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GEOLOGY AND ORE DEPOSITS OF THE WOOD RIVER REGION, IDAHO

BY
JOSEPH B. UMPLEBY, LEWIS G. WESTGATE
AND CLYDE P. ROSS

WITH A DESCRIPTION OF THE MINNIE MOORE AND NEAR-BY MINES

BY
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Prepared in cooperation with
the Idaho Bureau of Mines and Geology
Francis A. Thomson, Director

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SUMMARY

The rocks of the Wood River region comprise sedimentary beds of Algonkian(?), Ordovician, Silurian, Devonian(?), Mississippian, and Pennsylvanian age, granitic masses probably intruded in Cretaceous time, and lava flows with small amounts of interbedded tuff, and gravel of Tertiary (probably Miocene) age. There are also glacial and alluvial deposits of Pleistocene and Recent age and a small amount of basalt of Quaternary age. The following table and Figure 2 (p. 10) give, in descending order, the sedimentary formations of the region, with their general character and thickness. Because of the complexity of the structure, the thicknesses given are only approximate.

Quaternary:	
Valley alluvium.	
Gravel and sand in terraces.	
Glacial material.	
Basalt flows.	
Tertiary:	Feet
Miocene(?) lava flows interbedded with tuff and gravel	2,500–3,000+
Pennsylvanian:	
Wood River formation:	
Thick-bedded calcareous and quartzitic sandstones.	
Thin-bedded limestones.	
Massive blue sandy limestone.	
Massive conglomerate.	
Total	8,000±
Mississippian and Devonian(?):	
Milligen formation: Shales and slates with interbedded limestone and quartzite	3,000±
Silurian	500+
Trail Creek formation: Siliceous argillite and sandstone.	
Ordovician:	
Phi Kappa formation:	
Chiefly black shale and interbedded yellow shaly sandstone	4,600±
Aphanitic quartzites and interbedded quartzitic sandstones	4,750±
Early Lower Ordovician rocks (carbonaceous argillite carrying Beekmantown graptolites)	Few hundred.
Algonkian(?):	
East Fork formation: Crystalline limestone and interbedded vitreous quartzite	1,560±
Hyndman formation: Massive quartzites with an interbedded schist member in the lower part and a green hornfels member in the upper part	6,600±
	32,000

Igneous rocks ranging in composition from granite to diorite were intruded into the sedimentary rocks of the Wood River region, probably in the later part of the Mesozoic era, and these igneous rocks now occupy several areas. The largest of these areas is on the east side of the Hailey quadrangle, chiefly in upper Wildhorse Creek. Smaller areas occur west of the Big Wood River. These rocks are of the same age and similar in kind to those which make up the great granitic area of central-western Idaho, the eastern edge of which lies within 7 miles of the western border of the Hailey quadrangle. The small granitic areas of the Wood River region are believed to be outlying parts of this great central Idaho batholith.

During and shortly after the batholithic intrusions orogenic movements took place and produced the dominant structural features of the region. Forces acting from the southwest formed a series of overturned folds, which in places pass into overthrust faults. There are also numerous normal faults, both parallel and transverse to the strikes of the folds and thrust faults. Some are clearly later than the Tertiary volcanism, but others are probably related to the thrust faulting and folding, and still others can not be definitely dated. Two of the granitic masses are rimmed with faults at and beyond the contact with the surrounding sedimentary beds. These faults are probably closely related to the intrusion of the granite.

A long period of erosion followed the granitic intrusions and associated orogenic movements. Then during Tertiary time numerous lava flows with minor amounts of pyroclastic material accumulated to a total thickness of several thousand feet. Most of the lava is of latitic and andesitic composition, but rhyolite and basalt were also extruded. Such evidence as is available indicates that these volcanic rocks are of Miocene age. To-day the flows cover less than a third of the region, but in Miocene time they must have been continuous over most of it. Intrusive rocks related to the lava are abundant in the northwestern part of the region and a few similar dikes exist elsewhere.

The lava has almost everywhere been tilted, generally eastward. Dips of 30° to 50° are common, and in places the beds are vertical. The disturbance of the lava is probably largely attributable to normal faulting. In some localities the presence of faults can be proved and in many others they are inferred on good evidence. The almost geometrical regularity of the drainage pattern may result from faults not otherwise evident.

The rocks later than the Miocene (?) lava include flows of basalt in the lower valley of the Little Wood River, glacial moraines, and alluvium in the valleys, all of Quaternary age.

Ore was first discovered in 1864, and the boom days of the region were in 1880 to 1887. The total production has amounted to more than $25,000,000, most of which came from lead-silver ore, with minor amounts from gold, copper, and zinc ore. Most of the lodes of commercial importance occur on shear zones and are characterized by argentiferous galena with some sphalerite and tetrahedrite and subordinate pyrite and other sulphides in a gangue that consists of altered and crushed country rock, carbonates, principally siderite, and quartz. A few lodes contain much arsenopyrite, and others contain ruby silver. There are also contact-metamorphic deposits, which have not yet been profitably exploited; veins consisting of barite, calcite, or quartz with negligible amounts of metallic minerals; and some evidence of mineralization in the Tertiary lava. All the commercially important types of lodes are believed to be genetically related to granitic intrusions, probably of Cretaceous age.

Fine ore bodies have been found in many places in this region, but the greater part of those now known have been practically worked out. Few of them extended to depths of more than a few hundred feet below the surface. The hope for future success lies in the discovery of other ore shoots at greater depth. There is no reason to suppose that original deposition was confined to the shallow zone in which all the mining has so far been done. Some suggestions are given as to the reasons for localization of ore shoots, but unfortunately these are not of much assistance in the search for new ones. No evidence has been found to support the idea, held by some, that a great fault, the "Wood River fault," underlies the region and cuts off the lodes at shallow depth. The lodes persist, but valuable ore in them is localized in shoots, and the problem is simply to find new shoots of commercial value.

Graphitic coal is present but has not yet been proved to be of value.

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INTRODUCTION

OUTLINE OF THE WORK

The principal source of geologic information on the Wood River region, Idaho, since 1900 has been a report by Lindgren,[1] which has been out of print for several years. About 1912 urgent requests for a resurvey were made by people interested in the mining industry of the region. They were actuated by the hope that detailed studies over a larger area and in the light of mining developments since 1900 would aid in solving some of the practical problems of the district. In response to these requests work was begun in September, 1912, by J. B. Umpleby, who spent two weeks in a study of ore deposits in the northern part of the Hailey quadrangle and in the vicinity of Ketchum. Between July 28 and September 10, 1913, Umpleby, assisted by E. H. Finch, completed his examination of the ore deposits. Many of the mines were idle and inaccessible during these two years when mining was inactive and data on mining geology were correspondingly incomplete. During 1913 and 1914 the areal and structural geology of the Hailey quadrangle was studied by L. G. Westgate, assisted in 1913 by R. S. Knappen and A. C. Bevan and in 1914 by Knappen and E. V. Shannon. The Minnie Moore and neighboring mines had been examined in 1908 and 1910 by D. F. Hewett before he joined the United States Geological Survey. In 1913 and 1926 Hewett reviewed his work with a view to contributing the account that forms Part 3 of this report.

Umpleby and Westgate had made some progress on their reports when emergency requirements due to the World War interrupted the work. In 1919, shortly after the end of the war, Umpleby resigned from the Geological Survey, and it was not feasible at that time to assign anyone else to complete the report. In 1921, however, the then newly organized Idaho Bureau of Mines and Geology ar-

[1] Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, pp. 190–231, 1900.

ranged to cooperate financially with the United States Geological Survey to complete the report. As there had been a revival of mining in the region and requests for geologic information were again being received, C. P. Ross, of the Geological Survey, was sent to study recent developments. He spent from July 9 to August 20, 1923, in the district and visited a number of mines that were inactive or undeveloped when Umpleby made his examinations. Ross has revisited the region annually since 1923, to study the latest mining developments as well as certain details of the general geology. He has revised and coordinated the manuscripts of Westgate and Umpleby in the light of the new data.

SCOPE OF THE REPORT

The region studied includes the Mineral Hill and Warm Springs Creek mining districts and part of the Little Wood River district and thus essentially corresponds to the "Wood River region" as usually defined by the mining men of Idaho, although wider limits are sometimes assigned to the Wood River region. It lies in Blaine and Custer Counties in south central Idaho near the middle of the southern border of the great mountain mass that occupies most of the area of the State, and most of the region is included in the Hailey quadrangle. Its position is shown on the index map of the State (fig. 1). The topography and geology of the part of the region included in the Hailey quadrangle, 864 square miles in area, are shown in Plate 1. The map of the Mineral Hill district (pl. 9) shows the geology of an area that extends 5 miles south of the boundary of the quadrangle.

The report contains three parts: The first part, which is based principally on Westgate's work, describes the geology of the Hailey quadrangle, with incidental references to the part of the Mineral Hill mining district that lies just south of the quadrangle; the second part deals with economic geology and describes about 70 deposits, more than twice the number mentioned in Lindgren's report; the third part describes the geology of the Minnie Moore and neighboring mines studied by Hewett.

ACKNOWLEDGMENTS

The authors are indebted to the mining men of the region for innumerable courtesies extended throughout the investigation. Umpleby particularly expresses his indebtedness to Mr. Raymond Guyer for numerous mine maps and records and for the use of his office and engineering equipment while in Hailey; to Mr. J. G. Sawyer, whose thorough acquaintance with the Red Elephant mine enabled him to point out numerous significant relations; to

Mr. H. J. Hardess, manager of the Elkhorn, Bald Eagle, and Starlight groups of claims; to Mr. W. A. Wilson, of Salt Lake, who supplied maps of the mines near Bullion; and to the late Dr. W. P. Jenney, formerly of Washington, D. C., who for several years was

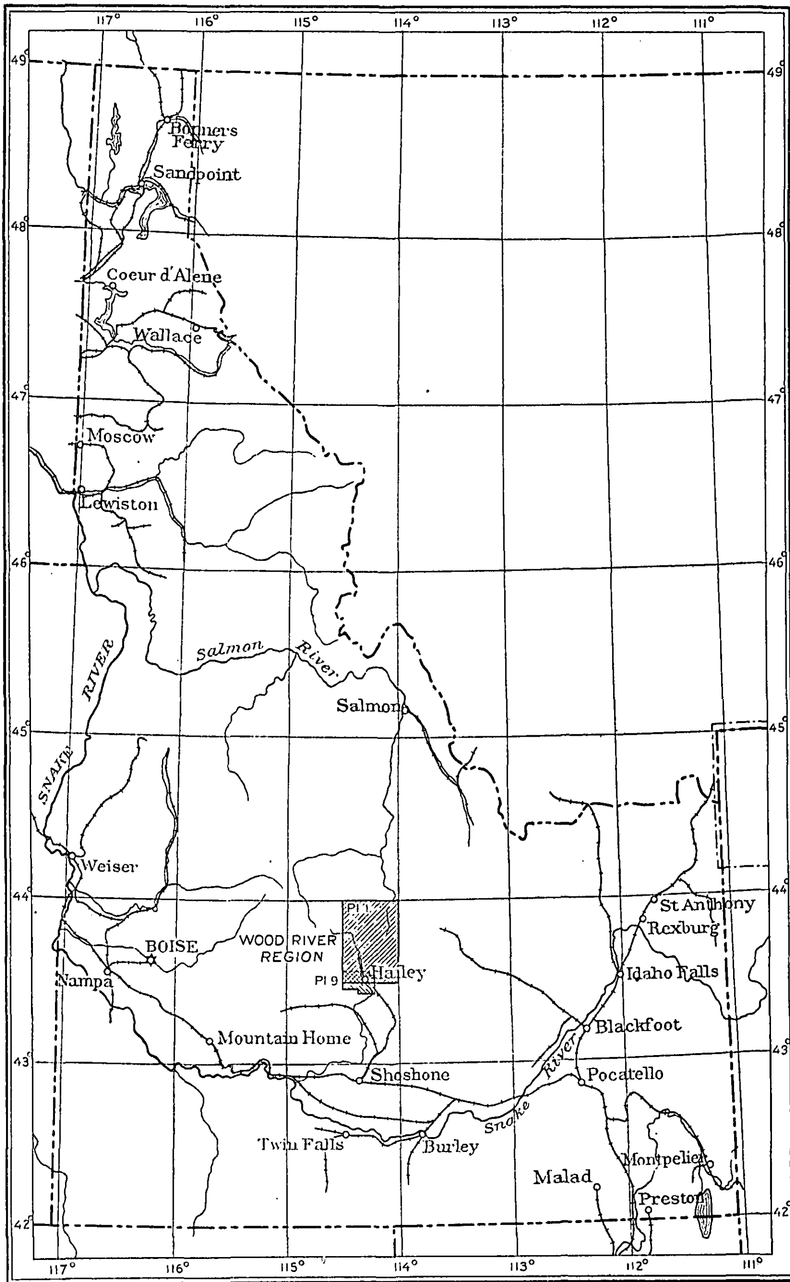

FIGURE 1.—Index map of Idaho, showing the location of the Wood River region

manager of the Parker mine. Ross's work was greatly facilitated by Mr. Stewart Campbell, State inspector of mines, who contributed his time and detailed knowledge of the region and supplied numerous mine and claim maps; and by Messrs. J. J. Beeson, E. Daft, J. W. Gwinn, Charles Peter, A. E. Ring, and numerous others, who supplied maps and information and extended courtesies. Information furnished by Messrs. G. M. Fowler and S. A. Steier, geologists of the International Smelting Co., aided materially in the study of several deposits.

EARLIER WORK

In 1894 Eldridge [2] made a geologic reconnaissance across Idaho, in the course of which he visited the Wood River region. He placed the sedimentary rocks, on lithologic grounds, in the Paleozoic, from the Cambrian to the Mississippian, and supposed that they rested on the older granite. He indicated the structure in a large way as anticlinal, the rocks dipping to the southwest in the Wood River region and to the northeast in the Lost River region, although he recognized the complexity of the folding and faulting. The lavas he barely mentioned. He gave a brief description of the method of occurrence of the ores.

In 1898 Lindgren completed a study of numerous mining districts in south-central and southwestern Idaho by making a detailed reconnaissance examination of the ore deposits of the Wood River region.[3] He described the mines south of Deer Creek in considerable detail and discussed at length the replacement phenomena which the deposits illustrate. He recognized the intrusive character of the granitic rocks and studied the results of the metamorphism that accompanied the intrusion of the main granitic mass. He also recognized and laid emphasis upon the distinctive characteristics of the Wood River ore deposits.

Other sources of information are the annual reports of the State inspector of mines,[4] which contain miscellaneous information on the Wood River mines, and Bancroft's History of Washington, Idaho, and Montana, which contains information largely of a historical nature. The reports of the inspector of mines for 1922 and following years contain essentially complete bibliographies on geology and mining for each of the counties of the State. The principal published source of statistical data for the early years consists of the annual reports of the Director of the Mint, and for later years the

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[2] Eldridge, G. H., A geological reconnaissance across Idaho: U. S. Geol. Survey Sixteenth Ann. Rept., pt. 2, pp. 211–276, 1895.

[3] Lindgren, Waldemar, Gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, pp. 190–231, 1900.

[4] Annual report of the mining industry of Idaho, for each year from 1898 to 1925, published at Boise, Idaho.

volumes of Mineral Resources issued annually by the United States Geological Survey and, since 1923, by the Bureau of Mines. Brief references have been made from time to time to particular mines in the technical journals, but most of these are of value only in supplying historical data. The more comprehensive articles are listed in the bibliographies prepared by the inspector of mines mentioned above.

Blackwelder [5] has published a list of graptolites from a locality in the Hailey quadrangle which shows the presence of Ordovician shales.

Several reports on near-by mining districts have been prepared by Umpleby.[6] They deal chiefly with the mineral deposits but give some account of the general geology.

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[5] Blackwelder, Eliot, New or little known Paleozoic faunas from Wyoming and Idaho: Am. Jour. Sci., 4th ser., vol. 36, pp. 174–175, 1913.

[6] Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, 1913; Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, 1913; Ore deposits in the Sawtooth quadrangle, Blaine and Custer Counties, Idaho: U. S. Geol. Survey Bull. 580, pp. 219–249, 1914; Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, 1917.

PART 1. GENERAL GEOLOGY

By LEWIS G. WESTGATE and CLYDE P. ROSS

INTRODUCTION

TOPOGRAPHY

The Wood River region is near the southern border of the great mountain mass of central Idaho and comprises the Hailey quadrangle and an area south of it. It is a rugged region of marked relief, in which the only level tracts are the terraces and alluvial flats along a few of the larger streams, such as the Big Wood River and the Big Lost River.

All the drainage from the Wood River region ultimately reaches the Snake River but by quite different routes. About 55 square miles in the northwest corner of the region is drained by West Pass Creek and other streams into the East Fork and the Salmon River and thence to the Snake River, on the west boundary of the State. The remainder of the area north of the main divide, nearly 240 square miles, is drained through the Big Lost River, first northeast and then southeast past Mackay to the Snake River Plains, where the water sinks beneath the lava floor. In the southeastern part of the Hailey quadrangle an area of about 120 square miles lies in the drainage basin of the Little Wood River and is drained south to the Snake River. The rest of the area south of the main divide, nearly half of the region mapped, drains south through the Big Wood River to the Snake River. The main divide, which separates the northern third of the Hailey quadrangle from the rest of the region, extends in an irregular line diagonally across the quadrangle with a trend of about N. 60° W.

The lowest part of the region is near Bellevue, on the Big Wood River, where the altitude above sea level is somewhat over 15,100 feet. From that locality as far north as the vicinity of Ketchum few peaks attain 8,000 feet in altitude, and the relief between mountains and valleys is in general from 2,000 to 2,500 feet. Farther north the relief is greater, and many of the summits along the main divide stand 3,000 and 4,000 feet or more above the valleys of the major streams. The summits along most of this divide in the Hailey quadrangle attain altitudes above the sea of over 10,000 feet, and they culminate near the east border of the quadrangle in Hyndman Peak, which is 12,078 feet above sea level.

The mountain slopes rise steeply from the valley bottoms to narrow interstream divides, as can be seen from Plate 2 and some of the other views. The larger streams have flood plains even well up in the mountains. An example of such flood plain is shown in Plate 3, *B*. There are breaks in the slopes of valley sides which probably are due to interruptions in the continuity of erosion. Level or gently sloping summit or high-level tracts, such as have been interpreted elsewhere in Idaho and other mountainous regions as remnants of old erosion plains or peneplains, are absent in this region.

The valleys are comparatively open at a distance from the main divide, particularly south and southeast toward the Snake River Plains. (See pls. 3, *A*, and 8, *B*.) They become much narrower and more gorgelike nearer the divide, but many open out at their very heads into glacial cirques with precipitous walls. The steepest slopes and most rugged areas in the region are found at the heads of these glaciated valleys. (See pl. 2, *A*.) Broad basin-like mid-valley expansions, which are common in neighboring regions, do not occur; the nearest approach to them is found north of the divide, at the head of the North Fork and the lower end of the East Fork of the Big Lost River.

CLIMATE

The climate of central Idaho has been described by Henry[1] as follows:

Adjacent to the district just described, comprising almost a third of the area of the State, lies what has been designated the central plateau region. This area includes several large valleys and many smaller ones. All of these valleys lie at considerable elevations, and they are separated from one another by irregular ranges of mountains, among which may be mentioned the Sawtooth Mountains, * * * some of which rise to a sufficient height to enable them to maintain a perpetual covering of snow. In this region periods of extreme cold are frequently experienced, when temperatures of 30° or more below zero are recorded in the mountains, while in summer there are times when the daytime temperatures in the valleys are oppressively high. Here lie a number of comparatively level prairies, producing an abundance of wild grass and, in some sections, good crops of grain and domestic grasses. A considerable area is also under cultivation in some of the more sheltered valleys, though the danger of killing frosts in the summer months and of extreme cold in winter prevents the successful growing of other than the most hardy crops. * * * The low temperatures prevailing in this region, resulting in heavy precipitation of snow in winter and slow melting of this snow in spring, make it an ideal place of storage for the waters of several streams. * * *

High winds are of more or less frequent occurrence in exposed portions of the State but are seldom destructive and in many sheltered valleys are almost

[1] Henry, A. J., Climatology of the United States: U. S. Dept. Agr. Weather Bureau Bull. Q, p. 810, 1906.

unknown. Hail storms occur frequently. Thunderstorms occasionally occur, being usually very light but sometimes attaining a degree of violence in limited localities. The loss from lightning is very slight.

The records of temperature and precipitation at Hailey, furnished by the United States Weather Bureau, are as follows:

Records of temperature and precipitation at Hailey, Idaho

	Average mean temperature	Average mean precipitation	Average mean snowfall		Average mean temperature	Average mean precipitation	Average mean snowfall
	°F.	Inches	Inches		°F.	Inches	Inches
January	20	3.72	40.4	August	67	0.33	0
February	24	1.79	14.1	September	56	.81	Trace.
March	31	1.57	6.1	October	46	1.17	1
April	44	1.01	1.9	November	34	1.30	10.8
May	52	1.47	1.1	December	20	1.72	22.2
June	59	.97	.3				
July	67	.62	0	Annual	43	16.48	97.9

The records of temperature and precipitation cover a period of 13 years, the record of snowfall a period of 8 years. Of the total precipitation of 16.48 inches, only 3.39 inches fall in the months of May to August.

About Hailey the hilltops in May still carry heavy drifts of snow in many places, though the weather is warm and the valleys are open. Snowstorms are frequent at the higher altitudes in early June. The earliest autumn snows come in September or the first part of October, after which there is likely to be a long season of clear, open weather. In the comparatively low country near and south of Hailey the daytime temperature in summer is frequently rather high, but uncomfortably hot nights are rare. In the mountains north of Hailey the summer temperature is usually delightful.

VEGETATION

The general character of the vegetation changes with the altitude. The valley bottoms and the lower slopes of the hills, especially in the less rugged and lower sections, are mostly treeless and are covered with sagebrush and grasses. The streams are lined with willows. Trees become more abundant at middle altitudes. Up to 8,000 or 9,000 feet patches of aspen are common. Evergreen trees predominate at higher levels than the aspens, especially in the deeper and more shaded valleys and on the northern slopes of the hills. Over much of the region they grow singly or in scattered groups and do not make a continuous forest. Above 9,000 feet the forest growth becomes more and more sparse, and the timber line lies at about 10,000 feet. About two-thirds of the area is included in national forests, that south of the divide in the Sawtooth National Forest and that north of the divide in the Lemhi National Forest.

POPULATION AND INDUSTRIES

The only towns in the Wood River region are Hailey, Bellevue, and Ketchum. Hailey is the county seat of Blaine County and the principal supply center for the ranches and mines of the upper Wood River Valley. In 1920, according to the census, Hailey precinct had a population of 1,316. Bellevue, nearly 5 miles south of Hailey, had a population of 526, and Broadford precinct had a population of 74. Ketchum, which had 252 people in 1920, in the boom days of mining in the region was a place of considerably greater size and business activity than at present. During this period the Pittsburgh & Idaho smelter was in operation for a number of years.

Ranches, devoted mainly to the raising of hay and stock, are operated wherever water for irrigation is available, mostly on the level lands along the Big Wood River, its East Fork, and Deer, Greenhorn, and Croy Creeks. There are no ranches north of the divide in Custer County nor in the valley of the Little Wood River in the Hailey quadrangle. In summer large numbers of sheep from the ranches along Big Wood River and from those on the lower plains above Shoshone graze on the forest range, and many sheep have been shipped from Ketchum. A little timber is being cut in the national forest.

Mining has in the past been the largest industry in the region. After a period of depression it experienced a revival in 1923. Several score of mines and prospects were being worked in the summer of 1923, but in August only one of these was shipping ore with any regularity. In the summer of 1924 there was comparatively little activity, and no ore shipments were being made except small ones by lessees at a few of the old mines.

SEDIMENTARY ROCKS

ALGONKIAN (?) ROCKS

The oldest sedimentary rocks in the region (see fig. 2) are a series of quartzites, limestones, and schists of probable Algonkian age that occupy an area of about 20 square miles in the east-central part. This area, which has a length of 10.5 miles from northwest to southeast and a maximum width of 3 miles, lies mainly south of the divide between the Big Lost and the Big Wood Rivers, although for a distance of nearly 3 miles near Hyndman Peak its northeast border crosses the divide. These old rocks form the summits of Hyndman Peak and the high mountains a mile to the southeast and are well exposed in the upper parts of all the valleys heading against the divide on the south, from Wilson Creek to the Little Wood River. They dip in general steeply southwest. On the northeast the old

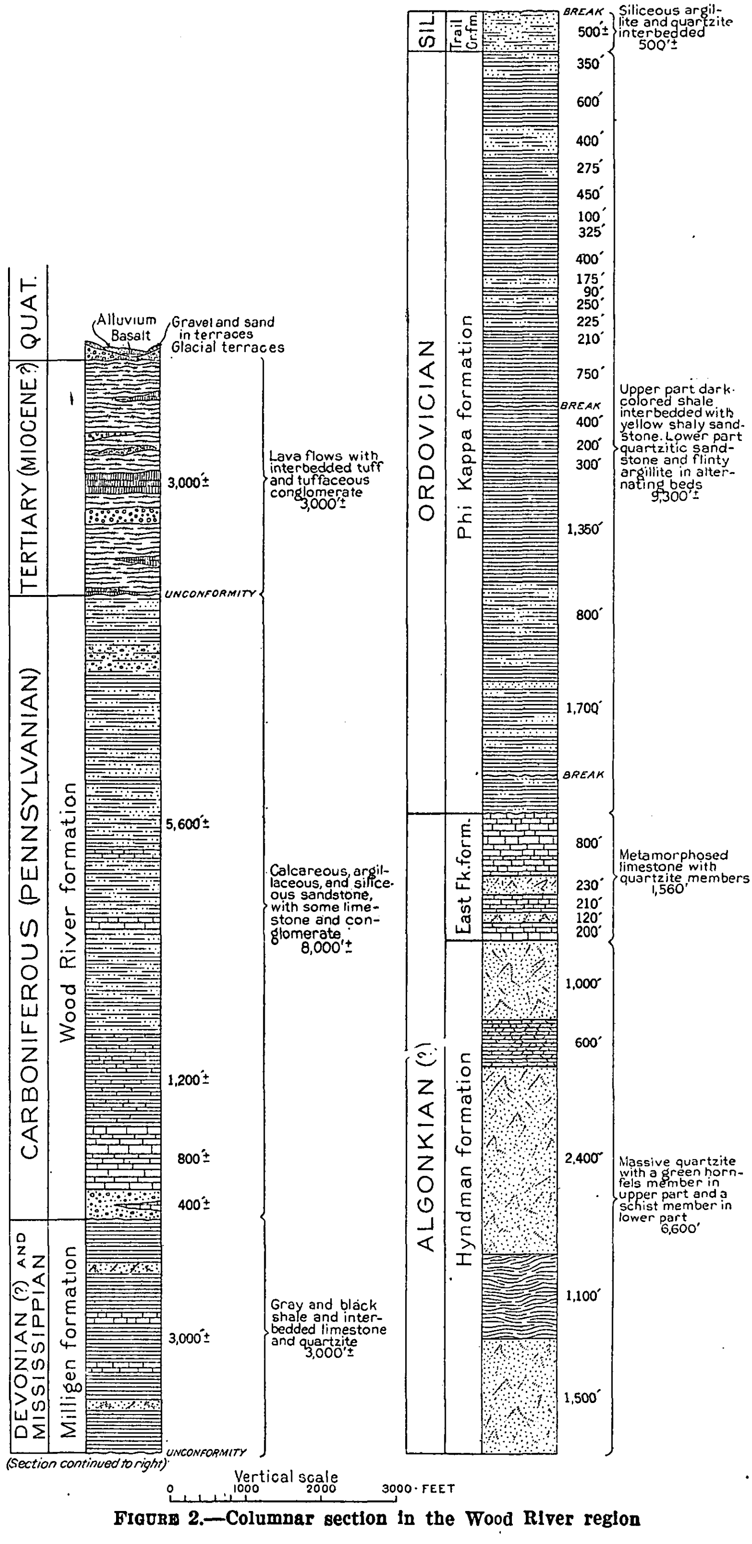


FIGURE 2.—Columnar section in the Wood River region

rocks adjoin an area of intrusive granitic rocks, and their base is therefore unknown. On all other sides they are separated from comparatively unmetamorphosed Paleozoic rocks by faults.

These rocks have been divided into two formations. The lower, named the Hyndman formation, consists mainly of quartzite and has a thickness of about 6,600 feet. The upper, named the East Fork formation, consists dominantly of limestone but has conspicuous interbedded quartzites and is at least 1,560 feet thick.

HYNDMAN FORMATION

Distribution and subdivisions.—The Hyndman formation is named from Hyndman Peak, the highest point in the Hailey quadrangle, (12,078 feet). The rocks are excellently exposed in the peak itself (see pl. 2, *A*) and in the cirques at its southern base. They occupy the larger part of the area of ancient sedimentary rocks, forming a belt along its northeast side which widens southeastward. East of the area shown on the map a narrow band of these rocks extends along the border of the granodiorite nearly to the east boundary of the Hailey quadrangle. The formation has a thickness between 6,000 and 7,000 feet and is dominantly composed of quartzite but contains two conspicuous intercalated members, a schist member in the lower part and a green hornfels member in the upper part. The presence of numerous strike faults introduces an element of uncertainty into all measurements of the thickness of the formation. The marked differences in the thickness of the subdivisions as exposed may result from such faults. In considering the estimates of thickness given below this qualification should be borne in mind.

Lower quartzite member.—The lowest member of the Hyndman formation is a light-gray quartzite with thick, even bedding.

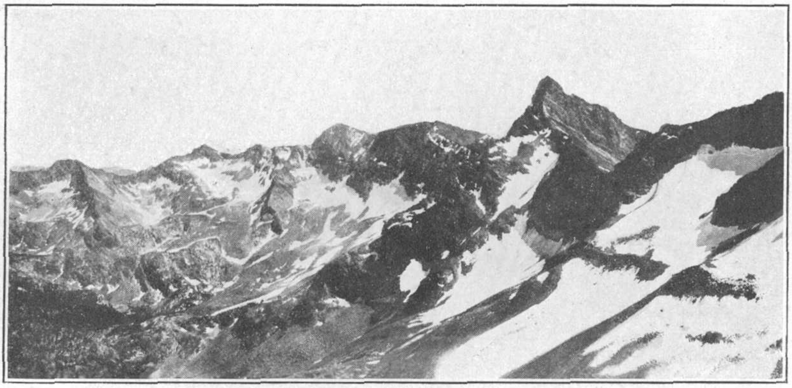
It ranges from a nearly pure quartzite to a quartzitic gneiss, which is locally banded and laminated. A few of the bands may even be considered schist. In many beds nine-tenths of the rock consists of quartz with hornblende, biotite, and minor amounts of sericite, microcline, plagioclase, titanite, and apatite. The quartz grains average 0.5 millimeter in diameter. Near the granodiorite border layers of the intrusive rock, in places as narrow as a foot or 6 inches, have been injected along the bedding planes of the quartzite. On the north slope of Hyndman Peak (pl. 2, *A*) and also in the cirque at the head of the East Fork of the Big Wood River a thickness of 1,500 feet of the lower quartzite member is exposed, but in both places the lowest beds are cut out by the granodiorite. Consequently the original thickness of the member can not be determined.

Schist member.—Above the lower quartzite member is the schist member, which crops out in a narrow belt, about 5 miles long, from the valley of the East Fork northwestward to and beyond Hyndman Peak. It is an evenly bedded rock and commonly breaks into slabby blocks. It is a fine-grained gray schist composed of quartz, andalusite, biotite, muscovite, and small amounts of magnetite, tourmaline, and hematite. The schist attains a thickness of 1,100 feet on the divide between the East Fork of the Big Wood River and Hyndman Creek. On the west branch of Corral Creek a dark mica schist lies below and grades upward into the strata at the base of the middle quartzite member. As it is in the same stratigraphic position this schist is probably the equivalent of the one just described, which is exposed farther east. It is a fine-grained banded and well-foliated schist, which weathers rusty and is composed of quartz, biotite, sillimanite, muscovite, and garnet with minor amounts of oligoclase, magnetite, and zircon. Some of the sillimanite occurs in fine threads, and many of the larger rods are frayed at the ends.

Middle quartzite member.—The next higher member is the middle quartzite, which forms a band southwest of the schist member that extends northward nearly to the Devils Bedstead. On Corral Creek it comprises 500 feet of white quartzite or quartzitic gneiss consisting largely of quartz, biotite, and plagioclase with a little colorless mica. It grades downward into the dark mica schist mentioned above and upward into a banded and contorted schistose rock 250 feet thick, which in turn is succeeded by the green hornfels member. Schistose beds intercalated in the more massive quartzite consist of quartz with abundant muscovite, green and brown biotite, magnetite, and scattered grains of tourmaline. The rock is banded in a manner which suggests cross-bedding. On the east branch of Hyndman Creek a thickness of 2,400 feet of the middle quartzite member is exposed.

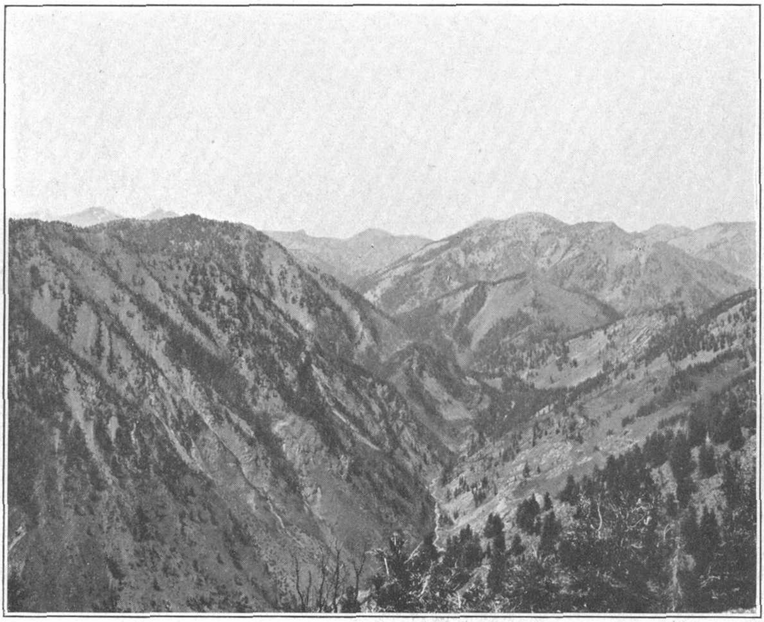
Green hornfels member.—The next succeeding member of the formation is a peculiar rock which may be designated a green banded hornfels. This rock crops out in a narrow zigzag band between the Devils Bedstead and Hyndman Peak and in irregular areas southeast of Hyndman Peak. The rock is made up of alternating light and dark layers. In places there are as many as 25 layers to the inch, but some layers are several inches thick. On weathered surfaces the rock appears green, but on fresh fractures much of it is almost black, with a blue or purple cast. The banding is in general remarkably even and permits the breaking of the rock into flat slabs from an inch to a foot or more in thickness. Some of these slabs have several square feet of surface.

The rock varies in mineral composition from place to place and from bed to bed. A specimen from upper Corral Creek consists of a greenish-gray fine-grained rock that has about 15 bands to the inch. On weathered pieces, along bands that consist largely of cal-



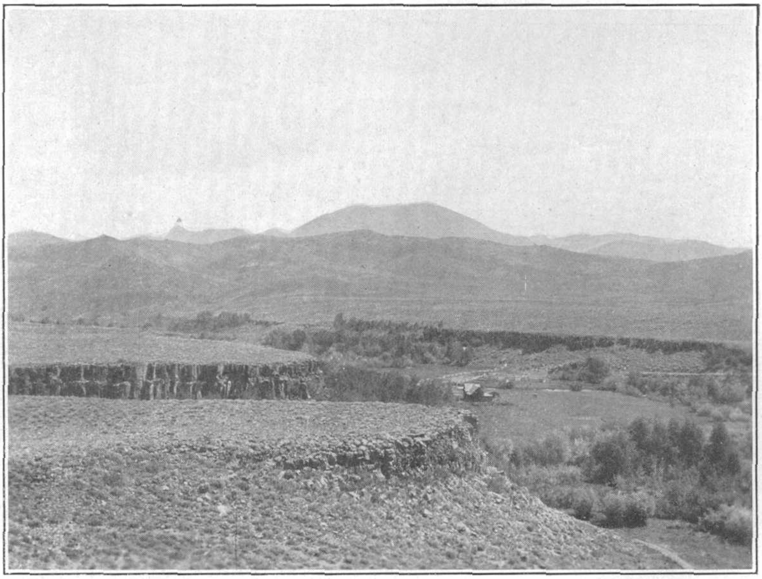
A. VIEW SOUTHEAST FROM HYNDMAN PEAK ALONG THE MAIN DIVIDE ABOVE THE CIRQUE AT THE HEAD OF WILDHORSE CREEK

Shows the glaciated topography of the summit region. The sharp peak at the right is Hyndman Peak. The rock in the upper part of the mountains to the right of the middle of the view belongs to the Hyndman formation, chiefly quartzite; the rest is granodiorite.



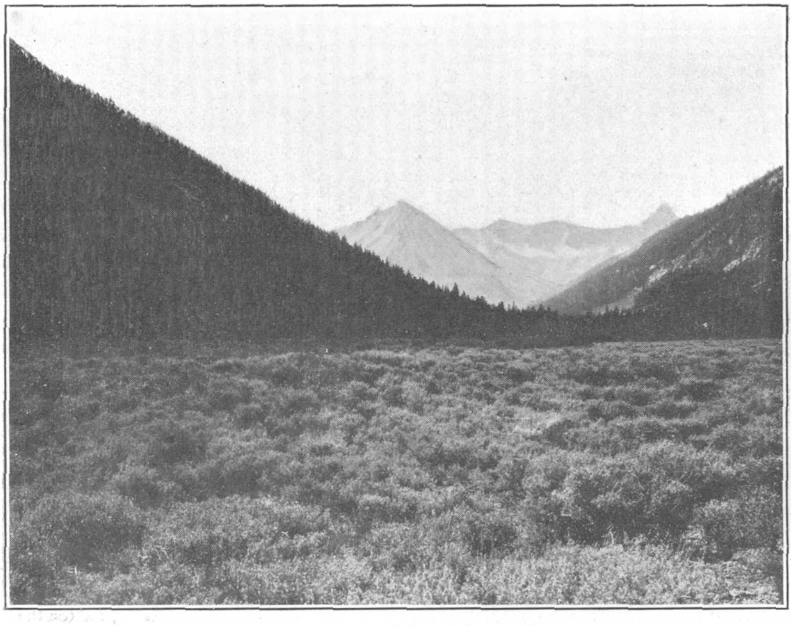
B. VIEW NORTH UP TRAIL CREEK

Shows the deep valley of the creek, the mountain topography near the main divide, and (on the right) the low pass to the Big Lost River.



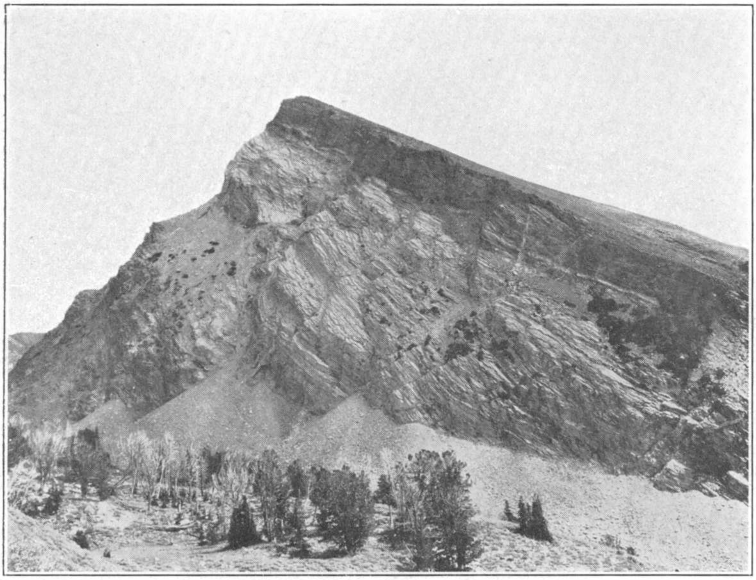
A. VIEW NORTHEAST ACROSS THE LITTLE WOOD RIVER, AT THE SOUTH BORDER OF THE HAILEY QUADRANGLE

In the foreground is Quaternary basalt trenched by the river—two flows exposed. The low hills in the middle ground consist of Miocene (?) lava.



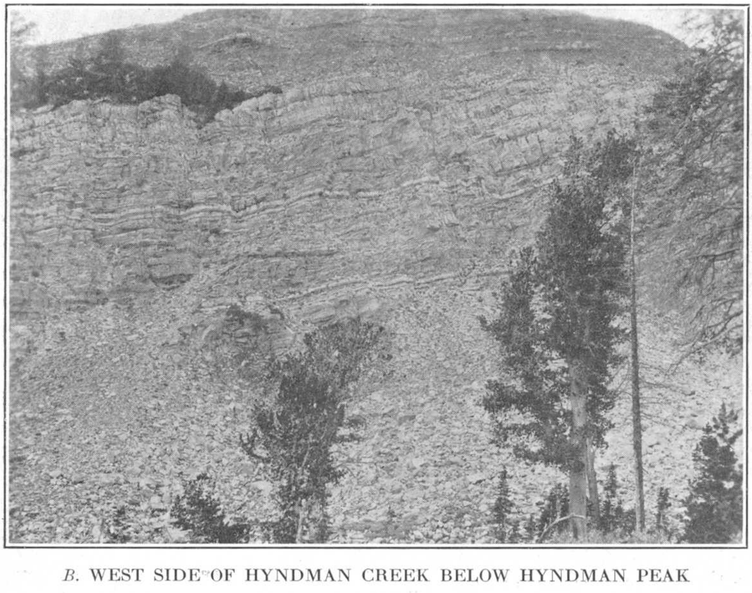
B. VALLEY OF WILDHORSE CREEK

Hyndman Peak in the distance. Shows a level flood plain in the midst of the mountains.



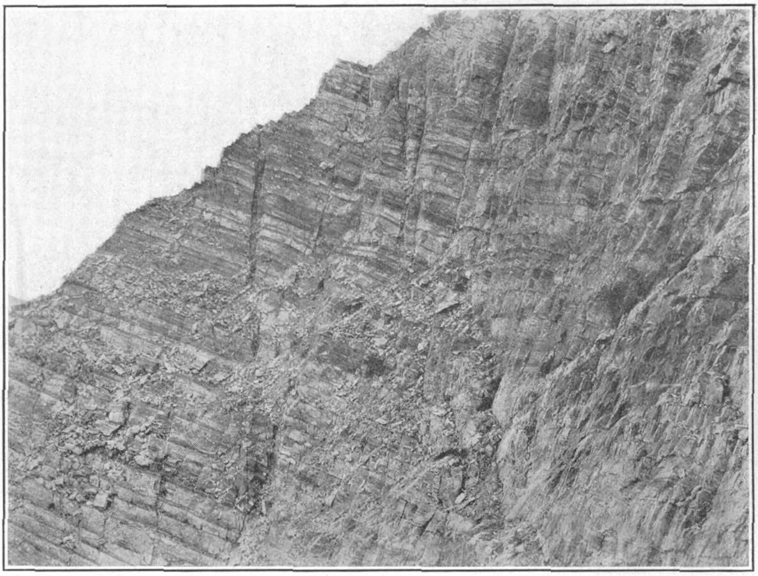
A. SOUTH WALL OF UPPER WILSON CREEK

The dark bed forming the dip slope is the quartzite member of the East Fork formation. The rock below it is the limestone member of the same formation.

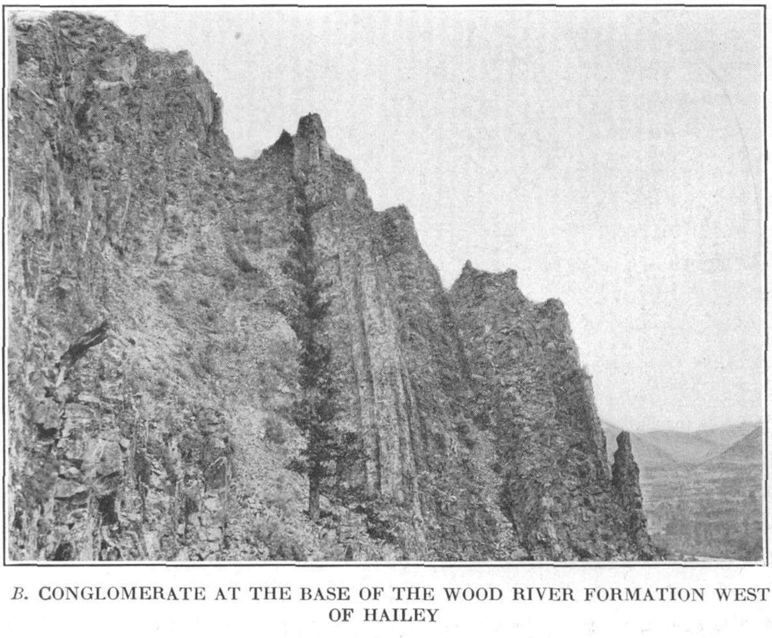


B. WEST SIDE OF HYNDMAN CREEK BELOW HYNDMAN PEAK

Shows alternating layers of coarsely crystalline limestone and tremolite rock in the lower limestone member of the East Fork formation.



