain.

[70] Ross, C. P., Geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, pp. 84–86, 1935.

[71] Umpleby, J. B., Ore deposits in Custer County, Idaho: U. S. Geol. Survey Bull. 539, p. 78, 1913.

The flat crests are as commonly underlain by lava as by tuff, however, and in numerous places, including some specifically referred to by Umpleby, deformation has been sufficient to render such an explanation improbable.

One of the best remaining examples of the post-Challis surface is the series of ridges extending from the head of Daugherty Gulch southwest beyond Buster Lake, southeast along the divide between Bayhorse Creek and upper Squaw Creek, and thence south past Bald Mountain to include Poverty Flat. These ridges are carved across Kinnikinic quartzite, Ramshorn slate, and Challis volcanics, all more or less deformed and varying much more in hardness than the ridge crests vary in relief. The ridges are notched in several places by younger lateral valleys. Their gently rolling crests range in altitude from somewhat more than 8,500 feet to somewhat less than 9,500 feet above sea level, and the knobs that surmount them rarely rise much more than 300 feet higher than the ridge surface at their bases. Bald Mountain (altitude 10,315 feet) and the slightly lower neighboring peaks were doubtless monadnocks on the post-Challis surface. They are some distance east of the line of flat-topped ridges but are girdled by an incomplete bench at an average altitude of about 9,000 feet. This bench, which is regarded as a remnant of the post-Challis surface, is more conspicuous on the ground than it is on the topographic map. In several places along the ridges, especially those underlain by Challis volcanics, weathering is deeper than in most other parts of the region, and there are patches of an originally more extensive cover of reddish residual soil several feet thick.

Poverty Flat, by far the most extensive and prominent of the erosion remnants in this part of the region (pl. 10, *B*), owes its preservation in some degree to the protection accorded by the Kinnikinic quartzite, which here is gently arched along the nearly flat top of a major anticline. In unsurveyed sec. 8, T. 11 N., R. 18 E., residual blocks of quartzite are strewn over parts of the surface underlain by Ramshorn slate (pl. 1). The slaty-cleavage planes in the Ramshorn slate are steeply inclined and sharply truncated by the surface of Poverty Flat. The bedding, however, is much more gently inclined, especially on and just west of the flat itself. The small patch of basaltic lava that locally floors the flat in unsurveyed sec. 5, T. 11 N., R. 18 E., is clearly a remnant of a much more extensive mass essentially similar to the larger residual patches of Challis volcanics that rest on Kinnikinic quartzite on the ridges farther north and are capped by remnants of a nearly flat erosion surface. This and the fact that the gentle upland is essentially continuous from Poverty Flat to the ridges carved on Challis volcanics, above the heads of Juliette and Big Lake Creeks, constitute strong evidence that Poverty Flat is a part of a post-

Challis erosion surface and not, as has been supposed, an Eocene peneplain.[72]

The erosion surface of which the upland areas above described are remnants possessed considerable relief. The remnants of much of the flatter part of it within the Bayhorse region stand at altitudes near 9,000 feet. A range corresponding to at least the southern part of the White Cloud Peaks appears to have risen some 2,000 feet above this. Another lower and less accentuated elevation existed where Bowery Peak now is. Presumably there were ranges on the sites of the present Sawtooth Range and of part of the Pahsimeroi Mountains. There appears to have been a depression corresponding to Stanley Basin but broader and shallower. Another depression headed west or southwest of Bowery Peak and extended somewhat east of north to and beyond the site of Round Valley. Both depressions may have been river valleys draining northward. The bottom of the one passing under the present Round Valley may have been below a point corresponding to a present altitude of 8,000 feet. On this assumption, there may have been within the region here considered a maximum relief of more than 3,000 feet. Although the major deformation of the region antedates the formation of the post-Challis surface, it is possible that the differences in altitude in that surface may have been accentuated in some degree by warping during subsequent uplift. The topography of south-central Idaho furnishes evidence that the uplift reflected in the rejuvenated streams was uneven. Areas close to the Snake River Plain appear to have been elevated relatively several thousand feet higher than certain parts of north-central Idaho.[73] Direct proof of local warping in the Bayhorse region was not obtained, but relatively recent warping such as has been found in the Elk City [74] and neighboring areas presumably exists.

LATE TERTIARY EVENTS

There is reason to believe that in the interval between the culmination of post-Challis erosion and the advent of the first Pleistocene ice there was in south-central Idaho a complicated sequence of geomorphic events, only partly understood. Full discussion of them would involve areas far beyond the Bayhorse region and is therefore postponed for consideration in a paper on the whole of south-central Idaho, now in preparation.

The approach toward peneplanation discussed above was halted by relative uplift, probably not everywhere uniform. The rejuvenated streams cut into the old surface, and locally steep-sided basins were

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[72] Umpleby, J. B., Ore deposits in Custer County, Idaho: U. S. Geol. Survey Bull. 539, p. 57, 1913.

[73] Ross, C. P., Geology and ore deposits of south-central Idaho: U. S. Geol. Survey Prof. Paper — (in preparation).

[74] Shenon, P. J., and Reed, J. C., Geology and ore deposits of the Elk City, Orogrande, Buffalo Hump, and Tenmile districts, Idaho County, Idaho: U. S. Geol. Survey Circ. 9, pp. 22-23, 1934.

formed, probably in more than one erosion cycle. In some of the basins and the valleys that drain them sediments and lava flows were deposited. In different localities such deposits appear to be of Miocene and Pliocene age. In places also Miocene and later basaltic flows overlap the post-Challis surface or abut against slopes incised into it by erosion. Removal of parts of the remaining cover of Challis volcanics resulted in the superposition of streams on rocks and surface forms materially different from those on which they originally flowed. This change, coupled with stream piracy and other factors, resulted in a complicated drainage pattern. There is no known evidence of major deformation subsequent to the development of the post-Challis surface, but the streams incised into that surface have been in part guided and aided by structural weaknesses produced during the preceding deformation and possibly have been affected by some renewal of movement along old faults.

Naturally streams already occupying valleys in the incompletely leveled post-Challis surface had an advantage when rejuvenation began, and consequently some of the larger of the present depressions correspond more or less closely to low parts of the post-Challis surface. Stanley Basin and the series of depressions in the eastern part of the Bayhorse quadrangle probably have such an origin, although complicated by other factors. The right-angled junction of the canyon of the Salmon River with Stanley Basin near Stanley is obviously anomalous. It suggests that a stream corresponding to the eastward-flowing section of the present river worked headward and tapped a preexisting valley trending west of north.

It is clear that drainage changes have taken place in the depressions in the eastern part of the Bayhorse quadrangle. Considered as a unit, the low area extending from Round Valley southeastward to the divide in T. 11 N., R. 21 E., just beyond the area mapped, accords closely in position and trend with the longer valley that stretches from this divide past Mackay to the border of the Snake River Plain.[75] It is conceivable that during the development of the post-Challis surface or somewhat later a single valley extended from the present Round Valley to the vicinity of the site of Arco. The direction of flow of the stream occupying such a valley is unknown, but the depth of Round Valley under the alluvium suggests that it may have been northward. An alternative explanation is that a divide existed, at least at one stage, in the area east of Lone Pine Peak, where hills composed mainly of Challis volcanics now partly fill the depression. The valley that extends northward from sec. 30, T. 12 N., R. 20 E., may well have once contained a comparatively active stream. Grand

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[75] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, p. 19, 1917. Kirkham, V. R., A geologic reconnaissance of Clark and Jefferson and parts of Butte, Custer, Fremont, Lemhi, and Madison Counties, Idaho: Idaho Bur. Mines and Geology Pamph. 19, p. 31, 1927.

View Canyon is obviously anomalous and doubtless resulted from superposition of a stream originating on the Challis volcanics that once covered the resistant Devonian strata in which the canyon is carved.

NEBRASKAN (?) GLACIATION

On both sides of the White Cloud Peaks there are masses of detritus of probable glacial origin that must be older than the Wisconsin glaciation, as it is cut into by cirques and V-shaped valleys in the upper reaches of streams now incised more than 1,000 feet below Railroad Ridge. The close analogy between conditions here and in the Glacier National Park leads to the supposition that the early glaciation in the two areas was contemporaneous.[76] Alden [77] regards the glaciation in the Glacier National Park as probably equivalent in age to the Nebraskan stage of continental glaciation. The larger masses of such rock now remaining are on Railroad Ridge and the interstream ridges between this place and Germania Creek. Much smaller but essentially similar masses occur on ridges south and west of the White Cloud Peaks, and the abundance of similar material dumped in the upper reaches of stream valleys between these ridges suggests that old glacial detritus may once have been widespread there, although now largely eroded. The material mapped as older alluvium bordering the heads of Champion Creek and other creeks in this vicinity is almost exclusively granitic, and therefore it cannot have been derived entirely from erosion concentrated in the present valleys.

The character and general relations of the unconsolidated material capping such interstream ridges as Railroad Ridge (p. 70) accord much better with the hypothesis of glacial origin than with any other. Most of it is clearly not of landslide or similar origin, and the larger boulders could have been moved only by a torrential stream or by ice. It might be conceived that such deposits constitute dissected remnants of a valley fill formed under semiarid conditions, but the stratification commonly visible in material of that kind is absent. There is no supporting evidence of aridity at this time, and it is difficult to conceive of a stream valley of suitable size and character in the position required by such a hypothesis. Nowhere does the shape of the surface underlying the gravel suggest a segment of a stream channel, and in some places it is clear that this surface is irregular in detail and that it contains small shallow undrained hollows. The apparent lack of space for a drainage basin of adequate size at altitudes above the present position of the material and the preponderance in it of a single rock type also argue against a fluviatile origin.

[76] Ross, C. P., Early Pleistocene glaciation in Idaho: U. S. Geol. Survey Prof. Paper 158, p. 128, 1929.

[77] Alden, W. C., Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 25, p. 406, 1924.

In order to present as definitely as possible the conditions believed to have existed at the time the detritus was deposited, an attempt is made in plate 12 to restore the topography of that time in the immediate vicinity of the White Cloud Peaks. This sketch map, which is an expansion and revision of one previously published,[78] is constructed on the basis of the distribution of the existing remnants of the detrital masses, the shape of the surfaces on which they rest, and the present topography. If possible later deformation is disregarded, it is evident that all parts of the surface not now protected by detritus are relatively lower than they were at the time of deposition, hence hills now higher than the existing detritus represent high ground at the time of deposition. This is the principal basis on which contour lines are interpolated on plate 12 in areas not now covered with detritus. It is obvious that the detritus has undergone erosion and was originally

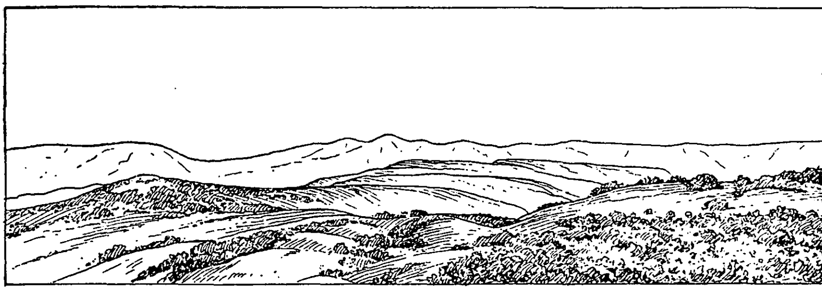


FIGURE 8.—View northeast from the dump of the Hermit mine. Shows high-level rolling surface carved on the Challis volcanics.

more extensive than it is now. Possibly it originally covered much of the area contoured in plate 12 and perhaps even extended beyond that area, especially toward the west. Its distribution with reference to the contour lines indicates that there is little correspondence between the location of the portions now remaining and the depressions of the old surface. The history of the region indicates that there has been uplift but not sufficient deformation since the deposition of the Nebraskan (?) detritus to affect materially the accuracy of the restored topography in plate 12. Figure 8 shows a portion of the old surface, now considerably dissected, north of the present limits of the detritus. If due allowance is made for later erosion this sketch may give an idea of the topography existing at the time that the Nebraskan (?) material was being laid down—that is, the topography diagrammatically contoured in plate 12. Clearly this area constitutes a portion of the post-Challis surface but little modified by later events. The canyon of the Salmon River, indistinctly perceivable in the middle distance in figure 8, is one of the master trenches

[78] Ross, C. P., Early Pleistocene glaciation in Idaho: U. S. Geol. Survey Prof. Paper 158, fig. 18, p. 125, 1929.

begun by the rejuvenated streams in late Tertiary time. It is obvious that the conditions indicated above favored a glacial rather than a fluviatile origin.

The fact that nearly all the detritus is composed of granitic rock also favors a glacial origin. Mountain glaciers that derive much of their debris from the cirques at their heads are more selective in their action than streams with tributaries. The rather small body of granitic rock in the White Cloud Peaks is the only probable source of the detritus on Railroad Ridge and the ridges south of it. The data summarized on plates 1 and 12 suggest that at the time of the early glaciation the granitic mass in the White Cloud Peaks may have occupied nearly the whole of the area sufficiently high to support glaciers. It is noteworthy in this connection that traces of pre-Wisconsin glaciation have so far been recognized only in the general vicinity of peaks more than 10,000 feet above sea level.[79]

Although both general relations and the character of the material favor glacial origin, the present shapes of the existing masses are not those of moraines. The mass on Railroad Ridge and, less distinctly, the other large masses to the south are so flat and smooth on top as to suggest the leveling action of water rather than direct dumping from a glacier. On both sides of Little Boulder Creek, particularly in secs. 9 and 16, T. 9 N., R. 17 E., the granitic detritus is in exceptionally well formed terraces, but this is doubtless a result of stream sorting subsequent to deposition. The larger patches of material not thus rearranged have large lateral dimensions in proportion to their thickness and in this respect resemble ground moraines. Such moraines, however, have generally more or less hilly or undulating topography. Consequently if the material is of glacial origin it has probably been somewhat smoothed, though for the most part not re-sorted, by running water, possibly in part by water derived from melting of the glacial ice. The long time that has elapsed since its deposition would permit considerable smoothing of the original topography through the agency of weathering.

PLEISTOCENE STREAM TERRACES

All the larger stream valleys of the region contain terraces at several altitudes. The higher ones in Stanley Basin along the Salmon River are at altitudes of somewhat more than 6,500 feet, and the highest bordering the upper reaches of the East Fork are at about 8,000 feet. The tops of these high terraces are believed to mark an originally widespread partial erosion surface, which in general has a somewhat lower gradient than the modern streams. The comparatively broad flats at altitudes of about 7,000 feet in the middle reaches of such streams as Warm Spring Creek, above

[79] Ross, C. P., op. cit. (Prof. Paper 158), p. 127.

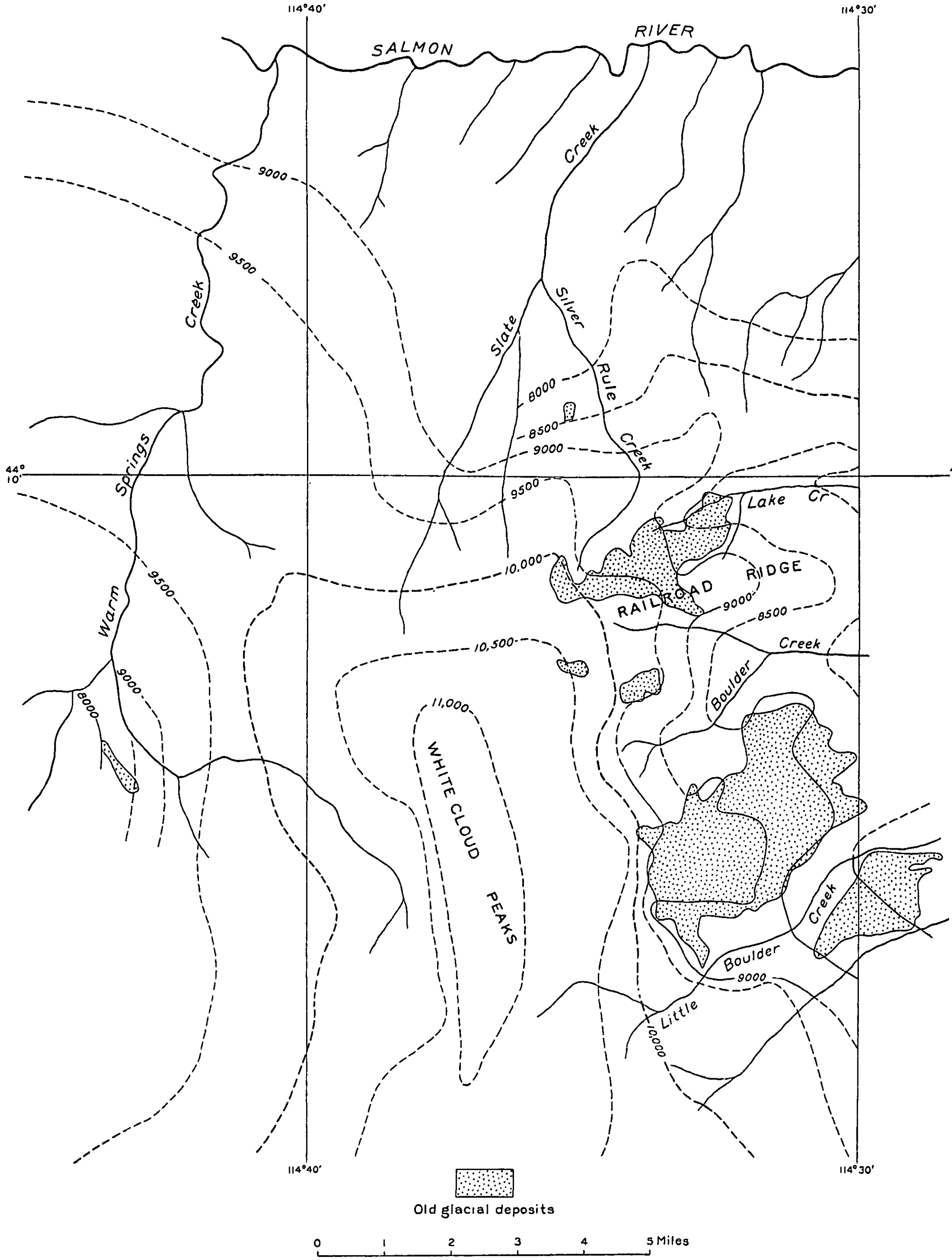
Robinson Bar, and Slate Creek, farther east, may also have been parts of such a surface. The conspicuously incised meanders along the Salmon River in the general vicinity of Robinson Bar probably originated in the meanders of the ancestral stream on this high-level surface. The higher terraces are only a few hundred feet above the modern stream near Stanley but are generally 1,000 feet or more above the stream below Robinson Bar. The highest of the terraces bordering the East Fork above Boulder Creek are more than 1,500 feet above the stream. As the amount of canyon cutting is thus comparable to that which took place after the Nebraska (?) glaciation in the neighborhood of Railroad Ridge, the partial erosion surface recorded by the higher terraces is thought to be early Pleistocene or at most not older than Pliocene.

Terraces at levels below those just referred to and above the inner stream gorges are common in the region. Much of the material mapped as older alluvium on plate 1 is related to these intermediate terraces. As the inner gorges are post-Wisconsin (p. 97), the intermediate terraces record incidents of erosion in the interval between the two glacial episodes. Such terraces are especially numerous and well preserved along the canyon of the Salmon River between Clayton and Stanley. There are well-defined terrace remnants at about 200 feet and more rarely about 450 feet above the river at intervals throughout its course within the Bayhorse region. Especially well preserved remnants on the north side of the river a short distance below Robinson Bar are shown in plate 13. Several remnants of well-formed terraces are present locally along the East Fork at altitudes of about 100, 200, and 300 feet above stream level, but there are long stretches where no terraces are recognizable above the inner gorge.

WISCONSIN GLACIATION

Most of the valleys in the Bayhorse region that head above an altitude of 8,000 feet have abundant evidence of Wisconsin glaciation in their upper reaches. The comparatively large glaciers descending from the Sawtooth Range reached altitudes as low as 6,500 feet, or possibly a little lower, but elsewhere the ice rarely got below 7,000 feet, and many of the glaciers stopped at or above 8,000 feet. The glaciated portions of valleys carved in pre-Tertiary rock, and less perfectly those in the Challis volcanics, preserve characteristic U-shaped cross sections and have one or more cirques at their heads. All the lakes shown on plate 1 above an altitude of 7,500 feet are in cirque basins. The highest parts of the White Cloud Peaks and the Sawtooth Range were intensely glaciated and consequently are characterized by bare cliffs and narrow castellated ridges (pl. 9, *A*).

In most places the Wisconsin morainal deposits have been so modified by subsequent stream action as to be indistinguishable from the



RESTORATION OF THE SURFACE ON WHICH THE EARLY PLEISTOCENE DEPOSITS WERE LAID DOWN.

TERRACES ON THE NORTH SIDE OF THE SALMON RIVER BELOW ROBINSON BAR.

alluvium of the valleys. East of Stanley Basin few masses of morainal shape remain. Along its western border several of the streams are dammed near their mouths by terminal moraines that have undergone little modification. The comparatively large lakes here have resulted from the glacial damming.

RECENT EROSION

Erosion subsequent to the Wisconsin glaciation has been relatively slight. In the glaciated areas it is recorded by well-defined, generally narrow gorges, rarely more than 50 feet deep, cut in the floors of the U-shaped valleys. Downstream these inner gorges deepen somewhat, but even along the Salmon River the inner gorge is generally less than 100 feet deep. The short section of steep-walled gorge about 120 feet deep at Robinson Bar is exceptional. Only about 75 feet of the excavation here is in rock, the rest being in gravel.

Locally patches of debris, in part loosely cemented with lime, cling to the sides of the inner gorge in the narrower stretches of the valley of the Salmon River. In the quartzite canyon below the mouth of Bayhorse Creek and in the cliff near the mouth of Squaw Creek such patches extend more than 100 feet above the river, but much of the debris is unsorted and unrounded. Probably the choking of the inner gorge by debris thus recorded resulted from landslides or similar local causes rather than from aggradation.

Most of the valleys have intermittent flood-plain areas within the inner gorge, and the stream channel is incised. In Round Valley, the only place where the flood-plain alluvium has been mapped, the terrace corresponding to the post-Wisconsin gorge of the narrower valleys is about 75 feet above the present stream, which flows in a channel incised 5 feet or more into the flood plain. There are local terraces below the 75-foot terrace, but none of these are as distinct or continuous.[80] Outside Round Valley such traces of postglacial fluctuations in erosion are rarely perceptible except that at stream mouths there tends to be a steepening of grade. In some places there is a rapid at the mouth. Here, as in the Casto quadrange,[81] this feature doubtless records incomplete adjustment following recent uplift, but it is less conspicuous here than in the Casto quadrangle. The junction of Warm Spring Creek with the Salmon River at Robinson Bar is one of the best examples.

Another feature that may have the same cause is the fact that in the apparently more arid sections of the region the channels of some of the tributaries diminish or disappear before reaching the Salmon River. The lack of adjustment which in the perennial streams results in rapids here causes the occasional floods to dump their loads of sediment in

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[80] Plan and profile of Salmon River, Salmon to Stanley, Idaho, U. S. Geol. Survey, 1926.