A. BANDED HORNSTONE OF THE PHI KAPPA FORMATION ON THE HILL NORTH OF PARK CREEK



B. CONGLOMERATE AT THE BASE OF THE WOOD RIVER FORMATION WEST OF HAILEY

Stands vertical.

cite, narrow reentrants have been produced by leaching to a depth of as much as half an inch. The microscope shows the rock to be composed of calcite, epidote, augite, orthoclase, and quartz, with small amounts of titanite. None of the minerals have crystal outlines. The average size of grain is between 0.5 and 1 millimeter. The constituents are grouped in layers; some composed largely of calcite with abundant grains of pyroxene and scattered grains of feldspar and quartz alternate with others that consist more largely of feldspar and quartz with augite and some calcite. One layer noted is composed largely of augite and epidote.

A second specimen from the same locality shows an alternation of coarser light-green and dark-green layers. Under the microscope the light-green bands are seen to consist of epidote with a little quartz, and the dark-green bands to consist of orthoclase, green hornblends, considerable epidote, and a small amount of quartz. Small quantities of apatite, titanite, and calcite are present.

On the east side of the cirque south of Hyndman Peak the rock is on the whole dark but has numerous greenish-white or gray bands. The darker part of the rock shows under the microscope an allotriomorphic mixture of quartz and orthoclase, with abundant biotite, a little nearly colorless amphibole, and a little magnetite. The light-colored bands are themselves banded, owing to the varying amounts of calcite, green augite, scapolite, quartz, and epidote which they contain. Some garnet and a little magnetite are also present.

The mineral composition of the green hornfels suggests that it originally consisted of alternating beds of calcareous shale and impure limestone. Augite and epidote, which are the most common accessory minerals in the lighter calcareous layers, are common in metamorphosed limestones, and this is true also of the hornblende, scapolite, and garnet, which occur in much less abundance. With less calcium carbonate and more clay and other impurities in the other beds of the series, there would come about, as a result of metamorphism, that increase in amount of quartz, feldspar, and mica which is found in the darker and less calcareous layers. The original calcareous rock does not seem to have been notably magnesian.

The hornfels is much contorted, and its irregular distribution may result from faulting. On the east branch of Hyndman Creek it is at least 600 feet thick, but the thickness may differ in different places.

Upper quartzite member.—The uppermost member of the Hyndman formation is a quartzite. It is best exposed southeast of Hyndman Peak but continues in a narrowing band northward to the Devils Bedstead. On the Roaring Fork of the Little Wood River it is a gray to white rock, well bedded, in beds 2 to 6 feet thick. Some layers have pebbles as much as an inch in diameter, and in places there is a coarse cross-bedding. This cross-bedding and pebbly character is common in the upper quartzite but was not noticed in the lower members of the Hyndman formation. About nine-tenths of the rock consists of quartz in irregular grains that average 0.5 millimeter in diameter. The original form of the quartz grains has been obliterated through metamorphism. Locally pale-green augite is abundant between the quartz grains. Small amounts of plagioclase, biotite, titanite, calcite, and chlorite are present; the last two are alteration products. The augite gives to the rock a minute pale-green mottling.

The patches of quartzitic material along the border of the granodiorite near the head of the Little Wood River contain conglomerate beds and are therefore assumed to belong to the upper quartzite member. They are thoroughly recrystallized rocks and consist dominantly of quartz, with biotite, muscovite, chlorite, diopside, epidote, and andalusite in varying amounts.

EAST FORK FORMATION

Distribution and subdivisions.—Above the Hyndman formation lie beds of limestone and quartzite which have been grouped as the East Fork formation. They form a belt on the west side of the area of metamorphosed rocks as far south as the divide between Hyndman Creek and the East Fork of the Big Wood River, and also crop out in two small areas farther east. They are best exposed on the east side of the headwaters area of Hyndman Creek. The formation comprises a lower and an upper limestone member with quartzite between them and has a minimum thickness of 1,560 feet.

Lower limestone member.—The lower limestone member occurs along the east side of the outcrop of the East Fork formation, immediately west of the border of the Hyndman formation. It extends in an almost continuous belt from the area north of the Devils Bedstead southward and southeastward to a point 3 miles south of Hyndman Peak. In the north, as a result of faulting, the apparent thickness of the limestone is less than in the south. In the east wall of the Corral Creek Basin this member is completely cut out, and the quartzite member of the East Fork formation rests directly on the Hyndman formation. South of this area the exposed thickness of the lower limestone increases, and its greatest mapped width is along the dip slopes on the southwest ends of the ridges between the different branches of Hyndman Creek.

The lower limestone member consists largely of beds of nearly pure limestone alternating with beds that contain diopside. Quartzite is intercalated in places but is everywhere subordinate in amount.

The succession of beds differs in different localities. Two characteristic exposures of the member are shown in Plate 4.

Several hundred feet of the lower limestone is exposed in the west wall of the basin of Corral Creek. Most of the beds are 2 to 3 feet thick and consist of buff or cream-colored limestone, and some of them contain diopside. Alternating with these beds are layers of diopside rock that range in thickness from a fraction of an inch to 2 feet. The most abundant beds consist of calcite with very small amounts of phlogopite, pyrite, pyroxene, and serpentine. Others contain gray knots or lenses of diopside, some of which are as much as 10 millimeters in greatest diameter, in a fine-grained calcite matrix with some muscovite and chlorite and a little quartz and pyrite. The diopside rock is white and fine grained and contains an average of over 95 per cent of diopside together with varying amounts of chlorite, calcite, and quartz and a little magnetite.

An excellent exposure of the lower limestone member, including a greater thickness than that in the west wall of Corral Creek, is found at the end of one of the divides that separate the upper branches of Hyndman Creek, about 1½ miles S. 50° W. of Hyndman Peak. The section here is as follows:

Section of lower limestone member of East Fork formation southwest of Hyndman Peak

	Feet
Light-gray or white limestone in massive beds 2 to 4 feet thick, containing thick beds of massive pyroxene rock	140
Heavy-bedded blue limestone	70
White vitreous quartzite	120
White, coarsely crystalline thick-bedded limestone, stained on the weathered surface to a brownish yellow and easily crumbling to a calcite sand (see pl. 4, *A*)	200

Quartzite member.—Above the lower limestone member is a massive vitreous quartzite (see pl. 4, *A*) which can be traced from a locality north of the Devils Bedstead a little south of east for about 7 miles. Its apparent thickness differs from place to place, presumably because of faulting. The maximum thickness measured was 350 feet, above the section of the lower limestone member just described. On the west side of the Corral-Hyndman Creek divide the quartzite is reduced to a few feet, and in places it is probably cut out entirely. On account of its hardness it forms the dip slope of some of the southwestward-facing hills. The most conspicuous of these is the hill on the divide between Corral and Wilson Creeks. The upper part of the quartzite here contains pyrite and is stained red by oxidation. This conspicuous red slope is easily recognized for miles to the south.

The rock is a massive vitreous quartzite, completely recrystallized, with rounded grains and crystals of pyrite. It contains small amounts of muscovite, hematite, and magnetite, and small inclusions, both solid and liquid.

Upper limestone member.—The quartzite member is overlain by a series of limestone beds of variable thickness, comprising the upper limestone member. They lie in a belt that extends from the vicinity of the Devils Bedstead south and east to the basin of Hyndman Creek, and in a few isolated localities to the southeast. They are best exposed on the divide between Corral and Hyndman Creeks, where the section is as follows:

Section of upper limestone member of the East Fork formation on the Corral-Hyndman Creek divide

	Feet
Grayish-white, rusty, thinly banded limestone	400
Massive blue-gray, thinly banded limestone, rather coarsely crystalline and nearly pure calcite	
Beds of thinly banded gneiss, usually dark, in some places calcareous and in others not. Interbedded in this are seams of medium to coarse grained cream-colored limestone, indistinctly banded, 1 to 2 feet thick. A hand specimen of the first rock shows it to be fine grained, with alternating blue-gray and white bands from one-tenth to one-half inch in thickness. Quartz and colorless pyroxene are the abundant minerals. Orthoclase is common. Magnetite and a little calcite are present	
Blue-gray, coarsely crystalline limestone	150
Heavy-bedded but thin-banded blue-gray limestone. The hand specimen shows a blue-gray rock, through which run white bands, commonly six or seven to the inch. Calcite and diopside are the more common minerals, the diopside most abundant in the white bands. Magnetite, pyrite, and orthoclase are also present	200
Gray-black thin-bedded slaty rock	30
Vitreous quartzite, massive below, thin-bedded and banded above	10
Thin-bedded light-gray or whitish gneissoid rock, an impure quartzite	15

AGE OF THE HYNDMAN AND EAST FORK FORMATIONS

The Hyndman and East Fork formations appear to be older than any of the other rocks exposed in the Wood River region. The East Fork, the younger of the two, is separated by fault contacts from all younger rocks, so that its exact relations to them can not be ascertained, but with due allowance for the probable throw of these faults it would seem to belong stratigraphically below the Phi Kappa formation (Ordovician). Available data regarding the formations above the Phi Kappa offer no suggestion that the Hyndman and East Fork formations, with combined thickness of 8,000 feet or more, belong at any higher horizon.

These formations are much more metamorphosed than the strata above them. However, the fact that this alteration is probably in part of igneous rather than dynamic origin makes it of doubtful value as an indication of age. The strata lie in a narrow belt bordering the largest mass of granitic rock in the region, and hence are in a favorable position to be contact-metamorphosed. Many of the minerals developed are the same as those formed by igneous agencies in younger rocks in several places in the region, and some of them, such as diopside, are typical of igneous and not of dynamic origin. These facts make it highly probable that the Hyndman and East Fork formations have been contact-metamorphosed. However, it is of course possible that they had previously been subjected to regional metamorphism. The highly schistose character of one member of the Hyndman formation and the fact that the degree of metamorphism in the Hyndman and East Fork formations is markedly greater than in the adjoining strata belonging to other formations both favor such a hypothesis. The contrast in metamorphism is noted wherever the formation boundaries are crossed, irrespective of the distance from intrusive rocks.

Recently C. P. Ross has worked in the Custer quadrangle, immediately northwest of the Hailey quadrangle. Here limestone with some quartzite similar in lithology and degree and character of metamorphism to the East Fork formation appears to be stratigraphically well above dolomite containing Silurian fossils.

The weight of present evidence in the Hailey quadrangle is in favor of Westgate's conclusion that the Hyndman and East Fork formations are probably Algonkian. However, this evidence is not conclusive, and in the light of the data obtained in the Custer quadrangle the possibility that these formations may be of post-Silurian age should be borne in mind.

ORDOVICIAN ROCKS

Ordovician sediments occur in the north-central part of the region in a belt that stretches southeastward from the North Fork of the Big Lost River for 12 miles and has an average width of 2 to 3 miles. For most of this distance they crop out along the principal divide of the Wood River region. The Ordovician rocks in most places are separated from the other sedimentary formations by faults. They are themselves cut by numerous faults, which form a complex structural mosaic within this great mass of sandstone and argillite, and are intruded by the quartz monzonite of the Big Lost River and overlapped in places by the Miocene (?) lava. The Ordovician sediments consist of sandstone and argillite. Practically the only fossils found are graptolites, and these occur at irregular intervals in the series. The graptolites indicate that the sediments range in age from Lower to high Middle or to Upper Ordovician.

EARLY LOWER ORDOVICIAN ROCKS

Along the Trail Creek road about 1½ miles south of the pass is a narrow block of carbonaceous argillite carrying an early Lower Ordovician graptolite fauna. This block is bounded on the north and south by fault planes. The occurrence of this Lower Ordovician fauna was first noted by Blackwelder.[2] The presence of these Lower Ordovician sediments is of so great scientific interest that the outcrop has been mapped separately. No formation name has been applied, however, as the section consists of but a few hundred feet of sediments and is incomplete at the top and bottom. These beds are the oldest fossiliferous sediments in the region. They contain the following fossils, determined by Edwin Kirk:

- Didymograptus bifidus Hall.
- Didymograptus caduceus (Salter) Ruedemann.
- Didymograptus extensus Hall.
- Didymograptus gracilis Tornquist.
- Didymograptus nanus Lapworth.
- Didymograptus nitidus Hall.
- Didymograptus similis Hall.
- Tetragraptus amii Ellis and Wood.
- Tetragraptus serra Brongniart.
- Tetragraptus similis Hall.
- Tetragraptus quadribrachiatus Hall.
- Tetragraptus woodi Ruedemann.
- Phyllograptus ilicifolius Hall.
- Phyllograptus typus Hall.
- Dichograptus octobrachiatus (Hall).
- Goniograptus perflexilis Ruedemann.
- Goniograptus thureaui (McCoy) var.
- Schizograptus sp.
- Bryograptus sp.
- Dendrograptus sp.
- Lingula sp.
- Caryocaris sp.
- Sponge spicules.

The age of the argillite as determined by these fossils is Deepkill (Beekmantown).

PHI KAPPA FORMATION

General features.—The Phi Kappa formation, named from exposures along Phi Kappa Creek, which enters the Big Lost River from the south, 3½ miles down the valley from the divide, constitutes the greater part of the Ordovician mapped in this region. The formation has a thickness of more than 9,400 feet. It may be divided for convenience of description into an upper and a lower portion. The separation of these two portions as distinct formations would have been desirable if the scale of mapping had permitted. An attempt to do so in the field, however, proved impracticable. The

[2] Blackwelder, Eliot, New or little known Paleozoic faunas from Wyoming and Idaho: Am. Jour. Sci., 4th ser., vol. 36, pp. 174–175, 1913.

lower portion of the Phi Kappa consists of medium and fine grained quartzitic sandstone and flinty argillite, commonly black, which weathers to rusty slabs. The upper portion of the formation comprises a series of dark shale with interbedded yellow shaly sandstone.

The lower part is best exposed on the Big Lost River, on the nose between Park Creek and the next creek north, where an apparently continuous section of nearly 4,800 feet was measured. This section from above down is as follows:

Section of lower part of Phi Kappa formation on west side of upper Big Lost River

	Feet
Upper hornfels, steel-gray and dark when fresh, with uniformly and closely alternating dark and light bands; thin-bedded. (See pl. 5, *A*.)	
Black argillite; in the middle breaks into flat rectangular fragments; generally hard and in places flintlike	200
Lower hornfels, similar to the upper hornfels	300
Flinty argillite, black, dense, fine-grained or aphanitic rocks, in places spotted with the incipient development of metamorphic minerals; breaks with a conchoidal fracture; ends above, just below the lower hornfels with a 25-foot massive layer.	
Heavy black to gray quartzite in beds, 1 to 5 feet thick, alternating with black flinty argillite, which is more abundant in the upper part	800
Black fine-grained massive argillites, thinner-bedded below but becoming more massive in the middle portion; in the upper part intercalated beds of quartzitic sandstone appear. They are mainly black, but here and there gray and white. The rocks are thin and even-bedded and break into slabs on weathering, but on fresh outcrops the beds are likely to make massive ledges. They pass gradually into the preceding division, with increase in quartzite	1,700

The black quartzite in the hand specimens is crowded with minute rounded glassy grains of quartz. With the microscope quartz is seen to occur in abundant rounded grains as large as 1.5 millimeters (average 0.5), in a fine mosaic of recrystallized quartz. Black dust composed of iron oxide is abundant in the cement, and this gives the black color to the rock. Pyrite and small flakes of colorless hornblende are present.

The finer-grained rocks (flinty argillite) differ from the quartzite in the smaller size of the quartz grains and in the presence of larger amounts of accessory minerals, but they are still essentially quartzites. They are black aphanitic rocks, with nearly the color and luster of cannel coal and with a rude conchoidal fracture. The microscope shows scattered irregular grains of quartz 0.05 to 0.1 millimeter in diameter in a groundmass consisting of quartz and abundant fine ferruginous dust. Pyrite, scattered prisms of tourmaline, and some colorless hornblende are present. Scattered irregular patches 0.5 to 1 millimeter in dimension mark the incipient development of unidentified metamorphic minerals which in some beds gives a spotted appearance to the hand specimen.

The hornfels is a dense quartzitic rock that shows alternating light and dark bands. (See pl. 5, *A*.) The black bands are gray-black and aphanitic and under the microscope show quartz grains as much as 0.04 millimeter in diameter. The quartz composes not over half the rocks; hornblende, iron oxide, and probably other minerals not identified compose the remainder. The light-gray bands are much the same in composition except in the small amount of iron oxide and, in the slide examined, in the presence of pyroxene instead of hornblende. Where the hornfels is composed of thin alternating bands these differ in the kinds and relative amounts of the accessory minerals.

Sections of the lower portion of the formation in other parts of the Phi Kappa area match the one which has been described. Whether the whole thickness of the lower division is greater than 4,750 feet is not known, as no definite beds identifiable in the different areas were recognized, unless the hornfels which caps the lower division in the section given is such a bed.

The hornfels and interbedded argillite are well shown along the east side of upper Trail Creek, from the northwest end of the Phi Kappa outcrop to a point a mile south of the Big Lost River-Trail Creek Pass. Good exposures of the hornfels occur just south of the pass. The beds are evidently repeated by faulting, though it has not been possible to decipher the details of the structure.

The upper portion of the Phi Kappa occupies the north half of the Ordovician belt and also crops out along its southern border. The two areas are separated by a belt of the quartzite of the lower Phi Kappa. The upper part of the formation is well exposed in the hills east of upper Trail Creek, where it turns southwest and leaves the Ordovician belt. It is variable in character, as is shown in the section below, 4,600 feet in thickness, which was measured at the head of the creek northeast of Park Creek. It is possible that this section may be faulted, yet it gives an excellent idea of the kind of rocks that make up the upper part of the formation and probably does not give an exaggerated idea of their thickness. Indeed, it appears that this section does not represent the maximum thickness of the upper division because beds that are stratigraphically higher than any in it are exposed along the upper reaches of Trail Creek.

Incomplete section of the upper portion of the Phi Kappa formation, measured on the ridge projecting from the west into the head of the valley northeast of Park Creek

	Feet
Yellow shaly sandstone and gray, fine-grained argillaceous sandstone, in part calcareous, weathering to rusty brown. They are well banded and evenly bedded, breaking into slabs about 6 inches thick. Parting planes show a blotchy color mottling	350
Dark shale, weathering to gray, brown, and black débris	600
Yellow sandstone, like highest member. Some clear quartzitic sandstone near the base. Abundant black flintlike layers commence 75 feet above the base and extend upward for 100 feet	400
Dark or black shale and sandy shale, passing at base into earthy sandstone 250 feet thick	275
Dark well-laminated thin-bedded shale, weathering gray in upper part, brown below. Intercalated dolomite bands, 1 to 2 inches thick, in lower part	450
Gray shale and quartzitic sandstone, the latter in massive layers as much as 10 feet in thickness	100
Black laminated shale, weathering gray, passing down into alternating gray flinty shale and yellow shale	325
Black laminated shale with graptolites, passing down into shales with interbedded dark flint layers	400
Yellow sandstone, like highest member	175
Flinty shale and flint, succeeded below by coal-black shale and gray-brown shale	90
Shaly sandstone, passing down into black laminated shale which weathers light gray and contains indistinct graptolites	250
Gray thin-bedded sandy shale with some yellow sandstone	225
Coal-black laminated shale with indistinct graptolites	210
Dark shale with thin-bedded flinty layers (mostly covered)	750
	4,600

The two outstanding lithologic elements of the upper part of the Phi Kappa formation are the black laminated shale and the yellow shaly sandstone. The shale contains the graptolite-bearing beds. It is well shown on the east side of upper Trail Creek and at points north of the divide as far as the North Fork of the Big Lost River. The yellow shaly sandstone is found east of upper Trail Creek and at intervals southeastward along the divide between Trail Creek and the valley next north. Excellent exposures are found above the Ketchum road about three-quarters of a mile south of the pass and again at the head of Phi Kappa Creek. Here, on the north slope of the divide from the upper Big Lost River, the following partial section appears:

Section of upper part of Phi Kappa formation at the head of Phi Kappa Creek

	Feet
Yellow shaly sandstone	300
Dark shale	250
Yellow shaly sandstone	285
Dark shale, containing graptolites, several hundred feet.	

A sill of rhyolite cuts the lower part of the lower shale. The lower yellow sandstone consists in the lower part of massive beds, 4 to 6 feet thick, of dark, spotted argillaceous sandstone, weathering rusty brown, followed by thin-bedded layers, 12 inches to 4 feet thick, of quartzitic sandstone with thin partings, passing up into broad, thin flags of shaly sandstone.

Fossils and age.—With the exception of a fauna collected from the uppermost 25 feet of the formation and unknown elsewhere in North America all the graptolite faunas found in the Phi Kappa formation are referable to the Normanskill (high Lower Ordovician or Chazy). The graptolites are rare and as a rule poorly preserved in the lower half of the formation. The following list of fossils identified by Edwin Kirk is a composite fauna representing several small collections obtained at different horizons:

Diplograptus (Orthograptus) calcaratus Lapworth var.
Diplograptus (Glyptograptus) teretiusculus (Hisinger).
Diplograptus (Glyptograptus) teretiusculus var. euglyphus Lapworth.
Diplograptus (Amplexograptus) cf. D. coelatus (Lapworth).
Dicellograptus gurleyi Lapworth.
Dicellograptus sextans Hall.
Climacograptus bicornis (Hall).
Glossograptus ciliatus Emmons.
Dicranograptus cf. D. rectus Hopkinson.

These fossils indicate lower Normanskill age. As represented by the collections, essentially the same graptolite fauna ranges throughout the upper 4,600 feet of the Phi Kappa formation, with the exception of the fauna at the extreme top, as noted above. In the 400 feet of shale 1,680 feet above the base of the first section described a rich graptolite fauna was found. This fauna includes all the species found elsewhere in the upper portion of the formation except that at the top. The following species were determined from this horizon by Kirk:

Diplograptus (Orthograptus) calcaratus Lapworth.
Nemagraptus sp.
Odontocaulis sp.
Corynoides gracilis Hopkinson var.
Cryptograptus tricornis (Carruthers).
Dicellograptus gurleyi Lapworth.
Dicellograptus sextans cf. var. exilis Ellis and Wood.

Dicellograptus cf. D. elegans Carruthers.
Lasiograptus bimucronatus (Hall).
Lasiograptus (Thysanograptus) cf. L. harknessi var. costatus Lapworth.
Glossograptus ciliatus Emmons var.
Climacograptus bicornis Hall.
Climacograptus bicornis var. peltifer Lapworth.
Climacograptus cf. C. scharenbergi Lapworth.
Dicranograptus contortus Ruedemann.
Dicranograptus nicholsoni Hopkinson var.
Dicranograptus ziczac Lapworth var.
Dicranograptus spinifer Lapworth.
Dicranograptus ramosus cf. var. longicaulis Lapworth.
Leptobolus sp.

The highest fauna found in the Phi Kappa formation came from about 25 feet of black shale immediately underlying the Silurian. The locality is on the west bank of Trail Creek, about a mile south of the point where the creek swings abruptly to the west. The following species from this locality have been determined by Kirk:

Diplograptus (Orthograptus) calcaratus Lapworth var.
Diplograptus (Orthograptus) truncatus var. socialis Lapworth.
Diplograptus truncatus var. abbreviatus Ellis and Wood.
Diplograptus var. intermedius Ellis and Wood.
Diplograptus (Glyptograptus) cf. D. crassitestus Ruedemann.
Diplograptus (Glyptograptus) type of D. teretiusculus Hisinger.
Diplograptus carnei T. S. Hall.
Mesograptus multidens var. compactus Lapworth.
Mesograptus sp.
Climacograptus hastatus T. S. Hall.
Climacograptus cf. C. medius Tornquist.
Climacograptus scalaris var. miserabilis Ellis and Wood.
Retiolites (Plegmatograptus) caudatus T. S. Hall.
Retiograptus type of R. geinitzianus Hall.
Dicellograptus elegans Carruthers.
Dicellograptus cf. D. pumilus Lapworth.
Dicellograptus cf. D. affinis T. S. Hall.

This fauna is of considerable interest in that it has not hitherto been found in America. It is correlatable approximately with the Hartfell of Great Britain and probably is of either high Middle or Upper Ordovician age.

SILURIAN ROCKS

TRAIL CREEK FORMATION

The Silurian, so far as known, is represented in this region by a series of siliceous argillite and thin-bedded quartzitic sandstone, to which the name Trail Creek formation is here given. These rocks are confined to a strip on the west side of the upper portion of Trail Creek and thus occupy only a small area.

General features.—The best exposure of the Trail Creek formation is on the west bank of Trail Creek about a mile south of the place where the creek swings abruptly to the west. Here there is about 500 feet of siliceous argillite and quartzitic sandstone. The contact with the underlying Phi Kappa formation is clearly shown. The upper part of the formation is found on receding slopes largely covered with talus and a heavy growth of forest.

Fossils and age.—In the basal 60 feet of the formation the quartzitic sandstone layers are separated by thin seams of carbonaceous argillite, in which was found an abundant graptolite fauna. The following list as determined by Kirk gives the more characteristic graptolites of the formation.

Monograptus priodon Bronn.
Monograptus flemingi Salter var.
Monograptus vulgaris Wood var.
Monograptus cf. M. turriculatus (Barrande).
Monograptus cf. M. planus Barrande.
Monograptus near M. crinitus Wood.
Monograptus cf. M. spiralis Geinitz.
Monograptus cf. M. dextrorsus Linnaeus.
Monograptus cf. M. acus Lapworth.
Monograptus type of M. scanicus Tullberg.
Monograptus cf. M. marri Perner.
Monograptus cf. M. convolutus Hisinger.
Monograptus griestoniensis Nicholson.
Cyrtograptus, 3 or 4 species.
Climacograptus, 2 species.
Gladiograptus geinitzianus Barrande.
Gladiograptus sp.

This fauna is of Silurian age and is comparable with some of the graptolite faunas of Great Britain and western Europe. It seems to be of early Wenlock age or possibly somewhat older, and thus the rocks are correlated approximately with the Niagaran of the eastern United States.

DEVONIAN (?) AND CARBONIFEROUS ROCKS

Strata believed to be principally if not wholly of Carboniferous age, masked in places by Tertiary lava and cut by stocks of granitic rock, spread over more than half of the Wood River region. With the exception of the Ordovician and Silurian of the vicinity of Hyndman Peak and the upper part of the valley of Trail Creek they are the only Paleozoic rocks exposed southwest of the main divide. They also crop out over extensive areas in the valleys of the Big Lost River and its tributaries. These are the rocks to which Lindgren[3] appears to have intended to apply the name Wood River

[3] Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, pp. 193–194, 1900.

formation. He considered them to be of Carboniferous age but recognized the fact that older rocks might be included. On his general map the formation is made to include the pre-Carboniferous rocks described in this report, but in the part of the Wood River region containing the mines which he studied the older formations are absent. As a result of more detailed studies not only have older formations been recognized but the rocks believed to be of Carboniferous age have been divided into two formations, to the lower of which the name Milligen formation is here applied and to the upper Lindgren's name Wood River formation is here restricted. The upper formation contains Pennsylvanian fossils, but the lower one is tentatively assigned to the Mississippian and Devonian(?) on less definite evidence, as explained on pages 26–29.

MILLIGEN FORMATION (DEVONIAN? AND MISSISSIPPIAN)

Distribution and thickness.—The fine-grained argillaceous rocks that underlie the Wood River formation as here restricted are named the Milligen formation, from Milligen Creek, near the center of the largest exposure of the formation 6 miles east of Ketchum. The formation crops out in three irregular belts that trend northwest and in a few small areas outside of these belts. One narrow belt lies along the southwest side of the head of the valley of Trail Creek. The largest belt extends from the head of the Little Wood River across the Hailey quadrangle for nearly 30 miles. It widens northwestward to a maximum width of about 6 miles. The exposures are interrupted by areas of Pennsylvanian (Wood River) beds and a few patches of lava. Northwest of Lake Creek the exposed Milligen beds are divided into two interrupted belts by a synclinal mass of Pennsylvanian rocks with irregular bodies of similar rock southwest of it. The third belt of the Milligen formation lies on both sides of the Big Wood River from a place near Hailey southeastward for several miles. Most of this belt is south of the area covered by Plate 1 but is shown on Plate 10.

The Milligen formation weathers easily and therefore does not offer continuous sections. It lacks outstanding and recognizable members and is folded and faulted. For these reasons it has been impossible to construct a detailed columnar section for it or to determine its thickness. In the central part of the quadrangle the formation covers exclusively a considerable area within which the vertical relief is between 2,500 and 3,000 feet, and it seems improbable that its thickness can be less than several thousand feet. A thickness of 3,000 feet is arbitrarily assigned to it for use in the tables and columnar sections.

Lithologic character.—The Milligen formation varies considerably in lithologic character, but most of it is a black carbonaceous argillite. Some beds are dominantly quartzitic and others calcareous. The argillite consists in general of fine-grained quartz and muscovite with abundant carbonaceous dust. Some of the rocks are more or less distinctly laminated, largely as a result of the grouping of the carbonaceous matter in wavy lenses approximately parallel to the bedding. In many exposures no lamination is visible, but there is a rather poorly developed cleavage which may be parallel to the original bedding. Many cleavage faces are coated with films of graphitic material. Much of the argillite has a texture resembling that of cannel coal. The rock weathers readily, first, into small platy fragments and then into black soil. The carbonaceous matter in the argillite is so abundant that mine dumps composed of it resemble those of coal mines.

In a few places actual beds of coal are intercalated in the argillite. The so-called "graphitic anthracite" in the old Parker mine on Elkhorn Creek is probably metamorphosed coal. In the Evelyn prospect on Trail Creek coal is exposed in several tunnels. (For further data on the coal, see pp. 113–114.)

In places characteristic beds of quartzite, limestone, and dolomitic limestone are intercalated in the argillite. As soon as one has become familiar with these beds they are of great assistance in identifying the formation. Unfortunately, it has not been found possible to use any of them as marking definite horizons. The quartzite occurs in beds from 1 to 6 inches thick and is commonly exposed in massive outcrops. It is fine grained, and much of it has a dense chalcedonic or flintlike appearance. In places laminations are visible on weathered surfaces. The limestone is a blue-black fine-grained thin-bedded rock, which weathers to a characteristic light blue-gray. It forms distinct ledges, in places a hundred feet or more thick, and weathers into thin rough slabs. Such limestone appears to occur at several horizons. The third type of rock is a thick-bedded dark-blue impure dolomitic limestone in beds as much as 4 or 5 feet thick. It weathers to a rusty brown color. All three rocks are comparatively resistant to weathering and stand out in prominent outcrops on the débris-covered slopes resulting from the weathering of the argillite, which makes up by far the greater part of the formation.

Age.—The presence of thick seams of impure metamorphosed coal is strong evidence that the Milligen formation is not as old as Devonian. No such coal beds are known in Devonian rocks elsewhere in the western United States, and in all the rare occurrences of coal in rocks as old as this anywhere in the world the deposits are smaller than those in the Milligen formation appear to be. The Milligen formation is stratigraphically below the Wood River formation, of Pennsylvanian age. In most places the exact character of the contact between the two formations is not clear. Conglomerate is almost universally present at the base of the Wood River formation, and in places the bedding in the Milligen formation near the contact does

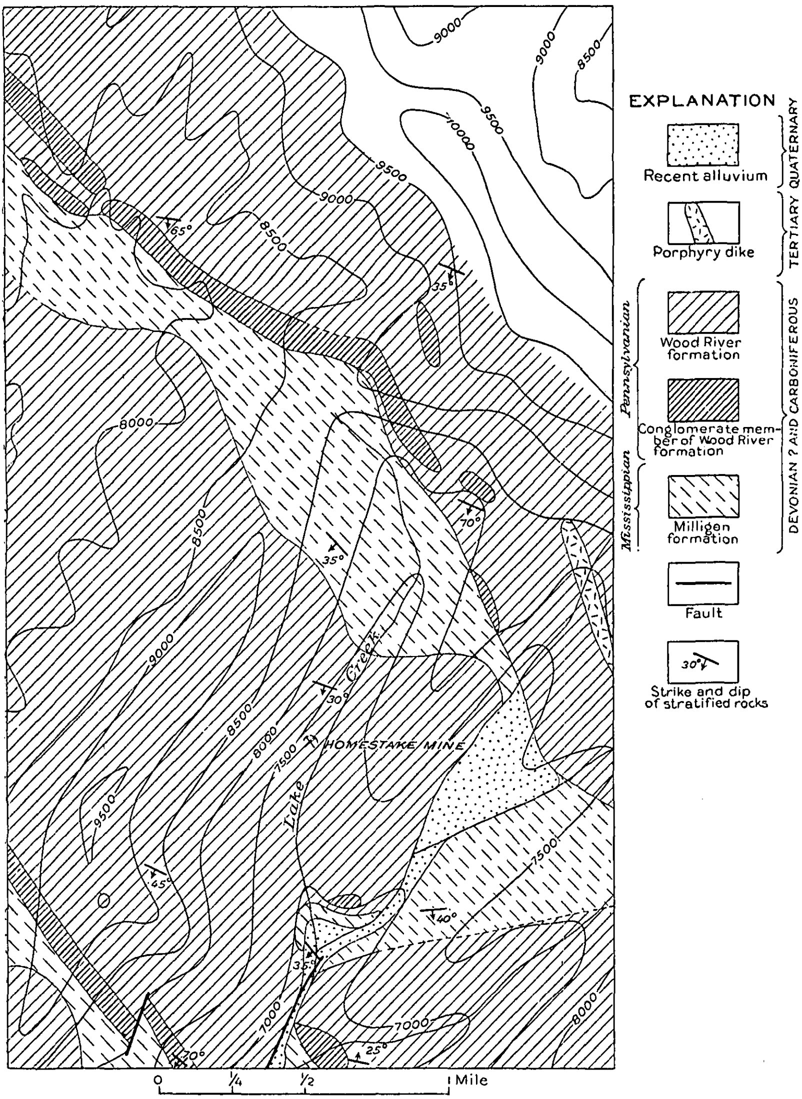


FIGURE 3.—Geologic map of upper Lake Creek

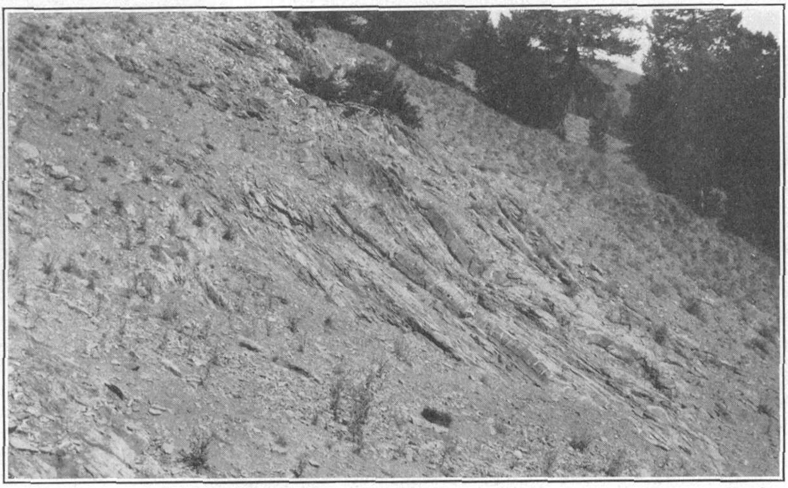
not appear to be parallel to the contact. These facts suggest that there may be an unconformity between the two formations. However, at the head of Lake Creek, where the contact is well exposed, the two formations grade into each other with no stratigraphic break. At this point, as can be seen from structure section 4 in Plate 1, the strata are overturned. Consequently in Plate 6, which shows two outcrops near the contact, the younger beds are on the left and below the older ones. Some details of the geology in the headwater basins of Lake and Eagle Creeks are shown in Figure 3. In the first exposure in this vicinity (pl. 6, *A*) most of the rock is the soft argillite characteristic of the Milligen formation. As the contact with the Wood River formation is approached beds of massive quartzitic limestone like those which make up a large part of the Wood River formation increase in abundance and thickness, and finally the argillite disappears almost entirely. At this place the conglomerate usually found at the base of the Wood River formation is a little higher in the section and is underlain by quartzitic and calcareous beds. The locality where the views in Plate 6 were taken is marked in the right-hand part of Figure 3 by the symbol indicating a general dip of 70° SW. At this locality the only interruption to the regular sequence of beds noted is the one shown in Plate 6, *B*, which appears to be a slip fault of small displacement.

Wherever the Milligen formation is in contact with sedimentary formations other than the Wood River rocks it is separated from them by faults. Consequently its exact relations to the other formations can not be determined. However, from the general relations it is evident that all the other Paleozoic strata except the Wood River formation are older than the Milligen formation.

In view of the relations just described and of the presence of coal the Milligen formation is regarded as at least in the main of Mississippian age. There is insufficient evidence of a time break at the base of the Wood River formation to account for the absence of any equivalent for the thick series of highly fossiliferous Mississippian limestone in the Mackay region,[4] which adjoins the Wood River region on the east.

Only one scanty collection of fossils has been obtained from the Milligen formation. On the crest of the divide east of Milligen Creek, at an altitude of 7,500 feet, a very few small corals, stromatoporoids, and crinoid fragments were found, the total making hardly a handful. The rock containing them was a fragmental blue limestone, possibly a conglomerate. If it is a conglomerate the fossils, which were badly broken and rolled, may have been originally deposited in some older formation and later redeposited as pebbles in the rock where they were found. Edwin Kirk, reporting on this material, writes: "The fossils, such as they are, are probably Devonian (Jefferson)." These few fossils are inadequate as a basis for age determination, and they may represent transported material. It will be noted that there is so much similarity in the rocks of this

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

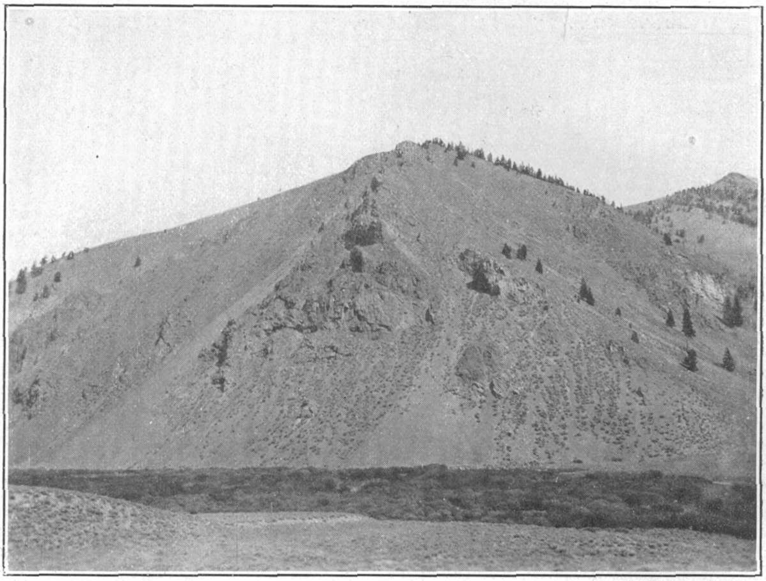


A. THIN, REGULAR BANDED ARGILLITE AND LIMESTONE NEAR THE TOP OF THE MILLIGEN FORMATION AT THE HEAD OF LAKE CREEK

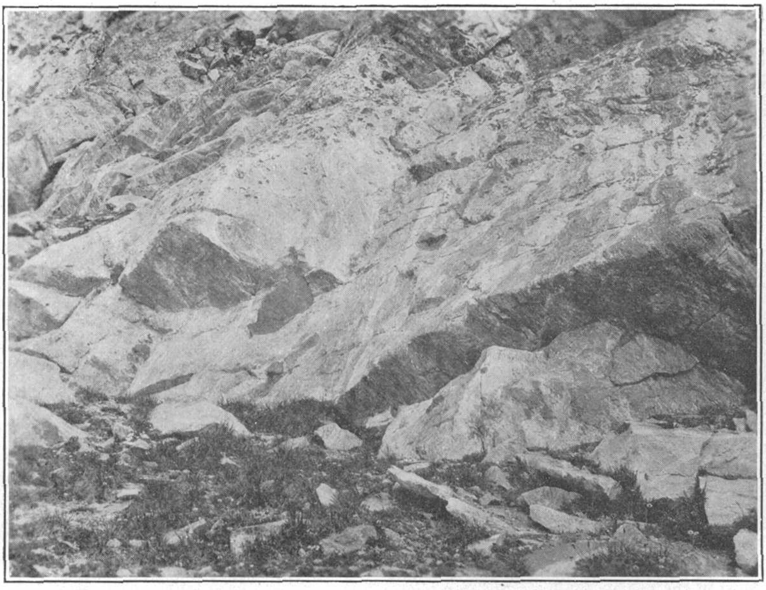
The beds are overturned.

B. APPROXIMATE CONTACT BETWEEN THE WOOD RIVER AND MILLIGEN FORMATIONS AT THE HEAD OF LAKE CREEK

The beds are overturned and broken by a slip fault. The Milligen formation is on the right.

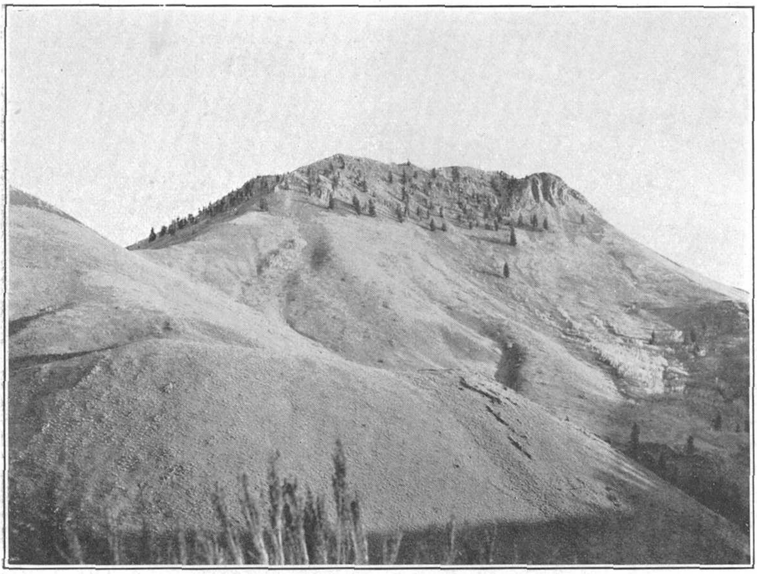


A. DÉBRIS-COVERED HILLS OF WOOD RIVER SANDSTONE ON THE NORTH SIDE OF THE EAST FORK OF THE BIG LOST RIVER

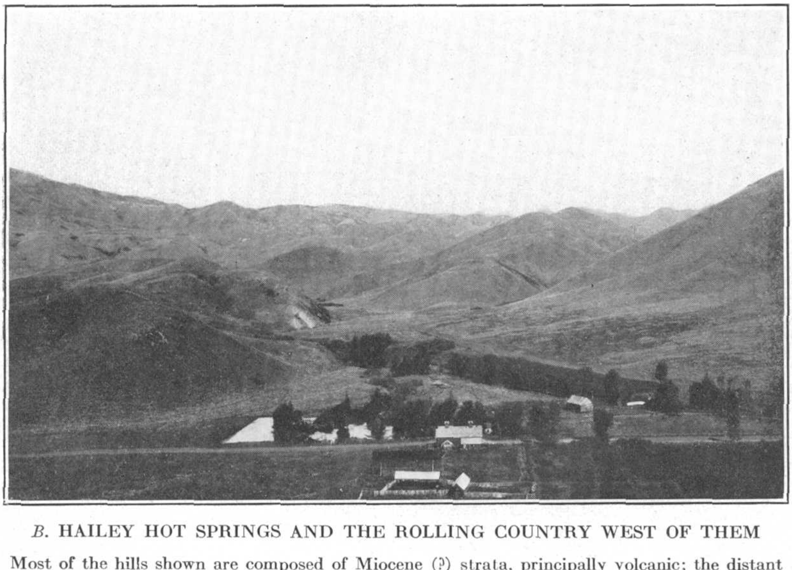


B. DARK BIOTITE GNEISS IN A CIRQUE AT THE HEAD OF WILDHORSE CREEK

Note the dark schlieren and the contorted gneissic banding.