[81] Ross, C. P., Geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey Bull. 854, p. 88, 1935.

the lower reaches of the valleys, tending to obliterate the channels. The eastern Warm Spring Creek and Malm Gulch are among the best examples. In Malm Gulch especially it is clear that no channel was ever cut down to the grade of the river. The arid appearance of this part of the country and the deficiency of water in the streams result in part from the fact that somewhat less rain falls here than in the high mountains. Another factor is the high porosity of the Germer beds, which are comparatively thick and widespread here. This operates to diminish greatly the proportion of the rainfall that is contributed to the surface streams.

Landslides and talus rivers have been factors in modifying the present topography. The principal examples of both are mapped on plate 1. Nearly all the lakes and ponds in the southern half of the Bayhorse quadrangle have resulted from damming of streams by landslides. The hummocky topography that is especially conspicuous near Sullivan Lake and in Lake Basin is due to landslides and not, as might be supposed, to glacial dumping.

Talus rivers are more or less lobate and elongate masses of talus that have moved downhill from the original place of accumulation in a manner suggestive of the movement of glaciers. Although in no way related to true glaciers, the analogy in shape and manner of movement is so striking that features essentially like those here described have been called talus glaciers.[82] They are genetically different from the rock glaciers of Alaska,[83] which are similar in outward appearance but contain ice as an essential constituent. The features here termed talus rivers are not to be confused with those termed talus streams by Behre.[84] The latter move precipitately through clefts on cliff sides in response to rain or to some other accelerating agency.

In the Bayhorse region the talus rivers are sharply bounded steep-fronted bodies of angular rock waste, most of which contain little fine material. They range in width from about 50 feet to rarely more than 500 feet, in length from a few hundred yards to somewhat more than a mile, and in depth from a few feet to more than 30 feet. The component fragments are generally a few inches to more than a foot in maximum dimension. The surfaces of the masses are undulatory and locally marked by curved transverse ridges, which are especially distinct near the lower terminus of the mass. These ridges appear to have originated by piling up of blocks in the course of the intermittent downward movement of the mass. Some result from obstructions or from changes in underlying slope influencing the movement. Others mark the culmination of particular pulsations.

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[82] Chamberlin, T. C., and Salisbury, R. D., Geology, vol. 3, pp. 471–472, New York, 1906.

[83] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 52–59, 1911.

[84] Behre, C. H., Jr., Talus behavior above timber in the Rocky Mountains: Jour. Geology, vol. 41, fig. 9, p. 634, 1933.

Talus rivers may form wherever talus accumulates under conditions that promote instability. Instead of remaining more or less in the position in which they first lodged, the aggregate of fragments tends to creep or flow downward at varying rates but probably always spasmodically or in response to seasonal changes. Some of the talus rivers are in T. 10 N., R. 17 E., and in other areas underlain by the Challis volcanics. Several derive their material from spalling off of fragments of rhyolite flows overlying basalt and tuff. Such flows, containing a large proportion of glass and commonly much jointed, are particularly susceptible to fracture under the stresses induced by the marked daily and seasonal changes in temperature characteristic of the region. Clay minerals in the tuff, and perhaps also in the lava, may have lessened friction and thus promoted movement of the talus in such a situation. Some of the larger talus rivers are partly or entirely composed of Paleozoic rock and have resulted largely from the rapid accumulation of talus from exposed peaks on very steep slopes. The best example of this variety is on Bald Mountain, north of Poverty Flat. In all the talus rivers snow would tend to fill interstices between the fragments and in melting would tend to make the mass unstable. In those masses containing fine material, especially altered tuff, solifluction [85] would have a marked effect. The aggregate effect of the minor movements of the fragments resulting from sharp changes in temperature may also tend to make the mass unstable. A mass of loose material thrown out of equilibrium by such processes would move downhill under the influence of gravity and, once started, the resulting momentum would be a potent factor in continuation of the movement.

ECONOMIC GEOLOGY

The Bayhorse region contains some of the most famous mines in south-central Idaho. The ore deposits contain lead, silver, copper, zinc, gold, and other metals such as molybdenum, antimony, and arsenic. The Challis volcanics furnish building stone for local use.[86] Sheep and cattle are grazed in the mountains of the Bayhorse region, and there is some farming, mainly of forage crops, in the valleys. Round Valley, parts of the valleys of the eastern Warm Spring Creek and of the East Fork of the Salmon River, and terraces here and there along the Salmon constitute the principal cultivated areas. Wild hay is grown in Stanley Basin and elsewhere. Small-scale lumbering is conducted along upper Garden Creek and at times in other places. There are several hot springs, some of which have been

[85] Andersson, J. G., Solifluction, a component of subaerial denudation: Jour. Geology, vol. 14, pp. 91-112, 1906.

[86] Behre, C. H., Jr., Tertiary volcanic tuffs and sandstones used as building stones in the upper Salmon River Valley, Idaho: U. S. Geol. Survey Bull. 811, pp., 237-249, 1929.

developed for resorts. The business of caring for visitors both during the summer and in the deer-hunting season is increasing.

The mines and most of the prospects in three mining districts were visited in the course of the present investigation. The largest and best known of these is the Bayhorse district. Neither this district nor any of the others in the region has definitely fixed boundaries. The Bayhorse district may be regarded as bounded on the east by the Salmon River from Round Valley to the mouth of the East Fork. Beyond the East Fork the district includes properties on both sides of the river, but mainly on the north, as far west as Slate Creek. From this point the boundary swings north to the head of Mill Creek and thence eastward along that stream and Challis Creek to Round Valley. A prospect in the northern Pahsimeroi Mountains, east of Round Valley, is described with the lodes of the Bayhorse district, although beyond the limits commonly assigned to this district. There are more than 50 known lodes in the district, but of these less than half have received any development beyond preliminary prospecting. Lead-silver ore has been mainly sought, although other metals are locally present. Among the principal mines formerly productive may be mentioned the Ramshorn and Skylark, on upper Bayhorse Creek; the McGregor, Beardsley, and others, near the old town of Bayhorse; and the Red Bird, on Squaw Creek.

The Boulder Creek district comprises most of the White Cloud Peaks. It may be assumed to terminate on the south at the southern boundary of the Challis National Forest. Its border swings north so as to include the valley of Warm Spring Creek above The Meadows and the headwaters of Slate Creek, thence east to include Jimmy Smith Lake and the valley of the stream that drains it. From the mouth of this stream it extends up the East Fork of the Salmon River to the boundary of the Challis National Forest. Almost the sole production in this district has consisted of silver, lead, and zinc from the Livingston mine, on Jim Creek. This and other lodes in the district are notable for the abundance of jamesonite, a comparatively rare mineral. Several prospects in the district contain molybdenum and arsenic, and several are similar to the Livingston.

The East Fork district consists mainly of the drainage basins of Germania Creek and upper East Fork of the Salmon River. It lies immediately south of the Boulder Creek district. The upper drainage areas of Fourth of July, Champion, and Pole Creeks are included. These streams enter the southern part of Stanley Basin from the east. The Aztec mine, although listed by the State mine inspector as in the Stanley district, is for convenience included in the descriptions below with the mines in the East Fork district.[87] Mining in this area was more active in the early days than at present. Lead-silver and gold

[87] Campbell, Stewart, 33d annual report of the mining industry of Idaho, for the year 1931, p. 128, 1932.

ores were produced. There are several prospects containing these and other metals. Recently there has been some renewal of interest, mainly in the gold lodes.

LODES

Most of the productive lodes in the Bayhorse region are interrelated in origin and characteristics. There are, however, certain differences in form, mineralogy, and other details that should be clearly understood by anyone interested in the operation of mines in the region. In order to facilitate the description of these features the different deposits are somewhat arbitrarily grouped under five heads. The first group comprises irregular replacement deposits in Paleozoic calcareous rocks. The second includes those lodes that follow shear zones in Paleozoic rocks of several kinds. This group is further subdivided into lodes without distinctive gangue, those with abundant siderite, and those characterized by jamesonite and calcite. All the lodes in the first and second groups are mainly valuable for lead and silver, although copper, zinc, antimony, and other metals are in places sufficiently abundant to be of commercial interest. The third group comprises lodes in granitic rock. Most of these are principally valuable for gold, although several contain other metals as well. The fourth group comprises a miscellaneous assemblage of lodes of several kinds, each of which has only a few representatives in the region. Most of these are similar to lodes included in the first three groups. None have yet received much development. This group includes deposits containing lead, copper, molybdenum, and arsenic. The fifth group comprises the quartz veins in the Challis volcanics, which are apparently without economic value.

PERIODS OF MINERALIZATION

There have been two recognized periods of ore deposition in south-central Idaho [88]—one following the intrusion of the Idaho batholith and the other following the extrusion of the Challis volcanics and the intrusion of the granitic and other rocks that cut these lavas. It seems clear that most if not all of the lodes included in the first four groups outlined above originated in the earlier period of mineralization, and the fifth group obviously was formed in the later period. The concept of the age of the first four groups is based in part on similarity to deposits regarded as related to the Idaho batholith elsewhere in Idaho, especially in the Wood River region, and in part on the relations of the lodes themselves. Most of the lodes of these groups have the characteristics of deposits formed at depths greater than appear to have been reached by the erosion that has taken place in post-Challis time in the localities where they are exposed. Those of the first two groups are related to and were formed after the defor-

[88] Ross, C. P., A classification of the lode deposits of south-central Idaho: Econ. Geology, vol. 26, pp. 169–185, 1931.

mation associated with the intrusion of the Idaho batholith. Those of the third group are enclosed in the batholith. The character of their mineralization, especially the presence of diopside, suggests relation to the igneous metamorphism associated with the intrusion. Several of the miscellaneous lodes in the fourth group likewise are closely associated with the granitic rock. Some of the less persistent and more irregular lodes whose mineral content is not diagnostic, such as the Badger and nearby lodes east of Jimmy Smith Lake, may perhaps be of Tertiary age. Typical epithermal lodes in the Challis volcanics rich in precious metals, such as in the past were highly productive in the nearby Yankee Fork district, appear to be entirely absent in the Bayhorse region, although the deposits of the fifth group are doubtless of the same age.

IRREGULAR REPLACEMENT DEPOSITS IN CALCAREOUS ROCKS

MINERAL CONTENT

Lodes localized mainly because of the greater ease of replacement of calcareous (mostly dolomitic) rocks constitute one of the most numerous and productive of the varieties of ore deposits in this region. They constitute the first group as defined above and include the deposits of the Beardsley, Excelsior, Pacific, Riverview, Last Chance, Red Bird, and many other mines. There is scarcely an exposure of the Bayhorse dolomite that does not somewhere exhibit the results of mineralization by replacement.

The hypogene minerals in these deposits are relatively few and of simple composition. The gangue minerals are quartz, barite, calcite, and fluorite. Commonly the rock in and near the ore is more or less completely silicified, silicification being evidently one of the earliest and volumetrically one of the greatest effects of the mineralizing solutions. Locally the quartz of this stage of deposition is crustified. Coarser-grained quartz veinlets, some of which contain sulphides, were formed somewhat later. These and the less abundant veinlets of barite and calcite fill fractures in the more or less altered rock that, at least in part, record readjustments in the course of the mineralization. The calcite may have come from material dissolved from the country rock. Both barite and calcite are present in small amount in veinlets and disseminated bodies in the Paleozoic rocks of the region, even in localities remote from ore deposits. Fluorite is visible in only a few places and is nowhere abundant. Etching of glass utensils used in connection with the study of heavy minerals described on pages 39–43 indicates, however, that like the two minerals just mentioned, fluorite in small grains is widely disseminated in the rocks of the region. These facts suggest wide diffusion of certain solutions associated with mineralization. The hypogene metallic minerals include galena, sphalerite, pyrite, tetrahedrite, and chalcopyrite, named in approximate order of decreasing abundance. Both the galena and the tetrahedrite are argentiferous. In many places galena is the only conspicuous metallic mineral. The galena and the sphalerite associated with it are commonly coarse-grained and fill the spaces in fractured silicified rock. Copper minerals are commonly present but seem nowhere to be sufficiently abundant to constitute copper ore.

STRUCTURAL RELATIONS OF LODES IN THE BAYHORSE DOLOMITE

Most of the deposits of this group are found either in or near pre-mineral faults or at the contact with argillaceous beds. Most of the deposits in the Bayhorse dolomite are in the latter environment. In some places, as in the most recent Beardsley workings, the relations suggest that solutions percolating upward through the dolomitic rocks were trapped and concentrated beneath a cover of relatively impervious Ramshorn slate. Somewhat more commonly the deposits are on the bulging flanks of the main anticline, where the beds are steep or locally overturned. In several such places the opportunity for trapping seems so slight that some other cause for concentration appears to be required. In some of these places, such as the Keystone, brecciation along the contact doubtless provided comparatively easy passage for the solutions with consequent increase in the amount of solution available to react with and replace the rock. Even where breccia is not visible the deposits tend to be in or close to those parts of the anticline that bulge outward and hence were doubtless under tension in much the same way as the rock along the crest of a simple anticline. Solutions seeking the path of least resistance would tend to concentrate in such parts of the folds. The Turtle and Riverview are examples of ore deposition in situations of this kind.

Although the factors outlined above served to concentrate mineralization in favorable localities, they did not closely limit or control the shape of most of the ore shoots. The outstanding feature of ore bodies of this kind is irregularity. In most of the lodes some tendency to conform to bedding, jointing, or local fracture zones can be discerned. In some mines, such as the Democrat and others near Bayhorse, parts of certain beds are thoroughly mineralized, whereas nearby and apparently similar beds are scarcely affected. Even in such deposits, however, individual ore bodies are in stringers, kidneys, or masses of diverse shapes and sizes. In most of the accessible mine openings individual shoots have maximum dimensions of scores rather than hundreds of feet. Even these include much barren rock. Although in several shoots the aggregate amount of ore that has been found is considerable, blocking out of large reserves in replacement deposits of this sort is difficult.

STRUCTURAL RELATIONS OF LODES IN CALCAREOUS ROCKS OTHER THAN THE BAYHORSE DOLOMITE

In several respects the Red Bird and other lodes in calcareous rocks other than the Bayhorse dolomite have characteristics different from those above outlined. In the Red Bird, although individual shoots are not very large, ore has been mined at short intervals through a vertical range of more than 700 feet, a range scarcely approached by any mine in the Bayhorse dolomite. The only workings of even comparable persistence are those of the old Beardsley and Excelsior mines, which together are reported to have a depth of about 500 feet. The zone of mineralization is well within the Saturday Mountain formation. It broadly parallels the strike of the containing beds but dips at somewhat steeper angles. The zone has no definite walls, and it is clear that the replaceability of the more calcareous beds was an essential feature of the mineralization.

The mineralized zone here, as in some of the deposits in the Bayhorse dolomite, is in a part of the west flank of an anticline in which the beds were flexed outward and in part overturned. In such a situation slippage of one bed on another and more or less tension are to be expected. The abundance of carbonaceous matter in some beds may have constituted a lubricant, facilitating minor movements of readjustment.

In spite of much variation in attitude, of fracture, and of locally intense brecciation, there is no evidence of faulting involving material displacement.

The abundance of clay and ferruginous oxides in the more thoroughly brecciated masses, as well as the fact that most of the ore in such masses is thoroughly oxidized, suggests the possibility that the widespread brecciation may be in part the result of processes operating close to the surface and, consequently, long after the original mineralization. The formation of caverns as a result of solution by ground water is not as effective in this region as in some others. This is partly because most of the limestones are more or less thoroughly magnesian and hence relatively insoluble in meteoric water. The thorough cementation of the Paleozoic rocks and consequent slow percolation of ground water through them also militate against such solution. Nevertheless some caves exist—in the Laketown dolomite in Spar Canyon, for example. At one place on the third level of the Red Bird mine there is an open fissure through which water flows. Well-rounded pebbles in the bottom of this fissure imperfectly cemented by calcium carbonate show that the water at times has a transporting power comparable to that of a surface brook. With these facts in mind, it seems quite conceivable that at some time in the past, when geomorphic conditions may have been more favorable, solution by ground water may have formed caverns whose subsequent collapse produced the breccia that is now locally conspicuous in parts of the Red Bird mine. On this hypothesis the metallic contents of the breccias would have been derived from ore oxidized by downward-percolating water prior to the collapse, although doubtless more or less rearranged by the ground water that has subsequently seeped through the breccias. Evidence favoring ore deposition in limestone caves and data regarding the characteristic of such caves and of breccias in them have been assembled by Walker.[89] In the examples he cites, however, the ore minerals are sulphides, and deposition is conceived to have taken place from ascending hypogene solutions.

LODES ON SHEAR ZONES IN THE PALEOZOIC ROCKS

LODES WITHOUT DISTINCTIVE GANGUE

The lodes of the second group, which follow zones of shearing and fracture, include three varieties. Those of one variety resemble the irregular replacement deposits just described in that they tend to favor the more calcareous beds, have much the same assemblage of metallic minerals, and have inconspicuous amounts of introduced gangue minerals. In both types of deposits the principal nonmetallic minerals are those of the original rock, in part rearranged and recrystallized. The comparatively coarse calcite locally present in the lode matter and in veinlets in the country rock is thought to be derived from the wall rock rather than from deep-seated sources. The chief difference between such deposits as those in the Dryden and Twin Apex mines and those just described is that the wall rocks are such that shear planes rather than breccias or permeable beds furnished the most favorable passageways for the solutions. The comparatively fine grain and large proportion of material other than carbonates in the rocks limited the ability of the solutions to spread through unbroken rock, which also affected the shape and size of the ore bodies. So far as existing development shows, lodes with the mineralogic characteristics outlined above but enclosed in rocks that include only small or highly impure calcareous beds do not contain large ore shoots. Some have been productive on a small scale, and some may well be connected with larger ore bodies in more favorable wall rocks.

LODES CHARACTERIZED BY SIDERITE

Mineral content.—Deposits in shear zones which contain siderite as an essential constituent of the gangue appear to be fundamentally different from those without conspicuous and characteristic gangue minerals. Lodes of this general type are among the most productive of the ore deposits of Idaho. In the Bayhorse region they include

[89] Walker, R. T., Deposition of ore in preexisting limestone caves: Am. Inst. Min. Met. Eng. Tech. Pub. 154, 43 pp., 1928.

such deposits as the Ramshorn, Skylark, Silver Bell, and Ella. Several of the siderite-bearing lodes here are distinguished from most of such lodes in other parts of the State [90] by the local predominance of tetrahedrite. The variations in relative proportions of tetrahedrite and galena do not appear to be systematic. The factors governing such variations are not known, but it seems clear at the Ramshorn, the only lode of this kind extensively developed, that zonal change with depth is not the controlling factor.

In addition to the tetrahedrite and galena pyrite, sphalerite, arsenopyrite, and chalcopyrite have been recognized. Pyrite is the most prevalent of these but neither pyrite nor any other sulphide is abundant in any of the workings examined. Sphalerite is commonly not present in sufficient quantity to be of commercial consequence. Most parts of the lodes contain no recognizable arsenopyrite or chalcopyrite. Copper is recovered from some of the ore, but this is derived mainly from tetrahedrite or its oxidation products. The principal value of the tetrahedrite, however, is in its silver content.

Siderite is the most conspicuous and abundant of the introduced gangue minerals. Quartz is only locally visible. Much of the ore of these lodes consists of sulphides in sheared country rock almost free from introduced gangue minerals, and between ore shoots there are long stretches of the lode marked only by shearing and slight alteration of the rock. In many localities there is no perceptible difference in appearance between a barren part of a valuable lode and a minor postmineral fault. Not uncommonly the fault, even though displacement on it is small, may be the more conspicuous of the two.

Why siderite should be the most abundant gangue mineral in certain lodes in this region and should be absent in other deposits nearby is not clear. Because both here and elsewhere the siderite-bearing lodes are among the most persistent and most valuable, the factors controlling their deposition are worthy of thorough study. The sideritic lodes in the Bayhorse region are in argillaceous rather than calcareous rocks and are, indeed, absent from the purer limestones and dolomites. It is a question whether the difference in chemical character of the rocks, the difference in texture with consequent differences in response to pressure, or the difference in some other structural condition is the controlling factor.

Structural relations.—Most of the sideritic lodes in the Bayhorse region strike north to N. 25° W., but there are several with markedly different strikes. Dips range from nearly flat to vertical and even in the same mine may swing to either side of the perpendicular. Most dips incline westward. Stope widths are rarely as much as 10 feet, and some of the rich ore veins in such mines as the Ramshorn are

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[90] Ross, C. P., A classification of the lode deposits of south-central Idaho: Econ. Geology, vol. 20, pp. 169-185, 1931.

only a few inches wide, although in such places the zone of shearing is commonly much wider than the vein. Several of the shoots have been mined for 300 or 400 feet both horizontally and down the dip.

In the Ramshorn and Skylark ground and probably also in the Silver Bell and elsewhere a number of more or less closely interrelated and linked lodes form lode systems. Some of the lodes of this type approximately accord with the bedding; others parallel joint systems; still others appear to be transverse to local structure or to be irregular and discontinuous. All tend to occur along zones of shearing composed of closely spaced and tightly closed parting planes rather than in breccias or gaping fractures.

Replacement has been the dominant factor in ore deposition. The media of transportation of the mineral substances must have been tenuous, in order to penetrate the tiny openings available and to produce the intimate intermingling of original and introduced material. Nevertheless it is clear that the relative ease of passage was a potent influence in localizing the mineralization. Deposition extended into unfractured rock on both sides of shear zones, but only where shearing was present. The largest and richest of the known lode systems of this character in the Bayhorse region are in the adjoining Ramshorn and Skylark mines. Like some of the replacement bodies in calcareous rocks, the deposits in these mines are in a part of a major anticline that bulges outward and consequently must have been under tension during the folding that produced the anticline.

A local example of the concentration of the ore solutions in areas of tension during deformation appears to be afforded by the ore shoots in the Ramshorn mine, where the dip of stoped portions of the veins is commonly less than the average inclination of the lodes and much less than the observed dip of the shear zone in many of the relatively barren parts of the veins. A similar tendency for sideritic lodes to occur in fine-grained rocks traversed by tight shear zones, with the ore shoots in the flatter parts of the lodes, exists in the Wood River region.[91] The explanation there offered, that a tendency to local tension in such portions of the shear zones aided ore deposition, is probably also applicable to conditions in the Ramshorn mine. In both regions some of the richest lodes are in rocks containing pyrometamorphic silicates.

The Ella and Silver Bell lodes appear to constitute exceptions to the rule that sideritic lodes of commercial importance are formed in places where tension during the deformation of the rocks was at a maximum. The Ella mine is in the zone of thrust faulting near the mouth of Kinnikinic Creek, and the principal Silver Bell workings are on Poverty Flat, in the gently inclined crestal portion of a major

[91] Umpleby, J. P., Westgate, L. G., and Ross, C. P., Geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814, pp. 96–105, 1930.

anticline. Both these mines are caved. If the details of ore occurrence in each were known they might prove less exceptional than they now appear.

LODES WITH JAMESONITE AND CALCITE

Mineral content.—The Boulder Creek district contains several lodes that have most of the characteristics of the siderite-bearing lodes but are distinguished from them by the facts that calcite takes the place of siderite and that jamesonite is an abundant metallic mineral. The lodes of this type are all somewhat lenticular bodies mainly valuable for their content of lead and silver, although zinc and antimony are also present. The hypogene metallic minerals are jamesonite,[92] galena, pyrite, and sphalerite, some chalcopyrite, pyrrhotite, and probably tetrahedrite. Stewart[93] in addition reports arsenopyrite and marcasite. The gangue is largely sheared siliceous argillite with considerable carbonaceous and locally calcareous material. Quartz has been introduced both by replacement of the argillite and by deposition along shear planes and fissures. Calcite is the principal gangue mineral in some of the ore from the Crater mine but is rare in most of the ore from other deposits, so far as observed during the present investigation. In the Livingston mine and elsewhere it coats shear planes and other partings at a distance from the ore shoots, but this may be merely the result of rearrangement of the calcareous material in the argillite by circulating ground water. In the Livingston, the only extensively developed mine, jamesonite is the principal lead mineral near the 2,300-foot level (measured from the apex of the lode), and galena is the principal one at higher levels, although both minerals appear to persist to some extent throughout the present workings. The lead ore has been so completely mined out in this part of the mine that the position of the boundary between jamesonite and galena ore cannot be determined by inspection of the stopes. This does not correspond to the usual zonal arrangement, in which antimonial lead minerals occur at levels above galena and sphalerite, and as galena is again prominent in ore on the 2,400-foot level and below, it is probable that the local predominance of the jamesonite is merely a detail without general significance.

Much of the higher-grade ore, especially in the Christmas stope of the Livingston, is very fine grained jamesonite almost free from gangue, resembling cast iron on fracture surfaces, but the average ore in most places is moderately coarse and contains a larger proportion of gangue minerals disseminated through it. Some of the material of the lodes outside the ore shoots consists of argillite and sparsely and irregularly disseminated sulphides. The preparation

[92] Shannon, E. V., Jamesonite from Slate Creek, Custer County, Idaho: Am. Mineralogist, vol. 10, pp. 194-197, 1925.

[93] Stewart, J. B., The Livingston mine, Custer County, Idaho: Mining and Metallurgy, vol. 7, p. 224, 1926.

of a high-grade lead concentrate is difficult, because so large a proportion of the metallic minerals is jamesonite, which contains only 40.3 percent of lead as compared with 86.6 percent in galena, and because sphalerite is abundant in some of the ore. There is a tendency for the sphalerite to be relatively abundant on the borders of the ore body, at least in parts of the Livingston mine, but selective mining permits the zinc content of the lead ore sent to the mill to be kept comparatively low.

Structural relations.—The lodes were formed along shear zones and fractures in the Milligen formation. The strike of the shear planes in general roughly approximates that of the bedding planes, although the two are probably nowhere exactly coincident. All the lodes have marked irregularities in trend, dip, and persistence. Deposition took place by a combination of replacement and the filling of openings, mainly the former, and the solutions clearly were so tenuous that they did not require profound shearing or large openings for their passage. Much of the ore is disseminated in altered country rock without bounding slips. Splits in the ore shoots and subparallel ore bodies separated by barren rock are characteristic. Under such conditions abundant crosscuts, even more than now exist, would seem to be desirable in order that all ore shoots may be found.

There are numerous unmineralized slips and fractures, many of which doubtless record postmineral movement. The mine maps accompanying descriptions of the individual properties below show a diversity of trends in these slips, but most of those which appear to have considerable displacement strike northwest.

Although the ore so far mined came, apparently without exception, from shoots in the argillaceous strata, some mineralization has taken place in the dikes and stringers of aplitic rock at the Livingston. In several places along the aplite dike that approximately parallels the Livingston lode at the surface sulphides are locally disseminated rather abundantly in the dike rock, and some of the igneous rock underground is also mineralized. It is reported that some of the ore mined in the main series of stopes in the Livingston was a replacement product of aplite.

The close structural association between these lodes and the Idaho batholith and related dikes, brought out in the mine descriptions below, offers more direct evidence of genetic relation with the batholith than is available for any of the previously described types of deposits. The predominance of the rare mineral jamesonite sets these lodes apart from all the other lodes in Idaho that have yet been described. Shannon [94] reports only one other occurrence of probable jamesonite in ore body believed to be of the age of the Idaho batholith. This specimen came from the Standard Mammoth mine, Shoshone County,

[94] Shannon, E. V., The minerals of Idaho: U. S. Nat. Mus. Bull. 131, p. 162, 1926.

in which boulangerite is a common mineral. Those parts of the North Star and neighboring mines in the Wood River region [95] in which boulangerite is abundant resemble in other respects the deposits here described. Boulangerite ($5PbS.2Sb_2S_3$) and jamesonite ($4PbS.FeS.3Sb_2S_3$) are so similar that slight variation in conditions might well be all that would be required to determine which of the two would form. The ore deposits of the Wood River region, including the North Star, probably belong to the period of mineralization related to the Idaho batholith, although the antimonial minerals appear to have been formed in general rather late in the history of the deposits. There is even reason to believe that some of the stibnite in that region was formed in a period of mineralization distinctly later than the main ore deposition and may well be of Tertiary age. Shannon in the paper just cited reports that jamesonite probably occurs in the Reliance mine,[96] Blaine County, and the De Lamar mine,[97] Owyhee County, in both of which the ore bodies are of Tertiary age.

LODES IN GRANITIC ROCK

Most of the existing lodes in granitic rock, comprising the third group of lodes as above defined, are held mainly for their gold content, although several contain lead and other metals also. The principal lodes of this kind visited are those in Washington Basin and the Aztec mine, a short distance farther north. One prospect in granitic rock was noted on Juliette Creek west of the Ramshorn mine. In valleys on both sides of the Salmon River below Stanley there are gold placers and small auriferous quartz veins in the granitic rock.[98]

The workings in Washington Basin and at the Aztec mine follow shear zones containing quartz lenses. In the exposures seen metallic minerals are irregularly and sparsely distributed in both the quartz and the sheared and altered granitic rock. According to observations during the present study and to published reports [99] they include pyrite, pyrrhotite, arsenopyrite, sphalerite, galena, stibnite, bismuthinite, native bismuth, joseïte, and possibly maldonite and tetradymite, named in approximate order of decreasing abundance, though this order varies materially in different places. Some of

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[95] Umpleby, J. B., Westgate, L. G., and Ross, C. P., The geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814, pp. 179–183, 1930.

[96] Umpleby, J. B., Geology and ore deposits of the Mackay region: U. S. Geol. Survey Prof. Paper 97, pp. 120–122, 1917. Anderson, A. L., Geology and ore deposits of the Lava Creek district, Idaho: Idaho Bur. Mines and Geology Pamph. 32, p. 54, 1929.

[97] Piper, A. M., and Laney, F. B., Geology and metalliferous resources of the region about Silver City, Idaho: Idaho Bur. Mines and Geology Bull, 11. pp. 93–112, 1926.

[98] Umpleby, J. B., and Livingston, D. C., A reconnaissance in south-central Idaho: Idaho Bur. Mines and Geology Bull. 3, pp. 13–17, 1920.

[99] Umpleby, J. B., Ore deposits in the Sawtooth quadrangle, Blaine and Custer Counties, Idaho: U. S. Geol. Survey Bull. 580, pp. 231–232, 244–246, 1915. Shannon, E. V., the minerals of Idaho: U. S. Nat. Mus. Bull. 131, pp. 50, 71, 82, 1926. News note in Eng. and Min. Jour., vol. 83, p. 23, 1907.

the lodes in Washington Basin, not seen during the present study, are reported to contain so much galena as to constitute lead ore, although even here the principal value of the ore is in the gold content. The presence of bismuth minerals is of especial interest, as few lodes in central Idaho contain bismuth. The only other reported occurrence in the vicinity of the Bayhorse region is the tetradymite (Bi_2TeS_2) at the Basin prospect, near the head of Trail Creek, east of Ketchum, Blaine County.[1] The joseïte, a bismuth telluride containing some sulphur and selenium, was determined by W. T. Schaller in a specimen kindly furnished by the late G. F. Blackman, former owner of the principal claims in Washington Basin. The presence of native bismuth and bismuthinite (Bi_2S_3) has been confirmed by Shannon. The identity of the other bismuth minerals reported has been less authoritatively determined. Maldonite was originally regarded as gold bismuthide (Au_2Bi).[2] However, some authors [3] regard it as merely gold containing some bismuth. The presence of bismuth minerals suggests a possible relation to the bismuth-bearing lodes of Tertiary age in the Boise Basin, although in other respects there is little resemblance.

In addition to including lenses and tabular masses of coarse-grained white quartz, the granitic rock in the shear zones has been sericitized and silicified. Locally barite [4] and diopside [5] are present.

MISCELLANEOUS DEPOSITS

The miscellaneous deposits classed in the fourth group include several varieties, each of which has only a few representatives in the region. These are (1) lead-bearing veins on conjugate fracture systems, (2) copper deposits in breccia zones in the Ramshorn slate, (3) molybdenite lodes, mostly in the Milligen formation, (4) irregular veins containing much arsenopyrite in addition to other minerals, and (5) deposits associated with gabbro.

The lead-bearing veins, represented by the Lucky Strike and Deertrail prospects, were formed by replacement along two sets of fissures, mainly in the Milligen formation but extending into a nearby mass of quartz monzonite. Galena and sphalerite have been formed in sheared rock that is somewhat altered but that contains no visible introduced gangue minerals. Presumably these veins constitute a minor variety of the lead-bearing lodes on shear zones, of which several kinds have already been described.

The copper deposits are represented by prospects on both sides of the stream that drains Jimmy Smith Lake. They comprise veins of glassy quartz with some calcite, of varying size and trend, in a

[1] Umpleby, J. B., Westgate, L. G., and Ross, C. P., op. cit. (Bull. 814), p. 95, 1930.
[2] Dana, E. S., The system of mineralogy, 6th ed., p. 15, 1909.
[3] Ford, W. E., A textbook of mineralogy, p. 401, 1932.
[4] Shannon, E. V., op. cit., p. 82.
[5] Umpleby, J. B., op. cit. (Bull. 580), p. 246.

shattered zone in the argillite. Pyrite, chalcopyrite, and their oxidation products are rather sparsely distributed through the lodes. Assays show that very little gold or silver is present.

Molybdenite is widely distributed in the Carboniferous strata between Spring Basin and the head of Boulder Creek, in the southeastern part of the Custer quadrangle. Development is as yet too slight to determine whether a deposit of commercial value exists. The molybdenite is doubtless a product of the igneous metamorphism effected by the nearby stock of quartz monzonite.

The Fuller & Baker prospect, on Little Boulder Creek, contains a variety of deposit not represented elsewhere in the region. Here are several apparently unrelated veins of massive glassy quartz, with bands and bunches of arsenopyrite, pyrite, galena, and sphalerite, together with some tourmaline, red jasper, and calcite. The calcite and especially the jasper may be much later than and unrelated to the rest of the assemblage. It may well be that these veins differ little in origin from the auriferous lodes of Washington Basin. The extensive shearing and alteration that characterizes those lodes is lacking at the Fuller & Baker prospect, but this may be due to the difference in the country rock. The tourmaline in this prospect, like the diopside in Washington Basin, indicates some connection between lodes of this kind and pyrometamorphism.

Two prospects, the Pedrino and Sadle, near Kinnikinic Creek, are closely associated with small masses of gabbro. The Pedrino contains chalcopyrite, both in quartz stringers and in amphibolite seams. The Sadle, which is in argillite close to gabbro, exposes galena in quartz stringers.

VEINS IN THE CHALLIS VOLCANICS

In several places on both sides of the East Fork of the Salmon River remarkably persistent quartz veins cut the Challis volcanics. These constitute the fifth group as above defined. In places these veins consist of silicified lava cemented by cryptocrystalline quartz, and in all exposures crustified and drusy cavities are plentiful. It is clear that, unlike most of the lodes in the older rocks, these veins were formed mainly by fissure filling comparatively close to the surface. Assays show that they contain small amounts of gold, silver, and copper, but no sulphides were observed.

OXIDATION

All the lodes in the region have been subjected to oxidation close to the surface, and in some of them most of the ore mined in the early days was oxidized. Here as elsewhere in south-central Idaho, however, oxidation generally has been neither deep nor thorough. Almost everywhere original sulphide minerals persist in surface exposures. In most mines the ore at a depth of 50 feet or less below the surface is little affected by oxidation. The few mines, such as the Ramshorn and Red Bird, that have yielded large quantities of oxidized ore are on steep slopes, so that ore even in the deeper levels is not far from the surface. To judge by available maps, most of the oxidized ore in both the Ramshorn and the Red Bird was within 250 feet of the nearest point on the surface, and much of it was within 100 feet of the surface. If, as has been suggested, caverns in the calcareous rock at the Red Bird permitted free circulation of meteoric water, oxidation of the sulphide ore would be facilitated. In the most thoroughly oxidized ore of most mines in the region some sulphide remains.

The ore in the Little Livingston mine, in the Boulder Creek district, is more thoroughly oxidized than that in most other deposits in the region. In this respect it contrasts sharply with the ore of the nearby Crater and Livingston mines. The extensive fracturing in the Little Livingston played some part in this marked oxidation, but a more potent factor may have been the protection from erosion effected by the cover of early Pleistocene glacial debris, which is only now being removed from the Little Livingston outcrops.

ENRICHMENT

The evidence of supergene enrichment in present exposures is meager. That some enrichment has taken place is indicated by the presence of cerargyrite, native silver, argentite, and pyrargyrite in some of the ore mined in the early days. Umpleby's statements, summarized in the mine descriptions below, show that such minerals were present locally in ore being mined even as late as 1911. Very little, if any, of such material exists in specimens collected during the present investigation. The only sulphides of apparent supergene origin observed during the present investigation are the galena and pyrite that have been deposited in otherwise barren rock on the ninth (lowest) level of the Red Bird mine. Similar pyrite is reported from upper levels, and small amounts of galena of apparently similar character have been mined on and just above the ninth level.

A conspicuously vuggy pyritic body is exposed in a drift in the eastern part of the ninth level. Lessees have stoped out lead ore immediately above it. Wulfenite and probably also cerusite occur in stringers in the pyrite, and there are also small amounts of limonite and manganese oxide. In comparison to the ore on the levels above, however, this pyritic body is almost unoxidized. It contains small amounts of quartz and calcite. Both the pyrite and the quartz were in part deposited in small open cavities or vugs.

In another part of the ninth level there is an ore body even less altered than the pyritic mass. This consists largely of rather fine-grained galena distributed in irregular streaks through the impure dolomite. In some of it galena is so abundant as to constitute ore of good grade. Much of the galena is so loosely cemented as to crumble easily when picked. Some pyrite is present. Nearby there are several vugs and crevices a few inches to a few feet in maximum dimensions. Cauliflowerlike radiating masses of pyrite encrusted with galena crystals project into and partly fill some of the vugs. In other openings, generally of fissurelike form, the pyrite is absent or subordinate and galena is more abundant. In these openings loose grains of galena can be scraped up by the handful. These grains generally have the form of elongated cubes and doubtless originally formed part of the coating on the walls of the vugs. In some of the crevices they cement angular fragments of the dolomitic wall rock.

Analyses of galena and pyrite from the cauliflowerlike masses and of galena from the crevices show that only a negligible amount of silver is present, although samples of hypogene galena from the Red Bird and the nearby South Butte mine were found to contain considerable amounts of silver, probably in solid solution. The results of the analyses are shown in the table below.

Silver content of selected samples of galena and pyrite from Squaw Creek, Custer County, Idaho

[Charles Milton, analyst]

	Percent	Ounces per ton
Bl 93 A, galena, Red Bird mine, by nephelometer	0.0004	0.13
Bl 93 B, pyrite, Red Bird mine	None.	None.
Bl 93 B, galena, Red Bird mine, possible trace of Ag by spectroscope	None.	None.
Bl 97, hypogene galena, 5th level, Red Bird mine	.021	6.7
Bl 82, galena, South Butte mine	.077	24.6

Thus the structural, textural, and chemical characteristics of the material in the crevices and vugs are strikingly different from those of the hypogene sulphides of the region and correspond to what might be expected if the material had been deposited by descending supergene solutions laden with acid constituents from the abundant and in large part easily penetrated ore bodies above.

As noted in the description of the Red Bird mine on pages 104–105, there is reason to think that both in the past and in recent times there has been an exceptionally copious flow of ground water through the mine, resulting locally at least in the formation of open cavities.

It is conceivable that the radiate pyrite and the loosely cemented galena were formed at a late stage in the hypogene deposition or in some more recent period of mineralization, when both temperature and pressure were relatively low, but evidence of any such late hypogene deposition is lacking here.

There is no district in the Rocky Mountain region in which enrichment of galena is known to be of economic importance. Ransome [6] believed that considerable galena crystallized from supergene solutions in the Breckenridge district, Colo. Recent work in this district by Lovering [7] indicates, however, that although this process may have been operative, the amount of galena thus deposited is very small. Thus if the occurrence here described is correctly interpreted it constitutes an interesting exception to the rule that galena throughout the Rocky Mountain region is hypogene. Even at the Red Bird mine it is clear that the amount of galena ore that may be of supergene origin is trivial compared to the size of the shoots stoped in the upper workings.

OUTLOOK

The most richly productive period in the history of mining in the Bayhorse region was that in which oxidized ore was chiefly mined. This doubtless resulted to some degree from the presence of local masses of ore enriched in silver and to a less extent in other metals by supergene processes, but the greater ease of mining in the soft, oxidized ground, the facility of refinement of carbonate ore with scanty smelting equipment, and the fact that hand sorting was used to a greater extent than is commonly practiced today were favorable features which together were probably at least as potent as enrichment in aiding the development of the mines. Hence the fact that most known bodies of oxidized lead ore in the Bayhorse region are largely depleted is not so unfavorable a factor as might appear from a comparison of the production record of the early days with that of recent years. Here as in many other regions the day of bonanza deposits easily mined and treated with slight equipment is over. The history of the Ramshorn, Livingston, and other mines, however, shows that bodies of hypogene sulphide ore of sufficient size and tenor to repay mining were deposited in numerous places in the region. It is to be expected that equally valuable ore shoots remain unmined. The individual ore shoots are of small to moderate size, and in several of the more promising lodes the sulphide ore is complex. These factors combined with the long motor-truck haul and long distance from the nearest railroad points to smelting centers make operation of the mines of the Bayhorse region costly. The facts that most of the lead-bearing ore contains considerable silver and that the tetrahedrite ore is rich in that metal may constitute one of the most favorable factors in the future of the region. The zinc, copper, molybdenum, arsenic, and other metals locally present do not in general appear to constitute resources of primary importance under conditions to be anticipated in the near

[6] Ransome, F. L., Geology and ore deposits of the Breckenridge district, Colo.: U. S. Geol. Survey Prof. Paper 75, pp. 168-169, 1911.

[7] Lovering, T. S., Geology and ore deposits of the Breckenridge mining district, Colo.: U. S. Geol. Survey Prof. Paper 176, pp. 31, 1934.

future, although eventually it may prove profitable to mine all of them, especially where it can be done in conjunction with the handling of lead and silver ore. The gold lodes locally present, especially in the western part of the region, have not yet been sufficiently developed to furnish many data as to their possibilities. Apparently most of the gold ore is not of high grade, but it may be sufficiently abundant in places for material of low to moderate tenor to be profitably handled.

THE MINES

BAYHORSE DISTRICT

GOOD HOPE MINE

The Good Hope mine is on Lyman Gulch in unsurveyed T. 15 N., R. 20 E., a short distance outside of the area surrounding Round Valley, which is shown on plate 1. Here a small prospect shaft has been sunk on an iron-stained breccia zone in Kinnikinic quartzite. The dump shows that coarse white vein quartz with chalcocite, azurite, and malachite was found in the shaft. A short distance away is an old stone cabin, and nearby a short tunnel following a vein of massive quartz. When visited, in June 1927, this prospect had recently been relocated, but most of the little development work there was obviously done long ago.

DEPOSITS NEAR GARDEN CREEK

There are several prospects and old mines on upper Garden Creek and its tributaries. The principal development is on Merrimac and Whetstone Gulches, south of Garden Creek. The Keystone mine is near the head of Whetstone Gulch and is reported to have once been productive. All the workings on both gulches are either within the Bayhorse dolomite or on the contact between that formation and the Ramshorn slate. In several places this contact shows silicification, brecciation, and mineralization. The ore at the Keystone comprises oxidized lead and copper minerals in a breccia zone containing veins of quartz and barite. This zone is in the dolomite close to the argillite contact. Most of the workings are caved, and none appeared to be safely accessible when visited by R. R. LeClercq in July 1928. Some prospecting has been done in the dolomite on Daugherty Creek.

Shallow prospect pits have been opened in several places in the Garden Creek phyllite on the north slope of the valley of Garden Creek, but most of these contain little visible evidence of mineralization. Close to the creek channel on the south side a short tunnel follows a vein in the phyllite. This vein is 8 inches wide at the tunnel portal and consists of white quartz with numerous vugs. Massive siderite was formed locally in the zone of shearing followed by the vein. Probably a pocket of lead ore was encountered in this tunnel, as there are several sacks of hand-picked galena in the cabin nearby. The vein strikes N. 15° W. and dips 35° NE. The cleavage in the phyllite trends N. 10° W. and dips 75° NE. Banding that appears to represent bedding is of variable trend but at the portal appears to strike about N. 25° W. and dip 15° NE.

RAMSHORN MINE

Property.—The Ramshorn mine, owned by the Ramshorn Mines Co., of Salt Lake City, is on the north side of Bayhorse Creek about 6 miles above its mouth. The property of the company includes the Ramshorn and Skylark group here and the Beardsley group near the town of Bayhorse. It comprises 14 patented and 5 unpatented claims,[8] of which only about 4 belong to the Beardsley group. The developments of the Ramshorn consist of 17 tunnels and 10 intermediate levels, about 6.5 miles in total length. The vertical distance between the uppermost tunnel and that near creek level is about 1,700 feet. The upper eight tunnels, several of the tunnels near the base of the hill, and large parts of the stopes are now inaccessible.

The principal tunnels from highest to lowest are designated Ramshorn 6 to 1, Utah Boy 1 to 5, and Post Boy 4 to 1. In addition there are the Wheelbarrow tunnel, between Post Boy 3 and 4, and the Mono tunnel, near the creek level. The ore was formerly sent by a gravity tramway down the hill to bins at the creek level, but this is now in disrepair.

The company has a flotation mill with a capacity of 60 tons a day at the old town of Bayhorse, about 3 miles down the creek from the mine.

History.[9]—The deposits of the Ramshorn mine were discovered in August 1877, and the mine was actively operated most of the time for the next 20 years. During this period the ore was treated at a smelter at Bayhorse, of which little trace except the slag dump now remains. Common red building bricks were made at the head of Bayhorse Creek.

During most of the period 1897 to 1917 little was done except in 1902, when large shipments were made. A mill was erected in 1905 but appears to have been little used. In 1917 and 1918 the mine was operated by the Aetna Mining & Investment Co. In the following year the Ramshorn Mines Co. was incorporated. This company remodeled the mill for flotation and continued in active operation of both mine and mill until October 1925. Since then lessees have been at work.

Production.—Estimates of the production of the Ramshorn in its first 20 years of operation range between $2,000,000 and $3,000,000. The only definite data available are the scattered references in the

[8] Mines Handbook, 1926, p. 889.

[9] Compiled from Mines Handbook, Mint reports, Mineral Resources of the United States, U. S. Geol. Survey Bull. 539, and annual reports of the State mine inspector.