A. ANDESITE HILLS 2 MILES SOUTHEAST OF CLARENDON HOT SPRINGS



B. HAILEY HOT SPRINGS AND THE ROLLING COUNTRY WEST OF THEM

Most of the hills shown are composed of Miocene (?) strata, principally volcanic; the distant hills in the middle are quartz monzonite, and the nearest on the right are underlain by the Milligen formation.

formation that details of stratigraphy and structure could not be determined. The stratigraphic position in it of the few fossils found is not known. Under these conditions it is entirely conceivable that the basal part of the Milligen may be of Devonian age and that these Devonian beds pass upward into beds of Mississippian age without observable break.

WOOD RIVER FORMATION (PENNSYLVANIAN)

Distribution and thickness.—The rocks to which the name Wood River formation is here restricted occupy a larger part of the region than any other formation, either sedimentary or igneous. If they were not largely covered by lava flows they would occupy probably not less than two-thirds of the total area.

One belt extends northwestward across the center of the Hailey quadrangle. Here the formation occurs in three roughly parallel faulted synclines, the one to the southwest shown only by isolated outcrops on the tops of the hills. A second and larger area occurs on both sides of the Big Wood River south of Ketchum, and a smaller but still good-sized area occurs on both sides of the Big Lost River in the northeast corner of the quadrangle. Good exposures are shown along the Ketchum-Mackay Road on both sides of Trail Creek and on the north side of the divide between upper Trail Creek and the heads of Lake and Eagle Creeks.

No single continuous and complete section of the Wood River formation has been found, and the columnar section given is a composite based on partial sections, in which it is not possible to exclude the effects of faulting. Separate sections, which differ from one another in lithologic character and so are believed not to overlap in any considerable degree, give a total of 7,700 feet. In all probability these measured sections do not represent the whole of the formation, and 8,000 feet is taken as a minimum thickness for the Wood River formation. The longest continuous section is the one measured at the junction of the East Fork with the Big Lost River, 6,700 feet. The beds in this vicinity are shown in Plate 7, *A*.

Lithologic character.—The Wood River formation consists in the main of calcareous and quartzitic beds but contains also conglomerate, shale, and dolomite. The following descriptions will give an idea of the succession of beds in a general way. Some stratigraphic details are given also in the mine descriptions. Hewett measured on the west slope of Lookout Mountain near Bellevue 2,037 feet of beds belonging to the Wood River formation. His section is given on pages 210–211.

Nearly everywhere the basal member of the formation is a massive brownish quartzitic conglomerate. Plate 6, *B*, shows a characteristic exposure. On account of its hardness the conglomerate forms conspicuous ledges and cliffs, and as it marks one of the few recognizable horizons it has been of the greatest value in working out the structure of the area. It is thick bedded and averages 300 to 400 feet in thickness. East of Hailey it has a thickness of 500 feet, and on the Wilson Creek-Big Lost River divide it reaches 800 feet. Pebbles of black flint or gray quartzite, as much as 2 or 3 inches in diameter, lie in a quartzitic groundmass. Except where sandstone layers are present it is generally impossible to recognize the bedding. In places layers of gray sandy limestone are interbedded in the conglomerate.

Conglomerate of this character is present almost everywhere at or near the base of the Wood River formation. In places, however, it occurs in lenticular beds. Near the head of Eagle Creek and in other localities there are two or more beds of conglomerate separated by calcareous and quartzitic beds. For short distances along the base of the formation no conglomerate is exposed. In some places it has doubtless been cut out by faulting, but in others it may never have been deposited.

Immediately above the conglomerate there are generally thick beds of dark-blue sandy limestone containing an abundant coral and brachiopod fauna. The rock weathers to a blue-gray color. It is a purer limestone than most of the beds in the formation and contains about 80 per cent of carbonate, principally calcium carbonate. The remaining 20 per cent consists principally of quartz in grains that average less than 0.3 millimeter in diameter. At one locality near the Little Wood River layers of fine conglomerate are interbedded in the limestone. This limestone is easily recognized by its lithologic character and its fossil content. It lies near the base of the Wood River formation and can be used in deciphering structure where the conglomerate is absent.

Above the blue limestone is black impure limestone. Most of it is thin bedded and weathers to thin lavender-colored fragments and slabs. Some beds are comparatively thick. On the west side of Trail Creek 1,200 feet of this limestone was measured.

The greater part of the Wood River formation is calcareous and quartzitic sandstone. Typical beds are well exposed on both sides of Trail Creek, north from Wilson Creek. On Corral Creek a thickness of 2,800 feet is exposed.

The rock is thick bedded. In many places the beds are as much as 4 feet thick and elsewhere 5 to 10 feet thick. Many of the beds are separated by shaly layers, so that the bedding is conspicuous from a distance. Much of the rock is finely cross-bedded, but this feature is in general visible only on weathered surfaces. Groups of beds form ledges on the valley sides from 20 to 100 or 200 feet in height.

The more siliceous varieties are light gray and rather fine grained. Some of them are coarse enough for the grains to be visible to the unaided eye. They consist essentially of a mosaic of quartz grains in a quartz cement, but most of them contain some mica and other impurities. Many of the original detrital grains have been secondarily enlarged. The rock containing calcareous material is darker and generally weathers rusty. Such rock consists essentially of angular to subangular quartz grains with minor amounts of feldspar, muscovite, magnetite, and zircon in a fine-grained calcareous cement. Carbonaceous material gives the dark color to the rock. A sample of calcareous sandstone containing *Fusulina* was analyzed by W. C. Wheeler, of the United States Geological Survey, with the following result:

Analysis of blue calcareous sandstone from the Wood River formation

Insoluble	74. 32
MgO	1. 85
CaO	11. 33
Loss on ignition	11. 68
	99. 18

This composition would correspond to $MgCO_3$, 3.86 per cent; $CaCO_3$, 20.21 per cent; total carbonates, 24 per cent; and it shows that the rock is only slightly magnesian. The insoluble residue contained a large amount of matter other than SiO_2.

Interbedded with these calcareous and siliceous sandstones are darker medium-bedded rocks of distinctly dolomitic character.

A facies of the Wood River formation, slightly different from the others, is found near the southwest corner of the Hailey quadrangle. The rock is a blue-black, fine-grained siliceous limestone, weathering dark gray. It consists chiefly of calcite through which are scattered small grains of quartz as much as 0.1 millimeter in diameter. Abundant dark carbonaceous material gives the dark color to the rock. It is commonly laminated, alternating bands varying in the proportion of siliceous and carbonaceous matter. In some places the bands of more siliceous material are irregular and appear to be flintlike aggregates in the rock.

In the upper part of the formation the typical rock is a dark fine-grained calcareous sandstone, which bears on the fresh surface a very characteristic bluish and brownish-black mottling. It is even-bedded, and the beds in places are as much as 5 feet thick, commonly separated by thin bands of shaly rock which bring out the bedding in a striking manner. The rock weathers generally to a rusty brown, and in some places to a brownish gray or gray.

It consists essentially of small subangular and subequal grains of quartz as much as 0.1 millimeter in diameter scattered through a groundmass of small grains of carbonates, in which larger rhomboidal crystals of dolomite occur. Muscovite and dark carbonaceous material, in wavy lines, give the shading to the rock.

A partial analysis of this rock by W. C. Wheeler gave the following result:

Analysis of calcareous sandstone from the Wood River formation

Insoluble	69.85
MgO	5.66
CaO	9.24
Loss on ignition	14.78
	99.53

Calculated to carbonates this composition would correspond to $MgCO_3$, 11.83 per cent; $CaCO_3$, 16.49 per cent; total, 28.32 per cent. Here, as in the analysis above, the insoluble material contains a large amount of matter other than SiO_2. The rock is a calcareous sandstone, in which the carbonate has almost the composition of a dolomite.

Interbedded in these calcareous sandstones are beds of black flint, which occurs in massive layers as much as 10 feet thick, breaking into bands 1 to 2 inches and in some places as much as 6 inches thick. Blue-black limestone weathering blue-gray and containing bands and lenses of black chert, is interbedded at a few horizons. In these gray limestone layers the gastropod fauna mentioned below (group 2) was found. Beds of quartzitic sandstone like that previously described are intercalated in places.

Over 2,500 feet of these calcareous and argillaceous sandstones, with their contained flint, limestone, and sandstone layers, were seen in crossing the Wood River beds south of upper Trail Creek.

On the high hills between the Big Lost River and its East Fork the Wood River formation contains more than 1,100 feet of coarse conglomerate with well-rounded boulders having a maximum size of over a foot. In a similar rock west of Wildhorse Creek a boulder 3 feet in diameter was seen.

Fossils and age.—Fossils from several localities within the Wood River formation were submitted to G. H. Girty, who reports upon them as follows:

These collections show different faunal facies by which they may be assembled into three or four groups. Each group is distinct so far as most of its collections are concerned, yet it contains one or more collections that connect it with the other groups. One group is characterized by containing

Fusulinas in abundance, and little else. Another group shows largely a gastropod facies, characterized by a species of *Euomphalus*, probably new, a *Bellerophon* of the *Euphemus* group, a straight dentalium (*Plagioglypta*), and certain other forms. Another group contains faunas which consist largely of brachiopods, with a subordinate coral representation. The last group consists of coral faunas, generally characterized by a large *Campophyllum*. These groups probably correspond in a general way with stratigraphic occurrence, yet they are not sharply defined, so that some of the lots may not be correctly referred, and no great difference of geologic age is suggested. All things considered, it seems that the relationships of these faunas would set off the *Fusulina* fauna on the one hand as against the three more closely related faunal groups on the other.

Regarding the geologic age, I may say that the faunas show more or less novelty of facies, which has hampered a satisfactory interpretation of the evidence. On the whole I am disposed to conclude that the Mississippian is not represented in these collections. Certainly the familiar and recognized Mississippian faunas are not found among them. On the other hand, *Fusulina* is generally regarded as an infallible index of Pennsylvanian age, so that the whole group of collections characterized by that genus may be referred to the Pennsylvanian. Although much less characteristic, *Campophyllum* is another Pennsylvanian genus, and the coral fauna of the collections may be referred also to the Pennsylvanian, though less conclusively than the other. The brachiopod faunas are not entirely typical or unequivocal, but they, too, show distinct Pennsylvanian affinities, an assignment which is mutually confirmed between the coral and brachiopod faunas by the brachiopod element in the coral fauna and the coral element in the brachiopod fauna. Were it not for the other types which sporadically accompany them, it might be difficult without the stratigraphic evidence satisfactorily to place the gastropod fauna, but with these factors considered the gastropod fauna also can, without much doubt, be included in the Pennsylvanian. The relative position of the different faunas in the stratigraphic series can not, however, at present be determined from paleontology.

The species identified, assembled according to the faunal grouping indicated, are as follows:

Group 1

Fusulina secalica.	Batostomella sp.
Zaphrentis sp.	Polypora sp.
Echinocrinus sp.	Rhombopora sp.
Stenopora aff. S. carbonaria.	Bellerophon sp.

Group 2

Zaphrentis sp.	Plagioglypta aff. P. canna.
Batostomella? sp.	Bellerophon sp.
Chonetes aff. C. geinitizianus?	Euphemus sp.
Productus cora group.	Pleurotomaria sp.
Martinia sp.	Euomphalus sp.
Ambocoelia sp.	Euomphalus aff. E. planidorsatus.

Group 3

Zaphrentis sp.
Amplexus? sp.
Campophyllum sp.
Syringopora sp.
Michelinia? sp.
Rhombopora sp.
Orbiculoidea.
Schuchertella n. sp.
Chonetes geinitzianus var.
Chonetes mesolobus var.
Productus semireticulatus.
Productus cora.
Productus aff. P. subhorridus.
Productus lineatus.
Productus aff. P. nebraskensis.
Productus aff. P. gruenewaldti.
Productus aff. P. porrectus.
Productus aff. P. lineatus.
Schizophoria resupinoides?
Spirifer aff. S. nikitini.
Spirifer aff. S. cameratus.
Spirifer aff. S. rockymontanus?
Ambocoelia sp.
Hustedia? sp.
Hustedia mormoni?
Hustedia mormoni var.
Cleiothyridina? sp.
Cleiothyridina aff. C. orbicularis.
Euomphalus sp.
Griffithides? sp.

Group 4

Zaphrentis sp.
Campophyllum n. sp.
Michelinia? n. sp.
Chonetes sp.
Productus cora group.

An inspection of the four groups made by Mr. Girty brings out the following facts:

Group 1, characterized chiefly by *Fusulina*, represents a series of collections from the calcareous sandstone facies of the Wood River formation, practically from bottom to top. *Fusulina* is found in calcareous sandstone interbedded in the conglomerate at the base of the formation, at various levels in the body of the formation, and 7,500 feet up in the Pennsylvania section measured in Muldoon Canyon, 18 miles east of Hailey, by J. B. Umpleby and G. H. Girty.

Group 3, chiefly a brachiopod and coral fauna, is confined to the heavy blue sandy limestone that lies immediately above the conglomerate and so but little above the base of the Pennsylvanian.

Faunas of group 2, which show chiefly a gastropod facies, are taken from certain thin limestone bands interbedded in the calcareous and shaly sandstones which have been placed in the upper part of the Pennsylvanian. In two localities they come from similar rocks in the lower part of the formation but well above its base.

These facts taken together suggest that the grouping of faunas made by Girty is one really determined by bottom conditions rather than age. The blue sandy limestone above the conglomerate, the dominant calcareous sandstone, and the limestone interbedded in the calcareous sandstone have each its own assemblage of species.

TERTIARY ROCKS

The only Tertiary sedimentary rocks in the Hailey quadrangle consist of fragmental material interbedded with the Miocene (?) lava at many places in the Wood River region. Except for the comparatively large belt of gravel east of Ketchum and the similar one southeast of Gimlet these sediments have not been mapped. In most places they are so intimately interbedded with lava that it is impracticable to separate them. These clastic beds occur at the head of Quigley Creek, near the mouth of Deer Creek, west of Hailey Hot Springs, at the head of Trail Creek, on Hailey Creek, and in other localities. A large part of the clastic material is tuffaceous, but much of the tuff has been sorted by water and more or less mixed with other material. Some of the massive, fine-grained tuff may be the direct product of volcanic explosions. Most of the tuff, however, is banded or even laminated, is in part cross-bedded, and has clearly been redistributed by water. Some of the thin and evenly bedded deposits, such as those at the head of Quigley Creek, may have formed in ponded water, but most are clearly of fluviatile origin. In some places the laminae are as little as one-thirtieth of an inch thick. In some localities beds of fine tuff contain isolated fragments as much as 6 inches in diameter.

The tuffs are cream-white, light brown, gray, and green, but green and brown are the most common colors. The more silicic varieties are predominantly light brown and appear to correspond in composition to latite and rhyolite. They consist of small angular fragments of oligoclase, quartz, orthoclase, and a little biotite in a microcrystalline or partly glassy groundmass. Others correspond in composition to augite andesite, and many of these are colored green by chlorite. They contain crystals of hornblende, augite, and labradorite in a microcrystalline groundmass. Some beds of such tuff contain bombs of augite andesite.

Much of the tuff contains material of nonvolcanic origin. There are all gradations between this rock and that which is composed exclusively of sedimentary material. On the divide between the head of Trail Creek and the North Fork of the Big Lost River a thickness of 150 feet of fluviatile deposits is exposed. These deposits rest on the upturned beds of the Milligen formation and are conformable with the lava that overlies them. Part of the rock is a conglomerate composed of well-rounded boulders of sedimentary rocks as much as 6 inches in diameter. On Hailey Creek, in the southeastern part of the Hailey quadrangle, tuffaceous sandstone and shale with a probable thickness of 200 feet are exposed. The beds here are 1 to 6 inches thick. Lindgren[5] has mapped and described

[5] Lindgren, Waldemar, op. cit., p. 197, pl. 32.

sandstone and shale, in part tuffaceous, on and near Democrat Creek, southwest of Hailey. These beds have a maximum thickness of 200 feet. Lindgren believed that they should be correlated with the Payette formation, which is extensively developed in the Snake River Plains, because they have yielded the fossil plant *Sequoia angustifolia*, which was considered to be characteristic of the Payette. Although they have several points of similarity to the Payette beds they can not, on available evidence, be considered the exact equivalent of them. For one thing, the beds near Hailey are dominantly fluviatile, whereas the Payette formation is usually considered dominantly lacustrine. In this report these rocks are therefore classified as Miocene (?).

QUATERNARY DEPOSITS

The clastic deposits of Quaternary age in the Wood River region are the products of glacial and fluviatile activity. Deposits of two glacial stages may be present, but those formed in the last or Wisconsin stage are much the more abundant of the two. They comprise morainal material laid down by the glaciers and outwash from their lower ends. Many of the stream valleys have fragmentary gravel terraces at several heights along the sides and more or less extensive flood-plain deposits in the bottom. Aggradation in connection with the damming of the Little Wood River by Quaternary basalt has already been referred to. The exact relation of the gravel thus produced to the other alluvial deposits has not been determined.

GLACIAL DEPOSITS

Earlier (?) moraines.—In some places erratic boulders occurs outside and above the limits of the principal glaciers described below. Opposite Iron Mine Creek, on the east side of the Little Wood River, scattered boulders of granite as much as 2 feet in diameter were found 500 to 700 feet above the river and half a mile down the valley from the mapped lower limit of the glacier. No similar boulders were found between them and the river. If, as is probable, they were brought by a glacier from the head of the valley, they belong to an earlier drift, which has since been almost wholly removed by erosion. No such higher drift was found elsewhere in the region.

Deposits of the principal or Wisconsin glacial stage.—Abundant evidence of extensive mountain glaciation is widespread in the region. In contrast to the erratic boulders of uncertain derivation mentioned above, most of the glacial deposits are so little modified by erosion that their original topographic forms are easily recognized. They were evidently formed during the last (Wisconsin) glaciation to which the region has been subjected. The approximate extent of the glaciers of that time, as determined from the distribution of glacial material, is indicated in Figure 4. The drift has been mapped on Plate 1 only where it is especially thick and conceals the underlying bedrock. The principal glaciers occupied the upper parts of the valleys of Trail Creek, the Big Lost River and its North Fork, the North and East Forks of the Big Wood River, and Hyndman Creek. Because few well-marked morainal ridges are present it is difficult to determine the exact limits of the glaciation.

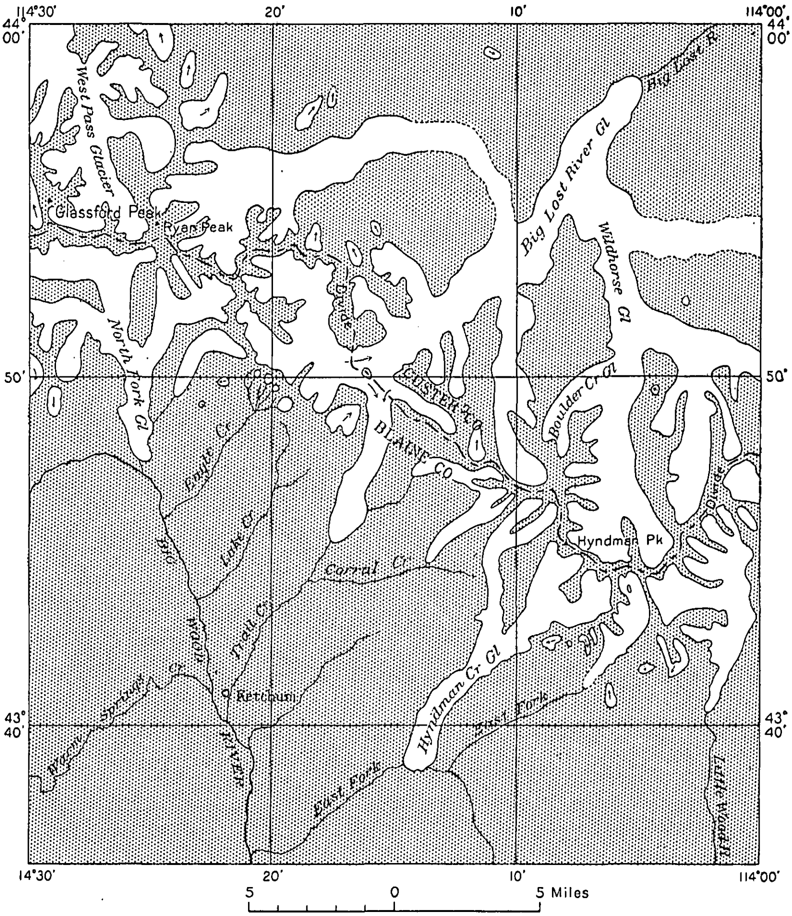


FIGURE 4.—Map showing Pleistocene glaciers of the Hailey quadrangle. Arrows show direction of flow

For the purpose of the map shown in Figure 4 the lower limits of the glaciers were in general assumed to correspond to the extreme down-valley occurrence of boulders deemed too large for stream transportation. The limits as sketched would presumably be somewhat modified as a result of more detailed study.

Most of the drift was deposited along the lower half or two-thirds of the course of the glaciers. It decreases gradually up the valleys.

At the heads of the old glaciers erosion was the dominant process. Drift is there present only in local depressions, and the greater part of the valley sides and bottom consists of bare rock. At the lower ends of the glaciers there is also a general thinning of the drift. The most striking fact about the drift is the almost complete absence of well-developed ridged moraines, either lateral or terminal. Most of the drift forms a sheet of bouldery débris on the valley sides. It conceals the bedrock over considerable areas and in many valleys reaches a height of 1,000 feet above the valley bottom. Exceptionally, however, ridged moraines exist. Low lateral moraines are present in the valley of the upper Little Wood River at places where the glacier which occupied it passed the mouths of nonglaciated valleys coming in from the east. There are well-developed recessional terminal moraines where the glacier in the valley of Wildhorse Creek debouched into the valley of the East Fork of the Big Lost River. Similar though less distinct moraines are present in the valley of Fall Creek, and these were made by a glacier which entered it from the south 2½ miles above its mouth.

The streams flowing from the ends of the glaciers were abundantly supplied with débris; they were overloaded and depositing streams. The result was that the valleys downstream were buried by the outwash gravel, in some places to a depth of several hundred feet. Such outwash gravel occurs as terrace remnants along the valley sides in several parts of the Hailey quadrangle and has been noticed particularly south of the divide. High-level terrace fragments are general along the Big Wood River and also exist along some of its tributaries. At the mouth of the North Fork a well-developed terrace occurs at a height of 40 feet above the stream channel, and gravel at the same height is found in a small side tributary a mile below Elkhorn Creek, on the west side of the river. At the junction of the East Fork of the Big Wood River and Hyndman Creek there is terrace gravel at a height of 350 feet above the stream.

In Ohio Gulch, a mile above the Big Wood River, the terrace is 80 feet above the stream. On the east side of the Big Wood River south of Hailey several fragments of terraces occur. At the southern edge of the Hailey quadrangle the lower terrace stands at 80 feet and a higher one at 140 feet above the stream. The higher terrace heads in the ravine that enters at the border of the quadrangle and slopes up from the river at an angle of 8°. In Slaughterhouse Creek, 4 miles above the Big Wood River, remnants of a terrace are found 175 feet above the stream. The higher terraces indicate that at the end of the glacial epoch the valleys were filled with alluvium in places to a height of several hundred feet above the present streams.

Along the Little Wood River the terraces near the southern boundary of the Hailey quadrangle stand 100 feet above the river, and 3 miles up the valley they stand 200 feet above the river. Some of this terrace building was probably due to the damming of the Little Wood River by the last flows that entered it from its East Fork at the extreme southeast corner of the Hailey quadrangle.

LATER ALLUVIUM

The gravel, sand, and silt of the flood plains and lower terraces in the principal stream valleys were probably deposited after the glaciers had disappeared. In the absence of detailed physiographic study it is impossible to trace out and distinguish between the different terraces throughout the region. The lower or younger terraces are best developed in the valleys of the Big and Little Wood Rivers. In these valleys on Plate 1 are shown one and in places two such terraces above the level of the lowest bottom lands, which are still subject to overflow. In addition remnants of the older high-level terraces are mapped in a few places along the valleys of the Big Wood River and other streams. As already noted, these high terraces may be genetically related to the glaciation. The exact correlation of the different terraces, which would require careful leveling, is not justified with the data at hand.

Flat-lying deposits of travertine occur in the middle and lower portions of the valley of Milligen Creek, along Elkhorn Creek, and to a less extent in some of the neighboring valleys. In places the travertine is distinctly bedded, and many beds contain abundant subangular pebbles.

Weathering has produced talus slopes at the foot of cliffs, many of which were formed by glaciation. Landslides are prominent features of the topography in numerous localities but are too small to be mapped separately on the scale of Plate 1. Some of the material mapped as Quaternary deposits is of landslide origin. Considerable masses of débris produced by slides have accumulated in places along the East Fork of the Big Wood River. Lake Creek takes its name from the ponds produced by the damming of its valley by landslides. In the small southward-trending valley just inside the west edge of the Hailey quadrangle, due west from Guyer Hot Springs, a rock slide of andesite blocks, some of which are 10 feet in diameter, extends a third of a mile in length and fills the valley to a depth of 20 to 40 feet.

METAMORPHISM IN THE SEDIMENTARY ROCKS

All the Paleozoic rocks are somewhat recrystallized and otherwise altered by regional metamorphism, but it is only in the vicinity of igneous masses, where contact metamorphism has been active, that the rocks are markedly changed. The Hyndman and East Fork formations are almost completely recrystallized and in general are much more metamorphosed than any of the younger rocks, with local exceptions. These two formations, however, lie in a narrow band that rims the largest mass of granite rock in the region, and their metamorphism is believed to have resulted largely from igneous agencies. The rocks contain, among other minerals, andalusite, scapolite, sillimanite, augite, diopside, tourmaline, and garnet, all of which are characteristic of igneous metamorphism. The pyroxenes in particular could hardly have been produced by regional metamorphism, as they are unstable under high pressure. Most of the minerals listed above are present also in zones of contact metamorphism in the younger rocks.

The Phi Kappa and Trail Creek formations consist in the main of originally clayey materials which have gone over largely to argillite, in some places spotted with incipient metamorphic minerals. The rocks are in general notably less metamorphosed than those of the Hyndman and East Fork formations. It is possible that the metamorphism in the Ordovician and Silurian rocks is in part due to the influence of the monzonite near the head of the Big Lost River. However, the uniform distribution of such metamorphism as exists in the Phi Kappa formation and also the small amount of Silurian rocks exposed makes it probable that most of the metamorphism is of regional character and is unrelated to the igneous rock.

The Milligen formation also has undergone moderate regional metamorphism throughout. The argillaceous material has been converted to micaceous minerals, and much of the carbonaceous matter has become graphitic. A rather imperfect cleavage has been developed. In some places this cleavage is at a small angle to the original bedding, as can be seen from Plate 6, *B*. Some of the coarser varieties, especially those that have a greenish-gray color, have a somewhat schistose appearance.

The Wood River formation has also been somewhat metamorphosed, but, except locally, it has undergone less alteration than the older rocks. Micaceous minerals have been developed and the form of the original clastic quartz grains has been somewhat modified, but cleavage is not prominent.

Both the Milligen and the Wood River strata have in certain small areas been metamorphosed to the point where distinct metamorphic minerals have been developed. One such area extends from the north side of Elkhorn Creek, east of Ketchum, to the East Fork of the Big Wood River. It is about half a mile wide at its northwest end and widens southeastward to about 2 miles. Most of this area contains beds of the Milligen formation, but near the East Fork some Wood River beds are included. Not all the rocks in this area have been metamorphosed, but certain beds are greatly altered. Dark slate-colored impure limestone east of Triumph Creek contains small black hornblende needles. On the east side of the ridge east of Elkhorn Creek beds of gray-black thick-bedded calcareous sandstone contain spherical and ellipsoidal concretions as much as 3 inches in diameter. Some of the concretions run together. They consist of radiating masses of diopside with a little quartz, calcite, and dark material. Many beds consist largely of garnet and diopside or augite with local masses of calcite. In others there are bundles of vesuvianite crystals and a little tourmaline and apatite. In still other beds there are bunches of wollastonite, tremolite, and biotite. Some of the contact-metamorphic rock on the dump of the old Noonday mine is lithologically similar to specimens of intensely metamorphosed rock of the Hyndman formation from the vicinity of the contact with granitic rock on the west side of the Little Wood River. There seems little doubt from the character of the metamorphism that the alteration in the rocks between Elkhorn Creek and East Fork was caused by igneous agencies, although no igneous rock except a few dikes and one small mass of granite is exposed in this vicinity. Further data on contact metamorphism here and elsewhere in the region will be found in the description of the ore deposits.

Near the contact with the granodiorite east of Wildhorse Creek the Wood River rock is a light to dark blue siliceous limestone and contains belts and bands of a dense white porcelain-like rock, which consists of a fine-grained aggregate of quartz, with some calcite, and with abundant diopside in small grains and granular aggregates. The metamorphosed limestone is here separated from the granodiorite by a fault contact.

The larger areas of metamorphic rock in the Wood River formation occur on the west side of the Hailey quadrangle, particularly near the network of intrusions about Ryan Peak. Here there has been a change in color from blue to white and the development of diopside, or rarely tremolite, in the rock. In some places calcite is still present. On the North Fork of the Big Wood River there is a blue calcareous sandstone that consists principally of quartz sand grains as much as 0.2 millimeter in diameter with calcite in abundance between the quartz grains and numerous small grains of diopside in the interstices. In addition there are small amounts of muscovite, feldspar, and zircon. A white rock adjacent to it consists essentially of an aggregation of sheaves of tremolite with some quartz and diopside. Farther south similar whitish bands occur within the Wood River formation. In a locality 2½ miles southwest of Guyer Hot Springs many small columns of andalusite altered to mica occur in one of these bands.

The metamorphism on the west side of the quadrangle is not confined to narrow bands about particular masses of igneous rocks. It is rather a general feature of the Wood River formation near an area in which intrusive rocks are common.

The rocks of the Milligen and Wood River formations bordering the granitic masses south and southwest of Hailey have been similarly but less extensively metamorphosed. Wollastonite, white pyroxene, and other silicates have been developed in some beds. The contact metamorphism southwest of Hailey was not sufficiently intense to alter the appearance of the rocks greatly. It has been described by Lindgren [6] and is touched upon in this bulletin in the descriptions of mines in that part of the region. The metamorphism in the vicinity of the Minnie Moore and other mines near Bellevue is described by Hewett on pages 215–217.

From these descriptions it will be seen that metamorphism of three kinds has affected the sedimentary rocks of the Wood River region—regional metamorphism, contact metamorphism as a result of the late Mesozoic granitic intrusions, and contact metamorphism as a result of the Tertiary porphyritic intrusions.

The regional metamorphism resulted from diastrophism, principally in late Mesozoic time, and affected all the Paleozoic sedimentary beds. It appears to have been of moderate intensity and resulted in a certain amount of recrystallization of the quartz and development of minerals of micaceous habit by the breaking down of minerals less stable under pressure. The partial graphitization of beds of carbonaceous shale and coal was probably brought about by regional metamorphism, but igneous agencies may also have played a part in it.

Around the granitic masses in the southwestern part of the region the effects of contact metamorphism are at first glance inconspicuous, but microscopic examination indicates that contact-metamorphic minerals have been very generally developed in aureoles as much as 1,000 feet wide around the larger masses. Farther north, between Ketchum and North Star, there are considerable areas in which similar metamorphism has taken place, but exposures of granitic rocks are lacking.

The Hyndman and East Fork formations, which flank the largest granitic mass in the region, are more intensely metamorphosed than any of the younger rocks, and the assemblage of minerals in them is such as to indicate that the metamorphism is of igneous origin. The limestone beds of the East Fork formation are more completely altered than any others, presumably because they were more susceptible to replacement by the solutions emanating from the granitic

[6] Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, p. 195, 1900.

magma. The pebbles of the conglomerate show little evidence of deformation, which would hardly be true if the beds had been subjected to regional metamorphism sufficient to produce the great mineralogic changes that have occurred.

The fact that the sedimentary beds in the vicinity of Ryan Peak contain an assemblage of contact-metamorphic minerals somewhat similar to those in beds near the granitic rocks farther south and east is of interest. If, as appears probable, these minerals result from the intrusion of the porphyritic rocks which are abundant near Ryan Peak it indicates that the Tertiary intrusive rocks in this part of Idaho are capable of exerting a powerful contact-metamorphic influence. This possibility is of obvious importance in the study of the age and genesis of ore deposits in the region.

IGNEOUS ROCKS

PLUTONIC ROCKS

GENERAL FEATURES

The outstanding feature of the geology of west-central Idaho is a great area of granitic rocks, about 80 miles in average width, which extends northward for probably more than 250 miles from the northern border of the Snake River Plains, generally called the Idaho batholith. The Wood River region lies east of the southern part of the main mass but contains a number of smaller bodies of granitic rock. From their general petrologic character and geologic relations it is believed that these are related to the Idaho batholith and may be actually connected with it at depth. There are three exposures of granitic rock of considerable size in the Hailey quadrangle, two others in the part of the Wood River region south of the quadrangle, and a number of smaller exposures. The total area covered by such rocks in the Wood River region is nearly 100 square miles. Petrographic studies of these rocks, though not exhaustive, have been sufficient to lead to the recognition of several local variations. These rocks range in composition from granite to diorite, but probably most of them have approximately the composition of granodiorite and quartz monzonite. Most of them occur in medium-grained rocks of hypidiomorphic texture, consisting essentially of quartz, potash feldspar, oligoclase or oligoclase-andesine, and biotite. Much of the potash feldspar is microcline, but orthoclase may be present in some specimens. Although biotite is generally the principal dark mineral, hornblende is also present in many places. Titanite, apatite, and magnetite are the principal accessory minerals.

In each of the areas where plutonic rocks are exposed there are features distinguishing the rock from the similar rock elsewhere. Descriptions of the rock in each area are given on the following pages.

GRANODIORITE AND RELATED ROCKS ON UPPER WILDHORSE CREEK

The largest body of granitic rocks in the Wood River region is on the headwaters of Wildhorse Creek, east and southeast from the Devils Bedstead. It underlies 50 square miles of the Hailey quadrangle and extends over nearly half as much area to the east.[7]

The main divide between the Big Lost and Big Wood Rivers east from the Devils Bedstead, except for about 2½ miles in the vicinity of Hyndman Peak, runs through this granitic area.

Unlike the smaller granitic intrusions described below, this body shows marked differences in both mineral composition and texture in its different parts. The greater part is of granitic texture and is in places porphyritic, and most of it has the composition of granodiorite, although some facies are more calcic. Another large part is of gneissic texture. The two phases are so intimately associated and so similar in composition that they are probably products of the same period of intrusion, although their exact relations to each other have not been determined.

MASSIVE GRANODIORITE

Massive granodiorite covers about 20 square miles along the east edge of the Hailey quadrangle, in the drainage basins of Wildhorse Creek and the Little Wood River, and extends eastward beyond the border of the quadrangle. Bare cliffs within this area look nearly white. The rock is light gray and of medium grain. Small black patches of biotite are scattered through a mottled gray (quartz) and white (orthoclase) groundmass. Titanite is present in small straw-yellow crystals. Both porphyritic and nonporphyritic varieties occur. In the former variety phenocrysts of pale-red potassium feldspar, many of them Carlsbad twins, of varying distinctness of outline, commonly reach a size of 0.5 to 1 inch and may make up one-ninth of the surface of the rock. The porphyritic and nonporphyritic facies grade into each other and are intimately mixed.

The rock contains quartz, potassium feldspar, oligoclase, biotite, and in places common hornblende, with titanite, magnetite, and apatite, and has an estimated average composition of 23 per cent quartz, 12 per cent potassium feldspar, 53 per cent plagioclase, and 12 per cent ferromagnesian minerals. Much of the biotite is partly chloritized. Titanite is so abundant in some specimens that it might almost be considered an essential constituent. Some of the potassium feldspar shows microcline twinning, but much of it does not. The large alkali feldspar phenocrysts present in places are not included in this estimate, so that the rock as a whole contains somewhat more

[7] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, pl. 1, 1917.

of this constituent than is indicated by the estimate. Some parts of the mass may have the composition of quartz monzonite, whereas others have more nearly that of diorite. Dark basic inclusions (schlieren) are common in the granodiorite. In the porphyritic facies such inclusions contain feldspar phenocrysts that are smaller and flatter than those in the surrounding rock.

BORDER FACIES OF THE GRANODIORITE

A darker and less uniform variety of the granodiorite crops out in a belt between the gneiss and the sedimentary rocks to the southwest. The ferromagnesian minerals, mostly biotite, which make up about one-fifth of this facies, occur in a coarsely patchy fashion through the white groundmass of quartz and feldspar and have a distinct parallel arrangement.

The estimated amounts of the different mineral constituents in specimens from the head of Chapparal Creek are quartz, 10 per cent; potassium feldspar, 20 per cent; oligoclase, 45 per cent; ferromagnesian minerals, 20 per cent. A sample from the head of the East Fork of the Big Wood River showed more potassium feldspar than plagioclase, and one specimen obtained north of the divide is a diorite. Except for the greater amount of ferromagnesian minerals the rock is similar to that of the main area and may also be considered a granodiorite.

In the field the darker facies is separated with difficulty from the main granodiorite. In upper Chapparal Creek the two rocks are fairly distinct, but a mile to the northeast the distinction ceases to be recognizable. The difference in appearance of the two rocks is more clearly seen from a distance than immediately on the contact. The granodiorite of the west side of the upper East Fork basin is darker than that of the east side, but the differences do not permit a separation of the two bodies of rock. Indeed, in the same outcrop differences as marked as the differences between the two facies occur, but the different parts grade into one another and are parts of a single intrusion.

Lenticular or banded dark inclusions or schlieren occur in the darker rock in Wildhorse Basin. They lie in a common direction, and both the inclusions and the patches of biotite in the granodiorite dip southwest, parallel to the contact of the granite and the sedimentary rocks. A view of this rock is shown in Plate 7, *B*.

A still more calcic facies is exposed in places for 4 or 5 miles along the western border of the main body of granodiorite. It crops out for about 2 miles northwest of a point on the border east of Hyndman Peak and is again exposed near the head of Corral Creek. At the north base of Hyndman Peak the rock is medium or fine grained and consists of gray feldspar mottled with black aggregates of biotite and hornblende, which make approximately one-third of the rock. The gray groundmass is largely fine-grained plagioclase, but indistinct crystals of the same mineral as much as 7 millimeters in diameter are present.

Essentially the same minerals occur as are found in the main granodiorite but in different proportions. Quartz and alkali feldspar are greatly reduced and in some sections are lacking. The plagioclase is an oligoclase-andesine. Hornblende may equal the biotite in amount, and the two together make a larger proportion of the rock. An estimate of the mineral composition gives plagioclase, 53 per cent; hornblende and biotite, 25 per cent; potassium feldspar, 14 per cent; quartz, 7 per cent. In addition augite is rarely present and the common accessories are titanite, magnetite, and apatite. The rock is thus a quartz diorite.

Near the contact the rock is a hornblende-biotite diorite. It is a dark medium-grained aggregate of hornblende and feldspar. At times a poikilitic texture is developed by grains of hornblende as much as 1½ inches in size, containing inclusions of the feldspathic constituents of the rock. The diorite holds inclusions of the sedimentary rocks and has numerous basic indigenous inclusions. It is abundantly cut by granitic dikes from a fraction of an inch to 5 feet in width.

Both of these border facies are regarded as more calcic portions of the main granodiorite, the products of magmatic differentiation before final solidification.

BIOTITE GNEISS

General features.—The remainder of the large body of igneous rock in this part of the region is biotite gneiss and occupies an area of about 18 square miles. Its outcrop is rudely rectangular in outline, with the longer axis trending northwest. It lies mainly in the upper part of Wildhorse Creek Basin, though it extends west into the upper part of Kane Creek. It is thus roughly parallel to the structural trend of the region. The gneiss is surrounded on all sides except the north by the granodiorite; here it is separated by a fault contact from calcareous sandstone of the Wood River formation.

Distinction has been made in mapping between an inner light-colored and an outer dark-colored gneiss. Neither the boundary between the gneiss and the granodiorite nor that between the two varieties of gneiss is sharply defined. The boundary between the two varieties of gneiss in particular had in places to be drawn arbitrarily, leaving to one side masses of gneiss quite as light or dark as the main mass on the other side of the line. The biotite gneiss, then, may be considered a single body with a twofold facies—an inner lighter, less biotitic, and more silicic gneiss, and an outer border facies of darker color, larger content of biotite, and more calcic composition. The darker border facies is continuous about the gneiss except at its southeastern end.

The gneiss ranges from a light-gray or nearly white rock at one extreme to a dark, richly biotitic rock at the other. It is foliated and banded. Both foliation and banding increase in distinctness with the increasing amount of biotite. The alternating bands of different mineral composition range from two or three to as many as sixteen to the inch. The darker varieties have as a rule more distinct and closer banding. In some of the lighter varieties the banding is not conspicuous, and the rock, particularly in hand specimens, becomes almost massive, resembling closely a fine-grained granite. The banding seems to have a strike parallel to the border of the gneiss and a dip toward the border at angles between 30° and 40°. At the south end this angle is slightly greater, reaching 50° or 55°. In some outcrops the banding is undisturbed, in others it is crumpled.

Schlieren, or black inclusions of more micaceous and hornblendic rock (see pl. 7, *B*), are common in the gneiss. In many places they are lenticular masses parallel to the banding of the gneiss and are themselves banded. Elsewhere they are more irregular. Veins of lighter granitic material cut the rocks in various directions and show movement in and displacement of the rock subsequent to the formation of the inclusions. Many of the smaller veinlets are parallel to the gneissic banding, and the smaller of these are indistinguishable from the light bands of the gneiss itself. Evidently part of the gneiss consists of granitic material injected subsequent to its original formation. The light-colored variety of the gneiss is a fine-grained, indistinctly banded light-gray rock. The banding results from the grouping of small individual flakes and aggregates of flakes of biotite. In addition to the bands thus formed there are coarser-grained white bands of quartz and feldspar. Many of these are parallel to the biotite bands, but others cut them at angles as high as 20°. The material in these lighter bands appears to have been injected after the formation of the rest of the rock.

The rock exclusive of these siliceous bands contains quartz, microcline, oligoclase, biotite, and magnetite, named in order of decreasing abundance, with minute quantities of apatite and zircon. Some specimens also contain allotriomorphic hornblende, and the average diameter of the grains is about 0.3 millimeter. Much of the material is in a fine aggregate of irregular grains in layers between the larger grains, apparently the result of crushing.

In the dark variety of the gneiss the dark constituents are collected into sharply defined and generally continuous bands, which average 10 to the inch. Locally these are not parallel but appear to have been forced apart by the entrance of some of the silicic material of the rock. The lighter portion of the rock is banded on a somewhat coarser scale. The essential minerals are quartz, microcline, and oligoclase, named in order of decreasing abundance, with hornblende and biotite in varying proportions. The accessory minerals are garnet, magnetite, zircon, apatite, and allanite. The texture is allotriomorphic, and the average diameter of the grains is 0.5 to 1 millimeter. Much of the quartz and oligoclase is in granophyric intergrowth.

In a broad way the biotite gneiss has a composition similar to that of the adjoining massive granodiorite. Apparently, however, it is somewhat more silicic. The average composition may be about that of quartz monzonite.

Origin.—In the cirque at the head of the south fork of Wildhorse Creek there is a small irregular mass of crystalline limestone containing chondrodite in the dark gneiss near its contact with granodiorite. Creamy-white crystalline limestone crops out in the bed of Wildhorse Creek at a point N. 65° E. from Hyndman Peak. Two miles below this place, at the confluence of the two forks of Wildhorse Creek, a band of impure crystalline limestone is exposed. The presence of these bodies of sedimentary rock and the pronounced banding in the gneiss suggest that the gneiss may perhaps be of sedimentary origin and have been subsequently altered beyond recognition by igneous and metamorphic agencies.

On the other hand, the banding dips toward the borders of the roughly oval mass of gneiss in a manner that would be somewhat difficult to explain as the result of deformation of a sedimentary rock. Inclusions of sedimentary rocks similar to those noted in the gneiss are also present in the granodiorite, which is clearly of igneous origin. In both the granodiorite and the gneiss the masses of sedimentary rock are probably inclusions engulfed during the intrusion of the igneous rock. The general shape of the bodies of light and dark gneiss and the appearance of their contact with the surrounding granodiorite more closely resemble those of igneous than of sedimentary rocks. All varieties of the gneiss contain minerals characteristic of igneous rocks, and the average composition is about that of granodiorite or of quartz monzonite. In general the gneiss is strikingly like the surrounding granodiorite in composition. It differs from the granodiorite only in texture, the absence of titanite and, in some varieties, the presence of garnet. The granophyric intergrowth of quartz and plagioclase in the dark gneiss and the schlieren, which are widespread and common, especially near the borders of the gneiss, could have been produced only by igneous agencies.