Mint reports. These, although far from complete, indicate that the correct figure may well lie between the two extremes given above and is probably closer to the larger one. In the report for 1884 the total production of the Ramshorn was given as 10,000 tons of ore averaging 8 percent of lead and 120 ounces of silver to the ton. At the average price of lead and silver at that time the value of the production in the first 7 years of the life of the mine was thus nearly $1,500,000, a figure which makes the estimate of $2,000,000 for the first 20 years appear distinctly too low. The table below shows in detail the production from 1902 to 1926, which includes practically all since the shut-down in 1897. This table includes some production from the Beardsley group. The value of the ore listed exceeds $1,500,000, so that it is probable that the total gross production of the Ramshorn is fully $4,000,000.

Production of the Ramshorn Mines Co., 1902–26

[From the records of the U. S. Bureau of Mines. Published by permission of the Ramshorn Mines Co.]

Year	Crude ore (tons)	Concentrates (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1902	636	----------	5.43	55,340	15,870	38,394
1912	32	----------	----------	3,480	11,767	8,352
1915	7	----------	.04	6,407	2,760	----------
1916	26	----------	----------	5,391	2,421	1,619
1917	554	----------	6.8	47,557	70,385	11,679
1918	492	----------	1.50	46,775	32,054	11,520
1919	599	----------	4.09	36,554	29,046	66,497
1920	5,043	660	5.84	239,369	75,174	239,409
1921	9,094	766	4.50	310,823	122,886	126,169
1922	5,206	946	17.00	221,170	58,441	670,079
1923	5,264	698	8.38	290,309	116,568	644,031
1924	4,234	730	17.06	182,152	64,909	74,759
1925	6,260	1,164	25.90	230,131	89,548	1,230,305
1926	133	----------	1.89	36,110	10,385	88,226
Total	37,580	4,964	98.43	1,711,568	702,214	3,883,877

All the ore mined from the Ramshorn has been high in silver, and most of it has contained considerable lead and copper. Probably some copper was recovered in the early days of operation. Much of the ore mined contained more than 100 ounces of silver to the ton, but the Mines Handbook for 1926 notes that mill feed carried 37.4 to 56.8 ounces to the ton. Reports indicate that selected ore containing 700 to 1,000 and even 3,000 ounces of silver to the ton has been shipped. The ore shipped by lessees in recent years contained several hundred ounces to the ton but was carefully hand-picked. The base metals have always been of secondary importance in this mine. The ore in the early days averaged 8 percent of lead, and some of the high-grade ore shipped more recently contained more than 30 percent. The Mines Handbook says that the milling ore contains 1 to 9.8 percent of lead and that shipped 4.8 to 49.7 percent. Here, as in many other lodes in this part of Idaho containing abundant sulphides, the amount of gold is trivial.

Copper is also present in notable amounts. Umpleby [10] says that the average ore in one of the larger ore shoots contains 3 percent of copper. Bell [11] notes that some of the ore contains as much as 20 percent of copper. The Mines Handbook gives the amount of copper in the milling ore as 0.97 to 1.6 percent, and that in the shipping ore as 4.35 to 8.3 percent.

Character of the deposit.—The Ramshorn lode comprises several veins in the Ramshorn slate. The slate trends somewhat west of north and has an average dip of about 20° or less but is intricately crumpled. Locally the attitude of the beds changes rapidly within short distances, and small tight folds are characteristic. As a consequence individual beds in many places are steeply inclined. The slaty-cleavage planes are not crumpled in this manner but show considerable variation in attitude. Their average strike is slightly west of north, and their average dip steep to the west.

The three principal veins now exposed are the East Utah Boy, the West Utah Boy, and the Post Boy. In addition there are the vein in the Wheelbarrow tunnel and minor branches of the Utah Boy veins. It is believed that all the veins in the Ramshorn mine are so closely related that they may be regarded as parts of a single lode. The fissures are all results of the same structural causes and were produced during a single period of deformation. Probably if development were carried far enough it would be found that all are interconnected so as to form a single linked system. As large parts of the workings were inaccessible when visited in 1928 and many that were open were closely timbered, it was not everywhere possible to trace out the interrelations of the different veins, especially in a vertical direction. Plate 14 and figure 9 show in plan and section the distribution of the veins as observed and inferred from accessible exposures. The workings above Utah Boy tunnel 2, from which the early production was derived, are now inaccessible, but from the map it appears that they contained two veins. The more continuous of these is inferred to be a continuation of the West Utah Boy vein; the other is probably a still more westerly branch that may have joined the West Utah Boy vein near Utah Boy tunnel 2 and is not represented in the lower workings. The average trend of the different veins down to Utah Boy tunnel 5 is nearly north. As is indicated by the trend of the main drifts shown on plate 14, there are considerable departures from this average, especially near junctions of the East Utah Boy and West Utah Boy veins. The average dip above Utah Boy tunnel 2 is about 40° W., and the average between tunnel 2 and tunnel 5 is somewhat more than 60° W. Observed dips in the tunnels generally exceed this

[10] Umpleby, J. B., Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, p. 65, 1913.

[11] Bell, R. N., An outline of Idaho geology and of the principal ore deposits of Lemhi and Custer Counties, Idaho: Internat. Min. Cong. Proc. 4th sess., p. 72, 1901.

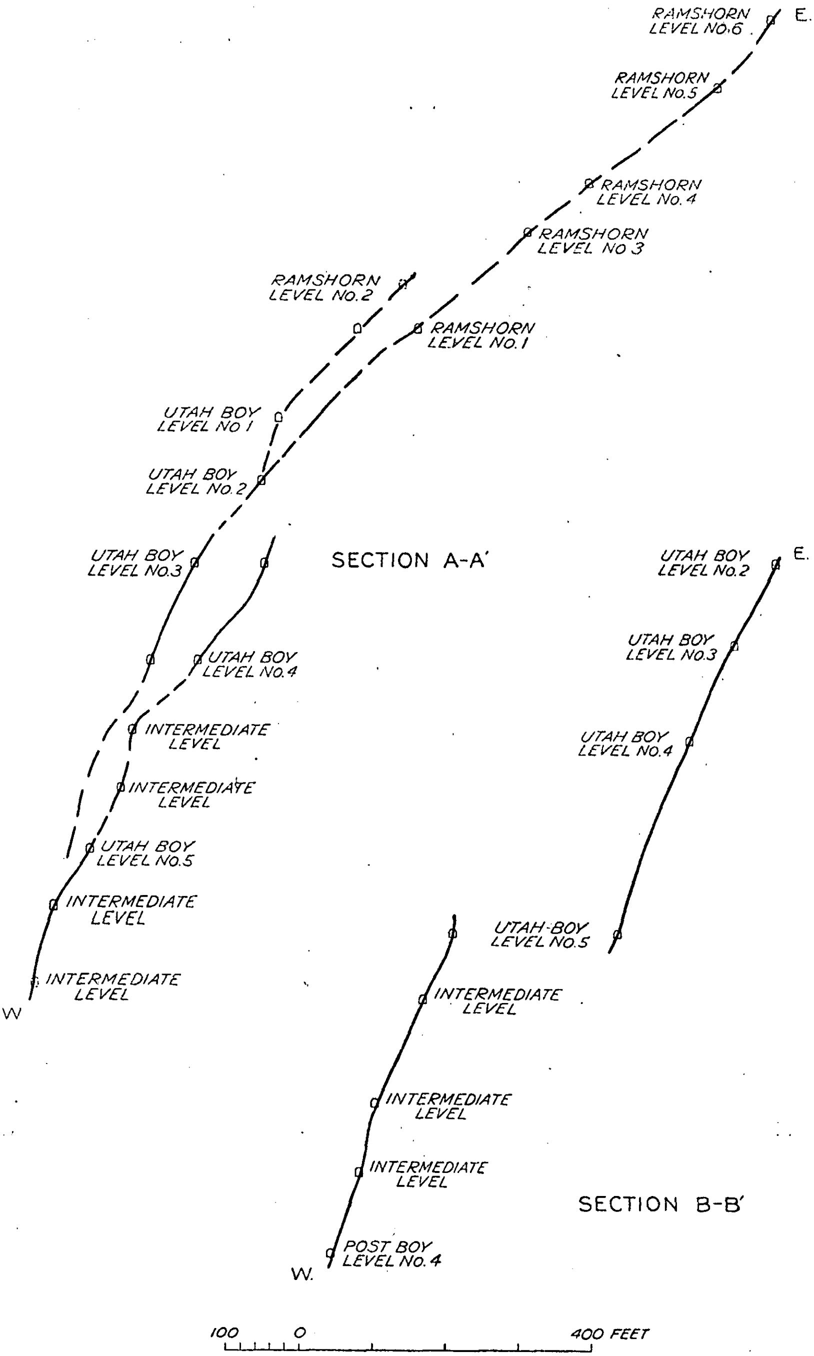


FIGURE 9.—Transverse sections through the Ramshorn mine along lines A-A and B-B, plate 14, showing the principal lodes.

COMPOSITE MAP OF THE RAMSHORN MINE.

Adapted from company's maps.

average and in places approach the vertical. Some of the stopes are inclined at angles considerably below the average dip.

From Utah Boy tunnel 5 downward, with the possible exception of the Wheelbarrow tunnel, inaccessible in 1928, the workings lie south of those above and are mostly on the Post Boy vein. This vein and the part of the West Utah Boy vein exposed in the southern part of Utah Boy tunnel 5 trend nearly N. 10° W. and dip on the average more than 70° W. In places the dip is more nearly vertical and rarely eastward. The veins are approximately parallel to the major cleavage in the enclosing Ramshorn slate and dip in the same direction as this cleavage but on the average at somewhat lower angles. Striations on the walls indicate that the displacement, at least in its later stages, was approximately horizontal. In places, especially in the upper tunnels visited, the veins are nearly parallel to the bedding. This, however, appears to have resulted merely from the fact that the contorted slate locally assumed attitudes parallel to the direction of later fissuring. In crosscuts between the veins and in the walls beyond known veins there are numerous small fissures approximately parallel to the veins. Many of these show slight mineralization. In the crosscut off Utah Boy tunnel 5 between the West Utah Boy vein and the Post Boy vein there are several such minor mineralized fissures, which serve as connecting links between the two veins.

A few cross faults appear to have preceded the fissuring along which most of the mineralization took place. For example, near the portal of Utah Boy tunnel 3 there is a fault slip that has been broken and offset 15 feet by the Utah Boy vein. This fault strikes N. 38° W., dips about 40° SW., and shows slight evidence of mineralization. It may have resulted from forces complementary to those causing the fissures along which the veins were formed. The vein matter has been much sheared and brecciated subsequent to its deposition. This postmineral movement thus indicated does not appear to have produced much displacement. The disturbance was more pronounced in the Post Boy than in the Utah Boy veins. Umpleby,[12] however, notes two places in the Utah Boy veins where faulting parallel in strike to the veins but opposite in dip has resulted in displacements sufficient to move the hanging wall downward about 25 feet relative to the footwall.

The vein matter comprises tetrahedrite and galena with minor amounts of chalcopyrite, pyrite, arsenopyrite, and sphalerite in a gangue of siderite, crushed and altered slate, and in places quartz. Considerable sections of the veins between stopes consist of sheared and somewhat altered slate with little evidence of mineralization, and the ore shoots are generally bordered by material of this char-

[12] Umpleby, J. B., op. cit. (Bull. 539), p. 65.

acter. In most stopes there are one or more narrow bands of siderite through which the metallic minerals are scattered in tabular and irregular masses. Most of the bands of ore are parallel to the major fissuring, but there are various departures from this rule. Later shearing and brecciation have in places destroyed the original regularity and produced a jumbled mass of ore and rock. In most places, however, such movements have not been sufficient to alter materially the original size of the ore bodies or to interfere with mining except that they tend to make more timbering necessary.

The total width of sheared and mineralized material is generally 3 to 6 feet, but the portions containing the valuable minerals are everywhere narrow. Much of that seen during the examination ranged from a small fraction of an inch to a few inches in width, but in the better ore shoots the average was doubtless considerably above this. The Mines Handbook says that the Utah Boy vein averages 14 inches in width and the Post Boy 18 inches. Umpleby speaks of one ore body between Utah Boy tunnels 3 and 4 that was 350 to 400 feet long on level 4, averaged 2 feet in width, and was continuous to level 3, 140 feet above, although considerably shorter on this level.

Bell,[13] writing in 1900, said that the pay streaks range from 6 inches to 6 feet in width. In spite of the narrowness of the ore it is remarkably persistent. A large proportion of the ground above Utah Boy tunnel 5 has been stoped out, and there is considerable stoping between that level and Post Boy tunnel 4, also a little in the less developed lower portion of the mine.

It appears that the character of the mineralization, except for supergene alteration in the upper levels, is essentially uniform throughout the mine. The proportions of galena and tetrahedrite vary somewhat from place to place, but this variation does not appear to be systematic. The tetrahedrite is most sought after because of its high silver value and is found on all levels, but galena, which is also argentiferous, is the principal ore mineral in several places and appears to be as widely distributed as the tetrahedrite.

The ore now exposed is almost all hypogene, although along Utah Boy tunnels 2 and 3 some oxidized ore remains. Above these tunnels most of the ore was more or less oxidized. The ore treated in the first 20 years of the history of the mine was in large part oxidized.

SKYLARK MINE

Property.—The Skylark mine adjoins the Ramshorn on the northwest. It is near the crest of the ridge north of Bayhorse Creek, near the head of the creek. The property originally comprised 10 claims, some of which are now owned by the Ramshorn Mines Co. There

[13] Bell, R. N., The deepest mine in Idaho, the Ramshorn at Bayhorse: Mines and Minerals, vol. 21, p. 174, 1900.

were 16 principal tunnels on the main part of the Skylark vein, 3 more in the Silver Wing workings above, and several short tunnels—in all perhaps 25,000 feet of work. Plate 15, adapted from an old map kindly lent for the purpose by Mr. Jerry Sullivan, shows the principal workings. Nearly all the tunnels were caved, at least at the portals, when visited in 1928. Only two of the tunnels were entered, but these were in such good condition that it is probable that several of the others could be made accessible with a little work near the portals. One of those entered is thought to be that called no. 1 on plate 15. If so, the other is probably no. 6 west. The tunnels east of no. 1 are on a steeper part of the mountain than those west of it. Consequently some of their portals have been so obscured by talus slides that it is difficult to find them, and some may be completely obliterated. Traces of old tunnels can, however, be seen at intervals along a gentle incline practically to the upper Ramshorn workings. The easternmost of these is roughly 200 feet vertically above the caved mouth of Ramshorn tunnel 1.

History and production.[14]—The Skylark was located in 1877 and was purchased by the Omaha Smelting & Refining Co. in 1880. It yielded 250 tons of rich ore in 1881. In 1883 the Ramshorn Mining Co. had the property bonded for $35,000, but owing to the poor showing of ore it allowed the option to lapse. A short time thereafter the ore bodies that afforded the principal production were encountered. The Mint reports credit the Skylark in 1886 with a production of 130,500 ounces of silver and 3,000 pounds of copper, valued at $168,727. Operations were carried on continuously until 1902, when the Clayton smelter, which had treated most of the ore, was shut down. The total production up to that time has been estimated as $2,700,000, derived from ore that averaged about 8 percent of copper and 80 ounces of silver to the ton. Some of the high-grade ore ran several thousand ounces in silver and as much as 20 percent of copper. From 1902 through 1921 there was intermittent production, mainly by lessees, but the total production has not been great. During most of this period the Skylark was under the same management as the Red Bird. It was acquired by the Ramshorn Mines Co. about 1921, but little has been done on it since then.

Character of the deposit.—It appears from plate 15 and such observations as could be made that the veins worked in the Skylark mine include the Skylark vein, the upper and lower Silver Wing veins, and several steep veins that have been little explored. The largest of the steep veins is probably that followed by part of the Shamrock tunnel. All are in the Ramshorn slate, which here is lighter-colored and more

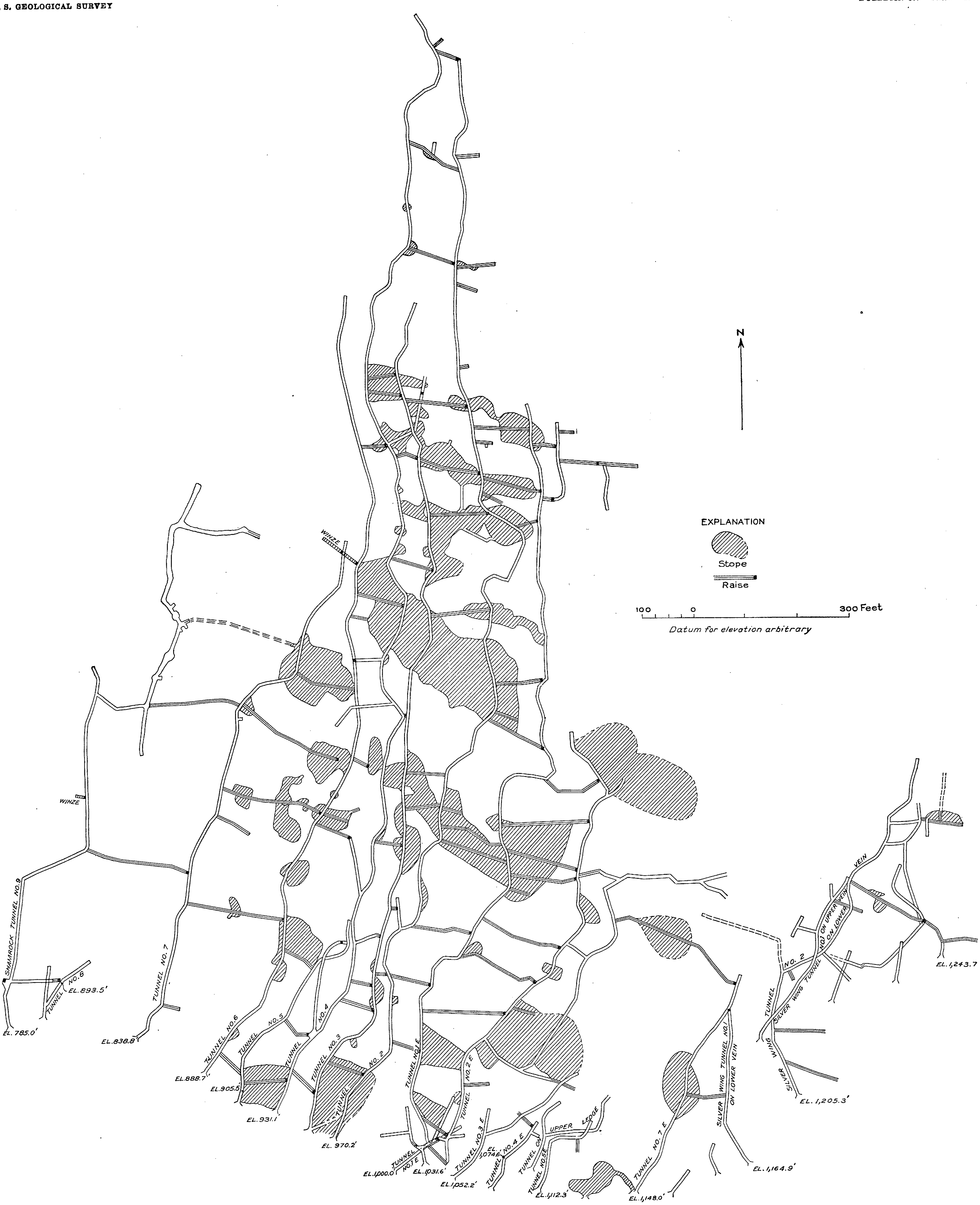
[14] Mainly from Umpleby, J. B., Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, p. 66, 1913, with additions from Mint reports and other sources.

quartzitic than in most other places. A few small pegmatite dikes cut the slate in and near the workings.

The Skylark vein is far more extensively developed than any of the others. To judge from the map, it strikes nearly north and dips on the average 17° W. In the two tunnels entered during the present study the dip ranges from 0° to 20° and rarely more. In the southeastern part of the workings the strike is somewhat east of north. The lower Silver Wing vein is similar in attitude to the Skylark and may be its upper extension. The upper Silver Wing vein appears to strike about N. 30° E. and dip about 5.5° E., provided the easternmost tunnel shown on plate 15 is on this vein. The steep vein in the Shamrock workings appears from the map to strike slightly east of north and to dip steeply west. Near the crest of the ridge there are a series of caved tunnels, each almost directly under the one above, on a vein striking N. 10°–15° W. and dipping very steeply west. These tunnels are not shown on plate 15 but may mark the upward extension of the steep vein in the Shamrock tunnel. In the more westerly of the tunnels accessible to the writer, probably no. 6 west, two veins with steep west dips were observed. Both had been stoped. They join the gently inclined Skylark vein from below, but whether they are truncated by or merge into that vein was not determined.

The bedding is obscure but dips in general gently westward. Umpleby notes that the strike is N. 8° W. and the dip generally 22° SW., although near the portal of tunnel 9 west the beds dip 60° W. The steep beds are separated from beds with a 22° dip by an east-west fault that displaces the beds on the north side 50 or 60 feet to the east. From observations in the two accessible tunnels it appears to the writer that the Skylark vein follows a locally discontinuous fissure approximately parallel to the average inclination of the beds but in places truncating them. The fissure locally frays out in several minor branches.

Plate 15 shows that there are numerous small stopes in the mine, most of which lie between tunnels 1 and 6 west. From this and other data it appears that the ore bodies mined were individually rather small and discontinuous. As indicated by the stoping shown on plate 15 the valuable ore shoots are interrupted by much material that was either too scant or too low in grade to be worked on. All stopes shown on this map have stope lengths much under 200 feet and most of them less than 100 feet. A few have been followed more than 300 feet down the dip, but most are far shorter. Umpleby says that in most places there is a zone of brecciation, rarely more than 3 feet wide and bordered by firm walls. He considers that this zone parallels the bedding. Within the crushed layer the ore, according to him, occurs in irregular lenslike shoots, generally elongate parallel to the dip, mostly less than 100 feet long and rarely more than 200 or 300 feet. The average width of the ore is reported to have been 20 inches.



MAP OF THE SKYLARK MINE.

From an old drawing supplied by Jerry Sullivan.

The Skylark ore is similar to that of the Ramshorn. The only conspicuous difference noted was the somewhat greater abundance in the Skylark of pyrite, which occurs in stringers in the wall rocks and in bands in the ore. Umpleby states that in the oxidized ore cerargyrite and the carbonates of copper were common, and argentite, leafy native silver, wire silver, pyrargyrite, and native copper were occasionally found.

VIRGINIA DARE MINE

Old dumps and cuts record former mining in several places along Big Lake Creek southwest of the Ramshorn mine. Most or all of the prospecting was in the Ramshorn slate, and none of the development was extensive. The principal workings noted are known as the Virginia Dare. They comprise a series of caved tunnels, none of which have large dumps. The tunnels are high on the south flank of the valley, a short distance below the granitic contact. They evidently followed a shear zone in the slate along which siderite, quartz, and some sulphides were deposited.

DEPOSITS ALONG JULIETTE CREEK

It is reported that considerable prospecting was done at one time in the contact-metamorphosed Ramshorn slate and also locally in the granitic rock along Juliette Creek, one of the principal tributaries to upper Bayhorse Creek from the south. Cuts and short tunnels are visible in several places, but none of the workings seen are extensive. In the few places where mineralization was seen to have occurred the ore consists of quartz with siderite and pyrite cementing breccia and in small stringers.

BEARDSLEY MINE

Property.—The Beardsley mine is on Beardsley Gulch north of the old town of Bayhorse, in sec. 34, T. 13 N., R. 18 E. The property comprises four or five claims and is controlled by the Ramshorn Mines Co. Most of the old Beardsley and Excelsior workings, originally separate mines, are now caved. Most of them are shown in figure 10, which is adapted from a map furnished by the Ramshorn Mines Co. This map does not give altitudes, but it is reported that the old workings attained a vertical depth of 500 feet. In recent years mining has been confined to new workings a short distance farther up Beardsley Gulch. A sketch map of these, made by W. D. Mark, is shown in figure 11.

History and production.[15]—The Beardsley and Excelsior were producing in the early eighties and were probably discovered in the late seventies. The Mint report for 1883 credits the Excelsior with producing from May to December 1883 a total of 100 tons of ore averag-

[15] Compiled from Mint reports, Mineral Resources of the U. S., reports of the State mine inspector, U. S. Geol. Survey Bull. 539, and other sources.

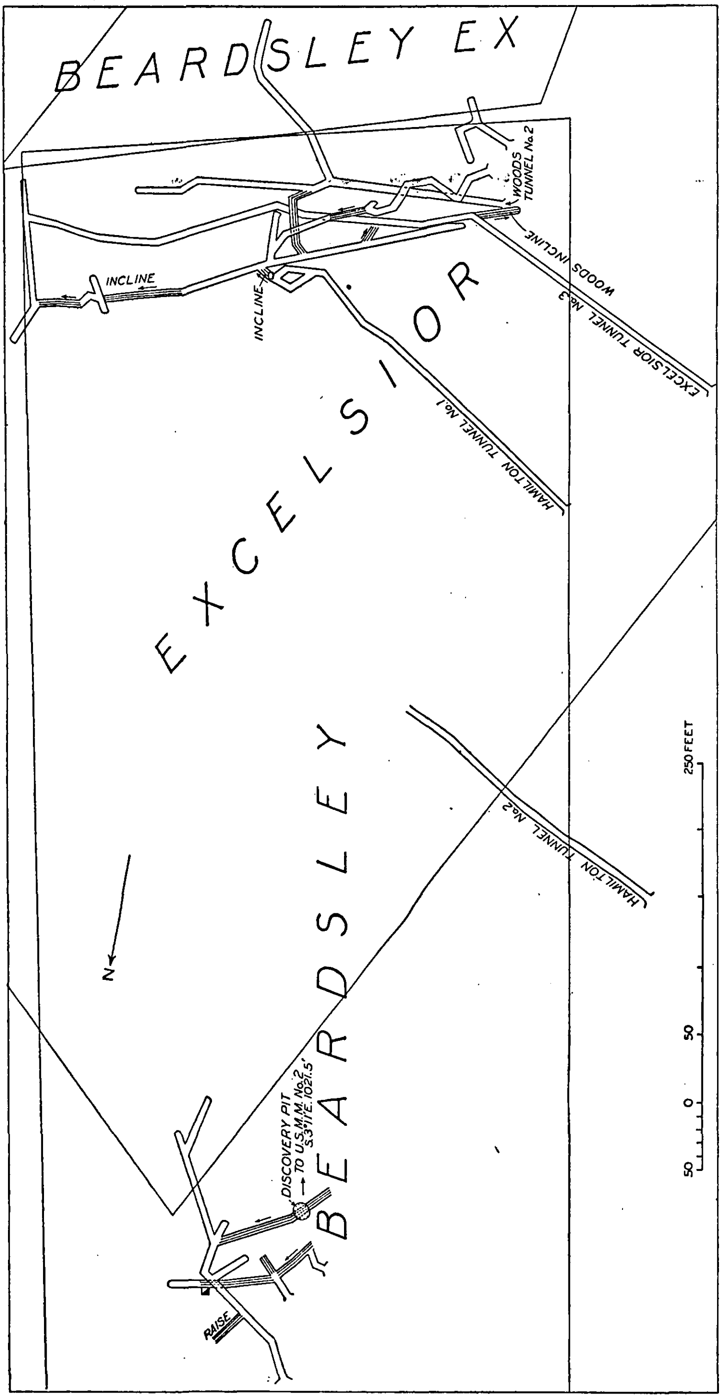


FIGURE 10.—Map of the Beardsley and Excelsior workings.

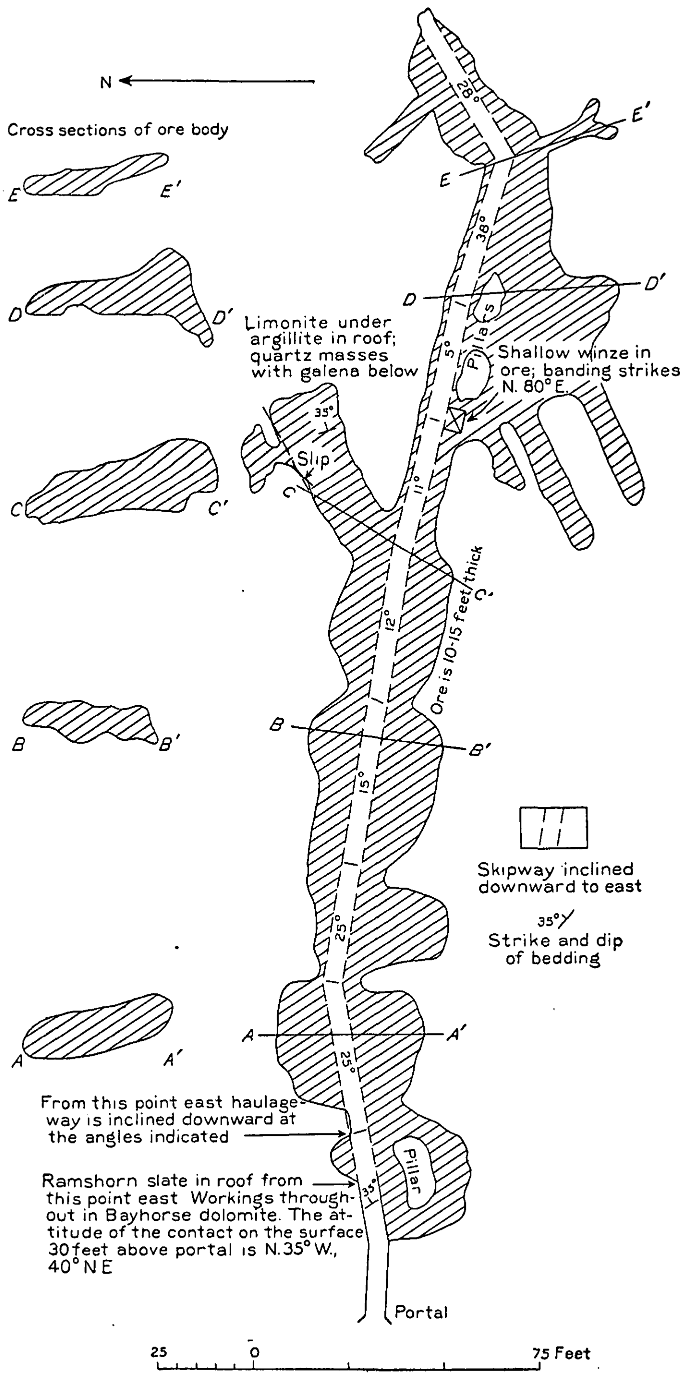


Figure 11.—Sketch map of the new Beardsley workings, with cross sections at intervals to show shape of stopes. By W. D. Mark, June 1928.

ing 35 percent of lead and 75 ounces of silver to the ton, valued at $8,000. This is the only known definite record of the early production. There appears to have been little activity at either mine from about 1890 to about 1920. From 1920 to 1926 the Ramshorn Mines Co. operated the property. Lessees have done some work since then.

Data on recent production are combined with that of the Ramshorn in a table given in the description of that mine (p. 118). Probably the amount to be credited to the Beardsley in that table is small. The early gross production [16] is reported to have amounted to 1,500,000 ounces of silver and 15,000 tons of lead from ore averaging 60 percent of lead and 60 ounces of silver to the ton, with small amounts of copper and gold.

Character of the deposit.—The old Beardsley and Excelsior mines were both on an ore body that is reported [17] to have been 100 to 200 feet long and 1 to 20 feet wide and to have been followed to a depth of 500 feet. At this depth it expanded into a mass 50 feet wide and 400 feet long containing ore averaging 5 percent of lead and 5 ounces of silver to the ton. Decline in the price of silver caused abandonment of the mine at about the time this mass was found. The numerous small dumps and the extreme irregularity of mineralization in the parts of the old workings accessible in 1928 give little indication of the former presence of so large and so continuous an ore body. During the visit in 1928 none of the old tunnels were entered more than a few feet, because of the extensive caving, but the impression gained was that the ore was of decidedly irregular occurrence in fissures and fracture zones of various trends and in kidneys in the solid dolomite.

Umpleby [18] in 1911 found only the northernmost tunnel accessible. His description of this tunnel, which follows, bears out the impression of irregularity gained from the less adequate exposures seen by the writer.

> In this tunnel 300 to 400 feet of work has been done on a ledge which strikes north-south and dips 30° E. The deposit, which consists of innumerable veinlets of ore along fractures and bunches in the solid limestone, is extremely irregular. The bunches range from lumps the size of baseballs to masses 14 or 15 feet across, yet all distributed along a zone perhaps 40 feet wide which dips 30° E. The minerals are iron-stained sand carbonate and cerargyrite, the latter in minute grains identifiable with difficulty. Stains of copper carbonate and druses of smithsonite are common; sheaflike aggregates of calamine crystals are less numerous. It is said that the purer grades of ore ran 40 to 60 percent lead, 2 to 3 percent copper, and 50 to 60 ounces in silver to the ton.

The scanty available data on the ore bodies in the old workings are presented at some length above because, if the figures given are

[16] Bell, R. N., An outline of Idaho geology and of the principal ore deposits of Lemhi and Custer Counties, Idaho: Internat. Min. Cong. Proc. 4th sess., p. 73, 1901.

[17] Bell, R. N., op. cit., p. 73.

[18] Umpleby, J. B., op. cit. (Bull. 539), p. 69.

correct, they indicate that the Beardsley-Excelsior deposit was the largest, the most continuous, and the most productive yet developed in the Bayhorse dolomite. Bell's estimates, quoted above, are in accord with common belief in the district, but it seems likely that this belief is tinged with the exaggeration frequently attached to estimates of the value of ore bodies long since mined out. It appears that low-grade ore remains in the lower part of the old workings, though the estimate of its value given, coupled with its probable size, does not make it attractive for development under any but the most favorable circumstances.

The ore body recently worked, shown in figure 11, appears to be distinct from any of those described above. This mass lies immediately below and is roughly parallel to the base of the Ramshorn slate. It is decidedly irregular but has been mined to widths of 10 to 40 feet for a distance of 320 feet on an average dip of about 20° E. The height of the excavation in places exceeds 20 feet, but the average is little over half that. Some ore remains on the walls. The distribution was irregular, and the material removed required considerable sorting. In the winze indicated in figure 11 tiny galena cubes are sparsely disseminated in the dolomite.

The ore on the dump consists of more or less completely silicified dolomite with stringers and bunches of galena, sphalerite, and pyrite in quartz. Smithsonite and calamine are common. Much of the galena is superficially altered to anglesite and cerusite. Small amounts of copper carbonate show the presence of copper, probably originally in tetrahedrite.

McGREGOR GROUP

Property.—The McGregor group comprises three claims near the town of Bayhorse. Most of the claims are on the north side of Bayhorse Creek and west of Beardsley Gulch. This group includes several old mines, of which the Pacific, Silver Brick, and Hoosier are the best known. The distribution of the claims and the principal workings on them are shown in plate 16.

There are several other old mines in this vicinity, such as the Democrat, Dave, and Forest Rose, which were mostly inaccessible in 1928. They are essentially similar to the McGregor group and are not further described in this report except that available data on the production of the Forest Rose are tabulated below. The Beardsley group, which adjoins the McGregor on the east, has already been described.

History and production.[19]—Some of the deposits of this group were being worked in 1881, and it is probable that most of them were known at that time. Records show that the Pacific was producing from 1901 to 1908 and in 1911 and that the Keno and Silver Brick

[19] Mainly from Umpleby, J. B., Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, pp. 69-72, 1913, supplemented by Mint reports, Mineral Resources of the U. S., and other reports.

and the nearby Forest Rose property produced occasionally during this period. Available data on this production are given in the tables below. Doubtless there were shipments at other times for which no data have been found. When visited in 1928 all workings of the group looked as if little or no work had been done for many years. Umpleby states that prior to his visit in 1911 the Pacific is estimated to have produced $65,000 and the Hoosier $70,000, of which $50,000 came from the upper vein. He gives no data on the production of the rest of the group.

Production of the Pacific mine

[From records compiled by the U. S. Geological Survey. Published with permission of Earl J. Michael]

Year	Crude ore (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1901	86	3.05	5,238		
1902	58	1.56	3,384		72,238
1903	75	2.61	4,668		73,965
1904	60	3.31	4,737		72,425
1905	31	1.01	2,127		39,137
1906	31	2.68	3,678	1,542	46,804
1907	42	1.70	3,338	1,135	41,197
1908	38	1.47	3,137	473	47,450
Total	421	17.39	30,307	3,150	393,216

Production of the Forest Rose mine

[Compiled by U. S. Geological Survey. Published with permission of Earl J. Michael]

Year	Crude ore (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1901	[1] 20				
1902	42	0.75	3,697		4,531
1904	7		276		7,960
1909	8	.08	546		12,058
1916	30	.42	953	656	20,935
1918	1		84	35	1,000
1925	[2] 65				
Total	173	1.25	5,556	691	46,484

[1] Value, $792. [2] Value, $4,000.

The Keno in 1902 produced 121 tons containing 7.58 ounces of gold, 9,885 ounces of silver, and 118,533 pounds of lead, and in 1911 the Pacific and Keno together produced 10 tons containing 0.28 ounce of gold, 734 ounces of silver, 236 pounds of copper, and 12,026 pounds of lead. The Hoosier in 1901 produced 1 ton containing 53 ounces of silver and in 1904 produced 17 tons containing 0.48 ounce of gold, 380 ounces of silver, and 3,808 pounds of lead. The Silver Brick in 1903 produced 52 tons containing 4,264 ounces of silver and 27,040 pounds of lead.

Character of the deposits.—The McGregor group includes several small deposits belonging to two general types. One type comprises replacement deposits in the Bayhorse dolomite and is represented by the Pacific, Keno, and neighboring deposits on the north side of Bayhorse Creek. Deposits of the other type are more veinlike and are enclosed in the Garden Creek phyllite. This type includes several small deposits on the lower slopes of Bayhorse Creek, of which the Hoosier is the only one that has a recorded production.

The Pacific mine is the largest of the replacement deposits in dolomite. The principal workings, most of which were still open when visited in 1928, are shown in plate 16. The mineralization consisted in silicification of the dolomite, with the formation of bunches of galena ore here and there. The silicification tended to follow certain beds in the gently rolling, almost horizontal dolomite, but within these beds ramified without apparent system. The caved tunnels at various levels in the vicinity of the main workings suggest that similar, presumably less extensive replacement occurred in other beds. The replaced material is in part a dolomite breccia recemented with quartz, but much of it is unbrecciated and shows banding and crustification by quartz, apparently deposited parallel to the original bedding. In addition to the quartz with more or less crystal form deposited in open spaces, silica largely replaced bleached dolomite. Numerous individually small bunches and stringers of galena, mainly coarse-grained, are scattered through the silicified material. These are superficially altered to cerusite and other oxidation products, but much of the ore seen in 1928 is still in the sulphide state. Evidently much of the ore seen by Umpleby [20] in 1911 was oxidized. He says that the ore minerals are sand carbonate [cerusite], cerargyrite, smithsonite, and a little argentiferous galena, so proportioned in the quartz gangue that average shipments of hand-picked material ran 50 to 60 percent of lead, 60 to 80 ounces of silver to the ton, 2 to 3 percent of zinc, 4 to 6 percent of sulphur, and 20 to 25 percent of silica. The production tables given above show that copper ore has been shipped from the Pacific and neighboring mines. Some of the ore on the dumps contains copper carbonates.

The other deposits of the McGregor group in the Bayhorse dolomite are similar to that above described except that some of them, instead of being controlled by bedding, are deposited in a fault breccia. One of the faults followed by such mineralization is mapped on plate 1. It is the fault trending west of north across the ridge on the north side of Bayhorse Creek. It has Bayhorse dolomite on the east side and Ramshorn slate on the west, but most of the mineralization has been effected in the dolomite. There are workings along this fault on the crest and south flank of the ridge, but none of them are extensive. Probably the longest are on the Democrat claim, which, as shown in plate 16, adjoins the McGregor group on the west. In a tunnel on or close to this claim there is a vertical breccia zone trending N. 40° W.

[20] Umpleby, J. B., op. cit. (Bull. 539), p. 69.

This has been followed upward by a vertical raise roughly 75 feet high. Near the top is a well-defined vertical wall in the dolomite which strikes N. 25° W. and is horizontally grooved. Exposures on the ridge crest at the contact with the slate show intense brecciation and silicification in both the slate and the dolomite. Oxidized copper and lead minerals are present in small amounts. A few small stringers of fluorite were noted. In the dolomite between this fault and Beardsley Gulch, on both sides of the ridge, there are several subsidiary fault breccias parallel to that mapped. Like it, they show intense silicification and the presence of minor amounts of oxidized copper, lead, and zinc minerals.

The veinlike deposits in phyllite on the McGregor group are in the Garden Creek phyllite. The most extensive workings are those of the Hoosier mine, on the south side of Bayhorse Creek. There are more tunnels in the phyllite on the north side of the creek than are shown on plate 16. All the tunnels are either caved at the portals or in such poor condition that they were not entered during the visit in 1928. The dumps show that the principal gangue minerals were massive white quartz and coarsely crystalline siderite. There is much pyrite both in these gangue minerals and as replacement lenses in the phyllite. Small amounts of malachite and azurite testify to the presence of copper.

KUNA MINE

Immediately below the contact between Ramshorn slate and Bayhorse dolomite in the cliffs above the town of Bayhorse is a prospect known as the Kuna mine. It was located in 1921 by J. J. Jarvis. A curved tunnel about 30 feet long shows quartz veinlets with galena and some copper stain in the dolomite.

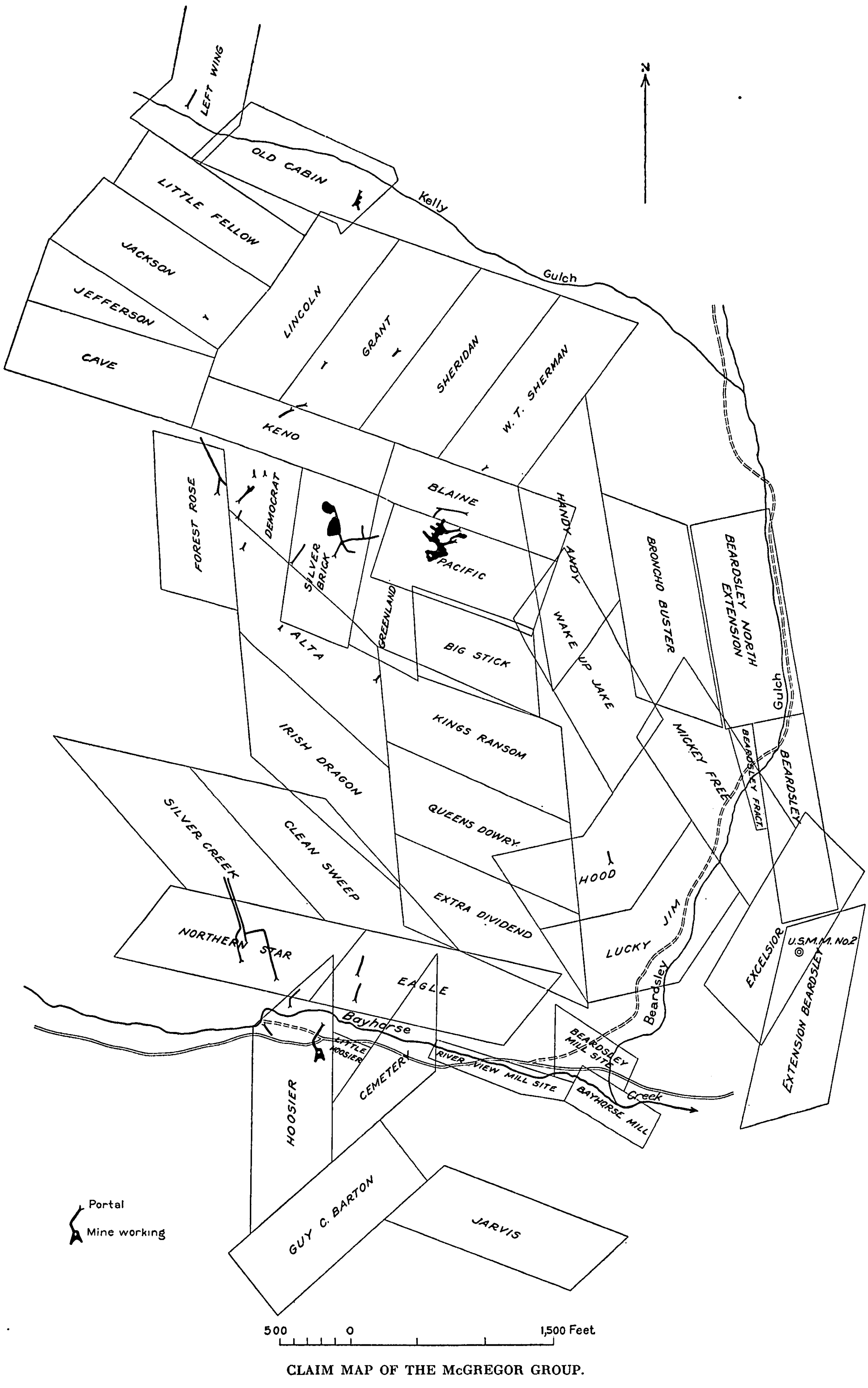
NAMELESS MINE

The Nameless or Henie Hinie mine is on the east side of Smith Canyon a little more than a mile south of Bayhorse. It comprises shallow openings in much-brecciated Bayhorse limestone close to a fault between that formation and the Ramshorn slate. The brecciated rock contains stringers of galena and quartz. The development is insufficient to show the extent of mineralization.

RIVERVIEW MINE

Property.—The Riverview mine, owned by the Aetna Mining & Investment Co., is on the south side of Bayhorse Creek nearly 2 miles above its mouth. It is on the mountain side facing the Salmon River immediately north of the low hills of volcanic rock east of Centennial Flat. The developments [21] consist of several tunnels and a 100-foot shaft, in all perhaps 5,000 or 6,000 feet of work.

[21] Umpleby, J. B., op. cit. (Bull. 539), p. 67.



CLAIM MAP OF THE McGREGOR GROUP.