The weight of the evidence is thus strongly in favor of the igneous origin of the gneiss. Its texture probably results from flowage and rearrangement of the material prior to complete consolidation. The gneiss grades into the granodiorite along its contact and is similar to the granodiorite in general composition. It is apparently part of the same general igneous mass, but whether it was intruded before or after the granodiorite can not be determined from available information.

QUARTZ MONZONITE ON BIG LOST RIVER

A short distance northwest of the large mass of granitic rock just described a rock that has the average composition of quartz monzonite crops out. It is exposed over a roughly oval area on both sides of the Big Lost River, immediately north of the pass between that stream and Trail Creek. Its longer axis extends a little over 3 miles and trends northeast, parallel to the Big Lost River. This rock was first mentioned by Eldridge,[8] who considered it the pre-Cambrian base on which the sedimentary rocks of the region were deposited. Excellent exposures, however, on both sides of the Big Lost River show that it is intrusive into the overlying Ordovician rocks. It cuts across the bedding of these rocks and sends tongues into them. It rises to about 8,000 feet in the hills on the northwest and to a maximum of 9,300 feet on the southeast, and a comparison of the heights about the border shows that it is an igneous body of domelike upper surface, whose summit is about a mile southeast of the Big Lost River. It has been bared and dissected to a depth of 1,800 feet in the cutting of the present valleys.

The rock is medium grained, light gray, and of uniform hypidiomorphic texture, with an average grain of 2 millimeters. It consists of dull white feldspar, gray quartz, and scattered flakes of biotite, as much as 3 millimeters in diameter. Orthoclase and oligoclase are present in about equal amounts. A little hornblende, apatite, and magnetite are present, and titanite is very abundant in some specimens. In some localities the rock contains a few phenocrysts of pale flesh-colored orthoclase as much as 1 centimeter in diameter. Much of the orthoclase is perthitically intergrown with plagioclase, and a few grains have the texture of microcline.

QUARTZ MONZONITE ON DEER CREEK

One area of granitic rock, about 7 square miles in extent, lies near the southwest corner of the Hailey quadrangle. It is roughly oval, trends northwest, and lies mainly in the basin of Deer Creek, though it extends beyond that basin in both directions. The mass of gra-

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[8] Eldridge, G. H., A geological reconnaissance across Idaho: U. S. Geol. Survey Sixteenth Ann. Rept., pt. 2, p. 227, 1896.

nitic and dioritic rock southeast of Croy Creek, described by Hewett on pages 211–214, is probably a continuation of it. Lindgren[9] studied the rock at the Democrat mine, near the southern border of the Hailey quadrangle, in some detail, and his description is quoted below:

Fresh medium-grained granitic rock. Black scales of biotite abundant; diameter 1 millimeter. Reddish orthoclase, grains up to 4 millimeters in diameter. Greenish oligoclase in about the same quantity as the orthoclase. Gray quartz.

The thin section shows grayish-brown, straight foils of biotite, containing a little chlorite and epidote, as well as some yellow serpentine. Microcline in large grains, partly also microperthite. Oligoclase, partly also andesine, in short prisms. All of the feldspars contain a little sericite. A few grains of magnetite are present, intergrown with biotite. Titanite in well-crystallized grains; also apatite. Structure hypidiomorphic granular. Oliogoclase in irregular prisms embedded in quartz and potassium feldspar.

The chemical analysis of this rock and the calculated mineral composition are given in the following table:

Analysis of quartz monzonite from Deer Creek

Chemical analysis [Analyst, W. F. Hillebrand]		Mineral composition [Calculated by Waldemar Lindgren]	
SiO_2	68.42	Quartz	29.21
TiO_2	.50	Potash feldspar (orthoclase and microcline)	18.07
Al_2O_3	15.01	Albite	3.00
Fe_2O_3	.97	Oligoclase	33.72
FeO	1.93	Biotite	9.68
MnO	.06	Apatite	.30
CaO	2.60	Titanite	.88
SrO	.03	Magnetite	.31
BaO	.12	Chlorite	3.00
MgO	1.21	Calcite	.45
K_2O	4.25	Pyrite	.03
Na_2O	3.22	Water below 105° C	.54
L_2O	Trace.		99.19
H_2O below 105° C	.54		
H_2O above 105° C	.73		
P_2O_5	.13		
CO_2	.20		
S	.02		
	99.95		

This description fits the average rock in this area, except that the potassium feldspar present is essentially all microcline, not orthoclase and microcline. In places along the west side so little alkali feldspar is present that the rock may be considered a diorite. On the other hand, much of the rock contains only half as much plagioclase (oligoclase) as alkali feldspar (microcline), and a third of the whole rock

[9] Lindgren, Waldemar, op. cit., pp. 81–82, 219, 223.

is quartz. The composition of this variety is that of a granite. Through the area there is a noticeable lack of basic inclusions. The quartz monzonite nowhere has a distinct porphyritic structure. It appears to differ from the rocks of the other areas in that it crumbles readily to a granitic sand.

SODA GRANITE ON WARM SPRINGS CREEK

On Warm Springs Creek, on the western border of the Hailey quadrangle, there is a mass of medium to light gray granitic rock of medium grain. This stock occupies only about a square mile, within the quadrangle, but it extends westward over a somewhat larger area.[10] The estimated composition is 40 per cent quartz, 35 per cent oligoclase, 15 per cent microcline, 10 per cent biotite, and a little titanite and apatite. It is therefore a soda granite.

SODA GRANITE NEAR KELLY CREEK

In the extreme southwest corner of the Hailey quadrangle and extending south and southwest beyond the limits of the quadrangle is a light-gray to flesh-colored granitic rock of medium grain. It consists essentially of quartz and feldspar with some mica. Quartz in some specimens makes up nearly half the rock. The feldspar is in part microcline, but most of that in the specimens examined is so thoroughly sericitized as to make exact determination impossible. It is probably a sodic plagioclase. The rock is evidently a soda granite which in its more silicic phases approaches the composition of alaskite.

SMALLER AREAS OF GRANITIC ROCKS

There are a number of small areas of granitic rock in the central part of the Hailey quadrangle. Nearly 3 miles northeast of Gimlet, in the SE. ¼ sec. 29, T. 4 N., R. 18 E., is an outcrop of biotite granite. This small area is the only known exposure of granitic rock in the vicinity of the large area of "contact-metamorphic" rocks between Elkhorn Creek and the East Fork of the Big Wood River. The small mass of granitic rock north of the quartz monzonite on the upper Big Lost River and the other one east of it are probably both outliers of the quartz monzonite. There are also two small outlying masses southwest of the granodiorite of upper Wildhorse Creek. One of these masses is 2 miles southwest of Hyndman Peak. It contains microcline, quartz, and plagioclase, named in order of decreasing abundance. The ferromagnesian minerals are biotite and hornblende, and the accessories are titanite, magnetite, and a little apatite and

[10] Umpleby, J. B., Ore deposits in the Sawtooth quadrangle, Blaine and Custer Counties, Idaho: U. S. Geol. Survey Bull. 580, pl. 4, 1915.

zircon. It has approximately the composition of a quartz monzonite. The other mass of similar rock is 3 miles southeast of Hyndman Peak on the west side of the East Fork of the Big Wood River. It is cut by dikes of tourmaline granite. At and near the junction of Federal Gulch with the East Fork of the Big Wood River are three small exposures of quartz-mica diorite. The largest is in the area between the two streams and the others are north and south of it.

DIKES ASSOCIATED WITH THE GRANITIC ROCKS

Numerous dikes with a wide range in composition cut the granodiorite and biotite gneiss on and near upper Wildhorse Creek. They are especially abundant in the gneiss. Similar dikes cut the surrounding sedimentary rocks but gradually decrease in abundance away from the contact with the granodiorite.

The more silicic dikes consist essentially of quartz, microcline, oligoclase, and biotite, with magnetite, apatite, titanite, and zircon as accessories. Some contain hornblende and, in marginal facies, augite. A few contain muscovite. The more calcic varieties consist essentially of andesine, hornblende, biotite, and quartz with titanite, magnetite, apatite, and in some varieties garnet as accessories. Some of the dikes are porphyritic, and the calcic dikes cutting the biotite gneiss are themselves gneissic. These dikes evidently represent one of the last phases of the igneous activity and are complementary dikes.

In the dikes of tourmaline granite southeast of Hyndman Peak, already referred to, microcline is the most abundant mineral. Quartz and oligoclase in varying proportions make up most of the rest of the rock, with tourmaline, muscovite, and rutile as minor constituents. Some of the scattered prisms of black tourmaline are as much as 12 millimeters in diameter, but the average is about 2 millimeters.

In the quartz monzonite near Deer Creek there are scattered aplite dikes and a few small pegmatitic masses, but in most of this exposure dikes are rare. In what appears to be a continuation of the same mass east of Croy Creek dikes of lamprophyre, aplite, and pegmatite are comparatively abundant. (See pp. 214–215). In and near the granite area near Kelly Creek there are a number of aplitic dikes.

AGE OF THE PLUTONIC ROCKS

The bodies of plutonic rock described above are sufficiently alike to make it probable that they all belong to the same general period of intrusion. As the rock is also petrographically similar to much of that in the Idaho batholith it may be regarded as probably of about the same age. Correlation based on petrographic similarity is uncertain, but with the data at hand is the only available way to arrive at any idea of the age of the granitic rock. In the Wood

River region the youngest rock cut by granitic intrusions is of Pennsylvanian age, and the oldest rock formed after the intrusions is the Miocene (?) lava. These limits leave a great possible range in age for the granitic rock.

The Idaho batholith has generally been regarded as of late Cretaceous or possibly early Eocene age, but the evidence is rather indefinite. In the Blue Mountains of eastern Oregon [11] similar rock cuts rock at least as young as upper Triassic, and sandstone of Chico (Upper Cretaceous) age farther west is undisturbed by the deformation associated with the intrusion. Thus the intrusion of granitic rock in that region took place in Jurassic or Lower Cretaceous time. Although direct correlation with the granitic rock in the Wallowa region can not be established, the data given above suggest that the granitic rocks in central Idaho, including those of the Wood River region, may be of early Cretaceous or even of Jurassic age.

VOLCANIC ROCKS

Lava flows with intercalated pyroclastic and sedimentary beds cover roughly a third of the Hailey quadrangle. Most of the lava is of Tertiary age, but two basalt flows of Quaternary age are present in the region mapped. Numerous dikes and irregular intrusive masses are associated with the Tertiary flows. The largest exposure of intrusive rocks of this age which has yet been mapped in Idaho occurs in the vicinity of Glassford Peak. Clastic deposits are interbedded with the flows in places, but they are subordinate in amount, and most of them are more or less tuffaceous.

MIOCENE (?) LAVA

Distribution and general relations.—Lava once covered most of the Wood River region, but it has been broken by orogenic movements and has been removed by erosion over large areas. The largest area remaining is the irregular belt along the northern border of the Hailey quadrangle. This belt extends an undetermined distance northward and connects westward with the extensive exposures of lava in the Sawtooth quadrangle.[12]

The exposures of older rocks in the valleys of the upper Big Lost River and its tributaries separate the northern belt from areas of similar lava in the northeastern part of the Hailey quadrangle and the northwestern part of the Mackay region.[13]

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[11] Ross, C. P., The Wallowa region, Oreg.: U. S. Geol. Survey Bull. — (in preparation).

[12] Umpleby, J. B., Ore deposits in the Sawtooth quadrangle, Blaine and Custer Counties, Idaho: U. S. Geol. Survey Bull. 580, pl. 4, 1915.

[13] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, pl. 1, 1917.

South of the granodiorite and gneiss of upper Wildhorse Creek, in the valleys of the Little Wood River and its tributaries, are other extensive patches of Tertiary lava. Along both sides of the Big Wood River there are still other outcrops, the largest of which is between the mouth of the North Fork of the Big Wood River and Adams Creek. Lava lies more than 10,500 feet above sea level in several places in the northwestern part of the Hailey quadrangle but does not elsewhere cap any of the peaks on the divide between the Big Wood and the Big Lost Rivers. This divide is the highest part of the region and may perhaps never have been covered by lava.

Slopes cut on lava are in general débris-covered and only here and there broken by bluffs resulting from the presence of thick, resistant flows. In a few places such flows are so numerous that the stratification is evident from a distance. Plate 8 shows examples of topography carved on lava. Hills composed of lava tend to be somewhat more jagged in outline and less thickly covered with vegetation than those composed of Paleozoic sedimentary rocks, but the difference is slight. Many slopes pass from one kind of rock to the other without noticeable topographic break at the contact.

In a large part of the belt of Tertiary rocks along the northern border of the region and in the area west of Hailey Hot Springs in the southern part of the region the lava has dips of 10° or less. In the greater part of the exposures, however, the lava beds are tilted at angles of 20° to 40° and more, and in places they even stand vertical. Sheet jointing is present in some of the lava, especially in the latite.

The surface on which the lava was poured out was uneven, certainly hilly, possible mountainous. This unevenness is inferred from the distribution of the lava with reference to the present topography. The base of the lava at many places is well below the mountain summits. The maximum difference in altitude is over 7,000 feet. In some places small islands of older rock project through the lava. Some such occurrences may have been produced by later faulting, but others probably resulted from the flooding of a hilly country by the lava. On the east branch of Wildhorse Creek lava lies against talus composed of Pennsylvanian débris. Locally lava rests on or is interbedded with coarse, well-rounded stream gravel. This material must have been laid down in rapid streams and therefore probably in a country of considerable relief.

It is impossible to determine how much of the irregularity in present distribution of the lava is original and how much of it has resulted from faulting later than the eruptions. Undoubtedly faulting was widespread in the Wood River region during the Tertiary period, and the displacements on some of the faults may be large. With due allowance for this factor it is evident that the Wood River region at the start of the eruptions had considerable relief.

The slopes are so thickly mantled with products of weathering that details of the stratigraphy of the lava could not be worked out in the time available. It is evident, however, that a large number of flows, many of them of moderate thickness, are present. At one locality on the northern border of the Hailey quadrangle at least nine horizontal flows of augite andesite were counted in a vertical distance of 300 feet. The total thickness of the Tertiary lava was not determined, but it is probably at least 2,500 to 3,000 feet.

In general the oldest flows are augite andesite and basalt. Above these are latite and hornblende andesite, and the youngest flows are rhyolitic in composition. These three subdivisions of the Miocene (?) lava are mapped on Plate 1. The order of eruption may vary in places from that given above. The augite andesite and basalt are black rocks, without feldspar phenocrysts, and weather to a deep-red soil. True olivine basalts are rare.

The latite and hornblende andesite form the largest division. They are reddish and commonly have feldspar phenocrysts and contain biotite and hornblende. The rhyolite is comparatively rare and is easily distinguished from the other two by its light color and prevalent glassy texture.

Augite andesite and basalt.—In the group of rocks mapped as augite andesite and basalt the basalt is rare. Most of these rocks are grayish or brownish black to black and weather to a deep-red soil. They have the composition of augite andesite. The phenocrysts are labradorite and colorless augite. In some specimens the feldspar phenocrysts are absent. The groundmass is very fine grained, consists of andesine, augite, and magnetite, and has a marked pilotaxitic texture. In one specimen an elongate, irregularly rounded aggregate of coarse quartz grains of a maximum width of 7 millimeters was noted. The rest of the rock does not appear to contain quartz.

Typical olivine basalt is present near the Red Elephant mine, in the southwestern part of the region and in a few other places. The basalt has no feldspar phenocrysts. The olivine in it is partly serpentinized. In the rock from the Red Elephant mine the olivine is abundant and exceeds the augite. The basalt and andesite are on the whole remarkably fresh.

Latite and hornblende andesite.—The rocks mapped as latite and hornblende andesite vary in composition within rather wide limits. They consist essentially of plagioclase, orthoclase, quartz, biotite, and hornblende, with augite in some of the more calcic varieties. The accessory minerals are magnetite, apatite, and zircon. The plagioclase in different specimens ranges from oligoclase to labradorite. The rocks are fairly fresh but contain chlorite, calcite, and iron oxides as alteration products. The most abundant variety is gray or pink and has numerous white, thick tabular andesine phenocrysts as much as 6 or 8 millimeters in diameter in a dark-gray or red microcrystalline groundmass. Between the feldspars are numerous smaller hexagonal plates of biotite and prisms of hornblende. Magnetite, apatite, and zircon are present in small amount. The groundmass seems to consist of quartz, orthoclase, untwinned plagioclase, small grains of some of the ferromagnesian minerals and magnetite dust.

In several localities on the Big Wood River rocks of similar composition have a black glassy groundmass crowded with feldspar microliths and showing flow structure. A specimen of such rock from the northwest corner of the Hailey quadrangle has abundant spherulites as large as 1 millimeter in diameter in the glassy groundmass. They have both radial and concentric structure and are probably composed of quartz and feldspar. Many of them have feldspar phenocrysts at their centers.

At several localities on the divide between Corral Creek and Hyndman Creek the rock is more silicic than the more abundant variety first described. It contains more quartz and less biotite and hornblende than that variety and oligoclase instead of andesine.

Feldspar phenocrysts are less prominent in the more andesitic flows than in the latitic flows. Some of the andesitic rocks are so fine grained that the components can not be determined even under the microscope. In the coarser varieties the phenocrysts are andesine or labradorite, hornblende, biotite, and augite. The biotite is rare. The augite is completely altered to an aggregate of chlorite and other minerals. It was originally present in only about half the specimens examined. Hornblende was originally abundant in all but in some specimens is largely altered to chlorite, calcite, and other secondary minerals. In some of the rocks the hornblende has been completely resorbed, and its original presence can only be inferred from the form of the residual aggregates of magnetite. The groundmass is largely fine-grained feldspar, with some quartz, which may be of secondary origin. The secondary minerals—chlorite, calcite, and iron oxides—are abundant. In places the abundant development of chlorite gives the rock a greenish tinge.

Rhyolite.—Two small areas of rhyolite are mapped, one on the south side of the East Fork of the Big Lost River, a mile inside the east border of the Hailey quadrangle, and the other at the northwest corner of a large area of andesite on the middle part of the Little Wood River.

The rhyolite on the Little Wood River dips about 50° SE. The rock is light gray or red, generally shows flow banding, and breaks into shaly débris. In places the rock is a breccia, composed of irregular fragments of laminated rhyolite lying in a rhyolitic matrix. In the less compact part spherulites as much as an inch in diameter are present. The greater part of the rhyolite is so fine grained that its constituents could not be determined under the microscope. In this aphanitic groundmass are thin bands and elongate lenses of fine-grained quartz, abundant small opaque grains that could not be determined, and a few grains of biotite and magnetite. On the north side of the rhyolite, and therefore stratigraphically near its base, black obsidian occurs in two beds about 20 feet thick, separated by 10 feet of rhyolite. The rock contains a little biotite, feldspar, and magnetite, but almost all of it is glass. The specific gravity is 2.44, and from this and its association the rock is believed to be a rhyolitic obsidian.

The rhyolite that crops out on the East Fork of the Big Lost River is similar in mineral composition and texture to that just described. It has flow banding bent in various ways.

MIOCENE (?) INTRUSIVE ROCKS

Distribution and general relations.—Stocks and large dikes of Tertiary age are abundant in the northwestern part of the Hailey quadrangle, and small dikes of related rock crop out in numerous other localities. The larger, coarser-grained masses range in composition from granite porphyry to diorite porphyry, and the narrower dikes are mostly andesite and rhyolite.

Tertiary intrusive rocks are extensively exposed around Glassford Peak, and outcrops in diminishing abundance extend southeastward past Ryan Peak as far as the head of Lake Creek. They are also abundant near the head of Boulder Creek along the western border of the Hailey quadrangle north of the Big Wood River. They occur in dikes that range in width from a few feet to over 1,000 feet and in irregular stocklike masses. Some dikes can be traced for nearly a mile. The thicker dikes are lenticular and approach the character of stocks. The larger masses mapped are complex and consist of igneous rock of varying composition interspersed with more or less sedimentary rock. The largest masses, those near Glassford Peak and Boulder Creek, are almost free from sedimentary rock, but those around Ryan Peak contain more or less of such material. It was necessary to generalize in mapping, because the intricacies of the relations between the separate masses of rock could not be shown on the scale used and because in many places the details can not be seen. The igneous rock is more resistant to weathering than the sedimentary beds it cuts. Consequently in some places the outcrops are composed exclusively of igneous material, although the hollows between them are underlain in part by sedimentary rock. In a southward-facing cirque just east of Boulder Creek, for example, only igneous rock is exposed in the floor, but on the bare ridge that forms its north wall both sedimentary rock and dikes can be seen. Eleven porphyry dikes, 50 to 150 feet thick, were counted. They make up over half of the rock in this part of the wall of the cirque.

The complex near Boulder Creek consists of a large number of irregular intrusive masses and dikes which in general have the composition of quartz diorite porphyry. Some of the dikes have a composition approaching that of granite porphyry.

The granite porphyry west of Glassford Peak has been mapped separately. More detailed work would result in further subdivision. There is much variation in composition, and the different varieties appear to grade into one another, so that accurate classification could only be accomplished by detailed petrographic study. A red rock is intruded by fine-grained diorite porphyry, which in turn is intruded by coarser diorite porphyry, and the whole is cut by dikes that vary in composition from quartz diorite porphyry to granite porphyry. The smaller masses around Ryan Peak are similarly made up of groups of dikes of different composition. Still other varieties can be found among the porphyry dikes in other parts of the region. Such dikes are widespread but except in the areas just mentioned are nowhere abundant.

The several intrusive complexes may represent the centers from which many of the lava flows were erupted. The range in the composition of the intrusive rocks, described below, corresponds fairly well to that of the two younger groups of flows. None of the intrusive rocks, however, appear to be as calcic as the lava of the augite andesite and basalt group. These flows may therefore have been derived from other sources.

Quartz diorite porphyry.—The most abundant of the Miocene (?) intrusive rocks is dark quartz diorite porphyry. The phenocrysts are oligoclase-andesine, biotite, in some specimens quartz, and rarely hornblende. The feldspar is in crystals as much as 5 millimeters in diameter but is much less abundant than in the more silicic rocks. The quartz is in rounded grains as much as 3 millimeters wide. The groundmass is an aggregate of quartz and feldspar which in places has granophyric texture. Rocks intermediate in composition between this quartz diorite porphyry and the granite porphyry are also present.

Granite porphyry.—The granite porphyry is light gray or pink. The phenocrysts are orthoclase and, in less amount, oligoclase in conspicuous red or white crystals 1.5 centimeters or less in diameter, quartz in rounded grains as much as 5 millimeters wide, and small flakes and aggregates of biotite largely changed to chlorite and other alteration products. The groundmass contains quartz and untwinned feldspar, largely in granophyric intergrowths. The accessories are apatite, zircon, magnetite, and pyrite. Chlorite, calcite, serpentine, and sericite are present as alteration products. The border facies of a few of the granite porphyry dikes is a fine-grained white rock which contains a little muscovite but much less biotite than the main mass. Granite porphyry is not common and was among the latest rocks to be intruded.

Finer-grained dike rocks.—A large number of the smaller and finer-grained dikes are of andesitic composition. The four briefly described below will serve to illustrate their general character.

A dark-gray aphanitic rock is common in the Glassford Peak area. It weathers to a rusty brown that contrasts sharply with the lighter color of the prevalent quartz diorite porphyry. It contains small phenocrysts of andesine, hornblende, and augite, named in order of decreasing abundance. The groundmass is a mosaic of quartz and untwinned feldspar. The accessory minerals are apatite, magnetite, and pyrite. The ferromagnesian minerals are much weathered.

Some of the small andesitic dikes are gray to black. One of these on the ridge north of the North Star mine is a nearly black rock in which the phenocrysts are too small to be distinguished with the unaided eye. There are abundant small phenocrysts of augite and many of altered olivine in a groundmass of abundant narrow brown hornblende prisms, lath-shaped plagioclase, and magnetite. Quartz phenocrysts are rare.

East of upper Elkhorn Creek there is a dike of dark-gray rock with phenocrysts of hornblende, biotite, and plagioclase, named in order of decreasing abundance. The groundmass is aphanitic and consists largely of plagioclase laths, ferromagnesian minerals, magnetite, apatite, and alteration products.

There are a number of greenish-gray dikes in which the most prominent phenocrysts are ferromagnesian minerals. One of these, which cuts the Pennsylvanian rocks on the north side of Eagle Creek, is a fine-grained rock without visible phenocrysts. It has a groundmass of quartz and feldspar and small phenocrysts of andesine, hornblende, and biotite. The ferromagnesian minerals are greatly weathered.

Dikes of gray rhyolite cut the tuff and lava near the northern edge of the large lava area on the Little Wood River. The rock contains abundant small phenocrysts of quartz and fewer phenocrysts of orthoclase in a felsitic groundmass. A medium-gray dike of glassy rhyolite cuts Phi Kappa shale at the head of Phi Kappa Creek. It has small orthoclase phenocrysts and aggregates of orthoclase grains in a glassy spherulitic groundmass. There are a few light-gray or greenish-white dikes that have a texture ranging from medium grained to aphanitic and consist essentially of quartz and feldspar.

QUATERNARY BASALT

In the extreme southeast corner of the Hailey quadrangle Little Wood River receives a tributary from the east. Basalt flows of late date follow this valley for 3 miles to the Little Wood River, where they turn south and leave the quadrangle. The flows dammed the Little Wood River, which first aggraded its valley above the dams to the level of the lava barrier and afterward cut through both the newly deposited gravel and the lava, carving a valley 75 feet deep and 600 feet wide. (See pl. 3, *A*.) Two flows are exposed in this gorge; the upper is about 10 feet thick, and the upper 20 feet of the lower is exposed. Both have columnar jointing. The surface of the upper lava flow, except for a veneer of gravel or of yellow-brown soil, is formed largely of blocks of lava and is essentially in its original condition.

The rock is a gray-black microcrystalline lava. Rounded steam holes as much as 0.5 millimeter in diameter are scattered through it, and there are abundant minute openings into which minerals project. The rock contains labradorite prisms averaging 0.5 millimeter but reaching 1 millimeter in diameter, lying in all directions, between which are the other constituents, augite, olivine, and magnetite, abundant in the order named. The rock is mineralogically and texturally a typical basalt.

AGE OF THE VOLCANIC ROCKS

The rocks described as Miocene (?) lava and the associated Miocene (?) clastic deposits are so related that all must be of the same general age. The only fossil identified from any of them is *Sequoia angustifolia*, found by Lindgren.[14] He remarks that this fossil plant appears to be characteristic of the Payette formation, which is of Miocene age. On this basis and because of their similarity in composition and general geologic relations to lava in other parts of Idaho that has generally been considered probably of Miocene age, the andesite, latite, and rhyolite and the associated basalt and clastic material in the Wood River region may be tentatively assigned to the Miocene.

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[14] Lindgren, Waldemar, op. cit., pp. 95, 197.

The texture of the quartz diorite and granite porphyries and the porphyritic dikes show that these rocks consolidated much closer to the surface than the quartz monzonite, granodiorite, and related rocks of probable Cretaceous age. In appearance and mineral composition many of the dikes are indistinguishable from some of the flows of andesite lava.

In places near Ryan Peak and in other localities porphyry dikes cut the Miocene(?) lava. Elsewhere the lava appears to rest on a surface that truncates porphyry dikes. In these places the lava must be younger than the dikes. In general the evidence favors the conception that the porphyritic rocks are closely related in age and genesis to the Miocene(?) lava, although direct proof is lacking for most of the intrusive masses.

The two basalt flows in the southeast corner of the Hailey quadrangle are clearly much younger rocks than the rest of the lava and are probably late Pleistocene or even Recent. When they were extruded the topography was essentially as it is to-day. The only change since then is the cutting of the narrow gorge (600 by 75 feet) occupied by the Little Wood River. These flows are the only representatives in the Wood River region of the basalt that floors extensive areas in the Snake River plains.

STRUCTURE

GENERAL FEATURES

The sedimentary rocks of the Wood River region have been greatly folded and faulted and are cut by igneous masses of many kinds and of at least two ages. The resultant effect of crustal disturbance and subsequent erosion has been to produce a belted or zonal arrangement of the masses of stratified rocks now exposed at the surface. These trend in a broad way N. 40°–50° W., although transverse faults and igneous masses interfere with the continuity and regularity of the zones.

The great thickness of the formation, the small number of reliable horizon markers, and the presence of abundant débris and rather thick vegetation make it difficult to decipher the complex structure. The major structural features and many of the details have, however, been determined and mapped in Plates 1 and 9. The structure sections on Plate 1 serve to illustrate the interpretation of the structural features. All available data have been taken into consideration in their construction, but the sections must be considered essentially diagrammatic. In many places they extend to depths far below the limits of observation. Question marks have been inserted in places to indicate that in these places direct evidence is lacking, and the attitude of the rocks has been sketched on purely inferential grounds.

HORIZON MARKERS

The two horizon markers that have been of greatest assistance in working out the structure of the region are the conglomerate at the base of the Wood River formation and the unconformity between the Tertiary and Paleozoic rocks. The conglomerate referred to is the only unit of the stratigraphic column that is sufficiently distinctive and persistent to be used as a horizon marker throughout the region. This conglomerate forms lenticular beds in some places, but on the whole it is uniform in character and has been found in so many places that it may be assumed to have been deposited almost continuously throughout the area originally covered by the Wood River formation. If its deposition had been absolutely continuous, any contact between the Wood River formation and older beds at which the conglomerate is absent would be an undoubted fault. In places fault breccias and other confirmatory evidences of displacement are found, but many of the faults mapped are based solely on the absence of the conglomerate, and some of them may not exist, because the conglomerate is known to form lenticular beds.

The easily recognized unconformity at the base of the Miocene (?) volcanic rocks is one of the most useful means available in fixing limits to the possible age of structural disturbances. Obviously any fault or fold in the older rocks which is truncated by this unconformity is of earlier date than the erosion period which ended with the Miocene (?) eruptions.

FOLDS

All the pre-Tertiary strata are strongly folded, but the beds of the Milligen formation are in places more intensely crumpled than any of the others, because the soft carbonaceous argillite, which is the principal component of that formation, was comparatively incompetent and yielded more readily to the stresses than the more rigid rocks, largely quartzitic sandstones, between which it lay.

In the basin of the Big Lost River, in the northeastern part of the region, the Pennsylvanian (Wood River) rocks lie in open folds which trend north-northwest and in the extreme northeastern corner of the Hailey quadrangle nearly north and locally even northeast. The folding there is irregular, and the trend is much less uniform than it is farther south, and the absence of suitable horizon markers made it impossible in the time available to work out the details of the structure of the Paleozoic rocks. Some of the major features are indicated in section A–A′ in Plate 1, and the diversity of trends can be judged from the strikes and dips plotted on the map.

In a broad way the beds appear to dip gently east and northeast away from the granitic masses on the northeast side of the main divide.

On and near this divide extensive areas of rocks of the Wood River formation are bent into long, moderately open but broken and somewhat overturned synclines. The most continuous of these synclines is exposed along and south of the divide from Ryan Peak southeast nearly to the head of the Little Wood River, where it terminates against a normal fault. This syncline is overturned toward the northeast. On its southwest side many beds are inclined as much as 20° beyond the vertical, and in places the rocks are closely folded and faulted. This syncline is bounded on the northeast throughout its length by a thrust fault. On its southwest side it is bounded along much of its length by normal faults that bring it against folded beds of the Milligen formation, in which the predominant dip appears to be toward the southwest.

Another synclinal mass of Wood River beds extends continuously from a place south of Ryan Peak to Lake Creek parallel to the syncline just described and separated from it by a narrow strip of Milligen rocks. Between Lake Creek and Hyndman Creek it is continued in a series of separate areas, whose structure indicates that they are fragments of an originally continuous syncline. The axes of most of them plunge to the southeast. Overturning has taken place in this belt but is less common than in the parallel syncline immediately to the northeast. Along parts of the synclinal axis the beds lie nearly horizontal. Here, as in the syncline previously described, the Pennsylvanian rocks are bounded on the northeast by thrust faults and on the southwest in part by normal faults. The pair of synclines indicated near the east end of structure section D–D′ in Plate 1 may be the southeast continuation of the two synclinal zones just described, but the intervening area of Tertiary lava masks the relations.

Between the areas just described and the Big Wood River the structure is less regular. Remnants of a third syncline parallel to the other two are represented by a belt of small areas of the Wood River formation over a distance of 16 miles between Hyndman Creek and the East Fork of the Big Wood River on the summits of the ridges. The one between Eagle Creek and Lake Creek is clearly synclinal. The others to the southeast as far as the East Fork are smaller and are either nearly flat or exhibit only gentle dips. The dips and strikes plotted in Plate 1 indicate that synclinal structure may continue across Hyndman Creek into the area south of Glassford Peak.

In the broad strip of Milligen rocks that extends from Eagle Creek across the East Fork of the Big Wood River almost to the Little Wood River the structure is obscure. Apparently in the greater part of this area the dips are predominantly to the southwest, but there are many variations. These soft rocks are probably crumpled into many small folds and broken by numerous faults, which could be worked out only by most detailed study. The representation of the folds in this part of the region given in the sections in Plate 1 is purely diagrammatic.

In the area northeast and east of Harley, occupied principally by the Wood River formation, the structure is probably that of a broad, unsymmetrical compound syncline, as is indicated in section C–C′ in Plate 1. Here also many details remain undetermined, and numerous faults besides those shown presumably exist. The boundary between these rocks and the strip of Milligen beds just mentioned is a thrust fault which disappears beneath the lava near Ketchum on the northwest and beneath that near the Little Wood River on the southeast.

Some idea of the structure of the Paleozoic rocks in the southwestern part of the Hailey quadrangle south of Adams Creek and west of the Big Wood River may be gained from sections A–A′, B–B′, and C–C′ in Plate 1. The eastern part of this area appears to consist of a compound anticline, which tends roughly N. 20° W. and is broken by normal faults, especially in the southern part. Anticlinal structure continues southeastward past Bellevue, with the axis along the Big Wood River, as can be seen from Plate 9, which in this part of the region is based on the work of D. F. Hewett. Farther west is a compound syncline, and in the extreme southwest corner of the quadrangle the structure appears to be anticlinal.

FAULTS

OVERTHRUST FAULTS

The synclines east of the Big Wood River are broken on their northeast sides by thrust faults. As few fault surfaces can be actually seen and none of the exposures can be followed very far, the only available method of determining their dips is by calculation based on the relations of the boundaries as mapped to the topography. In a region of moderately simple structure, where exposures are good and an accurate detailed topographic map is available, this method may yield excellent results, but in the Wood River region the structure is complicated and the exposures are in general unsatisfactory. In so rugged a country a map on a scale of 1:125,000 can not be expected to show accurately many of the details of the topography. The apparent presence of normal faults along many of the transverse valleys, where the most suitable exposures would otherwise be expected, introduces another large element of uncertainty into the calculations. The figures as to dips of faults, especially thrust faults, in this report must be considered merely approximations. Although observations in places indicate moderately high dips, it seems likely from the general distribution of the formations that the average dip of many of the thrust faults is very low.

The thrust fault near the main divide appears to be the longest, but if erosion had not removed the evidence some of the others might have been found to be equally extensive. The dip of this long fault, as indicated by the fault trace as mapped on Plate 1, is variable. In some places northwest of Wilson Creek it appears to be about 20°; elsewhere only about half that. Southeast of Wilson Creek the average dip is steeper, and in places it reaches 45°. This increase in dip may have been caused by tilting during the intrusion of the granitic rocks a short distance to the northeast. If so, this implies that the faulting preceded the intrusion. The fault, which has been traced along its strike for about 20 miles, is not a simple fracture but is made up of a number of fractures with branching and outlying subsidiaries. The strip of rock of the Milligen formation near the northwest end appears to be bounded on both sides by thrust faults, doubtless branches of the same general fault zone. Some of the faults in the metamorphic rocks near Hyndman Peak may, as indicated in section B–B′, Plate 1, be of reverse type, but the evidence is inconclusive.

A similar thrust fault, with dips of 30° and less, extends from a point south of Ryan Peak across Lake Creek and probably farther southeast. A fault supposed to be a continuation of it is indicated in section B–B′, Plate 1, and the same zone of faulting may perhaps continue southward to the junction between the two synclines shown near the east end of section D–D′, Plate 1. The distance between the synclinal axes is much too small to accommodate an unbroken anticline in the thick Wood River formation. Consequently, it may be assumed that part of this formation has been faulted out. Along the crest of the divide above the heads of Eagle and Lake Creeks for a distance of over 2½ miles a nearly horizontal fault separates the Wood River sandstones of the crest from similar rocks below.

Another large thrust fault forms the northeast boundary of the area of Wood River rocks east and northeast of Hailey. It is exposed from Decker Creek along an irregular line trending east and southeast to its disappearance beneath Tertiary lava near Little Wood River.

The faults on the northeast borders of the synclinal zones are considered to be thrusts for two reasons. Although the exact dip can not anywhere be determined, the average is clearly much less than the usual dip of normal faults. The more conclusive evidence, however, is in the relations between the rocks on opposite sides of the faults, which are such as could have been produced only as a result of thrust faulting. In each place a syncline, more or less overturned by a thrust from the southwest, is broken along a plane dipping gently southwest. The rocks in the axis of the trough or on the southwest flank of the syncline have been pushed over the rocks to the northeast. In most places the lower part of the original syncline is in the footwall down the dip from the present outcrop of the syncline and is consequently concealed. The character of the faulting is shown diagrammatically in Figure 5. The rock at the surface

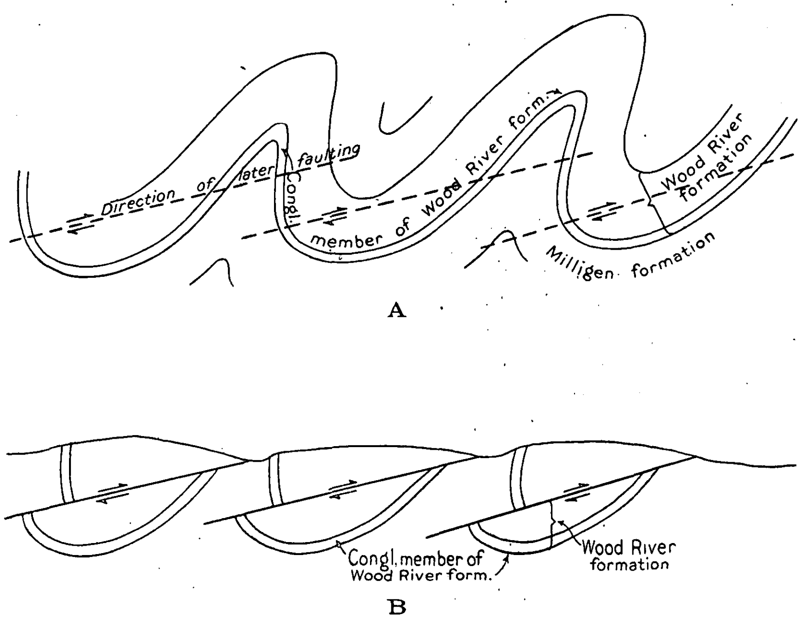

FIGURE 5.—Relation of thrust faults to folds. A, After folding but before faulting; B, after faulting and erosion—the present condition

on the hanging-wall side of each fault is younger than that on the footwall side. This condition arises from thrust faulting in folded and partly overturned rocks and from the depth to which erosion has extended.

NORMAL FAULTS

Numerous faults of apparently normal throw cut the rocks of the region. Some of these have already been referred to and others are indicated on Plates 1 and 9. Many probably exist for which direct evidence has not been obtained. In large areas covered by rocks of a single formation in which distinctive beds are lacking, such as the Wood River or the Milligen formation, faults can be recognized in few places and traced in still fewer, although they are probably abundant in such areas. For example, east of Hailey and in the valley of Slaughterhouse Creek numerous faults offset the basal conglomerate, and these doubtless extend into the adjacent areas of Milligen and Wood River rocks. The lack of recognizable horizons and the scantiness of outcrops make it impossible to trace faults through these areas. Some of those shown near the west end of section D–D′ in Plate 1 are based solely on inference from observations on the conglomerate at some distance from the line of the section; but, as shown on pages 27–28 and in Figure 3, some of the apparent offsets of the conglomerate have been proved by more detailed work to be due to the overlapping of parallel lenses.

Although few of the fault planes of the faults mapped were observed, numerous strikingly perfect fault faces of minor faults, in some places parallel to the larger faults, were found. The striae on such planes commonly depart, many of them by a large angle, from the perpendicular, thus demonstrating a large lateral element in the displacement.

In the area covered by the Wood River formation northeast of Hailey, and to some extent elsewhere, rock ledges, generally nearly vertical, stand out from the hillsides. From a distance these resemble outcropping ledges of the basal conglomerate, but they are really breccias, consisting principally of angular fragments of quartzitic sandstone which on recementation have become more resistant to weathering than the unbrecciated rock adjoining them. These breccias are probably due to crushing of the country rock along fault planes.

Most of the faults mapped as normal may for convenience of description be divided into five groups—(1) those with northwest trend along the southwest borders of the zones of rock of Pennsylvanian age; (2) those with an average northeast trend; (3) those associated with the granitic rocks; (4) those with northerly trend near Bellevue; (5) those which affect Tertiary rocks.

The faults of the first group trend N. 40°–50° W., approximately parallel to the zones and to the thrust faults that emerge on their northeast borders.

The second group comprises faults trending in general northeast but varying in strike between rather wide limits. Their dip appears to be commonly northwest. This group includes such faults as those on the north sides of the valleys of Lake and Slaughterhouse Creeks, the fault of northeast strike about 2 miles west of Hailey, and a number of smaller faults that cause offsets in the bands of basal conglomerate on the southwest borders of the zones of Pennsylvanian beds near and southwest of the main divide. The breaking up of some of the long synclines mentioned above into detached masses, which commonly dip southeast, may result from such faults.

From the data presented above it seems evident that the folding and overthrusting were essentially effects of the general orogenic disturbance in which the Paleozoic beds were compressed into folds and in places finally broken. The faults of northwest strike and supposed normal displacement are so nearly parallel to the strike of the folds and thrust faults as to suggest a genetic relationship. The faults of northeast strike cut both of the sets of faults of northwest strike. Both the northeast faults and the apparently normal northwest faults may have resulted from the relief of comparatively minor stresses late in the same period of disturbance in which the folding and thrust faulting took place, but definite proof of this hypothesis is difficult to obtain.

The third group of faults includes those along and related to the contacts of the masses of granitic rocks. These faults have various trends, corresponding more or less closely to the boundaries of the igneous bodies. The beds of the lower part of the Phi Kappa formation surrounding the outcrop of monzonite on the upper Big Lost River dip away from the monzonite on all sides, and the rocks thus domed up are bounded by an irregular group of faults. On the north side of the large mass of granitic rock northeast of Hyndman Peak the character of the intersection of the surface of contact between the granitic rock and the sedimentary rocks with the present topography indicates that the contact is an approximately plane surface. There is no direct evidence of intrusion along the contact, but the effects of crushing are manifest in rock adjoining it and indicate that this contact is a fault surface. Near the southeastern border of the same granitic mass a fault with northeast trend and southeast dip separates the Pennsylvanian (Wood River) and older rocks. This fault bears southwest toward and may possibly be continuous with the similar fault between the Wood River and Milligen formations at the head of Porcupine Creek. These faults and those in the older rocks southwest of the granitic mass may be conceived to constitute a rim of faults similar to that surrounding the smaller mass on the Lost River.

The granitic masses of the Wood River region are of later origin than the principal folding that has been described. In the southern part of the region most of them trend northwest, roughly parallel to the principal structural axes, showing that their shapes were controlled to some extent by preexisting structural features. In the northeast, however, they cut squarely across the old folds and to some extent domed up the rocks in their vicinity into new folds. This doming is most clearly shown around the monzonite at the head of the Big Lost River.

As was first suggested by Eldridge,[15] in its broadest aspect the structure of the Wood River region is that of a large compound anticline, broken by many faults. The axis lies approximately along the main divide between the drainage of the Big Wood River and that of the Big Lost River. The strike is thus about N. 60° W. and makes a small angle with the average strike of most of the folds and faults referred to above, which is more nearly N. 40°–50° W. This broad, regional upwarp superimposed on the previously folded Paleozoic beds may be one of the early results of igneous activity. The stocks now exposed are presumably offshoots of a larger batholithic mass not yet revealed by erosion. When the great body of granitic magma began to be introduced into the rocks of the crust, those above it may well have been domed up just as the strata around some of the exposed subsidiary masses are seen to have been domed. If not too deeply buried some of the strata would break under the strains set up during intrusion, and faults would be formed. Some of the faults now found near the intrusive bodies are presumably of this character and were formed during or immediately after the intrusion. Possibly the cooling rock in the upper parts of the stocks settled back on the still liquid magma below with consequent development of stresses in the surrounding rocks, and thus another means of producing faults in and near the granitic rocks would be created.

In general, faults formed as suggested in the preceding paragraph would be results of tensional stresses and be of normal displacement. The displacements on a few of the faults appear, however, to be so great that such stresses seem inadequate to account for them. The displacement on the fault northeast of the monzonite on the Big Lost River is especially noteworthy. It will be noted that this fault brings rocks of the Wood River formation (Pennsylvanian) against those of the lower part of the Phi Kappa formation (Ordovician). The entire Milligen, the upper part of the Phi Kappa formation, a large part of the Wood River formation, and probably part of the lower Phi Kappa are cut out. If the formations here originally were of the average thicknesses estimated in other parts of the region the beds cut out had a total thickness of well over 8,000 feet, and on the dip of the fault, which cuts the beds at a considerable angle, the throw would be much greater than this. The other faults in the group surrounding the monzonite or the Big Lost River merely bring the upper and lower parts of the Phi Kappa formation against each other and may therefore be of moderate displacement.

The displacement of the fault on the north side of the larger granitic mass appears to be large, at least at its west end, where it

[15] Eldridge, G. H., A geological reconnaissance across Idaho: U. S. Geol. Survey Sixteenth Ann. Rept., pl. 2, p. 265, 1895.

brings part of the Wood River formation against rocks supposed to be of Algonkian age. Along part of the fault on the southeast side of the granitic mass the same two formations are in juxtaposition. The metamorphosed rocks on the southwest dip away from the granitic rock and are broken by numerous faults, which may be of diverse origin. The original movements along the faults of very large displacement may antedate the intrusions with which these faults are now so closely associated. Thrust faults with throws of the order of those exhibited by the faults under discussion, appear to have existed in the region prior to the beginning of the igneous activity. If old thrust faults were tilted during the doming incident to intrusion, such relations as are now observed might be produced. The direction of dip of the fault planes involved in the uplift would be changed and might well be reversed in places. The original relations would probably be further obscured locally by normal displacements on planes approximately parallel to the old fractures but produced as a result of the intrusive activity.

The granite masses in the southern part of the region do not appear to be surrounded by any such plexus of faults as those discussed above. Many of the zones of fracture containing the ore deposits in this part of the region are roughly parallel to the intrusive contacts, but there is reason to believe that these fractures antedate the intrusions. (See pp. 96–97.) Whatever their age, the displacements along them are probably small.

A fourth group of faults comprises those mapped by Hewett in the general vicinity of Bellevue (pl. 9) and their extensions mapped by Westgate near Hailey. The strike of the faults of this group swings from nearly north, and even a little east of north, southeast of Bellevue, to N. 20°–30° W. near Hailey. East of Hailey several faults that trend about N. 40°–50° W. have been mapped. These have trends similar to the first group and may belong to it. In the area mapped and described by Hewett (pp. 217–219) the faults of northwest strike east of the Big Wood River dip southwest and those west of it dip northeast.

The faults that displace Tertiary lava and intrusive igneous rock and are thus definitely shown to be Tertiary or younger constitute the fifth group. These faults range in strike all the way from N. 60° W. to N. 60° E. The principal faults of this group that have been mapped include those bordering the basalt in the northwestern part of the Hailey quadrangle, the northeastward-trending fault southeast of Glassford Peak, the northwestward-trending fault along Two Bridges Creek, the two northwestward-trending faults east of Ketchum, and some similar fractures on both sides of the Big Wood River near Hailey.

The structure of the lava near Indian Creek north of Hailey is not entirely clear. Short faults involving Tertiary lava are indicated in several other places on Plate 1, and doubtless many exist which have not been mapped. The lava and tuff, believed to be of Miocene age, which cover more than a third of the Wood River region have a dominant dip to the northeast. The average is 30° to 40°; here and there, especially in the north, it is less; but in numerous localities it is much greater, and in some places reaches 90°. This dominant eastward dip at relatively high angles across the whole width of the quadrangle almost necessarily implies faulting. At one place lava dipping 30° E. and conformably overlying conglomerate which in turn lies unconformably on upturned Ordovician beds, can be seen to have been faulted, with a displacement of 400 feet. In most of the few places where such clear evidence of faulting can be observed the faults are minor ones.

Most of the fault lines in Tertiary rocks drawn on Plate 1 are based on inferences from the distribution of the lava and of the adjacent sedimentary rocks and from the relative attitude of the rocks involved. Most of the boundaries are marked by débris. The boundary along the northeast side of the lava area near Ketchum, north from Decker Creek, has a zigzag course as it crosses successive ridges and valleys; this course indicates that the surface which separates the lava from the Milligen beds is approximately plane and dips southwest. The lava dips toward this plane at angles of 30° to 40°. From these facts the presence of a fault is inferred. It could, of course, be inferred that the lava was laid down against a steep and essentially plane-sided valley and that the tilting took place subsequently, but this seems a much less reasonable supposition. On similar evidence the presence of a fault east of the lava and gravel traversed by Indian Creek is inferred. East of the lava on Mahoney Creek positive evidence of fault movement was found. In a number of places the lava has apparently excessive thicknesses. This condition is presumably accounted for by faulting, but where definite evidence of their existence was not found no faults are indicated on the map.

POSSIBLE RELATION OF FAULTS TO DRAINAGE SYSTEM

The striking regularity of the pattern produced by the principal streams in the region suggests structural control. This suggestion is not everywhere supported by direct geologic evidence, but there are a sufficient number of places where accordance in direction between valleys and faults gives support to the idea. Perhaps in places there was enough shattering to aid in determining the position of a stream valley without sufficient displacement of the rocks to be recorded on a geologic map.

Figure 6 shows the result of drawing lines along the principal stream valleys, disregarding minor irregularities in their courses. The pattern produced is markedly like a joint pattern, such as is frequently observed in rock outcrops. It is the sort of pattern that

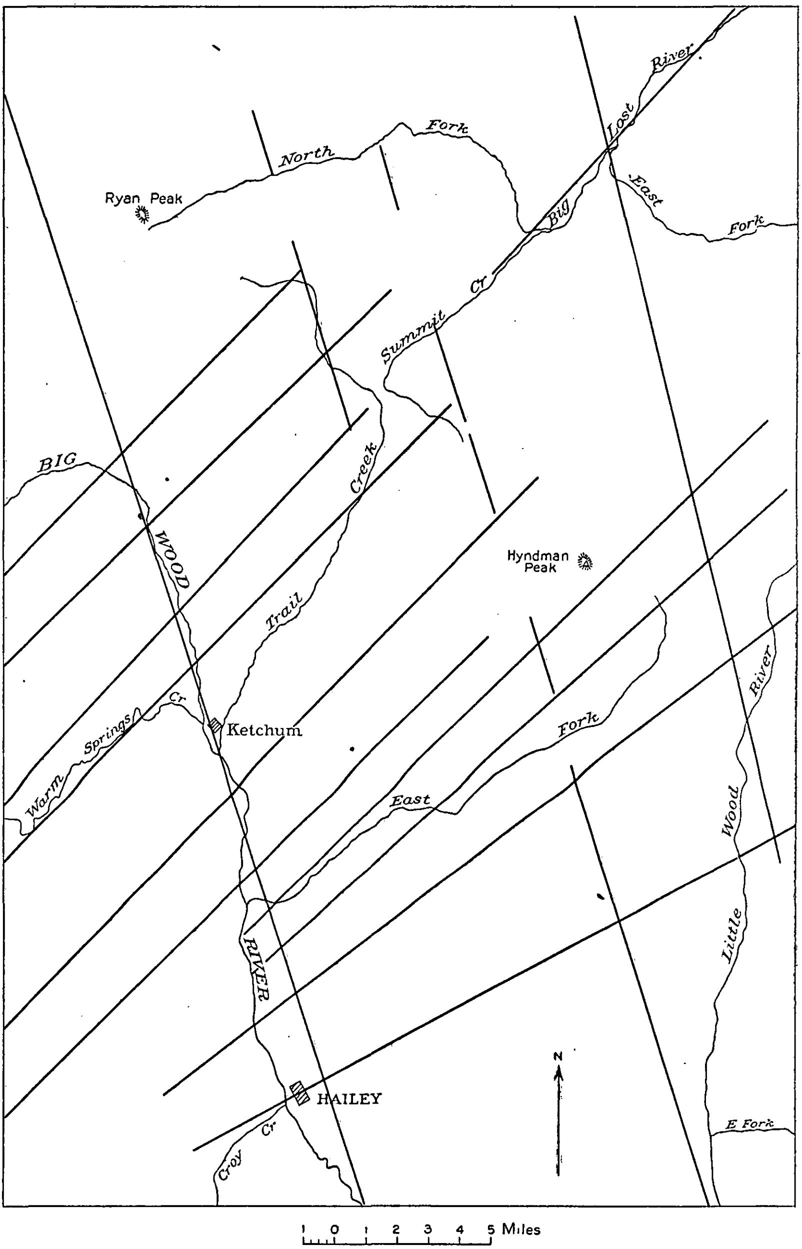

FIGURE 6.—Possible fault lines inferred from the drainage pattern in the Wood River region

might be expected if tensional stresses in the crust had been relieved by normal faulting.

This hypothesis implies that there are a number of rather long faults or zones of shattering with an average strike of N. 20° W. and a more closely spaced but shorter group, which in the northern part of the region has an average strike of about N. 50° E. but swings gradually in the southern part to nearly N. 60° E. Some of the stream valleys do not fall in either group, but the exceptions are remarkably few. The side gulches and headwater branches were of course formed subsequent to the development of the main drainage pattern and are largely independent of the factors that determined the directions of the main streams. Some of the component parts of the main divide and a number of the minor ridges are parallel to one or the other of the two sets of lines drawn in Figure 6, but in general the elongations of the principal elevations are parallel to old structure lines. Some of the faults of northeast strike previously described are nearly parallel to the northeastward-trending stream lines. A few of the faults in Tertiary lava, such as the one on Twin Bridges Creek and one near the head of Greenhorn Creek, are nearly parallel to those that trend N. 20° W., but most of the longer faults swing farther west. More or less continuous patches of Tertiary lava border the Big Wood River in a manner which suggests that either a valley existed here prior to the volcanism or else later faulting dropped these portions of the lava sheet down into the depression now occupied by the Big Wood River and thus protected them from the erosion that has removed the lava and related beds from most of the neighboring ridges.

Hewett suggests on page 218 that a scarp on the west side of the Big Wood River near Bellevue may be a result of recent faulting. The northern part of this scarp is shown in Plate 9. Similar scarps elsewhere in the region may also have such an origin. Most of the principal valleys and most of the side gulches near their mouths have side slopes that are distinctly oversteepened near the base on one or both sides. It seems more probable that this widespread oversteepening in the lower parts of valley profiles results from recent rejuvenation of the streams by uplift or other cause rather than that these steep slopes are fault scarps. The uplift may well, however, have been accompanied by faulting.

GEOLOGIC HISTORY

PROTEROZOIC (?) ERA

If, as here assumed, the Hyndman and East Fork formations are of Algonkian age they record the fact that here, as elsewhere in most of Idaho and adjoining regions farther east, there was prolonged marine sedimentation in the Algonkian period.

Nearly 5,000 feet of the Hyndman formation is a clean quartzite which contains at some horizons sand grains and even pebbles as much as an inch in diameter, and has a cross-bedded structure. Its purely siliceous character results from long wear, in which all the softer minerals of the original rocks were worn down and carried away, and this wear may have taken place either by the action of waves or through long carriage by streams. It is impossible to exclude either process, but the absence of finer sediments, such as would have been likely to occur in parts at least of any great river flood plain or piedmont alluvial slope, makes the first seem the more probable origin. If so, deposition must have taken place on a sinking sea bottom, for there is a thickness of nearly a mile of these shallow-water sands.

Twice the accumulation of sand seems to have been interrupted by subsidence. Only finer material could reach the region at those times, and two deposits of mud were laid down, the later one limy. These muds made the schist and the green hornfels members of the Hyndman formation respectively.

The East Fork formation records a period of limestone formation offshore yet in a sea shallow enough or near enough to land to receive at times noticeable amounts of land-derived sediment. Beds of schist and quartzite in the formation mark near-shore or land conditions. Each of the two pure quartzites, one within the lower limestone member and the other between the two limestone members, indicates a retreat and readvance of the sea, during which rivers and waves together made a deposit of sand across the region.

PALEOZOIC ERA

The Hyndman and East Fork formations are everywhere separated from the younger sedimentary rocks by faults. Consequently the character of the stratigraphic break between them and the overlying beds can not be determined. In early Ordovician time marine sedimentation was resumed, and the mud, fine sand, and local beds of coarser sand which made the early Ordovician and the Phi Kappa formations were laid down in the shallow waters offshore. These conditions continued into Silurian time, but the failure to find any large thickness of Silurian rock points to land conditions during most of that period.

According to the interpretation of the stratigraphy given in this report, no Devonian rocks are recognized in the Wood River region, although strata of that age are abundant a short distance to the east,[16] and it is possible that some Devonian beds are present in the basal part of the Milligen formation.

In Mississippian time a shallow sea covered the region, and in this sea were laid down the mud, in many places carbonaceous, and the subordinate amounts of sand that now make the shale and quartzite of the Milligen formation. From time to time either a deepening of the water or changed conditions on land afforded clearer waters, in which limestone accumulated.

There was probably a break in the continuity of sedimentation at the end of the deposition of the Milligen beds. This break is indicated by the almost universal presence of conglomerate at the base of the overlying Wood River formation, of Pennsylvanian age. On the other hand, at the head of Lake Creek the two formations seem to grade into each other without break. At this place and presumably at others the land remained submerged, but in most of the region there appears to have been emergence above the sea for a sufficient time to permit débris to accumulate on the land surface.

When the sea readvanced in Pennsylvanian time the waves reworked the débris that had accumulated and formed the conglomerate at the base of the Wood River formation. Locally even during the formation of this conglomerate quieter conditions favored the accumulation of calcareous sand. These conditions soon became general, and in an open sea, inhabited by an abundant brachiopod and coral fauna, thick deposits of limy sand were laid down. Later, with a shoaling of the sea or with altered land conditions, deposition of limy mud took place. Somewhat later still the deposition of the main mass of the Wood River formation began. Several thousand feet of sand, in part calcareous, in part clean quartz sand, was laid down. It is not easy to picture the exact conditions under which these deposits accumulated. Their even bedding, the occurrence of *Fusulina* at different horizons from bottom to top, and the presence at several horizons in the body of the formation of beds of blue limestone with marine fossils suggest that the whole series is of marine origin. On the other hand, cross-bedding at some horizons and the great thickness of the deposit (8,000 feet) point to a fluviatile origin. A much stronger indication of fluviatile origin is the presence in the formation of several hundred feet of conglomerate with well-rounded boulders as large as 15 inches in diameter.

[16] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, pp. 26–27, 1917.

Perhaps the truest picture one can form is that of a shallow sea, with the land on its border standing in a critical and balanced position with reference to the sea. During most of the time marine sand was accumulating. Occasional lowering of the sea floor permitted the formation of impure limestones, but at other times the land gained on the sea and stream-laid sand and coarse gravel were deposited. In the end land conditions prevailed, and sedimentation, even fluviatile sedimentation, if such there had been, ceased. When this change took place, whether at the end of Pennsylvanian time or during or at the end of Permian time, is not known. Permian rocks are known in eastern Idaho; they may have existed in this region and later been removed by erosion.

MESOZOIC ERA

Mesozoic sedimentary rocks are absent in the Hailey quadrangle. Both east of this region, in the main Rocky Mountain belt, and west of it, in eastern Oregon, seas were in existence during this era, but there is no evidence that these seas at any time extended over central Idaho. The region seems to have been throughout Mesozoic time a land area of no great height, which perhaps furnished sediments to neighboring seas.

Near the end of the Mesozoic era came tremendous structural and igneous disturbances. These are doubtless to be correlated with the great Laramide revolution, which resulted in profound crustal disturbances throughout the Rocky Mountain region. In the Wood River region a thrust from the southwest threw the Pennsylvanian and earlier rocks into a series of northwestward-trending folds, which in some places were not only overturned but broken, passing into thrust faults. Possibly, while the folding and thrust faulting was going on normal faulting was in progress, and certainly normal faulting took place on an extensive scale after the folding had ceased.

Structural deformation due to the intrusion of igneous rocks was added to that which resulted from the folding. The great granitic batholith of central Idaho, one of the largest on the North American continent, was intruded at this time, and the several bodies of granitic rock that lie wholly or in part within the Hailey quadrangle are satellites of this batholith. Although the several masses differ more or less in composition, there are sufficient resemblances to suggest that they were all derived by differentiation from the same parent magma. The process of differentiation was slow, and the different intrusions within the quadrangle are probably not strictly contemporaneous. The intrusions are clearly later than the principal folding and thrust faulting. Doming and normal faulting accompanied the intrusion of the granitic rocks in the northern part of the region, at least.

The presence of large bodies of hot rock buried within the crust and cooling slowly was the cause of considerable metamorphism in the surrounding formations. Chemical and mineralogic changes were favored both by the increased temperature of the sedimentary rocks and their contained water and by the contribution to them of materials from the igneous magma itself. Such changes are especially noticeable toward the west side of the area, in the direction of the great batholith.

The exact age of the granitic rocks generally grouped as the Idaho batholith and related intrusions is still an open question.[16a] It is probably Cretaceous but may be older. The Idaho batholith and its satellites have as yet received little detailed study and may perhaps be more complex and have a wider range in age than is usually conceived.

The crustal disturbances and batholithic intrusions resulted in the uplift of central Idaho. Subsequent erosion cut the region into mountains that were probably higher and more rugged than those of the present day, as is suggested by the relation of Tertiary rocks to the older rocks.

CENOZOIC ERA

After the production of mountainous topography in the Mesozoic era erosion continued to wear away the land. Thousands of feet of sediment were removed from central Idaho. In the Wood River region, for example, the Pennsylvanian rocks, which alone have a thickness of much more than a mile, were removed from large areas. Umpleby [17] believes that before the end of Eocene time central Idaho had been worn down to a peneplain. Remnants of a peneplain or at least of an old erosion surface of low relief have been recognized by numerous geologists in central Idaho and neighboring regions. Umpleby's conception of the age of this surface is, however, doubted by some.[18] In the Wood River region the old erosion surface has not been recognized. Consequently studies confined to this region have no direct bearing on the age of the surface. Whatever the sequence of events in early Tertiary time in the Wood River region

[16a] Ross, C. P., Mesozoic and Tertiary granitic rocks in Idaho: Jour. Geology, vol. 36, pp. 673–693, 1929.

[17] Umpleby, J. B., An old erosion surface in Idaho: Jour. Geology, vol. 20, pp. 139–147, 1912; Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, pp. 24–27, 1913; Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, pp. 14–17, 1912.

[18] Blackwelder, Eliot, The old erosion surface in Idaho; A criticism: Jour. Geology, vol. 20, pp. 410–414, 1912. Rich, J. L., An old erosion surface in Idaho; is it Eocene?: Econ. Geology, vol. 13, pp. 120–136, 1918.

the surface on which the Miocene (?) lava flowed appears to have had moderate relief.

The most striking event in the Tertiary history of the region was the great eruptions of volcanic material. It is not possible to fix closely the time limits of this period. Volcanic eruptions appear to have taken place intermittently in various parts of the Northwest throughout the Tertiary period and to have continued into the Quaternary. The maximum activity was in Miocene time, and there is some reason to believe that most of the volcanic rock in the Wood River region is of Miocene age.

The particular order of events differed in the different parts of the region. Along the northern border of the Hailey quadrangle several thousand feet of latitic and andesitic flows and tuffs were built up, to be followed by several hundred feet of flows of augite andesite and basalt. Along the Little Wood River the earliest flows, at many places, were augite andesite, and the same is true for the area south and west of Gimlet. It is not possible to state to what extent the preexisting topography was buried by the lavas. Along the northern border of the Hailey quadrangle the earlier valleys were filled, the divides were covered, and a broad lava plain was the final result. Along a rather broad summit belt southeast of Ryan Peak lavas are now lacking; away from that belt lavas are found in a few places on even the highest ridges. Probably along the present divide there were hills rising well above the highest levels reached by the lavas, and it is not unlikely that even at a distance hills of the older rocks were not buried. Nevertheless, broad plains of lava, similar to the Snake River Plains of to-day, are thought to have been perhaps the most distinctive feature of the landscape when the last lavas had been poured out.

The tuff interbedded with the lava proves that volcanic outbursts of great intensity occurred in addition to quiet outflows of lava. The area of abundant porphyry dikes and stocks in the northwestern part of the region doubtless includes the vents through which part of the lava and fragmental material came. A few of the andesitic outcrops have a stocklike appearance, as if they might be the filling of supply pipes. One of these outcrops is 3 miles northeast of Ketchum; others are along the divide south of upper Trail Creek. Other vents may be buried beneath the remaining lava or lie outside of the region studied.

The history of the time is not alone the story of igneous action, for streams were at work throughout the period. The bedding and cross-bedding of the tuff are the result of the reworking of the volcanic ash and dust by running water. The presence of gravel with well-rounded boulders testifies to the existence of streams with marked carrying powers. In some places such gravel lies at the base of the lava series, between the first flow and the underlying floor of older rocks. Gravel is also interbedded in the lavas, commonly with boulders of crystalline rocks and of lava more than a foot in diameter. This gravel is the product of aggrading streams which carried coarse materials and flowed from regions of high relief at a time when igneous action was still going on.

The lava flows could hardly have occurred in a hilly region, such as this area was at that time, without occasionally damming streams and producing lakes in which fine sediments would accumulate. It is possible that a few of the finest tuffs were laid down in such lakes, but even that is not certain. If any lake beds were laid down they occupied extremely small areas or else they have been destroyed by subsequent erosion.

After the Miocene (?) eruptions deformation by tilting and faulting took place. This revolution may have been that which quite generally through the Columbia River region marked the end of Miocene and the beginning of Pliocene time. The lavas were tilted until over large portions of the region they stood at angles of 20° to 30°. In places the beds are much steeper, even standing vertical. Faulting, usually in a northwest-southeast direction, accompanied the tilting. Central Idaho was probably once more broadly uplifted. The result was a topography in Pliocene time radically different from that of the broad lava plains surrounding or penetrating mountain masses that marked the end of Miocene time. During the uplift the streams, which were forced to find new courses, began a new cycle of erosion. The details of the post-Miocene history have not been worked out, but it is likely that here as in neighboring regions faulting recurred at intervals until geologically recent time. Successive disturbances of this character caused successive interruptions to the progress of erosion. These changes are recorded in partial erosion surfaces and gravel terraces at a number of different levels, but no attempt has been made to correlate the remnants of such surfaces with each other.

In the Pleistocene epoch here as in other mountainous regions in the Northwest glaciation was prevalent in the higher parts of the mountains. Glaciation probably took place at two or more times separated by periods of melting, but only the record of the last glaciation is now legible. Along both sides of the main northwestward-trending divide, but especially on the north side, large snow fields formed in the heads of the preglacial valleys and smaller fields on some of the higher lateral ridges. Glaciers of considerable length occupied all the main valleys leading away from the divide, except Eagle and Lake Creeks and the west branch of Wilson Creek. The largest of all was that of the Big Lost River, which, measured from the head of its longest tributary, was 19 miles long. Above the snow line, which stood at an altitude of about 9,000 feet, erosion was greatest. The preglacial V-shaped valleys were changed to relatively flat-bottomed, steep-sided amphitheaters or cirques. These cirques to-day are largely floored with rounded ledges of bare rock, many of which are smoothed and scratched by the glacier. In only a few places are small, shallow rock-basin lakes present.

As the cirque walls were pushed back by weathering and ice erosion, the intervening divides were reduced to steep, sharp, jagged ridges (arêtes or comb ridges). At intervals along the main divide, especially where it is met by lateral divides, sharp peaks are present. Hyndman Peak and the unnamed peaks to the southeast are excellent examples. (See pl. 2, *A*.) This topography of glacial cirques, arêtes, and peaks extends all along the main divide, except for a section in the central part of the region. It is best developed from the Devils Bedstead to the east side of the Hailey quadrangle and in the Ryan Peak area. In both areas the glaciated topography completely replaces an earlier topography shaped by stream erosion. Away from the divide in both directions features of glacial erosion rapidly disappear.

At the heads of some small valleys and in some localities on the faces of mountain ridges, at altitudes above 9,000 feet, hopper-shaped depressions mark the position of smaller Pleistocene snow fields. They are present around the head of Eagle Creek, and about a dozen are shown on Figure 3.

With the coming of warmer climates the glaciers became smaller and finally disappeared. The cirques, eroded by the ice of the snow fields, and the morainic débris of the lower valleys remain to-day almost as they were on the disappearance of the ice. The streams have been at work removing the gravel filling and making flats and terraces at successively lower levels. These features are best shown in the alluvium-floored valley of the Big Wood River, which, near Hailey is a mile in width. The rivers may still be flowing at a considerable height, possibly several hundred feet, above the rock floor of the Big Wood River in the area south of Ketchum.

At some time in the Quaternary period there was a recurrence of volcanism in the Wood River region. Two basalt flows extended into the southeast corner of the Hailey quadrangle from the region of intense eruptive activity farther southeast. The age relation between these flows and the glaciers has not been determined. They have so youthful an appearance that possibly they were formed even more recently than the glaciers.

PART 2. ECONOMIC GEOLOGY

By JOSEPH B. UMPLEBY and CLYDE P. ROSS

HISTORICAL SKETCH

The discovery of gold in the Boise Basin in August, 1862, started for Idaho a period of immigration in many ways similar to the early rush to California. Prospectors flocked to the area from the south, east, and west, and the thoroughness of their search is attested by the comparatively few discoveries of gold made since their early activity. At first they were only in quest of gold and passed by with casual inspection many now famous deposits of other metals. At that time some of the silver-lead deposits of the Wood River region were known, but little attention was paid to them for more than a decade. Bancroft[1] states that the first discovery in this region was made in 1864 by W. P. Callahan while on the way from Boise Basin to Montana. In 1872 Callahan returned and relocated the claim covering his early discovery. It was not, however, until after the subjugation of the Bannock Indians in 1878 that mining in the Wood River region became active. By 1880 hundreds of claims were located and several towns had sprung up along the Big Wood River. In 1883 four smelting plants, with a daily output of 50 tons of bullion, were operating on ore containing from 50 to 80 per cent of lead and from 100 to 300 ounces of silver to the ton. Some of the ore contained over 1,000 ounces of silver to the ton. Between 20 and 30 mines were successfully operated and prosperity reigned until 1887.

About this time the known ore shoots began to be exhausted at a much more rapid rate than new ones were found, and a sharp decline in production started, which lasted until 1895. From then until 1911 production continued to fall off slowly, with several periods of revival due to the discovery of new ore bodies in old mines. From 1911 to 1921 production increased, especially in the later part of the period, and part of this increase came from deposits that were unknown or little developed in the boom days. None of the famous mines of the early days is now producing any ore. The production decreased in 1922, and in the summer of 1923 the Independence mine, which in recent years had been the largest producer in the region,

[1] Bancroft, H. H., History of Washington, Idaho, and Montana, p. 551, 1890.

was shut down. Recently, however, the successful reopening of the Triumph mine has resulted in some increase in production.

PRODUCTION

The general course of production in Blaine County, most of which has come from the Wood River region, is shown graphically in Figure 7, which has been plotted from records in the annual volumes of Mineral Resources of the United States. Omission of data from other parts of the county would not materially alter the form of the curve. Blaine County was called Alturas County prior to 1895, and there have been several changes in the county boundaries, but no considerable number of producing mines have been either added to or cut off from the county by these changes. The production of Blaine County prior to 1902 and of the Mineral Hill and Warm Spring Creek districts from 1902 to 1926 is summarized in the following three tables, which are compiled from the records of the United States Geological Survey and Bureau of Mines:

Gold, silver, copper, lead, and zinc produced in Blaine County (Alturas County prior to 1895), Idaho, 1880–1901 [a]

Year	Gold		Silver		Lead		Total value
	Fine ounces	Value	Fine ounces	Value	Pounds	Value	
1880 [b]	7,213.00	$149,096	104,628	$120,322	------------	------------	$269,418
1881 [b]	8,224.00	170,000	425,400	480,702	1,420,000	$68,160	718,862
1882 [b]	8,466.00	175,000	595,560	678,938	4,750,000	232,750	1,086,688
1883 [b]	7,256.00	150,000	719,313	798,437	11,600,000	498,800	1,447,237
1884 [b]	4,838.00	100,000	1,121,510	1,244,876	10,000,000	370.000	1,714.876
1885 [b]	3,995.00	82,585	1,802,709	1,928,899	12,884,930	502,512	2,513,996
1886 [b]	10,338.00	213,715	1,490,065	1,475,164	16,464,884	757,385	2,446,264
1887 [b]	18,179.00	375,788	1,024,727	1,004,232	20,375,404	916,893	2,296,913
1888 [b]	14,513.00	300,000	641,968	603,450	11,000.000	484,000	1,387,450
1889 [b] [c]	2,882.00	59,576	831,300	781,422	7,940,000	309,660	1,150,658
1890 [b] [c]	4,482.00	92,651	673,144	706,801	9,489,020	427,006	1,226,458
1891 [b]	2,061.00	42,605	771,774	764.056	8,489,514	365,049	1,171,710
1892 [b]	1,102.00	22,780	700,362	609,315	7,703,993	308,160	940,255
1893 [b]	824.00	17,033	356,932	278,407	[d] 3,966,606	146,764	442,204
1894 [b]	836.00	17,282	294,207	185.350	[e] 2,216,710	73,151	275,783
1895 [b]	3,159.00	65,302	150,766	97,998	[e] 1,384,788	44,313	207,613
1896 [b]	3,236.00	66,894	260,889	177,405	[e] 3,698,958	110,969	355,268
1897 [b]	557.00	11,514	261,654	156,992	[e] 3,283,389	118,202	286,708
1898 [b]	537.00	11,101	248,354	146,529	3,725,310	141,562	299,192
1899 [b]	1,504.00	31,090	177,854	106,712	2,667,810	120,051	257,853
1900 [b]	1,666.00	34,439	157,548	97,680	2,363,220	103,982	236.101
1901 [b]	939.00	19,411	99,186	59,512	1,686,162	72,505	151,428

[a] Table by C. N. Gerry in U. S. Geol. Survey Mineral Resources, 1914, pt. 1, p. 613, 1916.
[b] Figures of Director of Mint. Commercial value of silver substituted and estimate for output of lead added by C. N. Gerry for years for which those figures were lacking.
[c] Combination of Alturas and Logan Counties. Lead for 1889 taken from Mineral Resources, 1889 and 1890, p. 80.
[d] Lead from Mineral Resources, 1893, p. 93.
[e] Lindgren, Waldemar, Wood River mining district: U. S. Geol. Survey Twentieth Ann. Rept., 1898–99, pt. 3, p. 192, 1900.

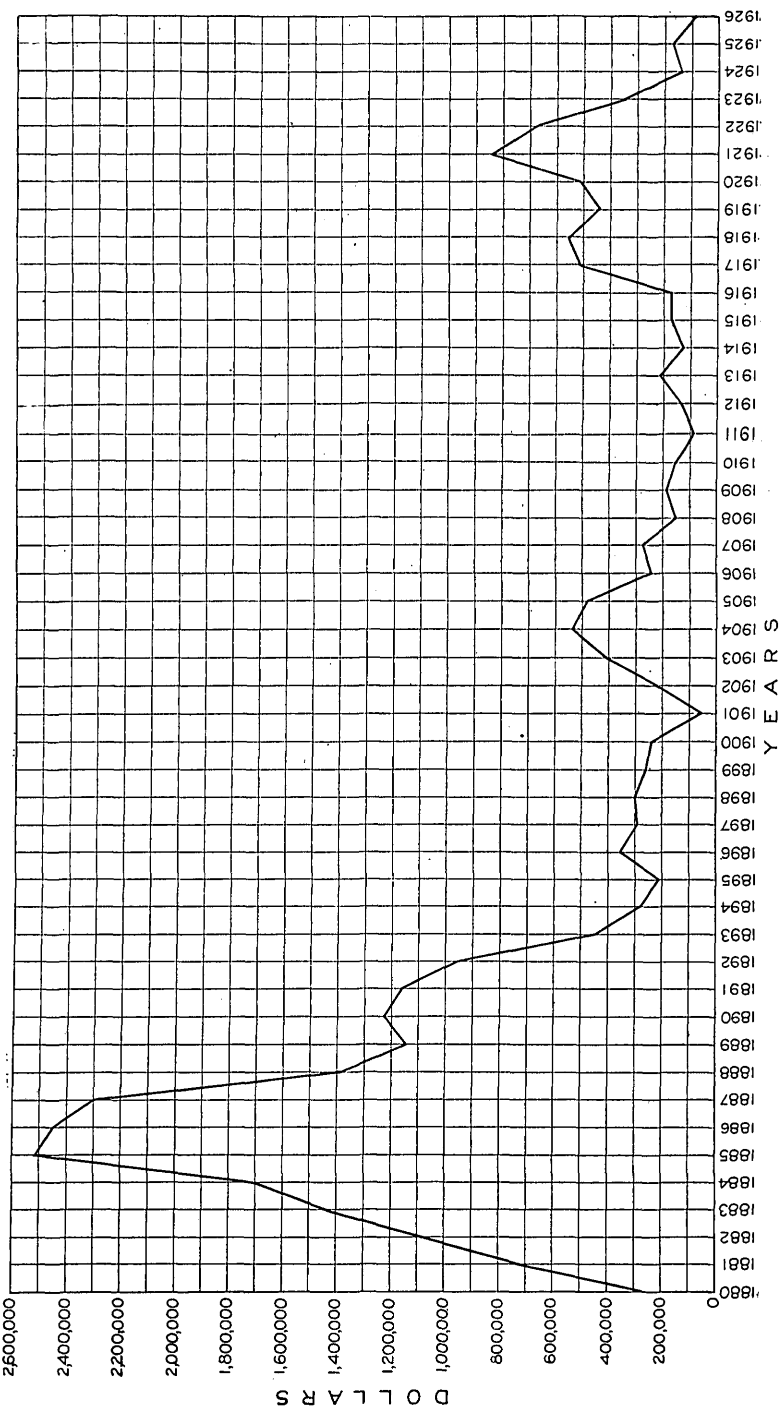

FIGURE 7.—Total value of metals produced in Blaine County, Idaho, 1880–1926

Gold, silver, copper, lead, and zinc produced in Mineral Hill district, Idaho, 1902–1926

Year	Gold	Silver	Copper	Lead	Zinc	Value	Ore sold or treated
	Fine ounces	*Fine ounces*	*Pounds*	*Pounds*	*Pounds*		*Tons*
1902	----------	186,420	----------	2,212,851	160,895	$188,408	1,894
1903	3.00	435,106	----------	5,243,905	----------	461,024	24,205
1904	----------	481,557	----------	5,504,667	26,125	475,933	27,666
1905	204.00	200,704	2,312	3,816,911	160,389	398,996	16,741
1906	543.00	164,510	----------	1,655,653	----------	210,884	16,488
1907	1,295.39	159,332	24,378	2,066,550	37,077	248,527	14,444
1908	35.88	101,509	10,305	1,247,710	----------	108,835	6,973
1909	1,932.19	103,292	22,223	1,328,113	54,642	156,636	18,567
1910	1,867.24	79,720	19,585	997,466	47,012	630,562	15,080
1911	333.98	28,690	3,669	412,864	29,814	42,820	2,871
1912	57.82	9,206	1,998	140,158	78,834	18,934	744
1913	103.57	75,914	7,500	815,951	1,753,213	183,238	17,800
1914	146.81	34,902	6,765	494,628	404,621	63,161	3,910
1915	219.27	36,913	2,080	511,266	352,324	91,320	5,582
1916	26.40	10,250	1,386	125,472	86,544	27,922	800
1917	16.97	22,389	2,232	258,724	28,055	44,520	1,261
1918	53.18	9,735	732	120,147	----------	19,545	299
1919	41.86	32,085	8,863	230,376	----------	50,659	10,171
1920	27.57	33,972	2,884	358,570	----------	66,816	4,593
1921	9.96	18,068	1,957	178,285	----------	26,550	676
1922	21.71	11,399	1,043	78,385	----------	16,300	540
1923	27.14	2,563	130	30,226	----------	4,798	55
1924	23.01	12,157	866	113,654	12,149	8,618	569
1925	20.90	24,519	3,460	208,629	7,965	36,195	322
1926	7.59	26,714	2,560	282,043	3,838	40,035	366

Gold, silver, copper, lead, and zinc produced in Warm Springs Creek district, Idaho, 1902–1926

Year	Gold	Silver	Copper	Lead	Zinc	Value	Ore sold or treated
	Fine ounces	*Fine ounces*	*Pounds*	*Pounds*	*Pounds*		*Tons*
1902	18.33	13,694	----------	20,860	----------	$15,795	510
1903	22.50	13,165	----------	179,122	----------	14,840	155
1904	----------	5,278	----------	54,952	----------	5,094	263
1905	----------	----------	----------	59,336	958,740	61,395	1,730
1906	.15	150	----------	1,650	----------	188	2
1907	9.34	3,835	470	71,024	----------	6,582	108
1908	15.19	11,655	----------	90,856	37,410	12,065	227
1909	4.74	5,909	553	42,045	13,368	5,922	74
1910	9.72	3,531	107	35,375	29,385	5,264	97
1911	72.00	11,907	5,594	119,422	----------	15,673	229
1912	319.95	12,563	608	111,599	26,487	21,289	707
1913	92.78	6,553	1,580	75,186	5,175	9,719	561
1914	83.58	36,174	1,820	357,041	----------	35,899	2,250
1915	326.04	36,619	843	374,070	89,412	54,122	3,607
1916	113.04	54,765	25,401	161,835	161,835	113,303	6,547
1917	485.04	131,006	17,135	1,143,726	2,090,320	460,027	19,444
1918	578.11	218,394	22,027	2,162,871	1,489,083	524,856	23,399
1919	597.68	241,194	9,780	1,926,924	----------	386,439	13,862
1920	605.56	251,272	27,882	1,791,023	----------	434,816	16,541
1921	1,129.39	573,861	33,877	9,747,131	----------	815,198	40,022
1922	831.49	449,386	26,491	3,516,268	18,121	664,578	44,970
1923	460.04	245,741	16,734	1,850,800	----------	343,036	26,486
1924	123.55	86,920	4,571	713,441	----------	118,465	1,233
1925	128.44	88,119	5,511	710,687	19,549	127,909	1,485
1926	41.99	38,541	3,013	298,549	----------	49,224	615

About three-quarters of the production of the Wood River region was made between 1880 and 1900, and most of this was made prior to 1890. After the sharp decline that started in 1887 the annual production never approached the maximum reached in 1885. The partial recovery between 1902 and 1906 indicated by the upward swing of the curve in Figure 7 resulted from renewed activity at the

Minnie Moore mine, in the Mineral Hill district, which has made a much greater production than any other mine in the region. The increase in production that began in 1917 came largely from the increased output of the Independence mine, in the Warm Springs Creek district, which was acquired by the Federal Mining & Smelting Co. in that year.

In the early boom days of the Wood River region most of the production came from the Mineral Hill district. Incomplete records and estimates indicate that the gross production of this district was well over $16,000,000 between 1880 and 1902, whereas the available records for the Warm Springs Creek district for the same period give only a little over $3,000,000. In recent years this condition has been reversed. According to the records of the Geological Survey, the total value of the production of the Mineral Hill district from 1916 to 1922 was only $232,287, whereas that of the Warm Springs Creek district was $3,397,217. A large part of the mining development in the region in 1923 and 1924, however, was in the Mineral Hill district, but the search for ore there was not successful. Part of the production of this district in 1924 came from the treatment of 800 tons of tailings. The production of the Warm Springs Creek district declined in 1923, when the Independence mine began to be worked only by lessees, but is now likely to increase again because of the activity at the Triumph, which started in 1927. The available data on ore produced and its content of gold, silver, lead, zinc, and copper are given in the detailed mine descriptions.

The most valuable sources of information on the production in the early years are the records of the Hailey Sampling Works, kindly made available by Mr. E. Daft, ore purchaser for the American Smelting & Refining Co., and of the Ketchum smelter. The books of the smelter in the possession of Mr. Alonzo Price were examined through his courtesy, but the record is incomplete. Most of the tables giving the early production included in the descriptions of the different mines are taken from Mr. Daft's records. For some of the mines the data are probably fairly complete. Shipments that did not pass through the Hailey Sampling Works are not recorded, and there are numerous shipments recorded only in the names of the individuals who made them, which can not be credited to the mines from which they came. In addition to the data here presented Mr. Daft's records contain data on many mines in the Wood River and adjoining regions not described in this report.

In 1902 the United States Geological Survey began gathering statistics of the production of the mines of the region, and these records have become increasingly complete with the gradual improvement in the facilities for obtaining them. The tables presented herewith give the best information obtainable, but for 1902 and the years immediately following they are incomplete. The figures for the several metals in these tables and those in the mine descriptions, which are compiled from the Geological Survey's records, represent metal recovered as calculated from assay contents of the ores with deductions for losses in smelting and refining. The values given are based on the average price for each metal in each year. Thus, in general, the amount of metal given is less than the total amount in the ore as mined, but the value assigned is greater than the net return to the mine operators.

TREATMENT OF THE ORE

Much of the ore, especially from the smaller mines, is shipped direct to the smelters, and most of the remainder is readily amenable to concentration up to shipping grade. A few of the deposits, however, contain ore differing from and less easily treated than that characteristic of the region. In the North Star mine the shoots now remaining contain sphalerite, galena, arsenopyrite, and pyrite in such intimate association and such relative amounts that the ore is exceptionally refractory and has not yet been successfully exploited, even by the latest improved processes. Similar ore in the Triumph mine, however, is reported by the present owners to be amenable to flotation. To be worked at a profit its lead, zinc, and silver must all be recovered. The ore is so exceedingly fine grained that it appears to be impracticable to grind it sufficiently fine to make possible the separation of the different minerals by mechanical means. The ore from the contact-metamorphic deposits, none of which have yet been extensively developed, also presents problems in treatment because of the high specific gravity of several of the gangue minerals.

During the early period of mining activity in the region several lead smelters were operated. The largest one was that of the Philadelphia-Idaho Co., at Ketchum, which was operated most of the time from 1881 to 1887 and at intervals since then. This plant had a daily capacity of 80 tons and made about 30 tons of bullion daily but has now been dismantled. Some of the slag from it has since been worked over. The other smelters in the region also have been long abandoned, as it is now more advantageous to ship the ore and concentrates to smelting plants in Utah.

A large number of concentrating mills have been built, but none of them are now in operation and most of them are dismantled. Until a few years ago the Minnie Moore mill, equipped with rolls, jigs, and tables, was operated on tailings from the Queen of the Hills and Minnie Moore mines. Some years ago the Quincy Junior Mining Co. operated an electrostatic zinc mill on the tailings and mine dumps at the Red Elephant. The mills at the Croesus, Eureka, and Independence mines were also operated up to a few years ago. The North

Star mill was remodeled in 1920, and ore from the Independence was treated in it until that mine shut down in 1923. In the summer of 1923 work was started on a project to re-treat the tailings from the Red Cloud mill, and the next fall and winter some of the tailings were treated. In the summer of 1924 a mill was being constructed at the Hailey-Bonanza mine, and it has since been put into operation.

The ore mined in the early days was very rich. Much of it is reported to have averaged 40 to 60 per cent of lead and 40 to 120 ounces of silver to the ton, and numerous shipments were of far higher grade. Small lots containing as much as 2,000 ounces of silver to the ton were mined. In recent years ore of much lower grade has been mined. According to the superintendent, Mr. A. E. Ring, the average mill feed from the Independence mine in 1921 and 1922 contained about 0.04 ounce of gold and 12 ounces of silver to the ton and 5 per cent of lead. The concentrating ratio was about 8 to 1. The ore shipped direct to the smelter from this mine in 1921 and 1922 contained about 0.15 ounce of gold and 132 ounces of silver to the ton and 50.5 per cent of lead. Study of the production records for the years 1912 to 1922 indicates that the ore mined in the Mineral Hill district contained an average of about 1.5 ounces of silver to the ton for each per cent of lead, and that mined in the Warm Springs Creek district about 2 ounces of silver to the ton for each per cent of lead. Some of the mines in the past have had a much higher proportion of silver. A number of shipments were made of ore containing 20 ounces of silver to the ton for each per cent of lead, and a few which had even more than this amount. The ores particularly rich in silver invariably appear to contain conspicuous amounts of tetrahedrite. This mineral is probably the principal container of silver in ore with a ratio of 2 ounces or more of silver to the ton for each per cent of lead.

Zinc is present in nearly all the ore. In most of the ore it is an abundant accessory. In a few places, as in parts of the North Star mine, it exceeds the lead in amount. In two prospects on Lake Creek zinc is the only valuable metal so far found.