History and production.[22]—The Riverview claim was staked in March 1877 and is the oldest property in the district. By 1881 it had produced a total of 130 tons of ore, averaging 130 ounces of silver to the ton. It was operated intermittently from 1881 to 1917 and is reported to have produced a total of about $500,000.

Character of the deposit.—The Riverview mine follows a zone in the Bayhorse dolomite that is approximately parallel to the bedding and has an average width of about 5 feet. It trends somewhat west of north and dips 10°–40° E. The ore shows the irregularity characteristic of this type of deposit. Umpleby [23] says that it occupies about one-fourth of the zone of mineralization. The larger masses follow the bedding, and many of the smaller ones lie along joints. The lode is cut and somewhat displaced by fracture zones that trend about N. 55° W. and have the downthrow on the northeast. It is reported that there is still good ore in the lower workings, which are now inaccessible. The character of the ore is essentially the same as that of the other deposits in the Bayhorse dolomite.

TURTLE MINE

Property.—The Turtle mine, owned by N. S. Churchill, is on the west side of the Salmon River above Centennial Flat, somewhat more than a mile south of the Riverview mine. Its workings, which were never extensive, are irregular and are now partly caved.

History and production.—The Turtle mine was worked during the early days, but no record of its production at that time is available. It was operated between 1919 and 1925, and its production during this period is shown below:

Production of the Turtle mine, 1919–25

[Compiled by U. S. Geological Survey]

Year	Crude ore (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1919	31		1,860	260	27,910
1920	8		509	260	5,721
1921	26	1.00	1,004	829	22,109
1925	2	.05	187	72	2,554
Total	67	1.05	3,560	1,421	58,294

Character of the deposit.—The Turtle mine is in a small window of Bayhorse dolomite that projects through the Ramshorn slate. The contact between the two formations as exposed in the mine ranges in trend from N. 20° W. to N. 10° E., and the average dip is about 45° W., which shows that the beds are here overturned. The ore occurs in irregular bunches and lenses in silicified dolomite. It follows joints and fissures and is generally not conformable with the

[22] Compiled from Umpleby, J. B., op. cit., p. 67, Mint reports, and Mineral Resources of the U. S.
[23] Umpleby, J. B., op. cit., p. 67.

bedding. The ore minerals are galena, tetrahedrite, and some chalcopyrite in a quartz gangue.

LAST CHANCE MINE

The Last Chance property, formerly known as the Homestake, is a collection of prospects on the south side of Rattlesnake Creek, owned by Robert E. Muir. The principal development is in two short tunnels, with branches and small stopes, at somewhat more than 8,000 feet above sea level near the head of Rattlesnake Creek. These tunnels are about 5 miles from the mouth of Bayhorse Creek. For most of this distance there is a road, now in disrepair, but the last mile is on a moderately steep trail. There are numerous cuts and short tunnels on the property. The locations of the largest are indicated on plate 1.

Deposits here were known and worked in the early eighties and have been intermittently operated since then. The aim of the owners has been development rather than production, but Mr. Muir estimates that a total of roughly 1,000 tons of ore, worth between $50,000 and $75,000, has been shipped, in part by lessees. The following table shows the production in recent years:

Production of the Last Chance (Homestake) mine, 1908–21

[Compiled by U. S. Geological Survey]

Year	Crude ore (tons)	Concentrates (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1908	71	14	0.64	2,356	1,290	59,490
1910	20	7		593	156	6,966
1911	6			363		6,114
1912	5			300		6,300
1917	6			342	155	3,943
1919	6			420	120	4,960
1920	3			381		2,280
1921	1			51	10	848
Total	118	21	.64	4,806	1,731	90,901

The ore is in veinlets and more or less irregular masses, both of which tend to conform to the bedding in the Bayhorse dolomite. Most of the ore bodies are close to the Ramshorn slate or to similar beds that appear to be intercalated in the dolomite. The rocks in this vicinity are intricately contorted and locally faulted. In the two principal tunnels it appears that the faulting is premineral, as the ore in the vicinity of the fracture zone is neither fractured nor displaced. The principal ore minerals are galena and locally tetrahedrite in a barite gangue. Specimens of cube galena are reported to assay 1 ounce of silver to the unit of lead. Locally the ore is rich in silver, doubtless because of the presence of tetrahedrite.

MAMMOTH MINE

The Mammoth or Sheridan mine is in the small exposure of Bayhorse dolomite north of Sink Creek in unsurveyed sec. 3, T. 11 N., R. 18 E. Location notices posted at the property are dated 1911 and 1903, but the appearance of the cabins and workings suggests that the principal work may have been done at a still earlier date. The workings are irregular and cavelike and are not extensive. The rock here trends N. 50° E. and dips 40° SE., flattening above. Little result of mineralization was visible when visited in June 1928, but the deposit is evidently one of the numerous irregular replacement bodies in the Bayhorse dolomite.

SILVER BELL MINE

As is indicated on plate 1, there are three places along the eastern border of Poverty Flat where there is evidence of former mining. The two at the heads of forks of Lyon and Sink Creeks, below the level of the flat, are caved tunnels. Between these and on the flat itself trenches, cuts, and shafts are scattered over a considerable area (pl. 10, *B*). One of the shafts has a dump that appears to represent several thousand feet of work. All are now caved and slumped. The workings on the flat belong to the old Silver Bell mine, and the two tunnels may have been part of the same property. According to Umpleby [24] the deposit of this mine was discovered in 1879, and most of the work on it was done in the following 18 years. He states that the total production was about $600,000, from some 10,000 feet of tunnels, with a maximum depth of 100 feet, in five unpatented claims. The lode, according to him, strikes N. 60° W., dips 30° NE., steepening in depth, and consists of a zone of fissuring, perhaps 100 feet wide, with narrow irregular lenses of siderite and tetrahedrite. In places oxidized ore was mined within 5 or 10 feet of the surface.

WILLIAMS, ROHLDS, AND ERNST MINE

In unsurveyed sec. 20, T. 11 N., R. 18 E., well up on the steep slope north of the Salmon River below Clayton, is a property that, according to a notice posted on it, is held by Bert Williams, H. R. Rohlds, and John Ernst. There are several tunnels close together, the longest over 600 feet long. It trends north but has numerous turns, and several short drifts and raises lead off from it. The tunnel is in much-brecciated Ramshorn slate. Near the portal the bedding is rolling, nearly flat. Over halfway in there is sheared and broken limestone. The shearing trends about north, dips 50° W., and appears to be in part parallel to the bedding in the limestone. Near the face is brecciated argillite. In places in the tunnel there are small gash veins of quartz bordered by siderite. At the portal there are some fragments of galena ore.

[24] Umpleby, J. B., Some ore deposits in Custer County, Idaho :U. S. Geol. Survey Bull. 539, p. 72, 1913.

SULPHIDE MINE

When visited by R. R. LeClercq in June 1928 the property of the Sulphide Mining Co.[25] comprised 17 unpatented claims on the north side of the Salmon River near the highway bridge about 2 miles below Clayton. Development at that time consisted of a tunnel nearly 350 feet long which for much of its length trends N. 20° E. and then swings northwest. Near the portal it cuts gabbro. The rest of the tunnel is in Ramshorn slate, which trends N. 20°–45° W. and dips 30°–45° NE. There is much shearing roughly parallel to the bedding. The slate close to the gabbro contains small quartz stringers with a little galena. At the tunnel face there is a little pyrite.

MULE SHOE MINE

The Mule Shoe Mining Co. has a group of seven unpatented claims across the Salmon River from the Sulphide property and has done intermittent work on them from 1927 through 1931.[26] When this locality was visited by W. D. Mark in June 1928 no one was at work. Two tunnels in unsurveyed sec. 27, T. 11 N., R. 18 E., presumably belong to this group. A notice at one of the tunnels says that it is on the River Queen claim, located in 1925 by Phillip Gossi. The tunnel was then about 75 feet long and followed a vein striking N. 40° W. and dipping 55° SW. The vein is about 2½ inches wide and consists of siderite and quartz with a ½-inch band of sulphide, mainly chalcopyrite, in the middle. A somewhat longer tunnel about 100 yards to the south traverses thin-banded argillite striking N. 40° W. and dipping 63° NE.

There are several pits and small cuts in the slate on both sides of the crest of the low ridge to the south. Some of them show a little galena in loose material. At an altitude of about 7,000 feet on the Salmon River side of the ridge there is a tunnel in Ramshorn slate which in 1929 was about 400 feet long.

PEDRINO MINE

In unsurveyed sec. 18, T. 11 N., R. 18 E., there are two prospect holes on the Pedrino claims, which according to a notice posted on the group were located in 1925 by Joseph Pedrino and several partners. One of the cuts is at the upper contact of the gabbro mass, the other about 100 feet below, within the gabbro. The dumps show the presence of quartz stringers containing slightly oxidized chalcopyrite. There is also some chalcopyrite in amphibole seams in the gabbro.

SADLE CLAIM

In sec. 12, T. 11 N., R. 17 E., there is a prospect trench that shows vein quartz with galena in Ramshorn slate close to one of the gabbro intrusions east of Kinnikinic Creek. A notice here states that the trench is on the Sadle claim, located by John C. Tam in 1925.

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[25] Campbell, Stewart, 29th annual report of the mining industry of Idaho, for the year 1927, p. 127, 1928.
[26] Campbell, Stewart, 33d annual report of the mining industry of Idaho, for the year 1931, p. 131, 1930.

COMPASS MINE

The Compass mine is in and near sec. 1, T. 11 N., R. 17 E., on the west side of Kinnikinic Creek. When visited in June 1928 it was being reopened under option by John W. Calvin. This mine was formerly productive on a small scale. There are several tunnels, most of which are partly caved. The upper workings show a nearly vertical fissure trending north in Kinnikinic quartzite. There is some galena along the fissure. Just below the fissure the mineralized area extends out somewhat into limestone. Tunnels roughly 200 feet vertically below the upper workings cut nearly flat-lying Ramshorn slate in which there is galena in a siderite gangue, probably the downward continuation of the same lode. In the face of one of the lower tunnels, which is about 150 feet long, is quartzite. If this belongs to the Kinnikinic quartzite exposed above, it appears to indicate faulting.

CLAYTON MINE

The property of the Clayton Silver Mines, formerly called the Clark mine, is on the Camp Bird group of 13 unpatented claims, on the west side of Kinnikinic Creek, nearly 2 miles north of Clayton.

The principal working is a branching tunnel with a total length of over 1,200 feet, shown in figure 12. Recently several stopes have been reopened above this tunnel. A shaft has been sunk 125 feet below it and a little work done at its bottom. In 1935 it was full of water. The small concentrating mill and power plant have recently been remodeled. When revisited in September 1935, this plant was reported to be handling 60 tons of ore and 30 tons of tailings daily.

The presence of ore minerals in the Camp Bird group has been known for a long time. In 1927 the Clark Mining Co. acquired control, erected a mill, and did considerable development work. Litigation halted its activities, and the mine was idle when first visited in 1928. Since then there have been several periods of activity under different managements.

The Clayton mine is mainly in one of the dolomitic members of the Kinnikinic quartzite. The ore is irregularly distributed along the somewhat shaly dolomite.

In the western part of the workings that were open in 1935 the dolomite interfingers with brecciated and altered quartzite. Here the strike of the steeply dipping beds is toward the northeast, although in most of the workings it is northwest, in accord with the average trend of the beds along the west side of this part of Kinnikinic Creek. Fracture planes and minor breccia zones are common and are in general roughly parallel to the bedding. The galena ore lies in part along fracture and bedding planes but spreads out irregularly from these planes into the country rock, which is mainly dolomite. The stopes opened since 1928, incompletely shown in figure 12, have an irregular ore zone with a length of more than 300 feet and a maximum reported width of 65 feet. The ore zone bends and apparently narrows toward the west where it enters the quartzite. The northern branch of the tunnel exposes altered dolomite but no ore where it crosses the projection of the stoped zone. Between this point and the junction with the main tunnel, however, galena is irregularly

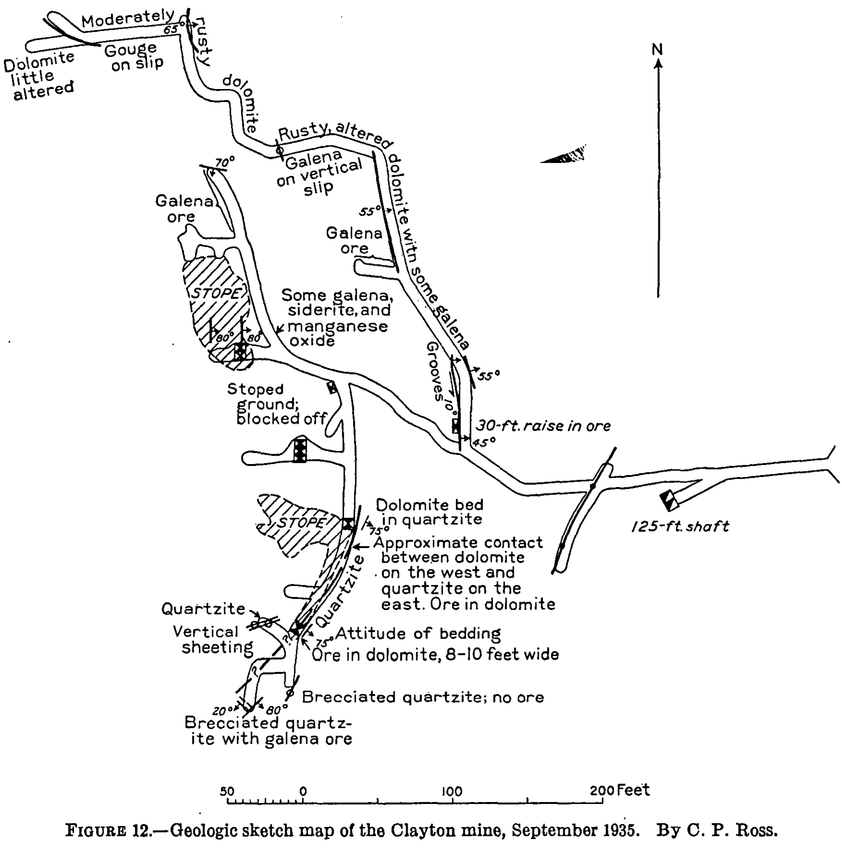


FIGURE 12.—Geologic sketch map of the Clayton mine, September 1935. By C. P. Ross.

distributed for a distance of about 270 feet as measured along the branch tunnel. It is not certain whether this body of mineralized material has been offset by a fault from that stoped or is an originally separate mass. Such data as are available favor the second alternative.

ELLA MINE

The old Ella mine is on the west side of Kinnikinic Creek, a short distance above Clayton. Rather large dumps are still visible, but most of the workings have long been inaccessible. Umpleby [27] says

[27] Umpleby, J. B., op. cit. (Bull. 539), p. 73.

that the property comprises four claims and that a considerable tonnage was produced from it in the early days, mostly from workings caved at the time of his visit in 1911. He saw several tunnels, one of which was 1,600 feet long and trended N. 15° W. The ore here lies along bedding planes between a general hanging wall of dolomite and a footwall of quartzite. Very little was in place in the tunnel, but the dumps show that the ore mined was argentiferous galena and subordinate pyrite and tetrahedrite in a gangue of quartz and siderite.

This mine is in the zone of thrust faulting so conspicuous on lower Kinnikinic Creek. The faulting is doubtless older than the mineralization, and consequently the disturbance of the rocks connected with the faulting may have had an influence on ore deposition. As the mine has long been abandoned it is evident that difficulty was encountered in picking up new ore bodies.

UNION-COMPANION MINE

The Union-Companion property, located in 1926 by R. W. Johnson and G. D. Acqua, is on the south side of the Salmon River a short distance east of the highway bridge above Clayton. When visited in 1928 there was a 30-foot tunnel and several cuts on the property. Some of the cuts show galena in quartz stringers, in part parallel to the bedding of the Kinnikinic quartzite. The tunnel is on a crush zone in argillaceous beds in the quartzite. Nearly vertical slickensided surfaces in the crush zone trend N. 25° W.

RED BIRD MINE

Property.—The Red Bird mine, owned by the Ford Motor Co., is on Squaw Creek near the western border of the Bayhorse quadrangle. It is about 8 miles by road from Clayton, the nearest post office and town. The Ford Motor Co.'s mining property in Idaho consists of the Red Bird and Silver Rule groups, comprising 44 patented claims and 6 mill sites.[28] The Silver Rule group is in the Custer quadrangle. Little work has been done on it for many years, and it is not described in this report. At the Red Bird the underground developments consist of nine levels and several sublevels, connected by numerous raises and stopes. It has been estimated that the mine contains a total of 18,500 feet of drifts,[29] which makes it the second largest mine in the district, the Ramshorn being the first. The vertical distance from the first to the ninth level is somewhat over 700 feet. Five of the levels are connected with the surface. Most of the stopes are above the sixth level. There is a well-equipped mining camp with all necessary buildings and equipment for operation of the mine, including accommodations for the men.

[28] Campbell, Stewart, 29th annual report of the mining industry of Idaho, for the year 1927, p. 123, 1928.
[29] Mines Handbook, vol. 17, p. 808, 1926.

History.[30]—The deposits worked in the Red Bird mine were discovered about 1878, but little work appears to have been done until about 1884, when the property, then comprising 10 claims, was acquired by the Omaha & Grant Co. The mine continued in operation until about 1904. It was reopened in 1912 by the Idaho Mining & Smelting Co. This company failed after 1 year of operation and was succeeded by the Red Bird Smelting Co., which in turn failed in December 1914. In the winter of 1916–17 the mine was operated under option by the Success Mining Co. In succeeding years it was operated principally by lessees, until in November 1924 it was optioned by the Ford Motor Co. This company equipped the property with adequate buildings and machinery early in 1925 and undertook thorough prospecting, both by drifting and by diamond and turbo drilling, started October 1, 1925. Production was confined to small lots shipped for metallurgical tests of various kinds. After a far more extensive campaign of drilling than has yet been attempted elsewhere in this region, the company in 1926 exercised its option and purchased the Red Bird, together with the Silver Rule, the old Clayton smelter, and other properties in the neighborhood. It did considerable development work in the Red Bird from January to July 1926, when all work was suspended. Since then a watchman has been maintained at the property. It is locally assumed that the results of the diamond drilling were sufficiently favorable to warrant the purchase of the mine, as it is known that the ore reserves otherwise are not very large.

Production.—Detailed data regarding the early production are not available. Umpleby[31] says that from 1880 to 1902, 1,000 to 1,500 tons of ore, which ran 30 to 40 percent of lead and 40 to 60 ounces of silver to the ton, was delivered to the smelter annually. This agrees, approximately, with Bell's estimate[32] of a total production of $700,000 prior to 1900, from ore averaging not less than 30 percent of lead and 30 ounces of silver to the ton.

Adequate data regarding the production since 1900 are not available. In such records as exist the production from this mine is grouped with that from others. However, from the data obtained it is thought that the current estimate of $2,000,000 as the total production of the Red Bird is probably too high. The Mines Handbook for 1926 states that the ore reserves on January 1, 1926, were estimated at 100,000 tons of milling ore, averaging perhaps 7 percent of lead and 5 ounces of silver to the ton.

[30] Compiled from Mint reports, Mineral Resources of the United States, U. S. Geol. Survey Bull. 539, reports of the State mine inspector, Mines Handbook, 1926, and oral account by J. D. Sullivan.

[31] Umpleby, J. B., op. cit. (Bull. 539), p. 73.

[32] Bell, R. N., The deepest mine in Idaho, the Ramshorn at Bayhorse: Mines and Mining, vol. 21, p. 176, 1900.

Character of the deposit.—The Red Bird mine is on the west flank of the Clayton anticline in the Saturday Mountain formation. The rock containing the ore body is argillaceous and in part highly carbonaceous dolomite. The beds on the east side of the ore body are 700 feet or more stratigraphically above the Kinnikinic quartzite. As a consequence of the westward overturning of the Clayton anticline, the average inclination of the beds above the fourth level is westward, whereas between this and the fifth level it bends eastward. There is, however, considerable crumpling, resulting in numerous local exceptions to this general statement. The crumpling in places is so intense as to result in minor overthrusts, generally eastward, with maximum throws of a few feet. In places the sharply contorted beds have slipped on each other sufficiently to produce slickensides, and here and there some movement has taken place on slips. There is no evidence, however, of faults of any considerable displacement anywhere in the workings seen. The shatter zone containing the ore shoots, which is described below, shows failure and collapse of the rocks on a large scale, but there does not appear to have been much displacement along it.

In most places the dip of the shatter zone is 70° and more, but on the lower two levels it is less than this, and in the more northerly and easterly drifts on the ninth level the dip in places is very gentle and even approaches the horizontal. The average strike is probably about N. 20° W., but in this also there is much local variation.

The zone of brecciation and alteration that contains the ore bodies is approximately parallel to the bedding, although it is independent of minor crumpling and in general dips somewhat more steeply than the beds. This zone has an average width of less than 150 feet except on the third and fourth levels. Development on the fifth level is not sufficient to show the full extent of the zone here. The total width of altered material on the fourth level is over 300 feet, divided into two parts with a zone about 100 feet wide of contorted but little altered beds between them. There is notably more contortion in the beds here than elsewhere in the mine. On the lower levels the zone of brecciation and alteration is less extensive than it is above.

The zone of brecciation described above consists of more or less completely crushed impure dolomite altered by hydrothermal solutions and later by weathering. In some places the material now consists of angular fragments of almost fresh dolomite enclosed in a matrix of ferruginous clay. The fragments have dimensions of a few inches or less. Elsewhere this intense brecciation has not occurred, but the rock is more or less kaolinized and impregnated with limonite and is traversed by numerous slips lined with red gouge. Veinlets of quartz and of calcite are present here and there.

The ore occurred in irregular bodies scattered through the zone of alteration and crushing. Many of the old stopes are now inaccessible, so that it is difficult to get an adequate idea of the mode of occurrence of the ore. The impression gained from such parts of the stopes as were seen is that the ore bodies were individually small and discontinuous, although the total amount of ore was considerable. They were elongated approximately parallel to the strike of the strata and appear to have been in general steeper in dip. In this, however, there is marked local variation: in places the dip was less than 40°. Irregularity in detail appears to have been the rule. Much of the stoping was done in the less thoroughly brecciated ground. Evidently there was considerable stoping above the fourth level. Below this the mine is less thoroughly developed, although the greater part of the known ore of good grade above the ninth level has been mined out. Those familiar with the mine say that there are places above this where small bodies of ore remain. It is believed that on the borders of the stopes some ore of too low grade to be handled at the time was left by former operators. On the ninth level there are two ore bodies on which little stoping has yet been done.