Gold is present in nearly all of the lead ore in amounts ranging from a few cents up to rarely $5 to the ton. The gold vein of the Croesus mine contained some ore that yielded as much as $300 to the ton in gold, a large amount of which averaged about $50, and even more that contained from $10 to $12. In the Starlight contact-metamorphic gold deposit the first-grade ore averages about $40 to the ton and the second-grade $10 or $12. The other contact-metamorphic deposits contain some gold. Samples from those near the head of the East Fork of the Big Wood River are reported to have assayed $6 and even $16 to the ton in gold. The gold content of many shipments containing very small quantities of this metal was not recorded, and consequently the tables of production in the mine descriptions are inaccurate in this respect.

Little attention appears to be given to copper by mining men in the Big Wood River region, but much of the lead-silver ore contains more or less of this metal. Between 1902 and 1922 more than 250,000 pounds of copper was mined in the region. A few deposits have been developed primarily for copper, but these attempts have not met with success.

The ores of some of the deposits in the region contain arsenic, antimony, quicksilver, and other metals, but none of these have yet been mined on a commercial scale.

GEOGRAPHIC AND GEOLOGIC DISTRIBUTION

Most of the ore deposits of the region are in the Mineral Hill and Warm Springs Creek mining districts. Those east of the main divide at the head of Trail Creek are in the Alto district, in Custer County. The boundaries of the Mineral Hill and Warm Springs districts do not appear to be definitely fixed, but their approximate limits as adopted for this report are shown in Plates 9 and 10. The Mineral Hill district, which contains most of the famous old mines, extends from the divide north of Deer Creek, which coincides roughly with the south border of the fourth tier of sections in T. 3 N., Rs. 17 and 18 E., south to the southern boundary of T. 2 N., R. 17 E., and to the middle tier of sections in T. 1 N., R. 18 E. The eastern boundary of the district is the eastern edge of the drainage area of the Big Wood River, and the western boundary may be arbitrarily taken as the meridian 114° 30′. The Warm Springs Creek district extends from the northern boundary of the Mineral Hill district to the boundary of Custer County on the north and northeast and to the divide between the drainage areas of the Big Wood River and the Little Wood River on the east. The western boundary is near meridian 114° 30′, although there are a few mines a short distance west of this line. Plate 9 shows the location of all the mines and prospects in the Mineral Hill district regarding which data are available. All the claims for which maps were obtained are plotted as nearly as possible in the correct relations to one another and to the topography and geology. It must be remembered, however, that both topography and geology are generalized and that in few places is there any direct tie between them and the claim surveys. Plate 10 shows the mines and prospects in the Warm Springs district and the upper drainage basin of the Big Lost River. The geology is omitted from this map because the whole of the area is shown on Plate 1.

Most of the deposits are in Pennsylvanian and Mississippian sedimentary rocks, but some are in granitic rocks, and those near the head of the Big Lost River are in Ordovician sedimentary beds. A large number of the deposits, including many of the most productive ones, lie in a belt that extends from the vicinity of Bellevue to a point about 2 miles north of Deer Creek. The deposits in this belt are all near or in an elongated mass of granitic rock, which except for a cover of younger rock near Croy Creek is exposed throughout the belt, as can be seen from Plate 9. The northwestern part of this belt is principally in quartz monzonite. That part between Croy Creek and the Big Wood River is inclosed in two distinct masses which have the composition of quartz diorite and granodiorite but which for convenience have been termed diorite and granite, respectively, in Hewett's description of that part of the region (pp. 211–214). One group of deposits lies along the northeast contact of the mass and stretches from the area south of Broadford to Hailey Hot Springs. This group is a linked lode system in which most of the deposits are in the Mississippian strata (Milligen formation), and the principal ones have average strikes approximately parallel to the igneous contact. West of this group are a number of deposits in the granitic rock itself. Near Bullion on the southwest side of the intrusion there are numerous deposits that belong to a linked lode system which parallels the contact on that side and lies almost wholly in the Pennsylvanian rocks (the Wood River formation). The Ajax and neighboring deposits may belong to a northern extension of the same system. The Nay Aug lode, still farther north, is exceptional in that it extends across the contact between quartz monzonite and the Wood River formation. East and southeast of the Nay Aug there are several deposits in quartz monzonite, and still farther east there are some prospects in the Wood River beds.

On Kelly Mountain there are a number of prospects. Some of the claims are shown on Plate 9, but there are probably numerous unpatented claims not shown. These deposits adjoin a mass of soda granite, and most of them are probably approximately parallel to the contact, but detailed data regarding many of them are lacking. The Jennie R prospect, which is south of the region mapped, is in granite that may be an extension of this mass, although its composition differs somewhat.

Another group of deposits lies in the area between Ketchum and Hyndman Creek. Mines in this area have yielded some of the richest silver ore found in the region, but nearly all have been shut down. The deposits occur in sedimentary rocks, principally Mississippian argillaceous beds. They are closely associated, however, with dikes of lamprophyre and granite porphyry. In the northwestern part of the area contact-metamorphic minerals have been extensively developed in the sedimentary rocks. These minerals, together with the dikes, suggest the presence of a granite mass not far below the surface.

In the upper part of the valley of the East Fork of the Big Wood River occur several deposits in sedimentary rocks of Algonkian (?), Mississippian, and Pennsylvanian age. Some of the Algonkian (?) beds contain minerals of° probable contact-metamorphic origin. There are a number of small dikes in the vicinity of the deposits, and a batholith of granitic rocks crops out about 2 miles northeast. A few deposits are known in Pennsylvanian rocks on Lake Creek. Several old mines are situated near Warm Springs Creek, in the western part of the Hailey quadrangle. These deposits are in Pennsylvanian beds. A small area of granite crops out a short distance west of them, and a much larger mass of granite rock is exposed only a little farther west.

A number of deposits on which only meager development work has been done are scattered along valleys in the upper drainage basin of Lost River and just over the divide on Trail Creek. There are several prospects in this part of the region which are not shown on Plate 10. These deposits differ from most of those elsewhere in that they are the results of replacement along the bedding planes of Ordovician rocks and the gangue consists largely of contact-metamorphic silicates. Masses of monzonite crop out near the deposits, and a batholith of granite rocks is exposed a short distance to the south.

From the foregoing summary it appears that most of the deposits are grouped in certain areas. They occur in rocks of a number of different types, but each of the groups except the small one on Lake Creek is near a mass of granitic rock. In most of the areas the igneous rock is exposed at the surface, and in the others its proximity is shown by the development of contact-metamorphic phenomena in the sedimentary rocks. All the different masses of granitic rock have points of petrographic similarity, and all are believed to have been intruded during the same period of igneous activity. The only igneous rocks exposed in the general vicinity of the deposits on Lake Creek are dikes of probable Miocene age, but these deposits, especially the Homestake, are so similar in other respects to those elsewhere in the region that they are doubtless of similar origin.

GENERAL CHARACTER OF THE DEPOSITS

The mineral deposits of the region comprise lodes along shear zones in sedimentary and granitic rocks, contact-metamorphic replacement deposits in calcareous strata, veins consisting essentially of nonmetallic minerals, and poorly defined deposits in the Tertiary lava.

The first group, from which nearly all the production has come, may be subdivided on the basis of a number of variations in detail, but the different lodes possess sufficient fundamental characteristics in common to indicate that they are all genetically related. Most of them are characterized by argentiferous galena with more or less sphalerite and tetrahedrite and subordinate pyrite and other sulphides in a gangue consisting of altered and crushed country rock, carbonates, principally siderite, and some quartz. Siderite is more abundant in the lodes in the southern part of the region. A few of the lodes contain notable quantities of arsenopyrite, and a few are characterized by ruby silver. All contain some gold, and in a few this is the metal of principal commercial importance. Mineralization took place principally by replacement rather than by fissure filling. Considerable stretches along the shear zones show extensive crushing and shearing but little mineralization. The causes of the restriction of replacement are only partly understood.

Some of the contact-metamorphic deposits contain argentiferous galena in a gangue consisting predominantly of grossularite and epidote, and others contain free gold and some sphalerite in a gangue consisting principally of garnet and pyroxene. There are a few replacement deposits that consist of magnetite with minor amounts of arsenopyrite, quartz, siderite, tremolite, and probably other minerals and that resemble the more typical contact-metamorphic deposits, but they contain some minerals more characteristic of the lodes.

The barite veins near Deer Creek are the only veins of nonmetallic minerals that are of any commercial importance. They are lenticular masses in the Wood River formation and consist almost entirely of barite. In numerous places there are gash veins containing calcite or quartz and almost nothing else. These three kinds of veins contain no metallic minerals except a little pyrite and have not been proved to have any genetic relation to the ore deposits.

Impure graphitic coal has been found on Trail and Elkhorn Creeks. No attempt has yet been made to exploit it as coal, but it has been tested for use in paint and other compounds that require low-grade graphitic material. The coal now exposed is much metamorphosed and crushed, and a large part of it has a high ash content, but under the proper conditions it could be used as fuel.

In some of the shear-zone deposits and in fracture zones in Tertiary lava not otherwise mineralized there are small amounts of mercury and copper minerals, marcasite, stibnite, hisingerite, zeolites, and opaline silica, which were clearly formed later than the ore characteristic of the shear-zone deposits. Most or all of these minerals are products of a period of mineralization related to Tertiary volcanism and much later than that in which the greater part of the ore deposits were formed. No ore bodies of commercial importance have yet been developed in these younger deposits, and in most exposures the mineralization of this character is so feeble as to offer little encouragement to prospectors.

MINERALOGY

The principal data regarding the minerals so far discovered in the mineral deposits of the Wood River region are summarized in the following table. Just as the present studies have added largely to the number of species listed by Lindgren, so future studies may be expected to add to the number now recognized. Seventy-five species are known in the mineral deposits of the region. Of these 29 are hypogene gangue minerals, 19 are hypogene metallic minerals, and 33 are products of supergene alteration. Six of the last group are also formed by hypogene processes. One nonmetallic mineral, barite, has been mined.

Some of the minerals listed are not strictly products of the mineralization that produced the ore, but they are closely associated with the ore. The minerals of the country rocks of the deposits, not included in the list, were formed prior to the mineralization but exerted more or less influence on it. The principal components of the sedimentary rocks are quartz, calcite, and argillaceous and carbonaceous matter. The granitic rocks contain alkali and soda-lime feldspars, quartz, hornblende, pyroxene, several micas, and minor constituents and alteration products.

Known distribution of minerals in the ore deposits of the Hailey quadrangle, Idaho

Species	Hypogene minerals								Supergene minerals	Mine or locality
	Contact-metamorphic deposits				Lode deposits					
					Lead-siderite		Gold-quartz	Tertiary lodes		
	Gold	Copper	Lead	Iron	In granite	In sediments				
Analcite								×		
Actinolite	×	×								Common in area east of Ketchum and in rock incasing Red Elephant veins.
Andalusite		×								Abundant in areas of metamorphosed shale.
Anglesite									×	Widespread in outcrops of lead veins, but not abundant.
Apatite	×	×								Rare in Starlight ore.
Aragonite									×	Prospect near mouth of Star Gulch.
Argentite									×	Rare in Jay Gould and Bullion ore, according to W. P. Jenney.
Arsenopyrite				×		×	×			Abundant in North Star and Croesus veins.
Augite	×	×	×							Common in Starlight and Bald Eagle ores.
Azurite									×	Rare in oxidized ore.
Barite						×				Reported by Lindgren north of Deer Creek.
Biotite	×	×								Small amounts.
Bornite									×	Rare in many of the surficial stopes.
Boulangerite						×				North Star, etc.
Calamine									×	Lake Creek, etc.
Calcite	×	×	×		×				×	Common as a minor constituent.
Cerargyrite									×	A little near surface.
Cervantite									×	Reported in Dana's Mineralogy.
Cerusite									×	Common oxidation product in the lead deposits.
Chalcopyrite	×	×	×		×	×	×		×	Very common. Locally secondary in Croesus mine, 800-*foot* level.
Chlorite			×						×	Common in oxidized granitic wallrock and in contact ore. Primary in Basin Prospect.
Chrysocolla									×	Copper deposits in Tertiary lava and elsewhere.
Cinnabar								×		Dockwell tunnel.
Diopside	×	×	×							Abundant in contact deposits.
Epidote			×							Abundant in contact lead deposits.
Fluorite			×							Locally abundant in Basin prospect and in vein near by.
Galena	×		×		×	×				Chief ore mineral; rich in silver; commonly twinned.
Garnet	×	×	×							Common in contact ores. Index of refraction from 1.74 to 1.815.
Graphite						×				Parker mine and elsewhere.

Known distribution of minerals in the ore deposits of the Hailey quadrangle, Idaho—Continued

Species	Hypogene minerals								Supergene minerals	Mine or locality
	Contact-metamorphic deposits				Lode deposits					
					Lead-siderite					
	Gold	Copper	Lead	Iron	In granite	In sediments	Gold-quartz	Tertiary lodes		
Gypsum									×	Rare.
Hematite									×	Abundant.
Hisingerite						×		×		Represents a late stage of mineralization, Minnie Moore and Bellevue King.
Hydrous iron-manganese oxide.									×	Rare as beautiful scaly crystals in specimens from Narrow Gauge dump.
Jamesonite						×				McIrvin prospect.
Laumontite						×		×		Occurs with hisingerite, in vesicles in lavas, and in other rocks.
Limonite									×	Abundant.
Magnetite		×	×	×						Uncommon in contact ores. Not observed in contact gold ore. Abundant in East Fork deposits.
Malachite									×	Small amounts.
Marcasite						×				Reported by Lindgren.
Metacinnabarite									×	Dockwell tunnel.
Minium									×	Down to 40 feet below surface in Jay Gould mine.
Molybdenite						×				Seen in one specimen from Bullion mine.
Native gold	×					×	×			Most abundant in Starlight, North Star, and Croesus mines.
Native lead									×	Rare in Jay Gould down to 40 feet below surface and in Arizona.
Native silver									×	Observed in Bullion and Croesus ores.
Opal								×	×	In one specimen from Narrow Gauge dump and in lavas.
Phosphate and arsenate of lead.									×	Reported in Report of the Director of the Mint for 1881, p. 179.
Phosphate of iron									×	Brilliant black mineral from Narrow Gauge dump.
Polybasite						×				Parker mine (oral communication by W. P. Jenney).
Prehnite			×							Abundant in Basin prospect.
Proustite						×(?)			×(?)	Reported in Dana's Mineralogy.
Pyrargyrite						×				Star mine.
Pyrite	×	×	×		×	×	×			Common in small amounts.
Pyrolusite									×	Common in and near oxidized lead ore.
Pyromorphite									×	Eureka mine, outcrop on slope above tunnel.
Pyrrhotite	×						×			Starlight and Croesus mines.

Quartz	×	×	×	×	×	×	×	×		Abundant only in Croesus mine.
Scorodite									×	Golden Bell mine.
Sericite					×		×		×	Abundant in Croesus and Democrat mines. Rare in oxidized contact ores.
Siderite				×	×	×	×			Abundant gangue. Scarce in gold-quartz veins.
Smithsonite									×	Lake Creek deposits.
Specularite		×	×							Rare.
Sphalerite	×	×	×		×	×	×			Most abundant in North Star, Queen, and Starlight mines.
Stibnite						×		×		Abundant in Independence ore. Also found in North Star and Minnie Moore mines.
Stilbite						×		×		Late mineral in Minnie Moore and Relief mines.
Sulphantimonate of lead						×				Silky gray aggregates, Independence mine.
Sulphur									×	Bald Eagle mine.
Tetrahedrite					×	×				Common in small amounts.
Tetradymite						×				Known only from Basin prospect on Trail Creek.
Tourmaline	×									Rare in Starlight mine. Also in pegmatite dikes.
Tremolite	×	×		×						Rare in Starlight and Bald Eagle mines.
Vanadinite									×	Above Eureka tunnel.
Vesuvianite	×	×								Abundant locally in Starlight mine.
Wollastonite	×	×								Locally in Starlight and Bald Eagle mines.
Wulfenite									×	Golden Bill mine and Eureka mine above tunnel.

LODE DEPOSITS

STRUCTURAL FEATURES

All the ore deposits known to be of any commercial importance, except those formed by contact metamorphism, are lodes along zones of fissuring. Most of the deposits are in shear zones in which the rock for a considerable width has been sheared, crushed and brecciated, rather than in sharply delimited individual fissures. The deposits in many places are bounded on one or both sides by walls that have been polished and grooved by differential movements along them. The crushing, shearing, and slickensiding so abundant in the mineralized shear zones and fissures show that some displacement has doubtless occurred along them. Nowhere, however, except possibly in the Independence mine, is there any evidence of large relative displacement along a lode fissure. The character of the rocks involved is such that details of structure are difficult to decipher, and displacements of a few hundred feet might well be overlooked.

Most of the lodes are on the southwest side of the complexly broken anticline, which is the major structural feature of the region. They differ widely in strike and dip, but nearly all those in which large ore bodies have been mined trend northwest and dip southwest, roughly parallel to the axes of the broken anticline. The veins west of Hailey lie parallel to the long axis of the granitic area whose sides they border. It might at first thought seem that this trend indicates that the intrusion by a doming effect caused the fractures. Were this true, the fractures on opposite sides of the mass should dip in opposite directions, toward the mass if a central segment had been raised and away from it if the effective stresses had been caused by slumping. As a matter of fact, however, the veins on the northeast side dip toward the mass and those on the opposite side dip away from it. The belief that the granitic invasion did not develop the fractures, although it may have caused later movements along some of them, is supported by the absence of similar relations of the veins of other systems in the area to the long axes of adjacent granitic intrusions.

There is thus some evidence indicating that the fissuring which produced the larger shear zones, at least, was genetically related to the major structural disturbance in the region and antedated the intrusion of the granitic rocks. None of the larger faults that are believed to have been produced at this time, either normal or reverse, are known to be mineralized, perhaps because the gouge on such faults was so finely comminuted and so tightly compressed that it was impervious to the passage of ore solutions. A number of the lodes are in granitic rocks, and the fissuring preceding their formation clearly took place after the intrusion and consolidation of these rocks. The major orogenic movements and the batholithic intrusions in this part of Idaho are probably intimately related parts of the same general process. Part of the disturbance of the stratified rocks at any particular place doubtless preceded the advent of granitic magma, and part of it took place concomitantly with and shortly after the intrusion. It seems probable that the fissuring which provided paths for the ore solutions was a minor feature of this great process of upheaval and intrusion and that it continued throughout the period of disturbance. Many of the fissures in the Wood River region were probably formed before the magma reached the positions in which granitic rock is now found.

There is abundant evidence of recurrent movement along the mineralized zones of fissuring after the major period of ore deposition. In several of the lodes, such as the North Star, the minerals first deposited were intricately brecciated before the later minerals were formed, and this process possibly took place several times and to a varying extent in all the deposits. Much of the ore, especially that in which galena is abundant, has been extensively crushed. Many of the galena crystals are striated and distorted, and in numerous places part of the galena has been ground into the fine-grained aggregate known as steel galena. The variations in both strike and dip noted in all the lodes that have been extensively developed may have resulted in part from postmineral movements. Many postmineral faults have been discovered in the course of development of the mines. A number of them have throws of a few hundred feet, but on most of them the displacement is so small as to offer little impediment to mining.

In studying the lodes of this region it should be remembered that the paths along which the ore-producing solutions traveled were not clean-cut fractures but shear zones composed of numerous fissures, some of which had strikes that differed widely from the average strike of the shear zone. In some places it may be difficult to determine whether a gouge-lined fissure against which an ore body terminated was formed before or after the deposition of the ore. The matter is complicated by the fact that there has been postmineral movement along many of the premineral fissures. Thus a fault that has a large total throw may offset the ore only a short distance. In other places ore may have been deposited a short distance into the gouge of a premineral fault but have failed to penetrate it. Later movement on such a fault might well truncate the vein filling and give the appearance of a postmineral fault that had displaced the ore. A premineral fault in which none of the gouge was replaced by ore may also have the appearance of a fault that has truncated the ore.

It has been shown that the fissuring preceding the initial ore deposition took place at about the time of the granite intrusions—that is, probably in the Cretaceous period. The only subsequent crustal disturbance recorded in the rocks of the region is that occasioned by the Tertiary volcanism, which was probably most pronounced during Miocene time. Most of the disturbances of the lodes just referred to probably took place at that time, although some movement may have occurred comparatively recently.

THE ORE

The principal valuable metals in most of the lodes are silver and lead. In others zinc, gold, or arsenic predominates. There is corresponding variation in the mineral content of the lodes, but the types grade into one another, and sharp distinctions can not be drawn. Some of the lodes are in sedimentary rock, others are in granitic rock, and a few pass from one rock into the other. There are variations in the character of the ore corresponding to variations in the country rocks, but these are comparatively insignificant, and all the lodes display the same major characteristics, irrespective of the rocks that contain them.

The texture of the ore in all the lodes in sedimentary rocks is similar throughout the area. It is characteristically massive. Cavities lined with crystals and definite crystal forms in the massive ore are rare, although they have been noted in the North Star and other mines. Many lodes are banded as a result of infiltration along parallel fissures. Here and there the rock between the fissures has been almost completely replaced. Some lodes include banded ore composed of several minerals arranged in definite order. In some of these lodes siderite lies along the walls with galena next to it and tetrahedrite in the center. In others the outer bands are pyrite, with arsenopyrite next to it, sphalerite within that, and galena in the center. Such textures doubtless indicate deposition in open fractures rather than replacement, but they are distinctly exceptional. In most deposits altered country rock is intimately associated with the ore, and in many it forms the major part of the gangue, with only minor amounts of nonmetallic minerals of hydrothermal origin. Siderite, which is the principal hydrothermal gangue mineral, appears to be more abundant in the lodes south of Deer Creek than in those north of it.

Much of the ore, especially in the southern part of the region, consists essentially of galena and sphalerite in patches and bands in massive siderite. Calcite is present in the gangue of some of the ore and also in irregular lenses without metallic minerals. A large part of the ore now exposed consists of sheared and crushed rock alternating with lenses and more or less irregular masses of nearly clean galena. Pyrite, much of it in crystal form, is developed in the gouge, and veinlets of calcite are present in much of it. The lodes appear to be rather definitely limited laterally. In places there are polished and striated walls, but elsewhere ore lenses terminate rather abruptly and there is a more gradual decrease in the amount of crushing and shearing in the rock. Some of the ore bodies terminate abruptly along the strike with blunt ends. As Lindgren[2] has pointed out, "most of the so-called faults are really only sudden terminations of ore bodies, often against a crack or small fissure, a frequently recurring feature in all silver-lead mines in the genesis of which replacement has played a prominent part." Abrupt terminations of ore bodies without visible fissure or other interruption in the shear zones were found in the Independence, Bullion, North Star, and a number of other mines.

The ore of the lodes in granitic rocks is in many respects similar to that in the sedimentary rocks. Banding is somewhat more pronounced, and the texture of the galena and sphalerite is coarser. Sphalerite is relatively more abundant than galena. Quartz is rather abundant in bands in the ore and impregnates the altered granitic rock adjoining it. Some of the quartz is in elongate prisms, and there is a suggestion of comb structure in some specimens. The granitic rock in the vicinity of the deposits is sericitized, and that adjoining the ore contains carbonates, quartz, and crystals of pyrite. Calcite is an abundant gangue mineral in places. In the Democrat mine Lindgren[3] found a clearly defined fissure in which was deposited first a narrow layer of quartz, then a comb of scalenohedrons of calcite. Within this material was laminated galena containing in the center a much shattered layer of tetrahedrite. Much of the ore consists of masses or isolated grains of galena, sphalerite, and pyrite scattered abundantly through altered granitic rock.

In the Utah Bellevue mine much of the ore consists of irregular stringers, bunches, and isolated grains of the metallic sulphides in a highly altered and crushed lamprophyre dike, although similar ore replaces the granite surrounding the dike. Similar replacements of dikes intruded prior to mineralization are reported from the Minnie Moore and other mines, both in sedimentary and granitic rocks. In the Singleterry and a few other mines similar dark dikes cut the lodes and are therefore clearly younger.

In most of the veins brecciation has taken place one or more times since the beginning of mineralization. Minerals formed in early stages are broken and cemented by those of later origin. The galena is extensively sheared and crushed and in places has been made to flow around other minerals, such as quartz or tetrahedrite.

[2] Lindgren, Waldemar, op. cit., p. 216.
[3] Idem, p. 215.

In the characteristic ore in both sedimentary and igneous rocks the minerals are intricately intermingled, and most of them unquestionably belong to the same period of ore deposition.

Clear evidence can be obtained from polished specimens that crystallization did not take place simultaneously but that the different minerals were formed successively. The intimate intermingling and the fact that the order of deposition differs in different specimens show convincingly that the great mass of the ore in all the lodes was formed from solutions of essentially the same character that underwent gradual change instead of from a succession of distinctly different solutions. On the other hand the minerals formed on fractures of various kinds in the previously consolidated ore are obviously of later date and may even belong to a totally different period of ore deposition. Ore from the North Star mine furnishes one of the best examples of these two stages of deposition. Although the order of crystallization varies and some of the minerals recurred at different stages in the process, some broad features of sequence of deposition appear to be constant in all the ore. The following data are based on the examination of a considerable number of specimens from widely distributed localities, but it has been impossible to make a thoroughly comprehensive study because so many of the better developed mines are now either inaccessible or barren of ore.

Quartz was one of the earliest minerals to form but continued to be deposited at succeeding stages. It is rare in most of the lodes but is more abundant in the veins in granitic rock than elsewhere. Carbonates were formed early, probably just after the first deposition of quartz. Siderite of variable composition is the most abundant carbonate and the principal gangue mineral of hydrothermal origin. In some of the ore its place is taken by calcite. In several of the mines, such as the Independence and the Mascot, there are stringers and lenses of calcite in the unmetallized parts of the shear zones and also in the rock at a distance from the deposits. Pyrite appears to have been the first sulphide to form in most of the ore, but, like quartz, it was also formed later in the process. This mineral is not abundant in most of the ore but is disseminated in the wall rock, in sparsely mineralized parts of the shear zones, and in layers and lenses of quartz without other sulphides. Pyrrhotite occurs in the Croesus gold vein, where it appears to be essentially contemporaneous with quartz, pyrite, and chalcopyrite. Sphalerite, galena, and tetrahedrite formed, with some exceptions, in the order given. Arsenopyrite and a little quartz fill fractures in crushed ore in the North Star mine. Antimony minerals, such as boulangerite, were produced even later and occur in vugs and along crevices in the other minerals in the North Star and several other mines. Hisingerite and various zeolites have been observed in several of the lodes. With the possible exception of the laumontite in an included fragment of limestone in the granodiorite on the hanging wall of the War Dance vein, these minerals are distinctly of late origin and may belong to a totally different period of mineralization. This lode comprises two parallel shear zones separated by comparatively barren material. The ore contains arsenopyrite, pyrite, quartz, and in one place a layer of galena. Except for the comparative abundance of arsenopyrite and scarcity of galena the lode is essentially similar to other lodes in the region.

ORE SHOOTS

One of the most peculiar features of the lodes of the region and the one of the greatest economic interest at the present time is the localization of ore shoots. In none of the mines has ore been found more than 800 feet vertically below the outcrop, and half of those which have been extensively developed contain no known ore bodies more than 200 feet below the surface. In two mines, the Minnie Moore and the Independence, ore has been followed down the dip of the lode over 1,000 feet, but most of them are much shallower. Microscopic examination of ore specimens shows conclusively that supergene processes have played a minor part in the formation of the ore now mined. Nearly all of it shows no trace of supergene alteration. In all the lodes the ore is confined to more or less sharply defined shoots, and considerable portions of the shear zones are so little mineralized as to be scarcely distinguishable from the unaffected country rock except on close examination. A number of the ore shoots lie essentially horizontal, but others pitch at different angles. The main ore shoot in the Bullion mine had a pitch length of about 1,200 feet, a breadth of about 100 feet, and a width that ranged from a few inches to more than 15 feet. According to the map, the largest shoot in the Red Elephant mine had a pitch length of over 700 feet. It is reported to have had a maximum width of 50 feet. A shoot in the Eureka mine, which was an unusually steep one, was over 500 feet in pitch length and 4 to 10 feet in width. The main shoot in the Idahoan mine, on the same lode, may have been even larger. The irregular shoot in the Independence mine was nearly 1,400 feet long. A number of other shoots of comparable size have been mined, and there are many smaller ore bodies.

The deposits are related in age and origin to the granitic rocks that were probably intruded in Cretaceous time. Since that period of igneous activity there has been a vast amount of erosion in Idaho.

The cover has been stripped from the granitic masses over an area of more than 16,000 square miles, and the igneous rock itself has been deeply eroded. The depth of erosion can not be calculated with any accuracy, but in other parts of Idaho it has been estimated [4] as several thousand feet, the minimum being perhaps 5,000 feet. The depth of erosion in the Wood River region and therefore the depth at which the lodes now exposed were formed is believed to be of this order of magnitude. As most of the lodes crop out at altitudes above sea level which are 2,000 or 3,000 feet lower than the average altitudes in the two regions where the estimates just referred to were made, it is possible that the erosion in the Wood River region has been somewhat greater. In view of the great erosion since the formation of the deposits and of the lack of much reworking of the ore by supergene processes it is evident that the relations of the ore bodies to the present surface are fortuitous. It is necessary to seek some cause for the localization of the ore shoots which was operative at the time of their formation, long before the present topography came into existence.

The deposits are of deep-seated origin, are essentially uniform in texture and mineral content throughout the portions exposed in mining, and lie in fissure systems, some of which are several miles long and contain individual shear zones with lengths of nearly a mile. All these facts appear to indicate that the deposits should persist in depth. On the other hand, the localization of ore of commercial value in shoots is the rule rather than the exception in most mining districts. There are many factors which may govern the formation and location of such shoots. When the ore shoots originally discovered have been mined out, as has occurred in so many of the mines of this region, decision as to whether and how further development should be undertaken should rest on careful study of such of these factors as may have been operative in each deposit. As this is the problem which faces or will face most of the mine managers of the Wood River region, the factors that may have governed the formation of ore shoots in this region are discussed below. It seems highly probable that undiscovered ore shoots exist at depth, even in some of those mines in which extensive search has been made for them. The question is, Can they be found without expending so much money in the search as to counterbalance the profit to be expected from them?

In spite of the similarity in character and genesis of the lodes the factors which have dominated the production of ore shoots appear to

[4] Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Coeur d'Alene district, Idaho: U. S. Geol. Survey Prof. Paper 62, pp. 139–140, 1908. Umpleby, J. B., Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, p. 36, 1913.

have varied markedly. On one theory, however, the localization of ore shoots in zones only a few hundred feet wide might be accounted for. This theory is that the mineralized fissures are reverse faults. not necessarily of large displacement, in which only the steeper parts were favorable for ore deposition. In most of the mines the nature of the displacement along the shear zones has not been determined because of the absence of easily recognizable horizon markers, but such a theory fits the known facts in most of them. The Independence lode, one of the best-developed lodes in the region, is considered by O. H. Hershey, who has studied it in detail, to be on a reverse fault. A large part of the faulting that took place in the general period in which the subsequently mineralized fissures were produced has been shown by Westgate to be of reverse type. Many of the mineralized shear zones are of moderate inclination, and some are in part almost horizontal. It is therefore a fair presumption that at least some of the lodes are on zones of reverse faulting.

Under the action of the compressive forces that produce reverse faults the shattered rocks are tightly pressed together. Fault zones thus formed are not in general as likely to constitute favorable channels for the passage of solutions as zones of normal faulting produced by slipping under tension. Reverse faults in general are consequently not favorable places for ore deposition. Under suitable conditions, however, there might well be buckling along a reverse fault, resulting in a tendency for a certain part of the walls to bulge apart instead of being jammed together. In these places solutions could circulate with comparative ease. Reverse faults are characterized by gentle dips, but buckling would tend to produce steeper dips in the parts affected by it. Consequently the steep parts of zones of reverse faulting might prove to be the places most favorable to ore deposition.

In few of the mines has development been carried far enough to enable the hypothesis to be adequately tested, but such data as are available indicate that the ore shoots are in portions of the lodes in which the dip is moderate or high and that shear zones of gentle dip contain little or no ore. The Independence and the Bullion, two of the deepest and most extensively developed mines in the region, are excellent examples of this condition. It is a question whether the ore-bearing solutions were forced through the flatter portions of the fissure zone without deposition or whether these portions were so tightly compressed as to be impervious and the solutions entered the favorable parts of the fissures in some other way. This suggestion is offered merely to be borne in mind by those who undertake further development of the older mines. Future prospecting at depth may show that the limitation of ore bodies to zones of small vertical extent is apparent rather than real.

Irrespective of the validity of this conception the variations in the ore shoots in the zones in which deposition has taken place remain to be accounted for. In zones of such short vertical range changes in temperature and pressure are probably not of great importance. Other things that might aid ore deposition are intersections of fissures, swells in fissure zones, and intersections of fissures with wall rock of a character favorable to chemical replacement, but none of these appear to have had great effect.

In the Wood River region there is little evidence of the formation of ore shoots at fissure intersections. On the Argent claim two intersecting fissures were worked, and the principal ore body, an irregular curved mass, followed roughly their intersection, but this is the only known instance of this kind in the region. In several mines small masses of ore are found at places where the main shear zone is cut by minor cross fractures of premineral age. Probably such cross fracturing with the resulting greater permeability has in places played a part in the complicated process of producing ore shoots.

Parts of fissures and shear zones in which the width of fractured rock is greater than the average and the rock was not very tightly compressed or extensively converted into gouge are favorable places for ore deposition because of their permeability. If movement along a fracture curved in one direction takes place in directions at angles to the axes of curvature, such comparatively open swells alternating with tightly compressed stretches may result. The zones containing the ore shoots in the Mayflower and some other lodes of the region are possibly of this nature. If it is found that the shape of the fissure surfaces and the character of the movements in a lode were such as to produce one swell filled with comparatively loosely compacted rock, other similar swells may be expected laterally and in depth.

As the deposits were produced principally by replacement, the character of the rocks through which the fissuring extends must exert marked influence on the formation of the ore. The sedimentary rocks involved are all broadly similar, and it is doubtless in part owing to this similarity that greater differences do not exist in the character of the ore in the several lodes. There are, however, numerous differences in detail, and the extremes of each type differ sharply from each other. Although many beds are composed of various mixtures of argillaceous, siliceous, and calcareous material, fairly pure shale, quartzite, and limestone are present in places. At the Homestake mine the ore appears to have formed by replacement of calcareous beds cut by the shear zone, the more siliceous beds being left comparatively unmineralized. At the North Star mine the part of the shear zone containing the ore shoots follows essentially a single horizon in the sedimentary rocks. In many of the other mines in sedimentary rocks the ore shoots may bear some relation to the character of the inclosing rock, but similarity in superficial appearance in the strata composing the Pennsylvanian and Mississippian formations is so great and satisfactory horizon markers are so few that much more detailed geologic work than has yet been attempted in most of the mines is necessary in order to evaluate any such possible relations.

The predominance of sphalerite noted in several of the lodes in granitic rock may be related in some way to the character of the wall rock, although it is perhaps more probably related to the distance from the source at the time of deposition.

Uglow [5] has presented a hypothesis to account for the localization of ore shoots of "gneissic galena" ore in the Slocan district which might be applied to the shoots in the Wood River deposits. The deposits of the two districts appear to be strikingly similar. His idea, in brief, is that originally more continuous ore bodies have been broken and offset by renewed movement along the original directions of shearing subsequent to ore deposition. There is abundant evidence of post-mineral movements in the lodes of the Wood River region, but it is doubtful if such great displacements as would be required under this hypothesis have occurred. The arrangement of ore shoots along the Mayflower lode has some resemblance to the en échelon arrangement in the Slocan district described by Uglow. This arrangement does not, however, appear to be characteristic of the ore shoots of the region. Crushing and flowage in the galena is common in much of the Wood River ore, and some of this galena appears to resemble the "gneissic galena" described by Uglow; but the gneissic texture is neither so widespread nor so striking a feature in the Wood River ore as it is in that of the Slocan district. It seems unlikely that the hypothesis by which Uglow explained the ore shoots in the Slocan district is generaly applicable to those of the Wood River region. Nevertheless there are sufficient points of similarity to justify consideration of this idea in a discussion of the Wood River deposits.

COMPARISON WITH DEPOSITS IN OTHER REGIONS

Many lodes in many districts have siderite among the gangue minerals, but in most of them it is not so essential a constituent as it is in many of the lodes in the Wood River region. Siderite is present in numerous veins in Colorado but appears to have been, at

[5] Uglow, W. L., Gneissic galena ore from the Slocan district, British Columbia: Econ. Geology, vol. 12, pp. 650–655, 1917.

least in part, formed later than the ore minerals and by different processes.[6]

Veins in New Hampshire have ankerite as a prominent constituent of the gangue. The ankerite is in rather irregular layers and is of nearly the same color as much of the siderite in the Wood River region. Much of the vein material from New Hampshire is similar in appearance to the more distinctly banded vein matter from the Wood River region. The sulphides in the veins of the two regions are similar in some respects, but the principal precious metal in the New Hampshire veins is gold, whereas in those of the Wood River region it is silver. The veins of New Hampshire have little commercial value but may be the deeper-seated equivalents of deposits analogous to those of the Wood River region. Much of the more distinctly banded siderite-quartz gangue in the Wood River region is in lodes in granitic rock, as in the Democrat and Le Despencer, or close to the contact, as in the Eureka. This arrangement may, perhaps, indicate that the lode material was deposited closer to its source than the veins in sedimentary rocks at a short distance from granitic masses.

Siderite is abundant in the gangue of the famous Coeur d'Alene[7] deposits and others in Shoshone County, Idaho. It was probably originally present in the deposits in the Texas district, Lemhi County,[8] and the Dome district, Blaine County,[9] but has not been definitely identified in the deposits of either district. The Coeur d'Alene deposits have more pyrrhotite and carry a lower percentage of silver than those of the Wood River district and differ in details of texture and structure. The similarities, however, are more striking than the differences.[10]

The deposits of the Slocan district[11] are even more closely similar to those of the Wood River district. The " dry veins " in the granodiorite are similar to those in the quartz monzonite in the vicinity of Deer Creek. The zinc deposits in calcareous beds may perhaps find their counterpart in the zinc deposits of Lake Creek. The

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[6] Means, A. H., Geology and ore deposits of Red Cliff, Colo.: Econ. Geology, vol. 10, p. 19, 1915. Patten, H. B., The Montezuma mining district of Summit County, Colo.: Colorado Geol. Survey First Rept., pp. 139–140, 1909. Spurr, J. E., and Garrey, G. H., Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, p. 259, 1908.

[7] Umpleby, J. B., and Jones, E. L., Geology and ore deposits of Shoshone County, Idaho: U. S. Geol. Survey Bull. 732, 1923.

[8] Umpleby, J. B., Geology and ore deposits of Lembi County, Idaho: U. S. Geol. Survey Bull. 528, pp. 89–109, 1913.

[9] Umpleby, J. B., The lead-silver deposits of the Dome district, Idaho: U. S. Geol. Survey Bull. 540, pp. 218–221, 1914.

[10] Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Coeur d'Alene district, Idaho: U. S. Geol. Survey Prof. Paper 62, pp. 137–738, 1908.

[11] Uglow, W. L., Gneissic galena ore from British Columbia: Econ. Geology, vol. 12, pp. 643–662, 1917.

lodes in the slate series are similar to many in the sedimentary rocks around Hailey, even to the presence of "gneissic galena."

In Europe also there are a few districts containing deposits similar to those here described. Many of the lodes of Siegerland, Westphalia,[12] have abundant siderite in the gangue and contain such sulphides as galena and sphalerite. The district, however, is principally noted for iron mining in the exceptionally wide siderite lodes.

The deposits of Siegerland, British Columbia, and northern Idaho have all been developed to greater depths than most of those in the Wood River district, but all show a tendency to decrease in the content of lead and silver at depth. This decrease takes place at depths of more than 1,000 feet below the surface, whereas few of the Wood River deposits have yielded ore at half that depth. The Coeur d'Alene deposits, in contrast to the Wood River deposits, contained exceptionally large ore bodies, some of which have been found to be continuous to considerable depths. One of the ore shoots has been followed down the pitch for a distance of more than 4,000 feet, to the fourteenth level of the mine,[13] and several others have been followed more than 1,000 feet on the pitch. The deposits of the Coeur d'Alene district are the outstanding examples of great lead-silver ore bodies in a dominantly sideritic gangue.

Although the ore bodies of the Wood River region are small compared to those of the Coeur d'Alene district, much of the ore is richer in silver. The Wood River ore bodies compare favorably in size with those of the Slocan district and in general with ore bodies in other types of lodes. The one outstanding unfavorable feature of the Wood River deposits is the apparent lack of persistence of the ore in depth. Ore shoots at greater depths may well exist, but no guides by which such shoots can be found have yet been established.

CONTACT-METAMORPHIC DEPOSITS

GENERAL CHARACTER AND DISTRIBUTION

A number of ore deposits in the Wood River region differ markedly from the lodes previously described and appear to be of contact-metamorphic origin. They are characterized by their occurrence in areas in which lime-silicate minerals are widely distributed in the rocks and by the intimate mixture in the deposits themselves of metallic sulphides and oxides with the lime silicates. Contact-metamorphic minerals are also abundantly developed about the margins of the igneous mass west of Hailey, but here they occur in the

[12] Beyschlag, F., Vogt, J. H. L., and Krusch, P., The deposits of the useful minerals and rocks, translated by S. J. Truscott, vol. 2, pp. 792–905, 1916.

[13] Umpleby, J. B., and Jones, E. L., jr., Geology and ore deposits of Shoshone County, Idaho: U. S. Geol. Survey Bull. 732, p. 57, 1923.

country rock, and in no place are they known to be constituents of the ore near by.

The contact-metamorphic deposits of the region may be considered in four groups according to the metals which they yield. The two groups east of Ketchum contain similar gangue minerals, but one is valuable for copper, with gold, silver, and zinc accessory, and the other for gold associated with abundant zinc, with copper and silver accessory. Silver, gold, copper, and zinc thus occur in both groups but in different relative amounts; lead minerals are only meagerly developed in them. In the deposits near the head of Big Lost River, on the other hand, argentiferous galena predominates over the other metallic minerals, and in those near the head of the East Fork of the Big Wood River the predominant metal is iron, with some gold. In the deposits east of Ketchum the common gangue minerals are birefringent garnet (index 1.805 to 1.815), diopside, augite, wollastonite, and vesuvianite, with rare crystals of actinolite, tourmaline, apatite, and biotite. In contrast to these deposits the Lost River deposits contain large amounts of epidote and considerable prehnite, along with birefringent garnet of a somewhat different type (index 1.74 to 1.76). The deposits near the head of the East Fork of the Big Wood River are of a third type, in which magnetite is the most abundant mineral and siderite is a common accessory constituent. It is noteworthy that here, as in several other contact deposits, abundant galena is associated with epidote.

DEPOSITS EAST OF KETCHUM

The area of contact metamorphism east of Ketchum includes the Starlight gold deposit and the Bald Eagle copper deposit, in both of which the ore and lime-silicate minerals are intimately intergrown. Thence the area extends southward as a belt about half a mile wide as far as the divide between Elkhorn Creek and the East Fork of the Big Wood River, beyond which it widens abruptly to about 2 miles between Peters Creek and Star Creek. The rocks are by no means made up predominantly of lime-silicate minerals, but within the area many of the rock layers are locally intensely metamorphosed and isolated bunches and patches of contact minerals are widely developed. The North Star, Triumph, and Elkhorn veins occur within the area near its eastern margin, but lime-silicate minerals have not been recognized within their ore. The character of the metamorphic rock in this area has already been described. (See pp. 40–41.)

The most common type of metamorphic rock in this area is greenish gray and is made up of predominantly small interlocking crystals of garnet and diopside or augite. Locally in such rock there is considerable calcite, in bunches and interstitial particles, and in the ore bodies sphalerite, chalcopyrite, and a little pyrrhotite, pyrite, galena, and specularite occur both interstitially and intergrown with the silicate minerals. Another type is a light-gray rock studded with bundles of vesuvianite and rare crystals of tourmaline and apatite. Elsewhere wollastonite, tremolite, and biotite occur in bunches and in scattered crystals, and in some of the gold ore sphalerite almost equals the silicate minerals in amount. In places bedding structure is preserved in the rock and accentuated by the distribution of graphitic patches residual from the original carbonaceous beds. Along these patches are thin tabular replacement deposits of pyrite, which are conspicuous in a few of the specimens.

The paragenesis of the contact-metamorphic minerals can not be definitely worked out, for many of them developed throughout most of the formative period. In different places each of the metallic minerals occurs within silicate minerals, and most of them have been observed as veinlets traversing the silicate rock. Their common occurrence, however, is interstitial, and from this it is believed that they tended to form later than the lime silicates. There is certainly no clear record of a succession of distinctly different solutions but rather of one solution which underwent gradual change, so that in general the metallic minerals formed later.