Bell [33] described some of the ore bodies as pipe-shaped shoots, round or oblong in plan, and others as larger masses of ragged outline. The shoots ranged in average diameter from 10 to 30 feet and were as much as 60 feet in length. Some of the more irregular masses were as much as 50 feet wide. Umpleby [34] says that at least five ore bodies had been found prior to his visit in 1911 and describes the two larger ones. He says that one of these, the Potato Patch shoot, was 60 to 80 feet long and 20 to 30 feet wide and was worked to a depth of more than 400 feet. Although of broadly regular outline, it was irregular in detail. Here and there it extended out along joint cracks; elsewhere great swells protruded into the enclosing rock. The average strike of the shoot was N. 65° W., and its dip was 45° W. The other ore body described appears to have been an aggregate of several small shoots. It was about 150 feet east of the Potato Patch shoot and on the second level was broadly parallel to it in both strike and dip, but lower the strike changed to N. 20° W. and the dip became 40° NE. Within the shoot the ore was formed in irregular bunches, generally with roughly tabular form parallel to the general trend of the shoot. In places there was a veinlike mass 50 to 75 feet long and as much as 12 feet wide. Ore was found in this shoot fairly continuously from the second level to a point 65 feet above the eighth level. The shoot terminated in a mass of pyrite that was 55 feet wide. This mass was exceptionally vuggy throughout and contained traces of gold and

[33] Bell, R. N., An outline of Idaho geology and of the principal ore deposits of Lemhi and Custer Counties, Idaho: Internat. Min. Cong. Proc. 4th sess., pp. 64-80, 1901; 14th annual report of the mining industry of Idaho, for the year 1912, p. 93, 1913.

[34] Umpleby, J. B., op. cit. (Bull. 539), pp. 74, 75.

copper. It is possible that the mass was similar in origin to the pyrite and galena on the ninth level described on pages 113–114 as of probable supergene origin. Umpleby notes that another large shoot was found on the seventh level after his visit.

All the ore heretofore mined has been more or less completely oxidized. Galena was noted during the present examination in various places throughout the mine, but except at one place on the ninth level, where it is thought to be supergene (pp. 113–114), it was everywhere in subordinate amount. It was nowhere found in the thoroughly brecciated ground. According to descriptions much of the ore mined consisted essentially of sand carbonate (cerusite). In addition to this Umpleby notes anglesite, cerargyrite, smithsonite, calamine, fluorite, and iron and manganese oxides. He says that the hypogene minerals, argentiferous galena and pyrite, remain only in protected spots. The ore in the ore bins and in the more recently worked stopes on the lower levels contains a large proportion of galena. The amounts of cerargyrite, the zinc minerals, and fluorite in the ore are evidently relatively small. None of these were identified during the present examination. It is clear both from such observations as could be made and from the statements of those familiar with the mine that zinc, although found in a number of places, was nowhere abundant. On both the seventh and ninth levels wulfenite was found.

SOUTH BUTTE MINE

Property.—The South Butte mine is on a gulch tributary to Squaw Creek, about a mile east of that creek and 2 miles south of the Red Bird mine. The property comprises 17 unpatented claims. The developments consist of a branching upper tunnel several hundred feet long, a lower tunnel nearly 1,000 feet long with short crosscuts off it, and a shaft that goes down about 250 feet from the lower tunnel. There are drifts and crosscuts at the bottom of the shaft. Most of the stoping is in the upper tunnel, but a little has been done from the lower one.

History and production.—The deposit of the South Butte mine was discovered early in the history of the district, but it appears that little work was done on it in the early days. The table below shows that the mine was producing on a small scale much of the time between 1901 and 1923. In 1926 the property was taken under bond and lease by the Hecla Mining Co., which installed the necessary camp and mine equipment and started underground work. In 1927 the company extended the shaft from a depth of 50 feet to about 250 feet and did a total of some 200 to 300 feet of development work at that depth. In October 1927 operations were suspended, equipment removed, and options relinquished. Nothing further had been done from that date to the time of visit in July 1928.

Production of the South Butte mine, 1901–23

[Compiled by U. S. Geological Survey]

Year	Crude ore (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1901	141		300		
1902	5		306		6,242
1903	5		2,738		55,296
1904	106		8,904		150,520
1905	108		9,281		127,452
1906	14		825		17,401
1908	29		2,145		33,764
1909	16		1,617		32,910
1916	32		1,574	600	31,213
1917	29		1,791		34,811
1923	27	0.27	824	56	20,523
Total	512	.27	30,305	656	510,132

Character of the deposit.—The South Butte mine is in interbedded impure dolomite and quartzite, both of which belong to the Kinnikinic quartzite. The bedding as exposed near the end of the lower tunnel strikes nearly north and dips 60° W. to vertical. In the upper tunnel the bedding strikes N. 10° E. and stands vertical. In both tunnels the rock is rusty and in most places markedly brecciated. Much of the movement was essentially parallel to the bedding, but the principal stope in the upper tunnel is on a slip that strikes N. 60° E. and dips 50° SE. There is considerable clay both in the impure dolomite containing the ore and in the matrix of the brecciated quartzite nearby. The ore was largely oxidized to cerusite and similar minerals, but specimens in the old office indicate that galena and pyrite were also abundant in places. A little pyrite was noted in place in the lower tunnel. About 100 feet below the tunnel level there is a short drift on the west side of the shaft. This exposes a mineralized shear zone with a well-marked hanging wall that trends N. 5° E. and dips 50° W. Recent work here had so blocked the shaft that it could not be further descended when visited in 1929.

SATURDAY MOUNTAIN GROUP

West of Squaw Creek and south of the mouth of Bruno Creek are several scattered workings, none of them extensive and most of them caved. These are termed the Saturday Mountain group. Umpleby [35] notes that there are two patented claims in this locality on which there is a shallow shaft and one or two tunnels. These were driven in the early days, and a few thousand tons of argentiferous galena ore was produced from them. Little has been done at any of these workings for many years. The principal prospect holes noted during the present investigation are at the point indicated on plate 1. They are probably not the same as the workings mentioned by Umpleby. At this place there are bunches of slightly oxidized galena, mostly on the bedding planes of dolomitic limestone of the Saturday Mountain formation.

[35] Umpleby, J. B., op. cit. (Bull. 539), p. 75.

DRYDEN MINE

The Williams-Dryden group of five unpatented claims, commonly called the Dryden mine, was developed under option in 1927 by the Golden Center Mining Co.[36] The workings are on the east side of Sullivan Creek, mostly in sec. 27, T. 11 N., R. 17 E. There are several cuts and short tunnels along the hillside that show mineralization in shear zones in the Saturday Mountain formation. Between 1911 and 1915 there was some production from this mine. Presumably the ore came from these tunnels. The recent developments

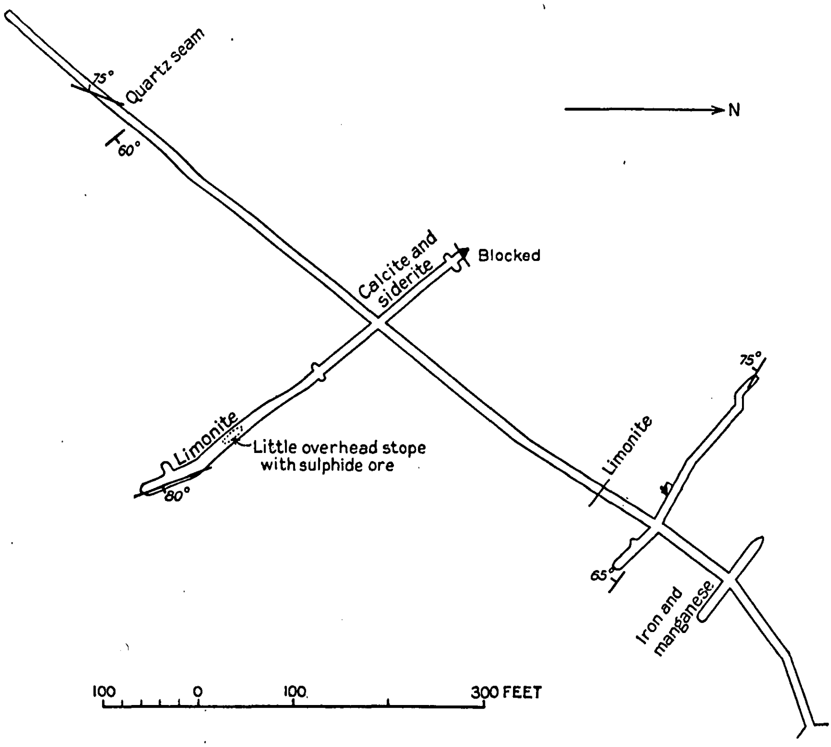


FIGURE 13.—Geologic sketch map of the lower Dryden workings, May 1929. By C. P. Ross.

comprise a tunnel close to creek level, which in 1928 was over 1,000 feet long, with drifts on each side at three places (fig. 13). The drifts aggregate about 600 feet in length and follow poorly defined zones of shearing and mineralization which approximately accord with the slaty cleavage of the country rock. In each of the drifts the rock is a dark impure dolomite, and in the tunnel it is mainly black slate. Less prominent veins, not yet explored, are traversed by the tunnel between the drifts. Where perceptible, the bedding is about parallel to the slaty cleavage. The strike in different parts of the mine ranges from N. 35° W. to N. 55° W. The dip is everywhere steep and is more commonly southwest than northeast. The min-

[36] Campbell, Stewart, 29th annual report of the mining industry of Idaho, for the year 1927, p. 123, 1928.

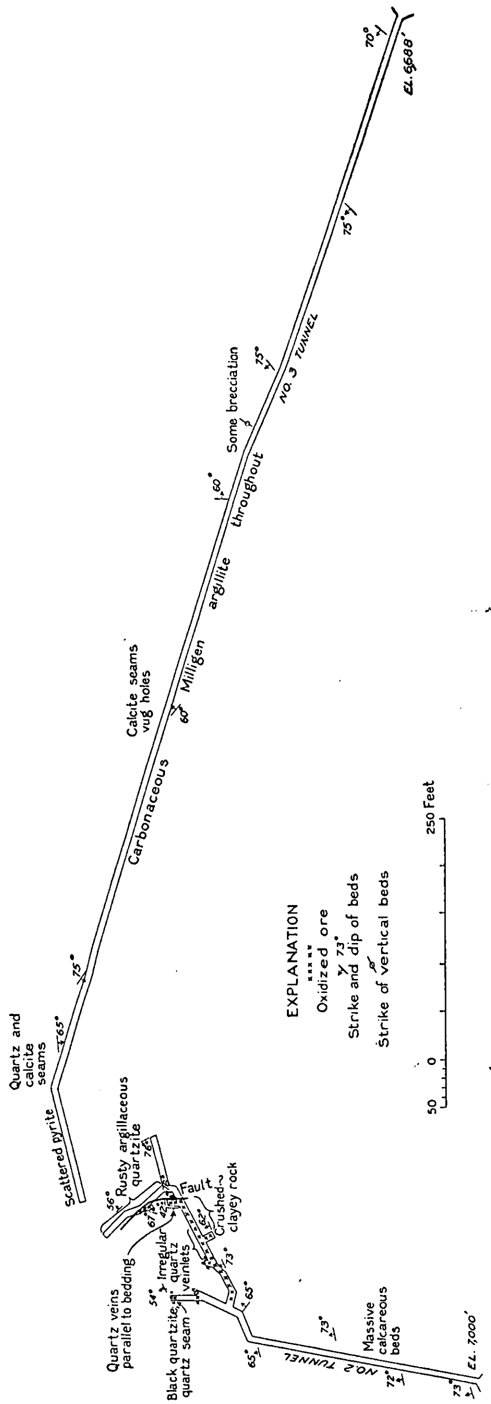


FIGURE 14.—Map of the Twin Apex mine. Base by C. W. Reese; geology by C. P. Ross, 1928, supplemented by data by C. W. Reese.

eralized zone includes galena, pyrite, a copper mineral, and siderite, calcite, and locally quartz. There is a little manganese oxide in the drift nearest the portal. In the third drift in, about 600 feet from the portal, is a small overhead stope in iron-stained rock with some galena.

TWIN APEX MINE

Property.—The Twin Apex mine, owned by the Twin Apex Mines Co., is on West Bruno Creek about 3 miles from the confluence of Bruno and Squaw Creeks and 10 miles from Clayton. It is a short distance west of the west boundary of the Bayhorse quadrangle. The property comprises 10 claims, 3 of which are patented, and 3 mill sites. There are three tunnels, numbered serially from the top down. The underground developments amount to about 2,200 feet. Near the portal of the lower tunnel there are a small gasoline power plant and several camp buildings.

History.—The two upper tunnels have been worked intermittently for the last 25 or 30 years. A small amount of ore has been mined, but efforts have been directed toward development rather than production. In 1925 the present company was organized and did considerable work in tunnel 2. The following year work on tunnel 3, intended to cut the ore at depth, was started. In August 1928 this tunnel had almost reached its objective, and the company officials were in hopes of soon striking ore.

Character of the deposit.—The Twin Apex is in highly carbonaceous, argillaceous beds of the Milligen formation. The large amount of carbonaceous matter in it results in sufficient gas to make artificial ventilation necessary in driving the lower tunnel. Figure 14 shows the geology in the two principal tunnels. It is adapted from a map prepared for the company by C. W. Reese, the geology being based mainly on observations by the writer, supplemented by those of Reese. Tunnel 1, not shown, is about 120 feet above tunnel 2. It is in crushed and crumpled shaly rock, somewhat altered, stained with limonite, and cut by quartz seams in places. Some comparatively unaltered beds in it strike N. 65° E. and dip 60° NW., which agrees broadly with the attitude of most of the beds in tunnel 2, below it. For most of its length tunnel 3 cuts beds whose strike varies within 30° each side of north, but near its face the strike swings much farther east and is thus more nearly in accord with that of the mineralized beds in the upper tunnels. In this part of tunnel 3 considerable pyrite has been encountered. In the upper two tunnels the variation in the attitude of the beds results in part from crushing and faulting, but in all three the major cause of variation is the contortion that has crumpled the whole Milligen formation in this part of the region.

It will be seen from figure 14 that sufficient ore to encourage further development has been exposed in tunnel 2. The shape of the ore body here is irregular and has been modified as a result of oxidation. The quartz stringers, however, which are not affected by oxidation, approximately parallel the bedding planes, and it is probable that the ore body will be found to accord broadly in attitude with the stratification. It is on this assumption that tunnel 3 has been driven, in the hope of cutting the ore at a depth of about 300 feet below tunnel 2. In tunnel 2 much of the ore is cerusite, accompanied by some limonite, but bunches of superficially oxidized galena remain in places.

BRUNO MINE

The Bruno mine is near the head of Bruno Creek, about 3 miles northwest of the Twin Apex mine. It is reported to have been productive in the early days, and the numerous dumps indicate that much work was once done there. It lay dormant for many years but in 1922 was opened up by the Bruno Mining & Milling Co., which built a road, brought in equipment, and did some development work. In 1924, however, activity had declined, and in 1926, according to a notice on the property, it was seized for taxes. Nothing has been done since, and when visited in 1928 the workings were in such poor condition that they were not entered. According to Campbell,[37] the property comprises 10 unpatented claims on which the principal developments are a tunnel 500 feet long, another 300 feet long, and a vertical shaft several hundred feet long. The ore formerly mined contained lead, silver, and gold.

BUCKSKIN MINE

The Buckskin mine is on a tributary to upper Thompson Creek, a short distance west of the Bruno mine. The property includes four unpatented claims held by David and William Fisher and W. J. Richards. A series of short tunnels at intervals through a vertical range of 200 feet exposes a nearly vertical fissure that trends about N. 60° W. except in the lowest workings, where it splits and the main branch trends N. 80° W. The country rock probably belongs to the Wood River formation and is mainly dark argillaceous quartzite with beds of white siliceous limestone. The ore contains chalcopyrite, sphalerite, and arsenopyrite in a siderite gangue, and the lode has a maximum observed width of 3 feet.

RAIN-IN-THE-FACE MINE

The Rain-in-the-Face mine is just across the creek from the Buckskin mine. It comprises caved workings, never extensive, on two unpatented claims. The tunnel is reported to have followed a small quartz vein containing molybdenite.

SILVER RULE MINE

The Silver Rule mine is on Silver Rule Creek, a tributary of Slate Creek, north of Railroad Ridge. It is held by the Ford Motor Co. This mine was at one time extensively developed and is reported to have produced lead-silver ore to a total value of $600,000 [38] but is now caved. From the dump and some short prospect tunnels in the general vicinity it appears that the ore contained galena, tetrahedrite, pyrite, and sphalerite. The country rock belongs to the Milligen formation.

BOULDER CREEK DISTRICT

BADGER CLAIM

The Badger property, held by Andrew Nielson and Marco Yacomella, is in sec. 31, T. 10 N., R. 18 E., east of the mouth of the stream draining Jimmy Smith Lake. There are several scattered outcrops of glassy white quartz in fractured Ramshorn slate. A tunnel about 95 feet long follows irregular seams and veinlets and crosses a mineralized shear zone several feet wide which strikes N. 9° E. and dips

[37] Campbell, Stewart, 25th annual report of the mining industry of Idaho, for the year 1923, p. 91, 1924.
[38] Bell, R. N., The central Idaho mineral empire: Mackay Miner, Mackay, Idaho, special mining edition, Feb. 3, 1926.

70° W. The ore consists of chalcopyrite, pyrite, cuprite, azurite, malachite, and limonite in quartz with a little calcite.

Two samples were taken from this claim by T. H. Hite, Jr. One tested for precious metals only, at the University of Idaho, yielded no gold and 0.2 ounce of silver to the ton. The other contained no gold or silver and 7.05 percent of copper.

There is a similar prospect on the opposite side of the creek at which development is confined to a tunnel 25 feet long on a poorly defined vein in a breccia zone in the argillite with a trend of about N. 40° W. and a dip of 30° NE. Small stringers extend into the broken argillite on each side. The ore is similar to that at the Badger except that oxidized copper minerals are less abundant and limonite more plentiful. A sample taken by T. H. Hite, Jr., yielded 0.02 percent of copper and no gold or silver on assay at the University of Idaho.

QUARTZ VEINS IN THE CHALLIS VOLCANICS

There are several conspicuous quartz veins in the vicinity of Pine and Germania Creeks, tributaries of the East Fork of the Salmon River. None show evidence of much prospecting. One of the largest of these veins is on the ridge west of Pine Creek in secs. 19 and 30, T. 9 N., R. 18 E. It is exposed for nearly 1½ miles and ranges in width from 10 to 25 feet. It consists of vein quartz and a breccia of silicified lava cemented by cryptocrystalline quartz. Much of the quartz has a dull to pearly luster. At the north end, where the vein is close to the contact between the Challis volcanics and the Ramshorn slate, the quartz is white, somewhat glassy in appearance, and comparatively coarse-grained. Here the vein projects above the ground in prominent outcrops that contain many cavities, some crustified, others drusy, ranging in size from tiny openings to narrow clefts over a foot long. A small grab sample of vein breccia taken by T. H. Hite, Jr., from the southern part of the vein yielded on assay no precious metals and only 0.02 percent of copper.

A similar vein crops out in tuff interbedded with lava on Germania Creek in sec. 9, T. 8 N., R. 17 E. A prominent outcrop here consists of a breccia of slightly brownish dull cryptocrystalline quartz with many small crustified cavities. A sample from this vein, like that previously mentioned, yielded no precious metals and 0.02 percent of copper.

LIVINGSTON MINE

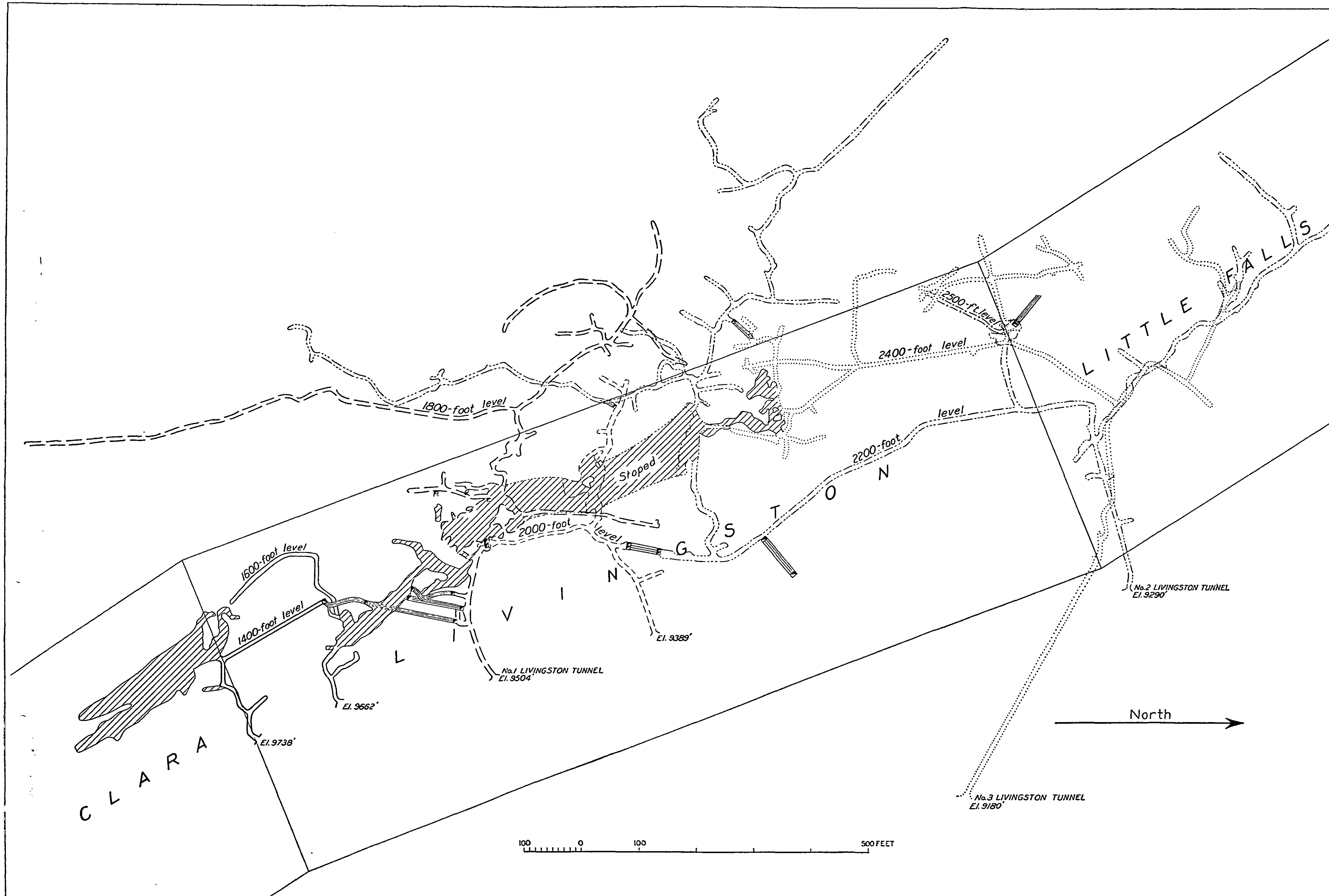
The Livingston mine is near the head of Jim Creek, south of Railroad Ridge, at an altitude of about 9,500 feet. The mill is on Boulder Creek at an altitude of somewhat less than 8,000 feet and about 3 miles along the aerial tramway or nearly 4 miles by road from the mine. The power plant is close to the mouth of Boulder Creek, nearly 6 miles by road from the mill. The property includes 7 patented claims and 16 unpatented claims.[39] The underground development on the Livingston lode totals about 22,000 feet of workings on seven levels (pl. 17). The mill has a capacity of 300 tons daily.