From the Starlight mine 175 tons of contact-metamorphic ore averaging 1.6 ounces of gold to the ton was shipped in 1913. This amount was hand sorted from about 3,000 tons of low-grade material averaging about $12 to the ton in gold. The average zinc content is not known, as it is not paid for by the smelters. The gold is free and occurs as minute flakes readily recoverable by panning. The mine is described on pages 189–190.

The Bald Eagle copper ore occurs in an irregular mass, 25 feet of which, where it is crossed by a tunnel, averages 2 per cent of copper, 0.002 ounce of gold, and 1.2 ounces of silver to the ton. The deposit is fairly well developed (see pp. 188–189), but no ore has been shipped.

DEPOSITS NEAR BIG LOST RIVER

The sedimentary rocks near the headwaters of the Big Lost River are similar to those near Ketchum, but here the metamorphism is definitely related to an exposed area of monzonite, whereas east of Ketchum no granitic rock appears at the surface, although several lamprophyric and granite porphyry dikes suggest its presence in depth. The monzonite at the head of the Big Lost River crops out in the bottoms of canyons over an irregular area of about 4 square miles. On the divides the Ordovician rocks extend out over it, and laterally it plunges beneath them at an average angle of perhaps 40°.

The rocks on the divide above the monzonite, where calcareous, and for a mile or more laterally from its exposed margin, are generally metamorphosed to a moderate extent and locally contact minerals are abundantly developed. Thus the metamorphosed area is much larger than the exposed area of monzonite. The outer limit of metamorphism is exceedingly irregular and illustrates well the influence of rock composition in determining the intensity and extent of metamorphism. In the Phi Kappa deposit, east of the monzonite area, a single bed of limestone about 6 feet wide has been almost completely transformed to lime-silicate minerals with associated argentiferous galena for a distance of about 6,000 feet, whereas near-by shale and quartzite beds are in most places but little altered. West of the monzonite the Basin and Black Rock prospects present similar relations, but here the metamorphosed beds are calcareous slate and are thicker. In each of the deposits chalcopyrite, pyrite, pyrrhotite, and sphalerite are associated with the argentiferous galena. West of the monzonite and also north of it veins of lead-silver ore occur in the outer part of the area of contact metamorphism. In these veins so far as is known, the gangue contains no lime-silicate minerals. Some of the deposits are traversed by lamprophyric and monzonitic dikes. These dikes are metamorphosed less thoroughly than the beds they cut but are doubtless offshoots of the intrusive mass that caused the metamorphism and were present during the mineralizing activity.

The Basin, Black Rock, and Phi Kappa prospects near the head of the Big Lost River, are not sufficiently developed to afford a fully reliable idea of the characteristics of their ore. Assays of metamorphosed beds aggregating 16 feet in thickness on the Phi Kappa claim, are reported to have afforded returns of 10 ounces of silver to the ton, 5 per cent of lead, and 6 per cent of zinc. The ore both here and at the Basin prospect is a dense aphanitic material in which few crystals with definite boundaries can be seen. Here and there a small but well-formed crystal of garnet, bundles of tabular prehnite crystals, and minute but brilliant faces of epidote crystals are distinguishable megascopically. The metallic minerals occur similarly as small individuals and as interstitial patches or interrupted veinlets and stringers. Galena and chalcopyrite are the most conspicuous minerals, although careful inspection reveals intermixed sphalerite. Pyrite occurs in some of the ore, and chalcopyrite is absent. Magnetite and specularite are rare. Quartz veinlets as much as 1 or 2 inches wide traverse the silicate rock in places, and in them the metallic minerals also occur, here developing larger individuals than elsewhere. When examined microscopically the garnet is seen to be rather uniformly distributed throughout the mass, most of it as grains and patches which are birefringent (about 0.01). Diopside, next in abundance, is in clusters of minute grains, many of them with the same orientation. In places it is accompanied or displaced by augite, similarly distributed. Epidote, which is very abundant in some of the specimens, is present in nearly all of them as grains and prisms in groups and scattered individuals. In places it is intergrown with prehnite, which occurs locally in great abundance as sheaf-like groups of tabular crystals. This association of epidote and prehnite is particularly striking in specimens from the Basin prospect, where fluorite also occurs in noteworthy amounts and wollastonite is present locally. Chlorite is abundant after diopside, augite, and epidote. It occurs as clusters of radiating leaves in the same sections with shreds and felted aggregates of sericite. The rock from the Black Rock prospect has not been examined microscopically but is broadly similar to that at the Basin and Phi Kappa deposits. There is a little arsenopyrite at the Black Rock.

DEPOSITS NEAR THE HEAD OF EAST FORK OF BIG WOOD RIVER

The deposits near the head of the East Fork of the Big Wood River are replacements of limestone and quartzite of the East Fork formation by magnetite, arsenopyrite, quartz, and siderite. Actinolite occurs in them and is abundant in adjoining limestone beds. Pyrrhotite has been reported. They have been worked for their iron content but are also reported to contain some gold. They are similar in general structural relations to the deposits just described and contain actinolite and magnetite, which are characteristic of contact-metamorphic deposits. On the other hand, the presence of siderite shows that they are related to the lodes in which this is a characteristic mineral.

COMPARISON WITH DEPOSITS IN OTHER REGIONS

In most districts contact-metamorphic deposits are exceedingly irregular in outline, but here certain thin, steeply dipping beds, almost completely changed to lime-silicate rock for long distances, are inclosed by strata of a type resistant to metamorphism, and thus to some of these contact-metamorphic deposits present a tabular form, like veins. This type of occurrence is well illustrated by the Phi Kappa deposit and to a less striking degree by exposures in the area east of Ketchum. In many districts the contact-metamorphic deposits are more closely related to the margin of the intrusive mass than the vein deposits, thus giving rise to the name of the group, but in the Wood River region such a relation is not applicable as a criterion, for veins occur locally within the igneous area, whereas in the contact deposits east of Ketchum no granitic mass is exposed. In all the deposits the transition is imperceptible from ore of excellent grade to material containing too little of the metals to be of value, and in much of the lime-silicate rock no ore minerals occur.

VEINS CONTAINING NONMETALLIC MINERALS

Small, more or less lenticular veins, consisting almost exclusively of quartz or calcite, are exposed in a number of the mines, such as the Independence and the workings on the Mascot property. Although both minerals are found in the gangue of the ore deposits, it is thought that those gash veins which contain no metallic minerals may not be directly related to the mineralization that produced the ore bodies. Such veins are common in regions in which there has been considerable diastrophism. They may result by leaching and reprecipitation of silica and calcium carbonate contained in the rocks by water circulating at considerable depths below the surface and consequently under pressure and at high temperature, but not necessarily directly related to igneous activity. It is possible, however, that part of the necessary heat was derived from the cooling granitic rocks, and emanations from them may have had some share in the production of these veins.

Both quartz and calcite lenses have in places been bent and broken by organic forces. In the Lydia tunnel of the Mascot mine quartz lenses are displaced by small reverse faults. If these faults are correlated with the large reverse faults of the region it is probable that they were formed prior to ore deposition. If so, it follows that the quartz lenses broken by them are distinctly older than the ore deposits. On the other hand, calcite veinlets on joint planes in the rocks were evidently formed by solution and redeposition from meteoric water after the erosion surface had been lowered to a position but little if any above its present one. It is obvious that such veinlets were formed much later than the deposition of the metallic ore, and in places there seem to be gradations between veinlets on joint planes and calcite lenses of greater magnitude. In many individual veins of quartz and calcite no direct evidence as to origin is available. It may well be that such veins have been formed in various ways and at various times.

South of Deer Creek several large lenses of barite containing a very little pyrite crop out. (See pl. 11, *B*.) None of the ore deposits are known to contain any barite. Samples of unaltered quartz monzonite from the Democrat mine and of quartz diorite collected by Lindgren were found on analysis [14] to contain 0.12 per cent of barium oxide each, but similar rock which had been subjected to alteration by the mineralizing solutions contained only traces of

[14] Lindgren, Waldemar, op. cit., pp. 219–221.

barium oxide, showing that the solutions were solvents for barium. The two analyses of rock belonging to the Wood River formation given on pages 31–32 do not show any barium, but it is possible that small quantities are present in some beds.

Most of the similar veins in other regions have been interpreted as resulting from the leaching of the barium from the inclosing rock, which in most places is sedimentary.[15] On the other hand, some consider that barite veins, like so many other veins, result from emanations from igneous rock.[16]

No direct evidence as to the origin of the barite veins near Deer Creek is available. No barite has been found in the other lodes of the region. In the middle portion of the Dockwell tunnel blocks of barite, broken and displaced in mining, are exposed. Much of the rock traversed by this tunnel shows crushing and more or less alteration. Cinnabar is exposed nearer the portal than the barite, and the gray altered limestone at and near the face, when visited in July, 1923, contained a little pyrite and sphalerite and small quartz stringers. No genetic relation between the three kinds of mineralization was discovered. The barium dissolved from the granitic rocks of the Wood River region must eventually have been redeposited somewhere and may have contributed to the barite deposits near Deer Creek. It is difficult, however, to visualize any process by which it could have been concentrated in large lenses of nearly pure barite in this small area. The amount of granodiorite that would have to be leached of its small content of barium to furnish sufficient material to form the masses of barite now exposed at the surface would be so great as to make it highly improbable that the barite in the veins was derived solely from this source. Perhaps the most probable source for most of the barite is emanations given off from cooling deep-seated granitic rocks during the last stages of igneous activity.

COAL

The graphitic material in the old Parker mine on Elkhorn Creek and in the Evelyn prospect on Trail Creek is almost certainly metamorphosed coal. Other hypotheses regarding its origin are discussed in the description of the Parker mine. (See pp. 185–188.) This coal is now so thoroughly graphitized and some of it is so high in ash that it can not be used in the ordinary way, although it could be burned in special apparatus under forced draft. It may perhaps also be used in the manufacture of such things as graphitic paint and foundry facings, in which impure graphite is required.

[15] Lindgren, Waldemar, Mineral deposits, 2d ed., p. 377, 1919. Warren, C. H., The barite deposits near Five Islands, Nova Scotia: Econ. Geology, vol. 6, pp. 799–807, 1911.

[16] Tarr, W. A., The barite deposits of Missouri: Econ. Geology, vol 14, pp. 46–67, 1919. Lewis, J., The magmatic origin of barite deposits: Idem, pp. 568–570.

Both the known occurrences are in the Milligen formation, which is widespread in the region and is largely made up of more or less metamorphosed carbonaceous shale. If the coal should become valuable other similar beds of metamorphosed coal might well be found in this formation.

MIOCENE (?) MINERALIZATION

The lava and associated tuff believed to be of Miocene age, which are widespread in the region, contain no known ore deposits of commercial value. At numerous places, especially in the southern part of the region, slight mineralization has been found along joints, fractures, and bedding planes and in porous tuff. A few prospect pits and short tunnels have been opened at such places, but nothing of value appears to have been found in any of them. The minerals noted include malachite and chrysocolla, opaline and chalcedonic silica, and zeolites, principally laumontite. The oxidized copper minerals were doubtless derived from sulphides. The presence of these minerals shows clearly that there was hydrothermal activity subsequent to the eruption of the lava and probably closely related to it. Perhaps the hot springs described in the following section are connected with this activity.

Some of the mineralization in pre-Tertiary rocks may also have resulted from heated solutions emanating from the lava. In and near a number of the ore deposits small amounts of zeolites line fractures clearly later than the main mineralization. Hisingerite occurs on similar fractures either alone or in association with zeolites.

The cinnabar and associated marcasite in the Dockwell tunnel also probably belong to the Miocene epoch of mineralization, although the evidence is indirect. This deposit consists of a network of seams of cinnabar with marcasite and a little metacinnabarite on fractures in altered calcareous rock belonging to the Wood River formation. The development so far accomplished is inadequate to indicate the extent of the deposit. There is no volcanic rock in the immediate vicinity, but patches of such rock remain on ridges less than a mile farther north, and a large mass is exposed a few miles to the east. The association of ore of this type with Tertiary and Quaternary volcanism elsewhere in the western United States and the apparent absence of mercury in the other ore deposits of the Wood River region lead to the conclusion that the mercury deposit in the Dockwell tunnel is genetically related to the Miocene (?) lava, which before it was eroded away probably covered the present site of the tunnel.

It will be remembered that the antimonial minerals in the lodes previously described were among the latest minerals to form. If the zeolites and hisingerite in these deposits are, as suggested, of

Miocene age, it is possible that the antimonial minerals are of similar age and genesis. Large sheaves of stibnite crystals are reliably reported to have been found on the ridge above the Broadway mine, in a deposit containing no other metallic minerals. On this ridge there are a number of veins that consist of angular fragments of impure limestone cemented by fine-grained quartz containing numerous drusy cavities. The character of the brecciation of the country rock and also that of the cementing quartz are such as would be produced under conditions existing near the surface. The texture of these veins is in striking contrast to that characteristic of the lodes which have yielded the great ore deposits of the region. Unfortunately stibnite was not found in them during the present investigations, but presumably that discovered in this vicinity in the past was in such veins. Veins of drusy quartz containing stibnite in genetic association with Tertiary lava are present in a number of places in the Rocky Mountain region. Many of the veins of this character contain also cinnabar and other minerals and more or less gold and silver. Veins containing most of these constituents, whether or not in Tertiary lava, may with some assurance be considered to have originated as a result of Tertiary volcanism.

HOT SPRINGS

Hot springs occur at four places in the southwestern part of the Wood River region. Along Warm Springs Creek, which joins the Big Wood River from the west at Ketchum, hot springs occur at two principal places—the Guyer Springs, 2 miles from Ketchum, and a group of small springs near the western edge of the Hailey quadrangle. About 9 miles south of the Guyer Springs are the Clarendon Hot Springs, on Deer Creek 3½ miles above its mouth, and 5 miles southeast of these are the Hailey Hot Springs, near the junction of Democrat Creek with Croy Creek. At each of the localities water issues from more than one opening. At the Guyer Springs more than 50 openings, which together yield about 1,800 gallons of water a minute, occur along a narrow zone 300 feet long. The other springs have less than half a dozen openings, and the flow from the largest of them is only 62 gallons a minute. The temperature of the water ranges from 125° to 160° F.

The springs all issue from sedimentary rocks, comprising calcareous shale, sandstone, and limestone. Three of them, the Hailey and Clarendon and the upper springs on Warm Springs Creek, agree closely in alinement with the general structural axes of the region, but none of them are known to occur along a fault plane of noteworthy displacement, and certainly no two issue at the same stratigraphic horizon. The Guyer Springs lie about 5 miles northeast of a line thus determined. These springs issue from a bare surface of hard rock, so that detailed structural relations are clearly shown. The waters rise through a number of nearly vertical joints along a zone about 300 feet long and perhaps 60 feet in maximum width, which strikes N. 62° W., across rock beds that strike N. 4° W. and dip 28°–30° W. The individual openings occur at points as much as 40 feet above the water line of the creek, and the water pours down to it in numerous places. As shown in Plate 12, A, the bedrock is whitened by a small deposit where the hot water flows over it, but deposits of noteworthy size are entirely lacking. This condition is also true of the other springs of the area. The white coating was not observed to be over a few millimeters thick in any place. Locally near the orifice it is slightly stained with iron, but characteristically it consists of calcium carbonate and silica. No sulphate or sulphide minerals were detected. The water of all the springs is pleasant to the taste, almost free of odor, and perfectly clear as it issues from the rocks.

Two-gallon samples were collected from each of the three principal groups of springs for analysis in the Geological Survey laboratory. Two of these, the Guyer and Clarendon waters, were collected through a 4-foot black rubber tube inserted in the principal orifice. The Hailey water was taken directly into the bottles by submerging them in the spring. After being filled the bottles were immediately corked with glass stoppers and sealed with paraffin. The analyses follow:

Analyses of water from hot springs in the Hailey quadrangle, Idaho

[Constituents in parts per million. Analyst, George Steiger]

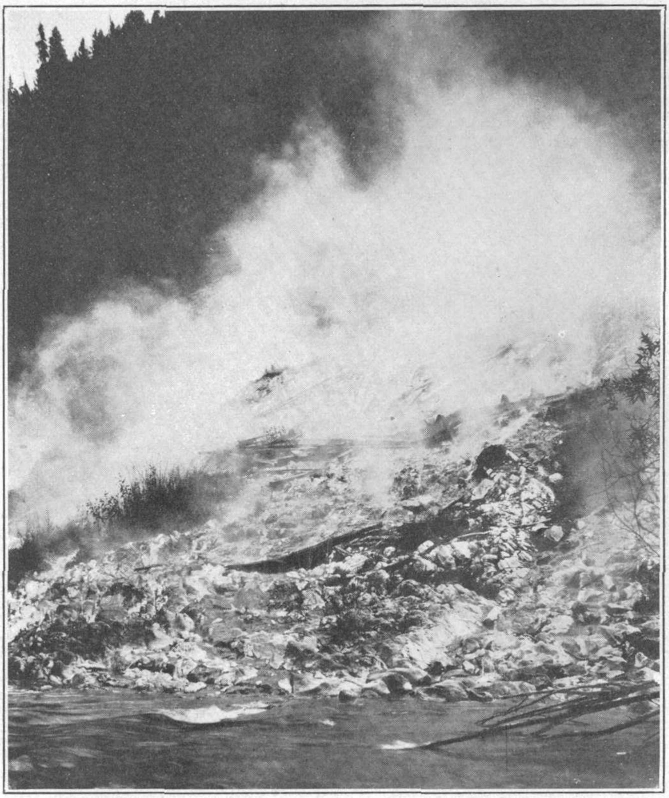
	Clarendon	Guyer	Hailey
Gallons a minute	[a] 15	[b] 1,800	[c] 62
Temperature ° F.	126	159	136
Constituents by weight:			
Silica (SiO_2)	74.8	148.4	124
Aluminum and iron (Al and Fe)	4.1	3	7.2
Magnesium (Mg)	None.	.8	None.
Calcium (Ca)	1.8	9.5	6.8
Sodium (Na)	81.6	96.4	80.5
Potassium (K)	None.	None.	None
Carbonate (CO_3)	55.6	56.4	50
Sulphate (SO_4)	66.8	72.0	60
Chloride (Cl)	12.7	11.1	5.7
	297.4	397.6	334.2

[a] Volume measured from flow in small ditch below swimming pool.
[b] Estimated by Raymond Guyer, the owner, for use in determining power possibilities (4 second-feet). It was impossible to measure the flow, as most of the water cascades to the creek over a wide area.
[c] Volume measured from flow in a flume 8 inches wide near the spring.

The analyses show that the waters are all of the same type, although they issue at widely separated points. They are high in silica and sodium and are similar in general to geyser and hot-spring

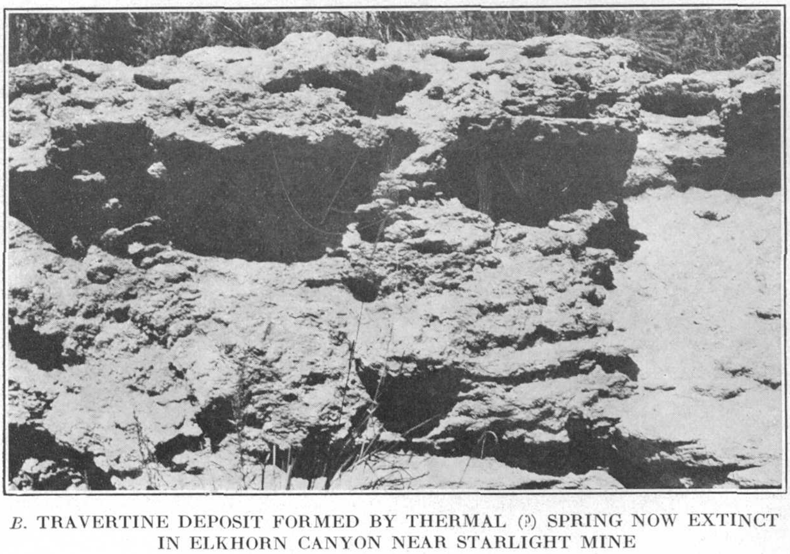
A. ONE OF THE NUMEROUS OPENINGS THROUGH WHICH THE WATER OF GUYER HOT SPRING ISSUES

B. BARITE OUTCROPS ON THE BONNIE GROUP



A. GENERAL VIEW OF GUYER HOT SPRING, WEST OF KETCHUM

Temperature 189° F. Note that the water has made only scanty deposits.



B. TRAVERTINE DEPOSIT FORMED BY THERMAL (?) SPRING NOW EXTINCT IN ELKHORN CANYON NEAR STARLIGHT MINE waters from other regions. They contain distinctly less calcium and magnesium than is characteristic of water that issues from calcareous sedimentary rocks. There is no conclusive evidence as to their origin, but the most probable explanation of their heat and composition seems to be that they are more or less closely related to the volcanic activity of Miocene (?) and later time.

In this connection the presence of travertine in the valleys of Elkhorn, Milligen, and neighboring creeks is of interest. In Elkhorn Canyon the travertine lies below a large cold spring which is not now depositing material of any sort. The deposit is in the bottom of the narrow valley and is not much eroded by the present stream. (See pl. 12, *B*.) The waters that formed it appear to have been low in silica and high in lime—quite different from the water of the present hot springs. If both are related to the volcanism there has been a marked change in the composition in the interval between the activity of the now extinct spring and that of the present day. This conception is not unreasonable in view of the parallel change shown by the paragenesis of minerals in the late Tertiary veins in southern Idaho.[17] In these veins calcite is commonly the first mineral to form and is followed by quartz pseudomorphic after it. It may be noted, however, that the valleys which contain the travertine are carved in rock of the Milligen formation. This rock is somewhat calcareous, and water circulating through it could dissolve some calcite. However, much more calcareous rock elsewhere in the region has no travertine associated with it, and the travertine in Elkhorn Canyon and neighboring valleys can hardly have been formed by surficial leaching alone.

OXIDATION AND ENRICHMENT

Most of the ore mined in the Wood River region has been unoxidized, although it was derived from stopes situated well above the level of adjacent drainage lines, and, with the exception of the Minnie Moore, Croesus, and Idahoan lodes, the larger deposits of the area have been worked from tunnels. Near the surface the ores were generally oxidized to masses of iron and manganese oxides with intermixed lead carbonate and sulphate. In these ores silver chloride is said to have been common. In the Jay Gould mine native lead and minium occurred in small quantities to a depth of 30 feet.[18] Native lead occurred in ore in the Arizona, and cerusite, wulfenite, and pyromorphite are present in an outcrop near the Eureka. No reliable information is available as to the average depth of oxidation,

[17] Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, pp. 168–170, 1900.

[18] Jenney, W. P., oral communication.

but probably it was not more than 50 feet. Sulphide ore is said to have come to the surface in the Minnie Moore and Idahoan mines. In the Red Elephant and Jay Gould it appeared at a depth of perhaps 40 feet, and in the Parker and Bullion at a depth of 80 or 90 feet. In those deposits in which ore remains near the surface, as the Independence, New Hope, Phi Kappa, and Starlight, oxidation ranges in depth from a few feet to perhaps 50 feet. At a number of places sulphides that show only incipient oxidation are exposed at the surface.

The depth to ground water, also, can not be accurately ascertained from the data available. In the vicinity of many of the mines it was well above the level of adjacent gulches. In driving the Bullion tunnel, for example, a flow of water was encountered which compelled suspension of work for several days while the water table back of a gouge seam was dropping to the new drainage level. Although the Bullion tunnel is said to be exceptional in the amount of water which escaped through it, the lower tunnels in nearly all the mines are drainage channels and warrant the conclusion that plans for sinking operations throughout the area must take into account the handling of considerable water.

In the Croesus gold veins oxidation is fairly complete to a depth of about 300 feet. The quartz at that depth is somewhat porous and heavily stained with iron oxides and a little copper carbonate, due to the oxidation of pyrite, pyrrhotite, and chalcopyrite. The features of particular interest, however, are partial oxidation and the presence of druses of chalcopyrite and films of native silver along crevices in galena from the lowest level, 800 feet below the collar of the shaft and 600 or 700 feet below the present water table. In the same stope where these minerals occur there is a partial change of siderite to limonite, galena to cerusite, sphalerite to smithsonite, and primary chalcopyrite to copper carbonate. Although oxidation is thus unmistakable, an inference that the solutions causing it operated to a depth of 600 feet or more below the water table is not justified. The water table at the time of this deep oxidation may well have been several hundred feet lower than at present, as the region is traversed by valleys, probably of Oligocene age, the beds of which are now buried by lavas and valley wash to an unknown depth, possibly in excess of 2,000 or 3,000 feet. On Lake Creek also there is an exceptional amount of oxidation. The ore in the zinc prospects is completely oxidized and that in the Homestake mine is somewhat oxidized at depths of over 200 feet.

As a whole the lodes of the area seem to be compact and unfavorable as channels of meteoric circulation, or else the deposits situated well up on the valley sides would have been oxidized to a greater depth. It is noteworthy, however, that this lack of oxidation is not due to lack of crushing, for few specimens from the area fail to show distorted and striated galena, and in some specimens this mineral has flowed around others, such as quartz and tetrahedrite. It would seem from these relations that in the galena-siderite ore the crushing has been so great as to leave the deposits fully as impermeable to oxidizing solutions as if no crushing had taken place. On the other hand, where the most abundant vein material was quartz, as in the Croesus deposits, the effect of the crushing was to make the deposit more permeable, and here oxidation extended to greater depths than in other deposits in the area.

It is possible also that supergene acid solutions descending through lodes with abundant carbonate gangue were more quickly neutralized than similar solutions descending through lodes with quartzose gangue. This theory might well explain the comparatively deep oxidation in the Croesus, which is in quartz diorite. Most of the other lodes in granitic rock have more carbonate in the gangue. It could hardly, however, explain the deep oxidation in deposits on Lake Creek, where the sedimentary country rock contains considerable calcite. The lack of deep oxidation in most of the deposits is probably due to rapid erosion. The few exceptions may result principally from preservation of remnants of the shallow zone of a previous erosion cycle, which has elsewhere been swept away and fresh material exposed by recent erosion.

A possible explanation of the fact that many of the mines, exceptionally rich in their upper parts, have yielded little ore at depths of more than a few hundred feet below the surface might be sought in enrichment by descending supergene water. Almost no evidence of such enrichment can, however, be found in most of the deposits, as is to be expected in a region of such shallow and irregular oxidation. Many of the larger ore bodies were worked out long before the present investigation commenced and can not therefore be studied at first hand, but the evidence obtained from the accessible prospects and mines, from published descriptions of the old mines, and from conversations with those familiar with the early work all bears out this conclusion. Very few of the many ore specimens collected by Lindgren and by the writers show any indication of supergene enrichment. Supergene chalcopyrite and films of native silver were found in the lower workings of the Croesus, and the native lead and silver reported as occurring in some of the mines in the southwestern part of the region were probably deposited by descending water. Some argentite may also have been formed in this way. Native silver and other minerals of supergene origin are abundant in the Jennie R. prospect. All these occurrences, however, are exceptional, and the quantity at any one place appears to have been comparatively insignificant. Certainly the great masses of ore that have been mined can not be attributed to the results of supergene processes. The one exception among the deposits examined during this investigation is the Jennie R., which is several miles south of the southern boundary of the Wood River region.

AGE AND GENESIS OF THE ORE DEPOSITS

The foregoing descriptions show that the lodes containing the lead-silver and gold ore bodies are localized along fissures and shear zones and were formed in part by metasomatic replacement, in part by deposition in fissures. Replacement is the dominant process, as was clearly demonstrated by Lindgren.[19] The mineralizing solutions pervaded the sheared rock of the fissure zones and in places made their way out into the adjoining unbroken rock. In parts of the fissure zones little chemical change has been effected. The rock has been softened, and small amounts of carbonates, quartz, and pyrite and other sulphides have been formed. In the ore bodies, however, the chemical attack has been vigorous. Large quantities of galena and other sulphides, with varying amounts of siderite and other gangue minerals, have metasomatically replaced the rock. In the ore of highest grade replacement has been essentially complete, but even in the best stopes there are slivers and more or less irregular bodies of rock that are only partly replaced or almost unaffected. In most of the concentrating ore altered country rock constitutes a considerable part of the gangue, and there are all gradations between essentially pure galena and unaltered rock. In all the deposits there has doubtless been a certain amount of deposition in fissure openings without replacement. Such texture as that in the Democrat mine, described by Lindgren, can not be explained on any other hypothesis, but the relative amount of such fissure filling is evidently subordinate.

The method of introduction of the ore minerals was thus dominantly chemical rather than physical. The solutions may have been forced out from their sources under considerable pressure, but it is difficult to see how a fluid so tenuous as to be able to pervade a rock in the intimate way that these clearly did could at the same time serve as the medium for the exertion of a rending force sufficiently powerful to shear the rock so thoroughly. Furthermore, there is reason to believe that the walls of some of the fissure zones have undergone lateral displacement. A fluid injection, even if under such pressure as to cause it to act like a solid wedge cutting a passageway for itself, would not cause notable relative displacement of the rock on either side. The fissure zones probably were produced before the advent of the mineralizing solutions, and the

[19] Lindgren, Waldemar, op. cit., pp. 217–231.

solutions followed them because the sheared rock offered less resistance to their passage. It has been shown (pp. 96–97) that the fissuring probably took place during the period of Cretaceous (?) diastrophism but before the Cretaceous (?) granitic rocks of the region were intruded into their present positions.

It has come to be generally recognized that ore deposits such as those here described are formed by heated solutions derived from igneous rocks. There seems little doubt that the major mineralization in this region is related to the Idaho batholith and its satellites. The characteristics of these deposits differ sharply from those of the mineral deposits in the Tertiary lava, which was erupted during the only other period of igneous activity of which there is record in the Wood River region. They resemble deposits associated with granitic rocks of similar age elsewhere in Idaho [20] and do not resemble deposits associated with Tertiary rocks either in Idaho or in other parts of the Rocky Mountain region.

In outline the history of the lodes appears to have been as follows: Probably in Cretaceous time there was widespread crustal disturbance in Idaho, accompanied, if not caused, by the introduction of great masses of magma. One result of the intrusion of the magma was to set up shearing stresses in the rocks above the advancing masses, producing fissure zones. As the magma reached higher levels the pressure of the crust above gradually decreased. As a result of this decrease in pressure and of incipient consolidation the more volatile constituents left the magma and found their own way upward along the paths of least resistance. By chemical interchange with the rocks encountered and by precipitation where conditions of temperature and pressure were suitable some constituents of the emanations were removed while they were still far below the surface. Probably most of the metals and other substances that went to constitute the ore deposits separated out thousands of feet below the surface then existing, and most of the water, which formed the greater part of the original emanations from the cooling magma, swept on, to mingle eventually with the ground water. The emanations doubtless varied somewhat in original composition and were given off from the magma at different times and places, with consequent differences in the prevailing conditions of temperature and pressure and in the character of the rocks encountered. The variations in these factors seem entirely adequate to account for most of the variations observed in the mineral deposits of the region.

[20] Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Coeur d'Alene district, Idaho: U. S. Geol. Survey Prof. Paper 62, 1908. Umpleby, J. B., Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, pp. 31–45, 1913.

Most of the emanations found the fissure zones the most convenient avenues of escape, at least at the horizons now exposed to view by erosion and by mining. They came from great depths and may have progressed long distances before reaching the zones in which they finally deposited their loads. Some of them came up after the granitic rock had been intruded to levels now exposed and penetrated along fractures in these rocks. The stocks and similar masses now exposed are probably mere projecting cupolas on a batholithic body below. This larger body may well be the source of the greater part of the emanations which formed the ore bodies, and the offshoots above it may have constituted the most favorable passageways for the emanations for considerable distances above the main batholith. Around each stock the volatile constituents oozed out during consolidation of the magma, and the chemical effect of these emanations, coupled with the heat given off by the magma, resulted in the changes known as contact metamorphism. In most places in this region the results are neither striking nor of any economic significance, but here and there certain rocks were readily attacked under such conditions, and these were almost completely replaced by contact-metamorphic minerals. Some of the minerals thus produced contained lead, silver, gold, iron, and other metals, and the result in such places was the production of contact-metamorphic ore bodies. Most of the heavy metals did not penetrate the rocks in this way, perhaps in part because the solutions which carried them were not sufficiently tenuous and in part because strata of suitable composition for replacement are lacking along most parts of the igneous contacts. Instead they found their way into fissure zones and were deposited there. After most of the galena ore had been formed there was sufficient movement to fracture it. Arsenical and antimonial minerals are found in these fractures, proving that they were deposited by later emanations. These minerals may have formed either in the last phases of the Cretaceous mineralization or during the less powerful mineralization in the Tertiary.

The greater part of the crushing and contortion of the ore bodies probably took place long after the mineralization that accompanied the granitic intrusions had ceased, very likely during the eruptions of lava and associated tuff which occurred in the Tertiary, probably in Miocene time. Valuable ore deposits are associated with lava of this general character and age elsewhere in the Rocky Mountain region,[21] but in the Wood River region the Tertiary mineralization appears to have been feeble. Copper is the only valuable metal known to

[21] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, pp. 86–89, 1917; Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, pp. 45–47, 1913; Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, pp. 54–57, 1913. Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, pp. 106–188, 1900.

have been deposited in the volcanic rocks themselves. Mercury and antimony deposits were probably formed at this time in the older rocks in or near ore deposits of the earlier period, but none of these have yet been shown to be of commercial value. Further development may possibly show that valuable mercury deposits are present here. Somewhat similar deposits from which mercury ore has been mined are known in other parts of Idaho.[22]

DETAILED DESCRIPTION OF MINES

JENNIE R. PROSPECT

The Jennie R. prospect, operated by W. P. Fowler and H. J. Koonce, is in the SW. ¼ sec. 15, T. 1 N., R. 17 E. Although south of the region mapped, a brief visit was made to it in 1924 by Ross. The deposit was known in the early days as the Montezuma, and considerable ore is reported to have been shipped from shallow workings. The following table shows all available data as to the production of the Montezuma up to the time the present operators started work. It may not be a complete record.

Early production of Jennie R. prospect

[From records of E. Daft, Ketchum smelter, and U. S. Geol. Survey]

Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*
1883	1.6	0.002	188.0	337
1884	12.5	.08	933.0	3,154
1885	127.5		10,740.4	32,539
1886	3.8		410.9	5,001
1887	5.2		689.5	3,679
1901	8.8	1.25	1,140.8	3,839
1908	1.5	.125	129.3	380
	160.9	1.45	14,231.9	48,929

The present developments comprise a tunnel 60 feet long and a winze below it. The winze is now about 20 feet deep but originally was somewhat deeper. On July 30, 1924, a shipment was made of 10,934 pounds of ore containing 0.14 ounce of gold and 185.9 ounces of silver to the ton, 19.5 per cent of lead, 0.9 per cent of copper, 14.5 per cent of zinc, 57.6 per cent of insoluble matter, 9.6 per cent of sulphur, and 2.3 per cent of iron.

Specimens of ore from the dump contain native silver, horn silver, galena, sphalerite, and a little chalcopyrite and pyrite in a gangue of quartz and calcite. The vein matter is irregularly banded, alternate bands being composed of sulphides and of crushed quartz. Calcite fills some of the interstices in the quartz and coats surfaces

[22] Larsen, E. S., and Livingston, D. C., Geology of the Yellow Pine cinnabar mining district, Idaho: U. S. Geol. Survey Bull. 715, pp. 73–83, 1920. Ross, C. P., Antimony and quicksilver deposits in the Yellow Pine district, Idaho: U. S. Geol. Survey Bull. 780, pp. 137–164, 1926.

of it. The lode is made up of stringers of such material in silicified and sericitized granite partly replaced by irregular aggregates and stringers of sulphides, principally galena. The assays of samples quoted below, which were collected by the owners on June 6, 1924, show that the ore is not particularly rich in gold or lead but contains a higher proportion of silver than is usual in the ore of the Wood River region. This richness in silver is doubtless due to the abundance of native silver in parts of the lode. This silver and the horn silver, which is visible in some specimens, are clearly of supergene origin. The Jennie R. is the only mine examined during the present investigation in which a large part of the value of the ore now mined has resulted from supergene enrichment.

Assays of samples from Jennie R. prospect

[Collected June 6, 1924]

Gold	Silver	Lead
Fine ounces per ton	*Fine ounces per ton*	*Per cent*
0.29	258.5	21.6
.08	299.3	1.5
.14	456.2	12.0
Trace.	1,062.7	.4

UTAH-BELLEVUE MINE

The Utah-Bellevue mine is in Townsend Gulch, about 6 miles by road southwest of Bellevue. It is operated by A. W. Kelly. Work has been in progress for nearly 11 years. Shipments were made in 1915, 1918, 1921, and 1922, as shown in the table below. The gross value of the total production is estimated by Mr. Kelly as about $10,000.

Typical ore shipped September 12, 1922, contained 9.8 per cent of lead, 0.130 ounce of gold and 66.85 ounces of silver to the ton, and 38.0 per cent of insoluble matter, 17.7 per cent of zinc, 1.0 per cent of speiss, 18.3 per cent of sulphur, and 7.7 per cent of iron.

Shipments from Utah-Bellevue mine

Year	Crude ore shipped to smelter	Metals recovered			
		Gold	Silver	Lead	Copper
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1915	42	0.84	440	8,390	168
1918	30	3.54	1,286	2,832	118
1921	69	7.93	3,253	12,207	312
1922	66	8.97	4,405	13,680	400
	207	21.28	9,384	37,109	998

The principal underground development, as shown in Figure 8, is a crosscut tunnel about 240 feet long connecting with a drift, which

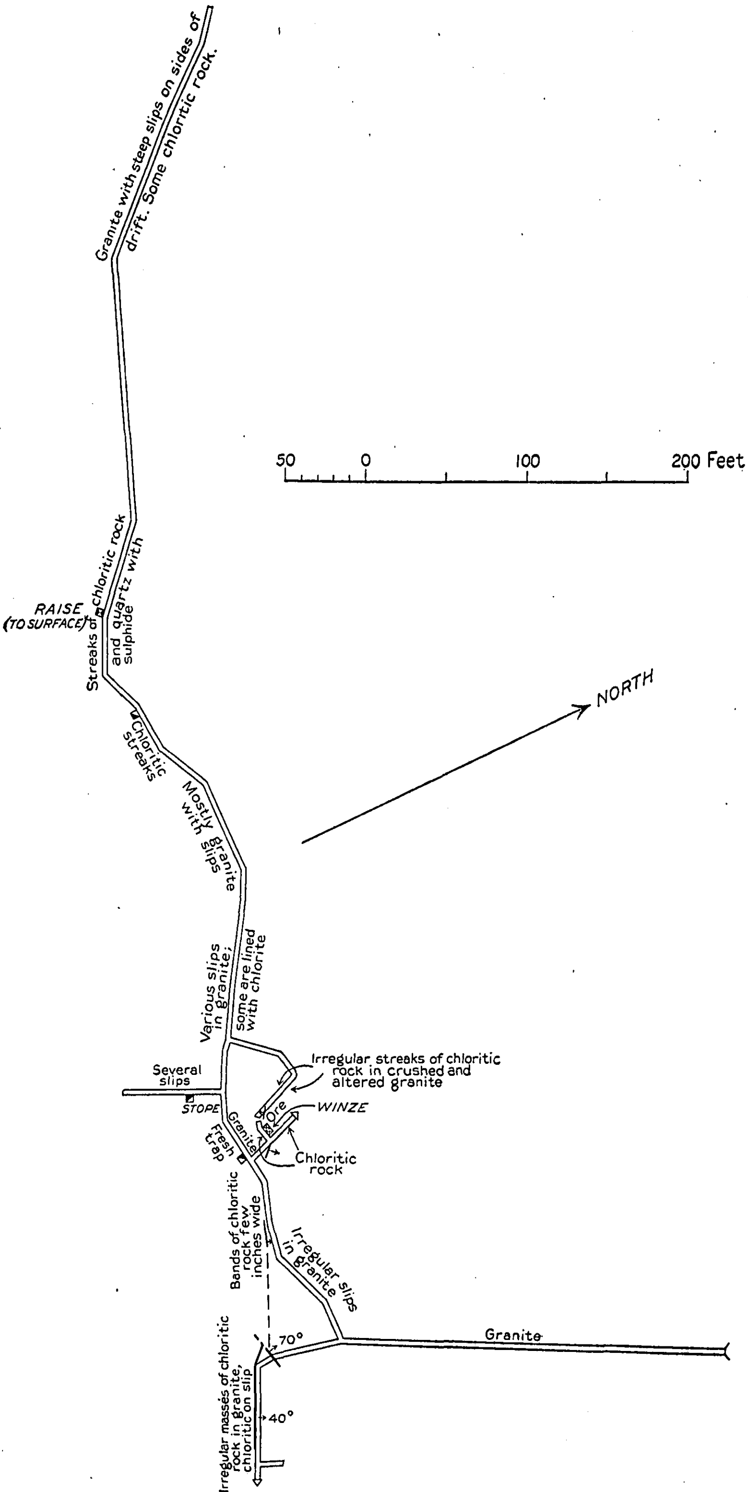


FIGURE 8.—Sketch map of the Utah-Bellevue mine

with its ramifications totals about 1,200 feet. There is a winze below this drift and several inclined raises above it, one of which connects with the surface. The winze was inaccessible at the time of visit, but a sketch map prepared by V. C. Heikes a few years ago shows that the winze has a length of 50 feet on an incline of about 45° N. At the bottom are short drifts northwest and southeast and another 30-foot winze. The raises above the main level slope upward 30°–40° S., and the one that extends to the surface has a drift off from it part way up and, according to Mr. Heikes, is 258 feet long.

The country rock is granite. In the main drift there are numerous exposures of altered and fractured lamprophyre. In places these are small irregular masses; elsewhere most of the rock exposed is lamprophyre. This rock was evidently introduced into the granite as a dike of irregular outline, probably with apophyses projecting from it, and was extensively shattered by the shearing forces that formed the lode fissure. Many of the slips in the shear zone are lined with layers of chloritic material, as if small masses of the lamprophyre had been drawn out along them. Under the microscope the lamprophyre is seen to consist largely of lath-shaped andesine feldspars with quartz in the interstices. There is considerable chlorite and calcite and some epidote. Originally the rock contained abundant ferromagnesian minerals, but these are now altered beyond recognition. The lode is a broad and poorly defined shear zone which trends about N. 70° W. and dips northeast. The granite and lamprophyre in the zone, especially the lamprophyre, are altered and fractured, and in places calcite, quartz, galena, sphalerite, and pyrite have been deposited in both rocks. Much of the ore has been found in the lamprophyre or in association with chloritic layers in the altered granite. Most of that shipped came from the main winze. There is also a stope above the crosscut to the southwest 50 feet from the winze, and some ore is exposed in the raise that reaches the surface and in the main drift near this raise.

PENOBSCOT GROUP

The Penobscot group is on the south side of the mouth of Galena Gulch in sec. 35, T. 2 N., R. 18 E. It comprises the Penobscot, Penobscot Fraction, and Riverview claims and a mill site and in 1923 was held under lease by W. T. Roberts. The only underground working of any size accessible when visited in 1923 is on the Riverview claim. This working is a tunnel 565 feet long, with a crosscut 100 feet long about 500 feet in from the portal. Most of this work was done in the early days, but a little has been done by lessees since. The only production of which record has been found is listed below.

The shipments in 1883 and 1900 are credited to the Penobscot and that in 1897 to a lease on the Riverview. The data are from the records of E. Daft.

Production of Penobscot group

Year	Ore and concentrates	Silver	Lead
	Tons	*Fine ounces*	*Pounds*
1883	11.1	767.2	13,160
1897	2.5	168.9	2,755
1900	1.6	69.5	1,605
	15.2	1,005.6	17,520

The country rock is banded shale. Near the crosscut it strikes N. 8° E. and dips 55° W. The tunnel follows a shear zone with fairly well defined walls. The zone strikes N. 9° W. and dips 60° W. and in places more. Its attitude thus differs markedly from that of most of the lodes in the vicinity, which strike much more to the west of north, as can be seen from the arrangement of the claims on Plate 10. The sheared material in the tunnel contains some vein quartz and calcite and in places a little sulphide. Specimens from these places and from the dump show that galena is the principal sulphide in the ore, but arsenopyrite, pyrite, stibnite, and sphalerite are also present.

In 1908 another tunnel on this group, some distance up the slope above that just described, was visited by D. F. Hewett. It was then accessible for a distance of 200 feet from the portal. The rock exposed was much crushed blue shale. The lode was not seen. The ore contains much siderite and sphalerite with some pyrite and is the result of a replacement of the shale. There has been little production. Ore valued at $1,200 was mined from a pocket in a tunnel east of the one described.