For the purposes of designation the distance between levels is measured on the dip, starting from a datum on the apex of the lode on the ridge above the mine, the 1,400-, 1,600-, 1,800-, 2,000-, 2,200-, 2,400-, and 2,500-foot levels having been driven. The designations are approximate only, as the distances between levels vary markedly. The 2,200-foot level has the most extensive development and the largest stope in the mine (the Christmas stope), although stoping is continuous from that level to a point above the 1,400-foot level. Much of the early development work was done on the Little Falls vein on what is now the 2,200-foot level, and the big strike of 1925 was made in a long crosscut on that level. The discovery tunnel on the Livingston vein is now known as the 1,800-foot level and is 214 feet vertically above that in which the main ore body was first found.

The Livingston vein, as locally designated, strikes nearly east and dips about 30° N., steepening on the lower levels. The main ore shoot has been stoped through a pitch length of 1,550 feet with stope lengths averaging well over 100 feet and widths from about 10 feet to several times this. It pitches N. 26° W., at an angle of about 26° with the horizontal. Between the 2,000- and 1,800-foot levels a separate shoot in the hanging wall has been stoped. The Little Falls vein is irregular but in general strikes N. 45° W. and dips steeply northeastward. It was presumably stoped only close to the 2,200-foot level, but the old stopes here are now largely inaccessible. In addition to these veins a small amount of ore, apparently a pocket, has been discovered during recent prospecting about 500 feet west of the main Livingston shoot on the 2,200-foot level.

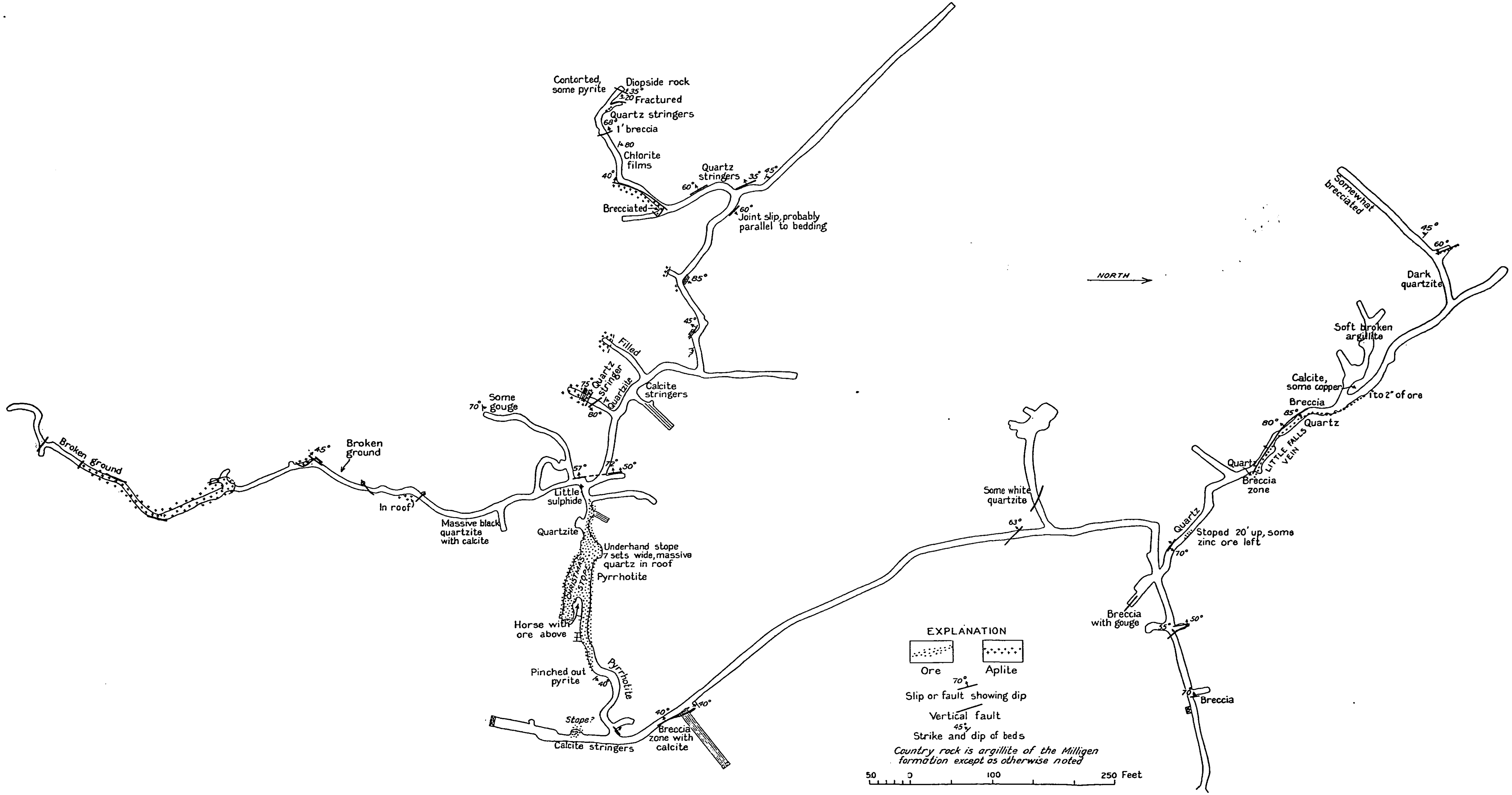
All the ore is in argillite beds belonging to the Milligen formation, which here as elsewhere is in part highly quartzitic. Some of the more siliceous rock is so bleached by hydrothermal action as to resemble a nearly white quartzite. Recrystallization in some of this rock gives it a superficial resemblance to an aplitic rock, but the difference is obvious on close inspection. In addition the light-colored rock in the face of drift 2,292 at the time of visit similarly resembles igneous rock. It is composed of diopside, alkali feldspar, and quartz, with some epidote and apatite. Similar rock is reported to have been found in the face of crosscut 1,808, on the 1,800-foot level. As plate 18 shows, igneous rock is exposed in numerous places on the 2,200-foot level. All of this rock is kaolinized, but most of it is clearly a silicic igneous rock of rather fine to medium grain. Some of the highly kaolinized rock in and near drift 2,292 now reduced to a soft clay may be altered marble like that in the face of that drift. The

[39] Campbell, Steward, 30th annual report of the mining industry of Idaho, for the year 1928, p. 118, 1929.



COMPOSITE MAP OF THE LIVINGSTON MINE.

Adapted from company's maps.



GEOLOGIC MAP OF THE 2,200-FOOT LEVEL, LIVINGSTON MINE.

Base adapted from company's map. Geology by C. P. Ross, 1929.

smaller bodies are doubtless aplitic dikes and stringers, but the larger ones may be apophyses of the main granitic mass. A little igneous rock is exposed in the stope walls at higher altitudes, and it is reported that some of the ore mined was formed by replacement of such rock. In the cirque face an aplitic dike 20 to 30 feet wide is exposed a short distance above the portals of the tunnels. It varies in attitude, cutting the contorted argillite at low angles, but in general strikes northeast and dips about 30° NW. This dike is probably cut by the Livingston vein at some point below the surface, but the intersection was not observed during the present investigation. It may be connected with the igneous rock south of the Livingston vein on the 2,200-foot level, or with the similar rock noted in at least one place on the footwall side of a stope above that level.

In a broad way the main Livingston vein roughly parallels the bedding in the argillite. Locally in the stopes mineralization appears to have advanced along the bedding. However, it is clear that the shearing, which doubtless furnished the principal channels for the mineralizing solutions, cuts the bedding. The discordance between the folded beds and the vein of relatively constant trend is shown in plate 18. The crumpling in the argillite indicated on that map and commented upon in the description of the structure of the region given above is exemplified by the fact that at the portal of the 1,600-foot level the beds strike N. 20° E. and dip 30° NW., at the portal of the 1,800-foot level they strike N. 12° W. and dip 57° SW., and at the portal of the 2,000-foot level they strike N. 45° W. and dip 50° SW., with sharp local contortion just above.

The ore in the main ore shoot in the Livingston vein where first found on the 2,200-foot level and for several hundred feet on the dip above this level was dominantly jamesonite. This has now been mined out. On the sides of the shoot sphalerite is relatively abundant, and the mining was so planned as to leave as much of this in place as possible. Pyrite, pyrrhotite, and chalcopyrite are also present, and the first two are also disseminated in the wall rocks at some distance from the ore body. The ore now visible on levels below the 2,200-foot consists largely of galena, sphalerite, pyrite, and chalcopyrite, although jamesonite is also present. In the upper levels, above the jamesonite ore, galena is the principal hypogene lead mineral, although jamesonite occurs here also. Here likewise the sphalerite is more abundant on the sides than in the center of the ore body and is partly avoided by selective mining.

LITTLE LIVINGSTON MINE

The Little Livingston mine is under the same ownership as the Livingston mine, just described. It is high on the east side of the valley of Livingston Creek at the north end of Railroad Ridge. Much of the early work by the Livingston owners was done at this property, and presumably a large proportion of the ore shipments listed by Bell and referred to in the historical outline given above came from this mine. Tunnels several hundred feet in total length have been driven, but most of these are now caved. Two of them have been reopened in recent years, and the following account is based mainly on an examination of these two by R. R. LeClercq, in 1928.

The workings are all in the Milligen formation, which is mainly argillite, although here as elsewhere some beds are relatively quartzitic and others calcareous. Two blocks of metamorphosed calcareous rock of the Wood River formation, presumably detached from the main mass as a result of faulting, are exposed in the immediate vicinity of the mine, and some of the oxidized ore is in calcareous rock that may belong to this formation. The argillite beds in general strike N. 45°–50° W. and dip 20°–30° NE. They are broken by a fault zone that in general strikes N. 25°–30° W. and dips 45° SW., although some of the slips within the zone dip northeast. LeClercq interprets the quartzitic bands shown in figure 15 as segments of an originally continuous group of quartzitic beds broken by repeated faulting. The rock between the fault slips has been broken and subsequently silicified, most of the ore is irregularly distributed in pockets in this breccia, and the masses now exposed are individually small and scattered. The ore is completely oxidized, yellow oxide of lead being the principal metallic mineral present.

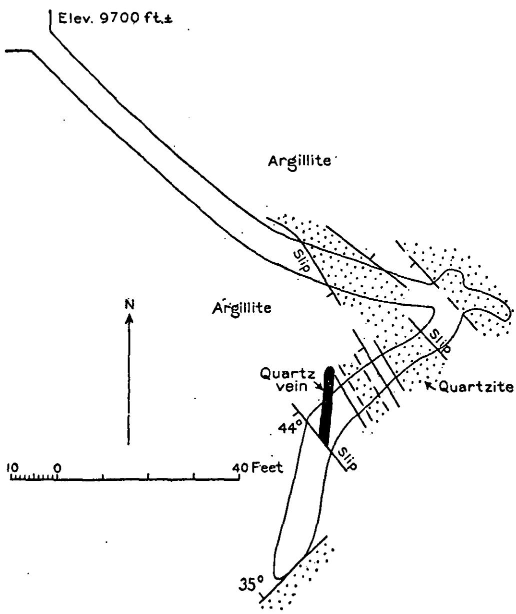


FIGURE 15.—Geologic sketch map of the upper tunnel, Little Livingston mine, August 1928. By R. R. LeClercq.

CRATER MINE

The Crater mine is close to the lake at the head of Livingston Creek. Active development was carried on only within the few years prior to 1929, and the only workings are the short tunnel shown in figure 16 and a few shallow cuts and shafts.

The country rock is all included in the Milligen formation, although some of the beds were originally impure dolomite, now metamorphosed into a siliceous rock containing tremolite. These beds somewhat resemble some phases of the Wood River formation. Near the portal the rock is argillite. In the branching drifts beyond it is more or less quartzitic. Figure 16 shows that the beds trend in general northeast, with diverse dips and considerable variation in strike. The mineralization was widely scattered. The ore minerals in part follow fractures but were formed largely by replacement, and in several places sulphides are disseminated through the country rock independent of fractures or other openings. The drift to the southwest shown in figure 16 is being driven in search of ore disclosed by cuts above and apparently distinct from any of that so far found in the tunnel. Most of the ore so far mined came from the workings about 40 feet from the portal. Several tons of ore from these workings is lying on the dump ready for shipment when opportunity offers. This ore consists of coarse-bladed jamesonite with subordinate amounts of pyrite, pyrrhotite, and chalcopyrite in a gangue of calcite and quartz.

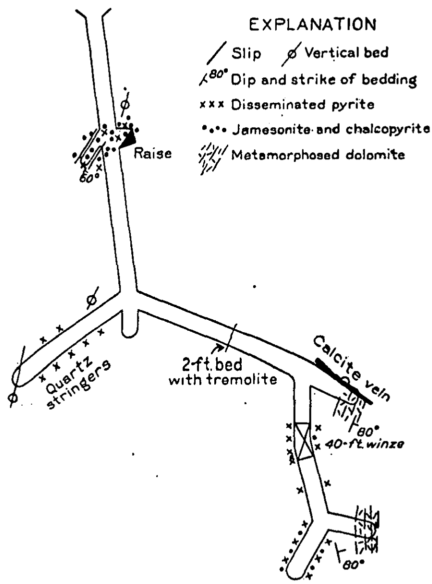


FIGURE 16.—Geologic sketch map of the principal tunnel, Crater mine, July 1928. By C. P. Ross.

HERMIT MINE

The Hermit mine is in a cirque at the head of Silver Rule Creek, on the north side of Railroad Ridge. Its principal workings are

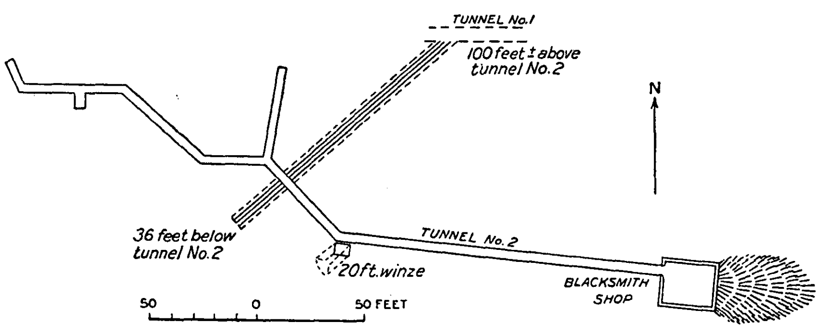


FIGURE 17.—Sketch map of the principal workings, Hermit mine. Adapted from map accompanying report by P. H. Lund to the company.

shown in figure 17, adapted from a map furnished by the company. The country rock is carbonaceous argillite with some dolomitic beds, which is contorted and locally highly crumpled. Tunnel 2 approximately follows the bedding from the winze to its face. In the vicinity of the shaft there is some shearing parallel to the tunnel. A small shipment of lead ore is reported to have been made several years ago from the bottom of the shaft, which was full of water at the time of visit.

MOLYBDENITE PROSPECTS

Molybdenite occurs in several places in the small mass of Carboniferous strata that extends from Spring Basin to the head of Boulder Creek, mostly in small quartz stringers and as films on parting planes in the sedimentary rocks. The principal development is close to the southern tip of the Carboniferous rocks, on the north side of one of the numerous lakes in this vicinity. Its location is marked on plate 1. This property is held by C. L. Kirtley and others. In 1930 there was a 30-foot tunnel and several shallow cuts at this place. The tunnel is mostly in slide rock but at the face exposes Milligen beds, which strike N. 15° E. and dip 65° SE. This is close to the contact with a granitic stock, along which the sedimentary rocks are much fractured and metamorphosed. The molybdenite-bearing quartz veins occupy fractures. They contain minor amounts of pyrite, pyrrhotite, and galena.

FULLER AND BAKER PROSPECT

On Little Boulder Creek about a mile south of Spring Basin there is a property held by Messrs. Fuller, Jesse Baker, and others. It is in a small mass of sedimentary rock whose appearance suggests that it belongs to the Wood River formation, which emerges from the cover of Challis volcanics along the granitic contact. There is a tunnel that trends northwest for about 90 feet and exposes two somewhat mineralized shear zones. One of these strikes N. 25° E. and dips 85° NW., and the other is more irregular but trends roughly N. 20° W. The strata in the vicinity of the tunnel strike N. 35° E. and dip 60° NW. The shallow cuts show several veins. Those a short distance above the tunnel expose massive glassy vein quartz with bands and bunches of arsenopyrite, pyrite, galena, and sphalerite, together with some tourmaline, red jasper, and calcite. The jasper appears to be later than the sulphides and quartz.

STRAWBERRY BASIN MINE

Strawberry Basin lies at the head of one of the tributaries of upper Warm Spring Creek, nearly a mile north of Blackman Peak. At a point on its western rim there are a cabin, several cuts, and a curved tunnel, probably over 200 feet long, all the workings in the Milligen formation. Just above the cabin a cut exposes a rusty seam that trends N. 20° W. and dips 80° SW. The tunnel is about 60 feet vertically above this cut. A little sacked ore is stocked on the dump, the sacks rotted. The tunnel traverses argillaceous and in part somewhat quartzitic rocks that strike N. 20° E. and dip 80° NW. Above and connecting with the tunnel is a cut following sheeting parallel to the bedding, which here trends north and dips 80° W. The ore that has been mined evidently came from this sheeted zone. It is essentially similar to the jamesonite ore of the Livingston mine.

To the southeast, in the Warm Spring Creek drainage basin near Blackman Peak, there are several tunnels and cuts. Some of these may originally have been over 100 feet long, but they were in such poor condition when visited in 1930 that they were not entered. Some are in the Wood River formation, others in the quartz monzonite.

EAST FORK DISTRICT

AZTEC MINE

The Aztec Mining & Milling Co. holds the three unpatented claims of the Kingfisher group [40] near the head of Pigtail Creek, which is tributary to The Meadows on Warm Spring Creek. The property is reached from Stanley Basin by a wagon road up Fisher Creek. This is an old mine on which there has been a resumption of activity on a small scale since 1926. The underground workings are reported by Campbell to amount to about 1,750 feet, including an inclined shaft 650 feet long. There is an old mill, locally known as the Fisher mill, in which new equipment has been installed.

The shaft follows a mineralized shear zone in granitic rock. Gold is the metal principally sought, although it is reported that base-metal sulphides are present. When visited in July 1930 the shaft was full of water up to a level 150 feet below the collar. Several drifts lead off from the accessible portion, but most of them had been filled. One, open for a short distance, shows a shear zone in which the granitic rock is softened for a width of 1½ feet. The strike is N. 60° W. and the dip about 60° SW.

LUCKY STRIKE MINE

The Lucky Strike mine, held by Tony Cuprella, is on the north side of upper Fourth of July Creek, just south of Blackman Peak. It is developed by a ramifying tunnel, which with its branches has an aggregate length of about 350 feet, and by several cuts, including one shaft 32 feet deep and another 20 feet deep. There are several lodes which have been formed mainly by replacement along a conjugate fracture system. One set of fractures strikes about N. 50° E. and dips 50°–70° NW. The other and less prominent set trends about N. 40° W. and dips 65° SW. Most of the country rock belongs to the Milligen formation, stands nearly vertical, and trends northwest. The mineralized areas extend across the contact into the nearby mass of quartz monzonite, and small offshoots of that rock are

[40] Campbell, Stewart, 33d annual report of the mining industry of Idaho, for the year 1931, p. 128, 1932.

exposed in some cuts. At one place in the tunnel a porphyry dike of probable Tertiary age lies in a zone of shearing in the Milligen beds. but apparently was unaffected by the movement. The crushing in the shear zone locally attains a width of 10 feet, but the greatest observed width of mineralized rock is 3 feet. The principal sulphides are galena and sphalerite.

DEERTRAIL MINE

The Deertrail mine, held by George Blackman, adjoins the Lucky Strike on the west and probably includes a continuation of the same system of mineralized fractures. The only working seen is a tunnel in the Milligen beds that trends north and northwest for about 320 feet.

MINES IN WASHINGTON BASIN

Washington Basin is close to Washington Peak, at the head of one of the tributaries of upper Germania Creek, on the southern border of the Custer quadrangle. There are several lodes in this basin that have been known since about 1880. Much of the work here was done between 1894 and 1910, although some development work has been continued up to the present time, and there has recently been renewed interest in the lodes. Most of the property was held by the late G. Z. Blackman, who resided here since the beginning of activity in the basin. One group of three claims is held by Fidele Giampedraglia and his brother. When visited in 1930 all the workings, except one irregular excavation some 30 feet deep, were reported by Blackman to be either caved or unsafe, so that little information regarding the mineralization was obtained. The excavation that was open is on the Empire vein, the most extensively developed in the basin. In this working the vein is about 30 feet wide, stands nearly vertical, and trends N. 15° E. It is enclosed in sheared and somewhat altered granitic rock. The vein matter consists of white coarse-grained quartz and altered rock with small amounts of pyrite, pyrrhotite, and probably a little sphalerite. Blackman reported that samples from this vein yielded $34 to the ton in gold and silver and that some of the other workings in the basin contained lead ore, although the principal value in all is in gold. He furnished a specimen from the Empire vein that consists of plates of joseite in quartz.

Umpleby [41] visited this basin in 1912 and obtained considerable information regarding its lodes. He states that five lodes were then known, but that the only noteworthy development was on the Empire group of 11 claims. According to him the Empire vein strikes N. 25° E., dips 55° SE., and has an average width of 30 feet and a maximum observed width of 72 feet. There were at that time a lower tunnel 450 feet long, an upper tunnel 150 feet long, two shallow

[41] Umpleby, J. B., Ore deposits in the Sawtooth quadrangle, Blaine and Custer Counties, Idaho: U. S. Geol. Survey Bull. 580, pp. 244–246, 1915.

shafts, and several trenches on this vein. At the surface the vein matter is intensely oxidized, but primary sulphides begin at a depth of a few feet. The sulphides noted by Umpleby include arsenopyrite, sphalerite, galena, stibnite, and pyrrhotite. The granitic rock in the lode is intensely sericitized, and at one place he noted a band of pyrrhotite with about an equal amount of intermixed quartz and diopside 15 to 20 feet wide replacing the granitic rock. He states that the ore in different parts of the vein is reported to contain $6 to $12 in gold to the ton but that panning of specimens collected by him suggests that the latter figure is high. The other lodes in the basin are similar in character, though not so wide.

MINES IN GERMANIA BASIN

Germania Basin includes most of the drainage area of a tributary of Germania Creek that lies immediately south of Washington Basin, in the Sawtooth quadrangle. In the period between 1880 and 1890 several mines were operated on the northern slopes of this basin, as well as some openings across the divide, in the cliffs on the Washington Basin side. The principal mines then active were the Bible Back, Parnell, Idahoan, and Tyrolese. Their aggregate production may have been as much as $500,000, mainly from silver-lead ore shipped to the smelters at Galena and Ketchum. Since 1890 there has been only desultory, intermittent activity here, and when the locality was visited in 1930 no work was in progress. In most places caved ground prevents access to the parts of the workings containing the stopes, although several hundred feet of tunnels in barren beds of the Wood River formation are still in good condition. Such observations as could be made indicate that the lodes were irregular and most of the shoots small. Mineralization was guided in large part by shearing but consisted mainly in replacement of calcareous beds. Some of the mineralized zones strike northwestward, others northeastward. Much of the ore mined was oxidized.

LODES NEAR THE HEAD OF GERMANIA CREEK

Along the ridges bordering Galena and Grand Prize Creeks and elsewhere in the general vicinity of the head of Germania Creek old dumps and cabins testify to former mining activity. Most of the lodes here are reported to have been worked for lead and silver, and little has been done since 1890.

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