OVERLAND MINE

The Overland mine is on the south side of Galena Gulch half a mile west of the Minnie Moore mine, in sec. 34, T. 2 N., R. 18 E. This is one of the older mines of the district but is small compared to the Minnie Moore and some others. Lindgren[23] estimates the production in the early days as $30,000, and according to estimates reported by A. J. Walker ore of a total value of about $125,000, containing an average of roughly 54 per cent of lead and 167 ounces of silver and 7 ounces of gold to the ton, was mined before the property

[23] Lindgren, Waldemar, op. cit., p. 189.

was shut down in 1893. The following table shows some of the early production:

Early production of Overland mine

[From records of E. Daft]

Year	Ore	Silver	Lead
	Tons	*Fine ounces*	*Pounds*
1883	17.4	1,748.4	22,451
1884	11.2	1,151.9	15,643
1885	56.5	4,530.4	68,377
	85.1	7,430.7	106,471

According to notes made by D. F. Hewett in 1908 the vein strikes N. 55° W., dips 70° SW., and is 30 inches wide between well-defined walls. The shaft was caved within 40 feet of the surface but is reported to have been originally more than 180 feet deep. The gangue of the lode is principally siderite with some calcite and contains dark sphalerite, galena, chalcopyrite, and some tetrahedrite. There is some tendency to banded disposition. Mr. Walker has been informed that lead-silver ore 10 to 24 inches wide was exposed in the bottom of the shaft.

In 1922 the Overland and Little Giant patented claims and the California unpatented claim were taken under bond and lease by A. J. Walker. A tunnel has been driven under his direction 678 feet southwestward with the intention of cutting the Overland vein, but another zone of mineralization was encountered in January, 1923, 25 feet from the present face of the tunnel, and this has been drifted on for 315 feet in a southeasterly direction.

The principal rock on the claims is quartz diorite. The shear zone on which drifting was in progress in the summer of 1923 strikes in general N. 50° W., and its inclination ranges from vertical to 70° SW. It is bounded by fairly well defined walls. The diorite between these walls is altered and contains small amounts of siderite, quartz, galena, pyrite, and hisingerite. The amount of metallic minerals in the part of the zone exposed is too small to be of commercial value. The main zone is crossed by small slips with a little quartz on them which strike about N. 50° E. and dip steeply southeast. There is a little variation in the lithologic character of the rock exposed in the drift. Part of it was originally of somewhat more calcic composition than the unmineralized rock in the tunnel. In several places there are exposures of a soft, rather fine grained chloritic rock, which is probably a dike. It has been broken into fragments and altered during the shearing and mineralization, so that its original relations are obscured.

MONDAY MINE

The old Monday mine is in sec. 31, T. 2 N., R. 19 E., about a mile east of Bellevue. It has long been abandoned and was never very large, but some of the galena found in it is reported to have been exceptionally rich in silver. Data on the early production are contained in the table below:

Early production of Monday mine

[From records of E. Daft]

Year	Ore	Silver	Lead
	Tons	*Fine ounces*	*Pounds*
1883	6.3	616.3	3,227
1886	8.0	489.1	2,399
1889	1.0	98.1	1,014
	15.3	1,203.5	6,640

It was developed by several tunnels, but these are now so caved that the ore body could not be reached when the mine was visited in 1923.

The country rock is black shale that probably belongs to the Milligen formation. This shale changes to a rusty color on weathering. The ore body is reported by Stewart Campbell, State inspector of mines, to have been in this shale and inclined at a low angle approximately parallel to the bedding. A black calcareous shale containing seams of calcite was encountered in the mine, but ore was not found in it. In the hanging wall of the deposit a white rock thickly studded with pyrite is reported to have been found. Rock stated by Mr. Campbell to be of the same type was observed in a prospect tunnel nearly a mile northwest of the Monday. This rock is a micaceous quartzite, consisting essentially of quartz and muscovite. The rock in the parts of the tunnels at the Monday which are still open shows evidence of considerable movement. The principal metallic mineral, to judge by reports and the scanty material on the dumps, was silver-bearing galena, but there was also pyrite and some copper-bearing mineral, perhaps tetrahedrite. Quartz appears to have been the predominant gangue mineral.

CROESUS MINE

The Croesus mine, in Scorpion Gulch, about 3½ miles southwest of Hailey, in secs. 29 and 30, T. 2 N., R. 18 E., lies well within the area of quartz diorite. It extends to a depth of 860 feet and is the deepest mine in the region. It is distinct from all the others in that in the upper 600 feet it is a gold mine and in the lower 200 feet a lead-silver mine. The Croesus lode was discovered in 1881 but was not seriously exploited until about 1895. For the next four years the mine was worked most of the time, but the principal period of its development was during the following decade. Between March 29, 1899, and April 12, 1911, the records of the company show a return of $133,137.60 from ore shipments over and above freight and treatment charges. Of this amount about $23,000 has come from lead ore and the remainder from gold ore. The table below gives the data on the production of this mine contained in the records of E. Daft.

Production of Croesus mine

Year	Ore and concentrates	Gold	Silver	Lead	Copper
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1895	7.2	1.77	6.5	1,224	
1896	14.4	15.92	47.7		23,166
1897	27.3	28.35	228.8		
1899	82.3	165.11	773.6		1,948
1902	4.3	7.85	34.9		
1906	21.4	33.85	340.6		
1907	1.2	.09	31.3	1,553	
	158.1	252.94	1,463.4	2,777	25,114

In 1913, when it was examined by J. B. Umpleby, five men were at work on the property, but not long afterward the mine was shut down. Prior to 1908 a 10-stamp mill was operated on the lower grades of ore, but in that year a 100-ton mill equipped with rolls, Wilfley tables, jigs, and other machinery was erected. In 1923 plans were being made to reopen the mine, but nearly all the workings were full of water and consequently inaccessible. Nothing further had been done at this mine in 1925. The developments comprise a vertical three-compartment shaft 800 feet deep, about 10,000 feet of openings on eight levels, and a 60-foot winze from the lowest level. The principal workings are shown in Plate 13.

The vein crops out in quartz diorite at a point about half a mile from the nearest exposures of sedimentary beds. On the ridge west of the mine pegmatite dikes consisting of quartz, orthoclase, and muscovite are abundantly developed as lenticular masses. Younger than these dikes and also younger than the vein are lamprophyre dikes of about the composition of spessartite, although all the specimens examined are so much altered that the determination is somewhat uncertain. Aplite also occurs in the vicinity, but its age relations to the other dikes were not determinable.

The ore bodies occur as lenses that consist of quartz, pyrite, chalcopyrite, arsenopyrite, and pyrrhotite with a little siderite and galena and are irregularly distributed along a nearly east-west fracture zone. Near the outcrop of the vein the dip is steeply north in places, but elsewhere it is steeply south. Below the 200-foot level it is rather uniformly about 70° S. down to the 700-foot level, below which the main fissure is only meagerly developed. On the 800-foot level another zone which bears a distinctly different assemblage of minerals and is known as the lead vein, has been explored. This vein contains siderite, galena, and a little sphalerite, quartz, pyrite, chalcopyrite, and tetrahedrite. It dips about 65° N. and has been followed up to a point between the 500 and 600 foot levels, where it intersects the main or Croesus vein. Parallel to the Croesus vein and about 90 feet south of it in the vicinity of the shaft is the Hope vein, a similar fracture, which has a northward dip down to the 200-foot level, the lowest point where it has been definitely recognized. Each of the three fracture planes shows clear evidence of strong premineral movement and minor postmineral movement. The walls are as much as 40 feet apart locally, although in most places they are not over 6 or 8 feet apart. The material between them is principally crushed and ground wall rock, and their surfaces in many places are strongly striated. The striae dip steeply eastward, in general conformity with the pitch of the ore bodies.

A lamprophyre dike, probably spessartite, is intimately associated with the ore bodies either on one side or the other. In many places it cuts across the vein, and elsewhere it includes fragments and slabs of ore, as on the sixth level near the shaft.

The ore lenses have a wide range in size and shape, but their long axis generally inclines steeply to the east. The largest bodies were opened on the second and third levels, where the main shoot ranged from 100 to 187 feet in length. Two of these bodies were between 4 and 5 feet in average width. A portion of the shoot from 7 to 54 inches wide was of shipping grade.

The vein matter between the several fractures defining the fissure zone is shattered, and the sericitized wall rock is ribbed with quartz seams that are thickly studded with pyrite, chalcopyrite, pyrrhotite, and arsenopyrite. Such ore runs from perhaps \$3 to \$12 to the ton in gold, but locally the quartz is almost free of wall fragments and this ore may contain as much as \$200 in gold and 50 ounces of silver to the ton. The so-called shipping ore is said to average \$40 to \$50 to the ton, and the milling ore \$10 to \$12 to the ton.

The Croesus vein and the Hope vein are fairly similar in mineralogy and general characteristics, except that the Hope is of much lower grade and has been far more extensively crushed. The lead vein, however, is of an entirely different type. It corresponds to the characteristic veins of the region, argentiferous galena being embedded in a siderite gangue. Quartz and sphalerite are meagerly developed, and in places chalcopyrite occurs instead of galena. The ore averages from 5 to 20 per cent of lead, and each per cent of lead is accompanied by about 1 ounce of silver to the ton; in small stopes the ore is nearly pure galena. In this ore no pyrrhotite has been observed, but it contains $5 to $8 to the ton in gold, considerably more than most other lead veins in the region.

The lead vein is later than the gold vein, which it cuts between the 600 and 700 foot levels, and in addition to its different minerals it dips in the opposite direction. Like the gold vein, however, it is older than the lamprophyre dike and is traversed by it.

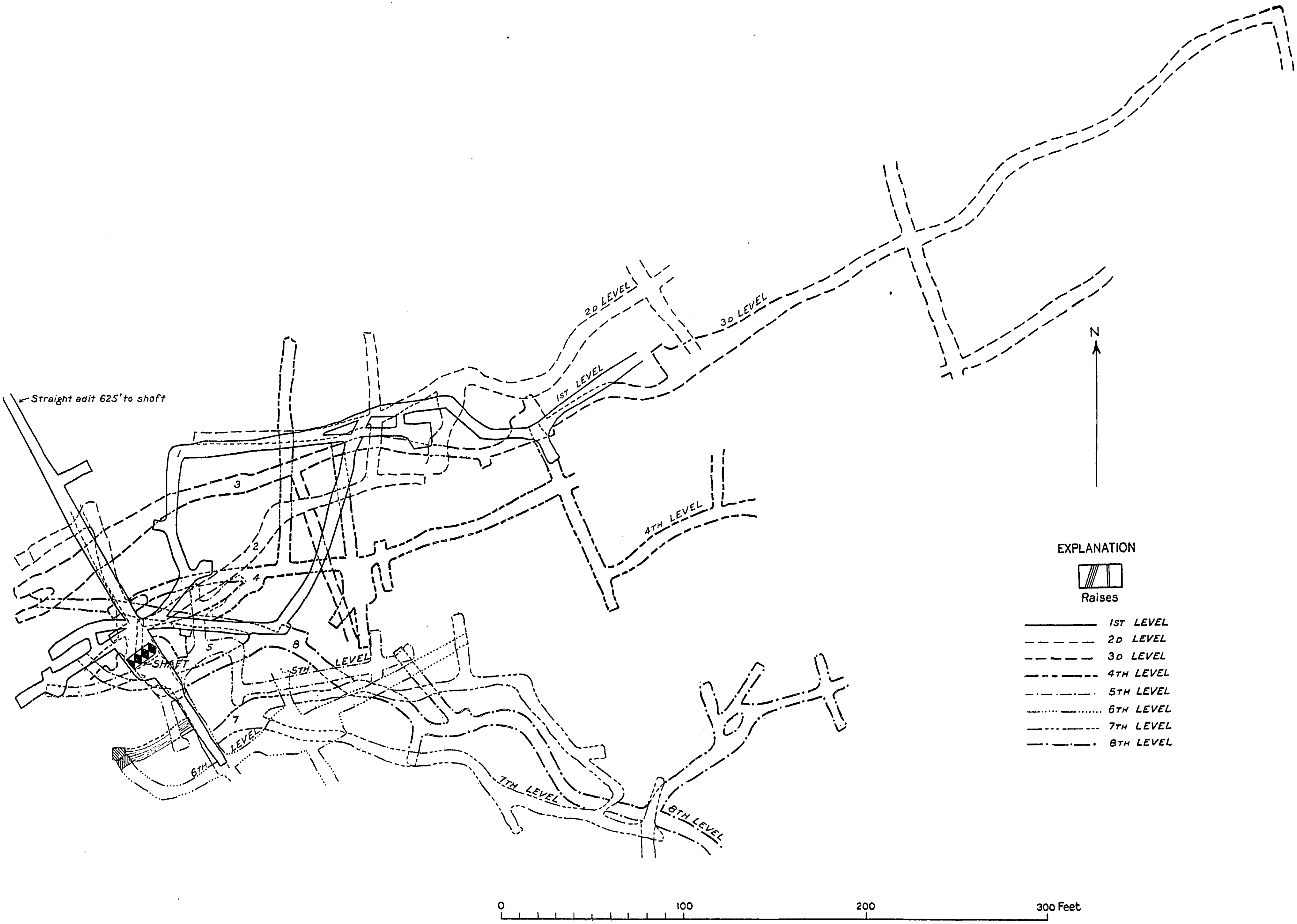
The ores of the deepest levels are partly oxidized, but only in the upper 300 feet of the vein is oxidation well advanced. Specimens from places near the shaft on the 800-foot level show siderite partly changed to limonite, a little cerusite after galena, smithsonite after sphalerite, and copper carbonate stains after chalcopyrite. On one specimen collected by D. F. Hewett, thin films of native silver and drusy surfaces of secondary chalcopyrite occur along shearing planes in the galena. The evidence of supergene processes is thus unmistakable and is particularly interesting because the specimens were collected at an exceptional depth—between 600 and 700 feet below the present water table.

An interesting feature in this mine is the rapid increase in temperature on successively lower levels. It ranges from a minimum of 57°, on the 200-foot level, to a maximum of 92° on the 800-foot level. On the 800-foot level there has been very little stoping and timbering, whereas down to the 500-foot level there are extensive stopes and many decaying timbers. The high temperature on the 800-foot level, therefore, does not appear to be due to oxidation. It is also noteworthy that if oxidation caused the heat it should attain its maximum in the poorly ventilated drifts of the intermediate levels, where disseminated pyrite and associated sulphide minerals are most abundant. For these reasons it is believed that the increase in temperature below the surface represents a particularly high geothermal gradient for the vicinity.

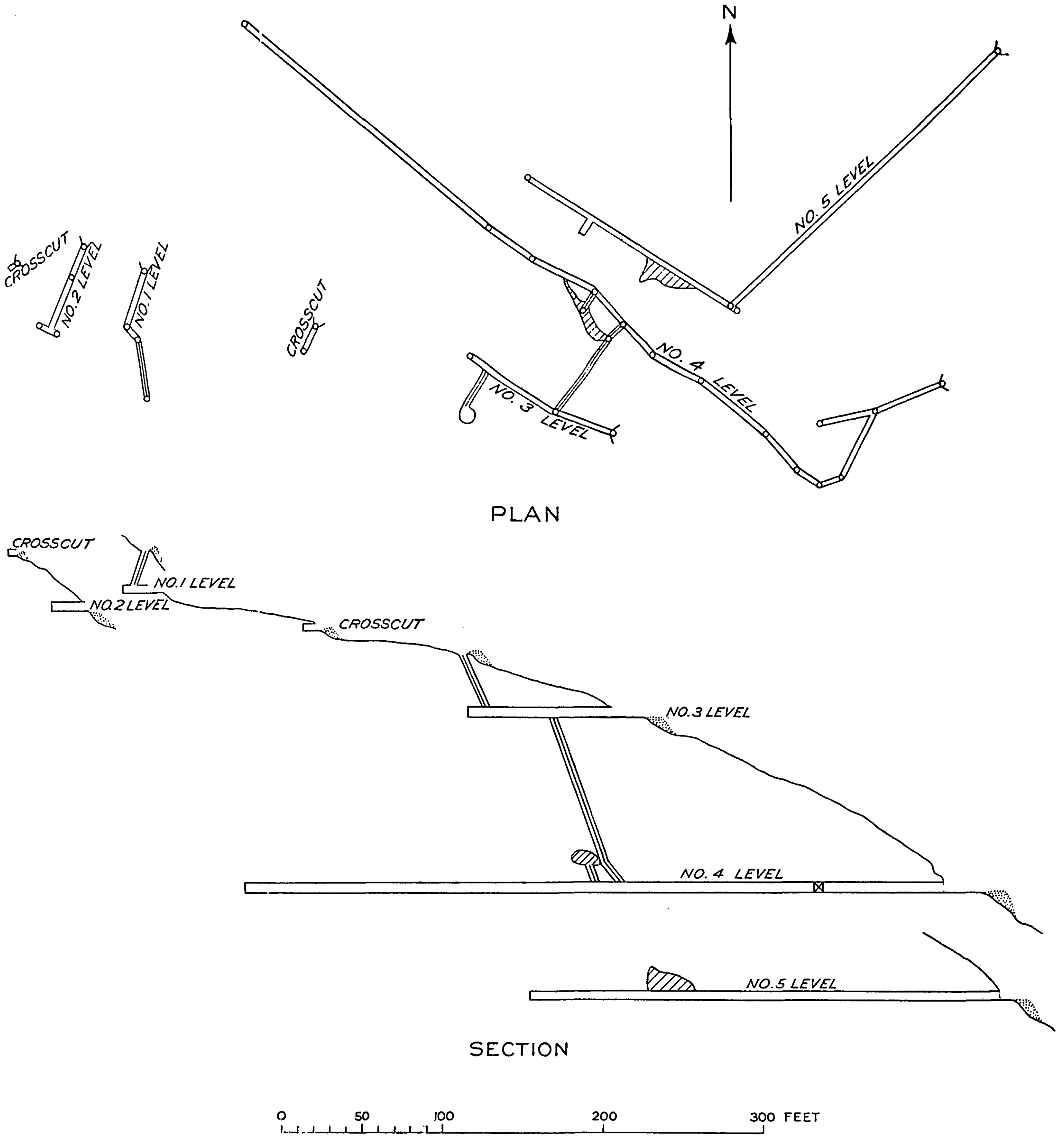
OTHER MINES IN SCORPION GULCH

Several small mines, also in quartz diorite, are situated in Scorpion Gulch, about 1 mile above the Croesus group. All these mines are on fracture zones in the igneous rock and yield ore made up of galena, auriferous pyrite, and chalcopyrite in a quartz-siderite gangue. In each of them lamprophyre dikes are intimately associated with the ore. The principal mines are the Comet and Keystone, and each has yielded a small production.

The Comet mine is developed by three tunnels and several shorter tunnels and cuts, as is shown in Plate 14. This plan was prepared



LEVEL MAP OF THE CROESUS MINE



PLAN AND SECTION OF THE WORKINGS OF THE COMET MINE

August 2, 1910, and a little work has been done since then. Only the middle tunnel, which is estimated to be about 750 feet long, was accessible at the time of Umpleby's visit. Here a stope 100 feet long extends above and below the tunnel level. The stulls average about 4 feet in length, but from faces in the ends of the stope it appears that only 1 foot or so of this material was ore. The vein strikes N. 80° E. and dips 55° N. The ore contains massive pyrite and a little pyrrhotite, galena, chalcopyrite, and sphalerite in a quartz gangue containing some siderite. The ore is intricately fractured, and the sulphide minerals and siderite are crushed about angular fragments of quartz. A lamprophyre dike of about the composition of camptonite, follows the footwall of the fracture zone at points well beyond the ore shoot. The following table gives the available data on production:

Production of Comet mine

[From records of E. Daft and U. S. Geological Survey]

Year	Ore	Gold	Silver	Lead	Copper
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1883	2.1		264.1	2,417	
1884	4.1		631.9	4,278	
1891	5.3	.267	497.8	556	
1895	.1		16.0	182	
1901	3.7	.653	7.4		
1909	54.0	1.79	2,725.0	72,302	317
1910	74.0	.66	3,810.0	101,092	
1912	41.0	1.84	1,282	35,223	217
1913	96	23.93	2,641	53,963	700
1918	1.		37	547	
	281.3	29.13	11,912.2	270,560	1,234

The Keystone mine is northeast of the Comet, across Scorpion Gulch, at an altitude of 6,000 feet. A tunnel, now inaccessible but in 1911 about 700 feet long and caved beyond this length, is run S. 70° E. in quartz diorite, which here, as elsewhere, is traversed by narrow lamprophyre dikes. The ore, as indicated by material on the dump, resembles closely that from the Comet mine. Two other tunnels extend in about the same direction at altitudes 70 and 145 feet higher. No ore appears on their dumps. The following data are abstracted from a report by Campbell:[24]

Depressions of the surface and variation in the vegetation indicate that the vein has a length at the surface of 1,500 feet. Its average strike is N. 69° W. and its dip is 70° NE. The width of the vein ranges from a few inches to 4 feet and averages 3 feet. The ore was found in pockets that decreased in size and number from the upper workings down to the lowest tunnel, known as No. 3. Camp-

[24] Campbell, Stewart, unpublished report on the Keystone mine, dated Aug. 10, 1911.

bell estimates from the size of the stopes that not more than 300 tons of ore has been mined and states that little ore is exposed in the present workings. The tunnels and stopes accessible to him are shown in Figure 9.

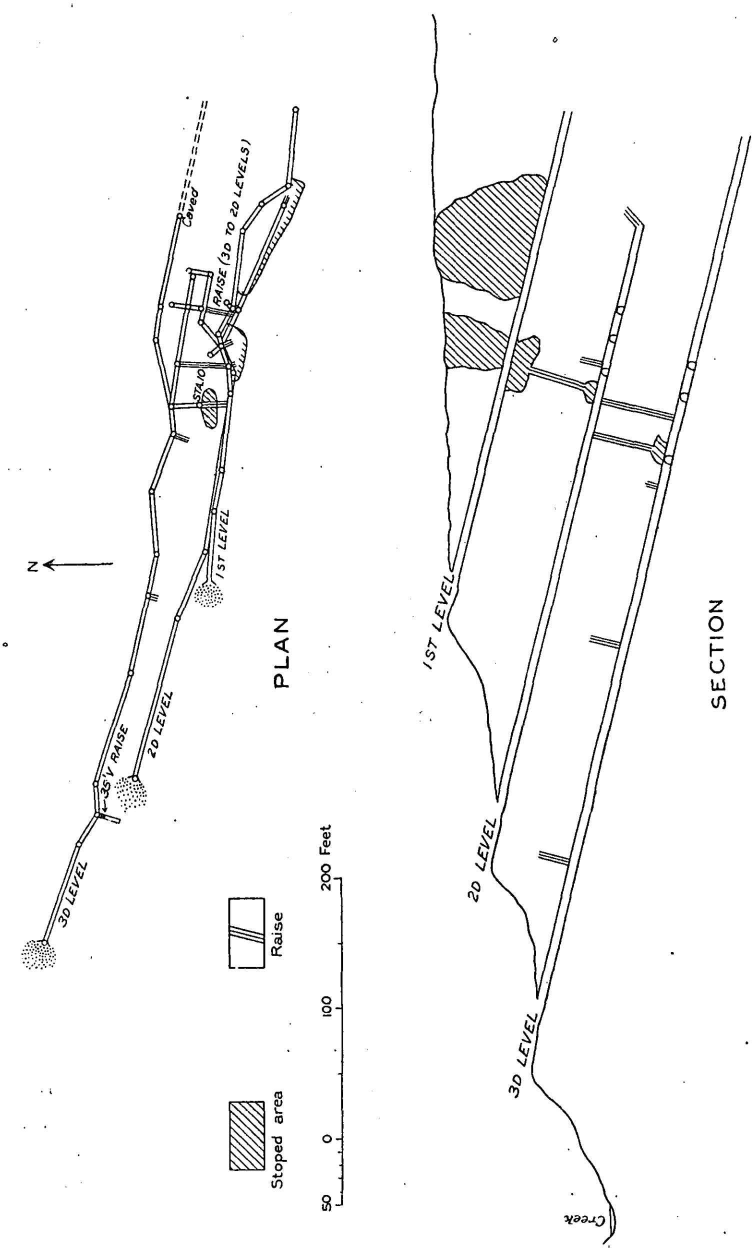


FIGURE 9.—Plan and section of the Keystone mine. (After Stewart Campbell, 1911)

Production of Keystone mine

[From the records of E. Daft and the Ketchum smelter]

Year	Ore	Gold	Silver	Lead	Copper
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1883	2.7		194.5	2,443	
1885	13.2		1,179.7	2,773	
1886	5.2	1.14	227.20	886	
1891	7.6		628.3	10,835	
1892	9.0		622.8	8,667	
1893	1.1		58.3	471	
1897	1.5		160.2	1,384	230
1898	.4	.02	41.8	525	
1907	37.0	1.48	1,081.7	15,100	8,232
1908	31.2		920.50	5,617	4,306
	108.9	2.64	5,115.00	48,701	12,768

CLIMAX MINE

The Climax mine is at an altitude of about 5,500 feet on the slope south of Hailey Hot Springs, 2 miles southwest of Hailey, in sec. 20, T. 2 N., R. 18 E. Since the discovery of the deposit in the early eighties the mine has produced about $80,000 from ore bodies within 65 feet of the surface. The principal developments consist of a series of five or more irregular branching tunnels driven at successively lower points on the hillside below the original discovery. The upper three tunnels are connected by raises and stopes, with drifts at intermediate levels. The total length of drifts and crosscuts is over 1,000 feet. The principal stopes and the workings immediately below them are now mostly caved and inaccessible. A little work is done annually, but there has not been much extensive mining for 15 years. The following table shows the available data on the production of this mine. If the estimate of total production given above is correct the table is obviously incomplete.

Production of Climax mine

[From records of E. Daft and U. S. Geological Survey]

Year	Ore	Gold	Silver	Lead	Copper
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1885	39.2	4.59	3,809.8	9,904	
1886	3.9	.21	420.4	3,815	
1888	13.2		1,307.8	19,946	
1893	.9		90.9	240	
1907	8.0	.0	63.1		9,285
1908	93.0	4.0	7,097.0	103,705	69
1909	5.0		288.0	3,864	
	163.2	8.80	13,077.0	141,474	9,354

The mine is in black carbonaceous and limy shales of the Milligen formation which have been greatly crumpled and fractured. Much of the folding doubtless took place before the deposition of the ore, but there has been considerable faulting since that time. Some of the postmineral fractures lie nearly flat and are probably reverse faults. Most of those seen, however, appear to be normal faults of small displacement. One of the flat-lying faults that cut ore in the lowest stopes may have a reverse throw of about 50 feet, but the accessible exposures were insufficient to prove this statement.

The vein strikes nearly east with variations of 5° to 10° either side of this direction. It dips southward at various angles. The average dip of the portion mined is over 60°, but in places in the stopes the dip is much less. In the upper workings exposures show vein matter striking N. 45°-55° E. This vein may be a different one from that observed elsewhere, but it is somewhat more probable that the variation from the average strike is a result of displacement by faulting.

The material in the old stopes and on the dump indicates that the ore consisted of galena, tetrahedrite, and a little sphalerite in a gangue of siderite and country rock, with lenticular masses of white quartz. There were stopes on the upper levels, but the ore is said to have ended at a fault plane 25 feet below level No. 2. This fault is reported to be of normal displacement and to dip 10°–30° N., suggesting that exploration for the ore body should extend southward. In the accessible parts of the lowest stopes, however, the ore is split up into a number of bands so narrow and so low in grade that they were not mined. In places shearing can be traced downward some distance below the end of visible mineralization. It thus appears to the writers that ore deposition petered out gradually, perhaps because of exhaustion of the local supply of mineralizing solution. The drifts on lower levels disclose no ore, but there are numerous slips and some alteration in the rock. In a short raise in the next to the lowest level there are masses of white quartz and small quantities of rusted siderite. On this level a narrow dike of light-colored altered igneous rock containing pyrite is exposed at some places. This dike has been much faulted, and some exposures show small blocks of this rock inclosed in the fractured shale.

ROWLEY PROSPECT

In sec. 16, T. 2 N., R. 18 E., on the left side of the Big Wood River, James Rowley has driven a tunnel. He has also built a footbridge across the river to make his prospect accessible from Hailey. The tunnel is somewhat more than 600 feet long and has four short drifts off it. The trend is S. 40° W. for the first 400 feet and about S. 70° W. for the remainder. It crosscuts Milligen carbonaceous shale, which strikes N. 30°–50° W. and dips 35°–50° SW. In one drift to the south a few small masses of quartz are exposed. Just beyond the principal bend in the tunnel and also in the face there are some stringers of calcite.

MINES ON THE MAYFLOWER LODE

The Bullion, Mayflower, Jay Gould, and Ophir mines are on the Mayflower lode on the hill south of the old town of Bullion, in secs. 15 and 22, T. 2 N., R. 17 E. (See pl. 15.) These famous mines, some less well-known adjoining claims, and the Red Elephant mine on the same hill farther west were held under lease by the Bunker Hill & Sullivan Mining & Concentrating Co. when visited in 1923. The Red Elephant mine is described on pages 146–150.

Mines on the Mayflower lode were in operation with few interruptions from 1880 to 1898. Since then lessees have been active in one or another of the mines at short intervals. The Bunker Hill & Sullivan Mining & Concentrating Co. started work in 1921 and continued development until 1924 but did not discover any ore bodies of commercial value. The total production up to 1898, as estimated by Mr. W. H. Watts, of Hailey, is given by Lindgren [25] as follows:

Ophir	$50,000
Bullion	750,000
Mayflower	1,100,000
Jay Gould	750,000
	2,650,000

E. Daft gives the gross value of production of mines on the lode up to 1887 as follows:

Bullion	$1,309,037
Mayflower	899,525
Jay Gould	536,641
	2,745,203

The following table, compiled by G. L. Havens, superintendent from 1882 to 1888, shows the amount and character of the ore produced between July, 1880, and August 31, 1887, at the Mayflower mine. This table, however, shows net returns, and Mr. Daft's compilation gives gross production. The freight charges on ore shipped by the company were $90,446.51, and the treatment charges were $140,898.65, according to Mr. Havens. About 60 per cent of the material shipped was first-class crude ore; the other 40 per cent was concentrated from jigs.

[25] Lindgren, Waldemar, op. cit., p. 202.

Shipments from Mayflower mine

[According to G. L. Havens]

Year	Produced by—	Ore	Lead	Silver	Amount received (net)
		Tons	*Per cent*	*Ounces per ton*	
1880	Original locators				[a] $75,000.00
1881	Col. Wall	1,029.00	68.00	138.00	156,408.00
1882	G. L. Havens	728.20	63.30	155.64	134,600.96
1883	do	1,566.27	64.77	170.70	275,033.85
1884	do	875.22	58.15	175.60	153,342.98
1885	do	184.17	60.80	163.13	30,287.42
1886	Lessees	148.12	37.54	115.47	34,933.04
1887	do	92.00	57.12	153.85	
		4,622.98	62.92	159.53	859,606.25

[a] Estimated.

The following tables, compiled from Mr. Daft's records, give the most complete and detailed data now available as to the production of the mines on the Mayflower lode. The ore attributed to the "Durango" presumably came from the Bullion mine near the present Durango tunnel, but possibly it came from some other mine of that name. The tables indicate that a total of 10,966 tons of ore, in part concentrated, containing 1,523,968 ounces of silver and 13,133,220 pounds of lead, was obtained from 1882 to 1908. These figures, however, are undoubtedly lower than the actual totals. Considerable quantities of ore mined and shipped by lessees are not represented, and it may be that some of the shipments made by the companies are likewise not recorded.

Production of Mayflower mine

[From records of E. Daft and the Ketchum smelter]

Year	Ore	Silver	Lead	Year	Ore	Silver	Lead
	Tons	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Pounds*
1882	82.5	14,660.6	114,030	1892	25.0	2,469.5	19,252
1883	1,233.5	205,566.1	1,649,119	1893	19.7	2,261.4	18,330
1884	927.0	164,307.3	1,106,705	1894	3.9	525.3	3,988
1885	270.8	44,100.0	322,907	1895	1.6	170.2	1,481
1886	588.4	51,859.67	715,044	1896	2.7	351.1	3,699
1887	99.0	14,109.9	99,213	1898	1.2	192.7	861
1888	134.5	21,506.9	130,781	1899	.4	68.1	420
1889	35.5	5,301.5	32,825	1901	1.6	224.2	1,324
1890	105.1	10,455.2	50,860				
1891	73.2	7,262.5	37,292		3,605.6	545,493.0	4,308,131

Production of Bullion mine

[According to records of E. Daft]

Year	Ore and concentrates	Gold	Silver	Lead	Year	Ore and concentrates	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1881	157.55		26,086.2	167,182	1895	12.9		1,603.8	10,716
1882	18.0		2,999.5	19,740	1896	18.5		2,697.8	17,239
1883	1,002.7		171,737.3	1,175,044	1897	37.7		6,783.2	43,077
1884	902.2		143,342.88	1,034,587	1898	43.5		7,399.6	45,723
1885	427.1		48,044.0	450,667	1899	24.3		3,524.7	33,848
1886	82.7		9,532.1	77,516	1900	49.1		6,679.9	56,777
1887	48.7		7,413.3	49,105	1901	73.1		10,059.3	98,477
1888	14.0		2,290.7	14,077	1902	46.4		6,302.9	44,621
1889	69.3		12,333.6	62,115	1903	10.3		1,690.1	8,958
1890	12.1		1,613.6	5,449	1904	2.4		294.9	2,113
1891	6.7		838.7	4,192	1908	2.5	0.051	332.1	1,952
1892	31.1		3,384.8	35,404					
1893	32.5		3,390.4	33,692		3,275.9	.051	485,182.5	3,518,288
1894	50.6		4,807.12	26,017					

Production of Jay Gould mine

[According to records of E. Daft and the Ketchum smelter]

Year	Ore	Gold	Silver	Lead	Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1882	66.8		7,328.0	84,737	1897	1,241.6		118,677.1	1,706,198
1883	517.4		55,672.7	649,403	1898	639.8		60,121	893,815
1884	14.4		1,707.7	16,560	1890	888.2	1.125	27,491.2	372,917
1885	42.4		4,436.1	46,382	1900	36.2		4,602.0	49,214
1889	119.5		12,933.2	133,465	1901	41.0	4.211	6,227.38	56,570
1890	194.9		19,872.4	206,875	1902	42.9		5,137.3	60,315
1891	193.4		25,732.9	218,079	1903	20.7		2,764.89	28,798
1892	51.2	1.000	6,525.9	65,241	1905	3.0		268.1	3,742
1893	63.3	.470	9,318.9	85,404	1906	11.0		1,023.3	15,312
1894	162.8	.779	22,267.1	221,794					
1895	64.7	.898	8,844.4	76,387		4,019.0	4.785	422,564.9	5,282,590
1896	202.9		21,613.5	291,382					

Production of Durango mine

Year	Ore	Silver	Copper
	Tons	*Fine ounces*	*Pounds*
1888	0.8	88.3	834
1890	36.7	2,764.9	12,487
1891	25.0	1,980.7	10,884
	62.5	4,833.9	24,205

The amount of ore shipped since 1900 has been small. The following table, compiled from the records of the United States Geological Survey, shows nearly all the ore mined in the Bullion property in 1902 and later years:

Production of Bullion mine, 1902–1909

Year	Ore mined	Silver	Lead
	Tons	*Fine ounces*	*Pounds*
1902	42	5.7	40,310
1908	3	.329	1,932
1909	2	.305	1,900
	47	6.3	44,142

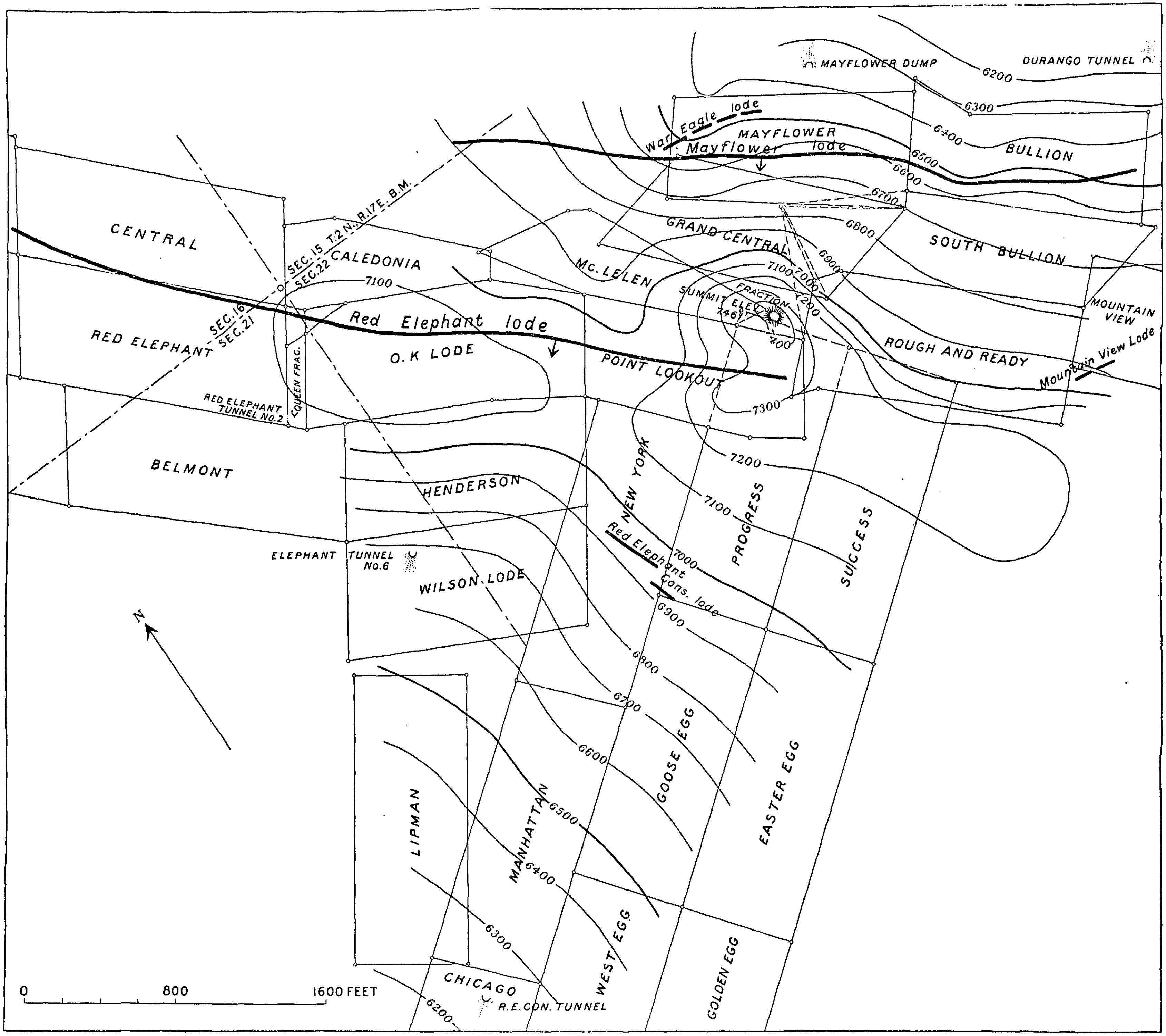
In 1923 no ore was exposed in the parts of the old workings visited, and the others are reported to be equally barren. Work was in progress only in the Bullion mine, and most of the workings in the other properties were inaccessible both in 1913, when the mines were visited by Umpleby, and in 1923, when they were visited by Ross. When the district was revisited by Ross in 1924 the prospecting work in the Bullion had been abandoned and the mine was being closed down.

Development has been carried on principally through tunnels. It is continuous for about 4,300 feet on the course of the vein and extends through a vertical range of about 480 feet, although no ore bodies have been found in the last 150 feet of depth. The principal workings are shown in plan and section on Plate 16. The development work since 1921 has been done on the Boggs level of the Bullion mine and in the Durango workings. In 1923 the Boggs level was being extended northwestward along the lode and the Durango crosscut was being extended westward. A branch of this crosscut was being driven to the northwest. In 1924 development work ceased.

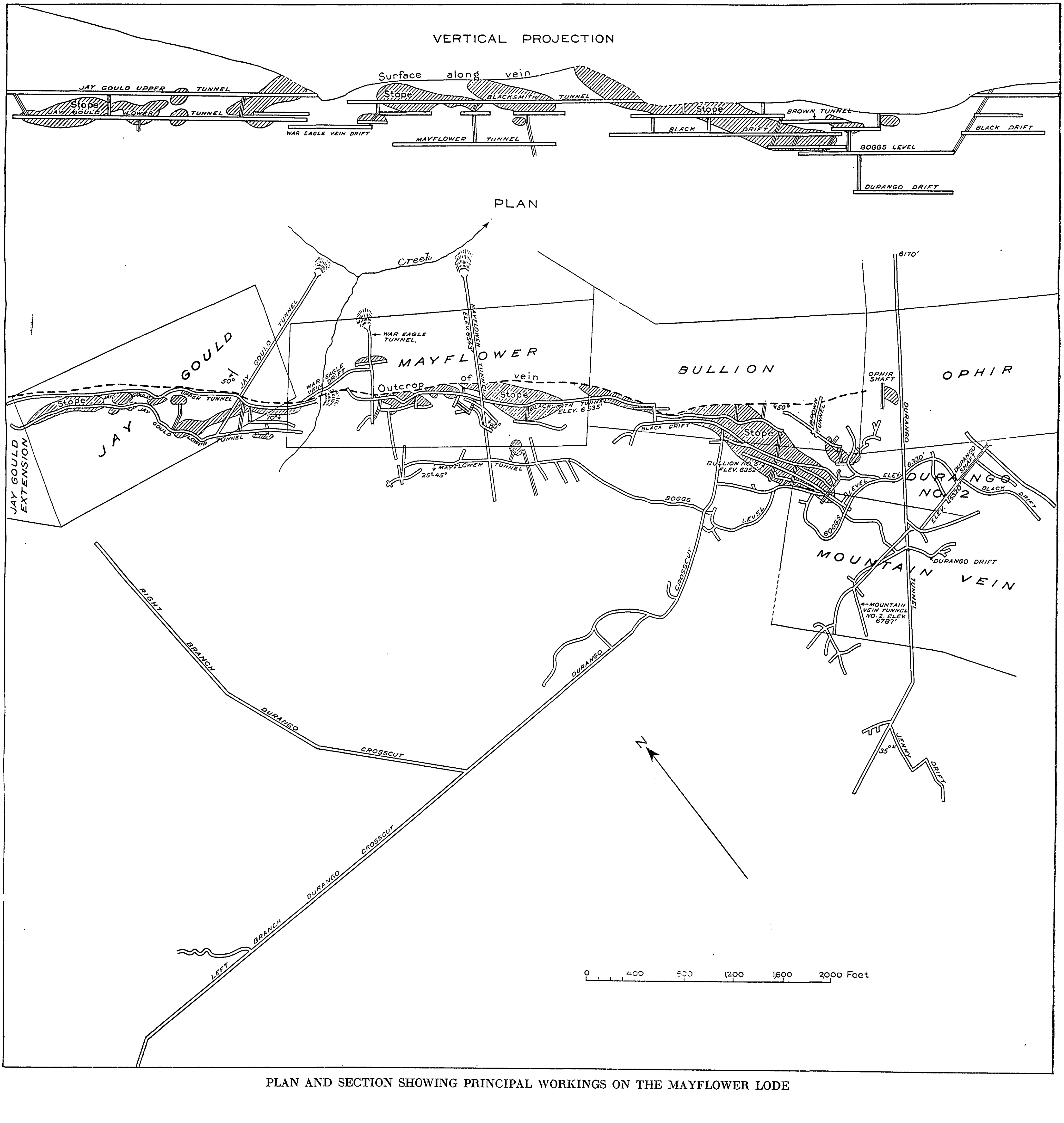
In the summer of 1924, when the Bunker Hill & Sullivan Mining & Concentrating Co. abandoned its work, the Boggs level had been driven on the vein until it encountered the old workings on the Mayflower tunnel level, without finding any ore. Each branch of the Durango crosscut was then about 1,800 feet long. From the left branch there is a short irregular drift in which is exposed the only ore discovered in the course of the company's work on the Durango tunnel level.

The Mayflower lode strikes about N. 50° W. and dips southwest. The variations in strike and dip are indicated by means of structure contours in Plate 17. The lode is one of a group that forms a lode system, as can be seen from Plate 15. The only other one in this system on which there has been extensive development is the Red Elephant lode, which is about 1,000 feet southwest of the Mayflower and approximately parallel to it. The lode disclosed by the Red Elephant Consolidated tunnel may be a branch of the Red Elephant lode or a parallel one. It has yielded some ore but has not yet been extensively developed. The position of its outcrop as plotted on Plate 15 is only roughly approximate, as it was obtained by projection from the underground workings. Further data on the Red Elephant are given on pages 146–150. The ore bodies on which a little stoping has been done in the Mountain View workings are either in an extension of the Red Elephant lode or in a branch of that lode. The War Eagle lode appears to be a branch of the Mayflower lode. There is a small stope on this lode, as shown in Plate 16.

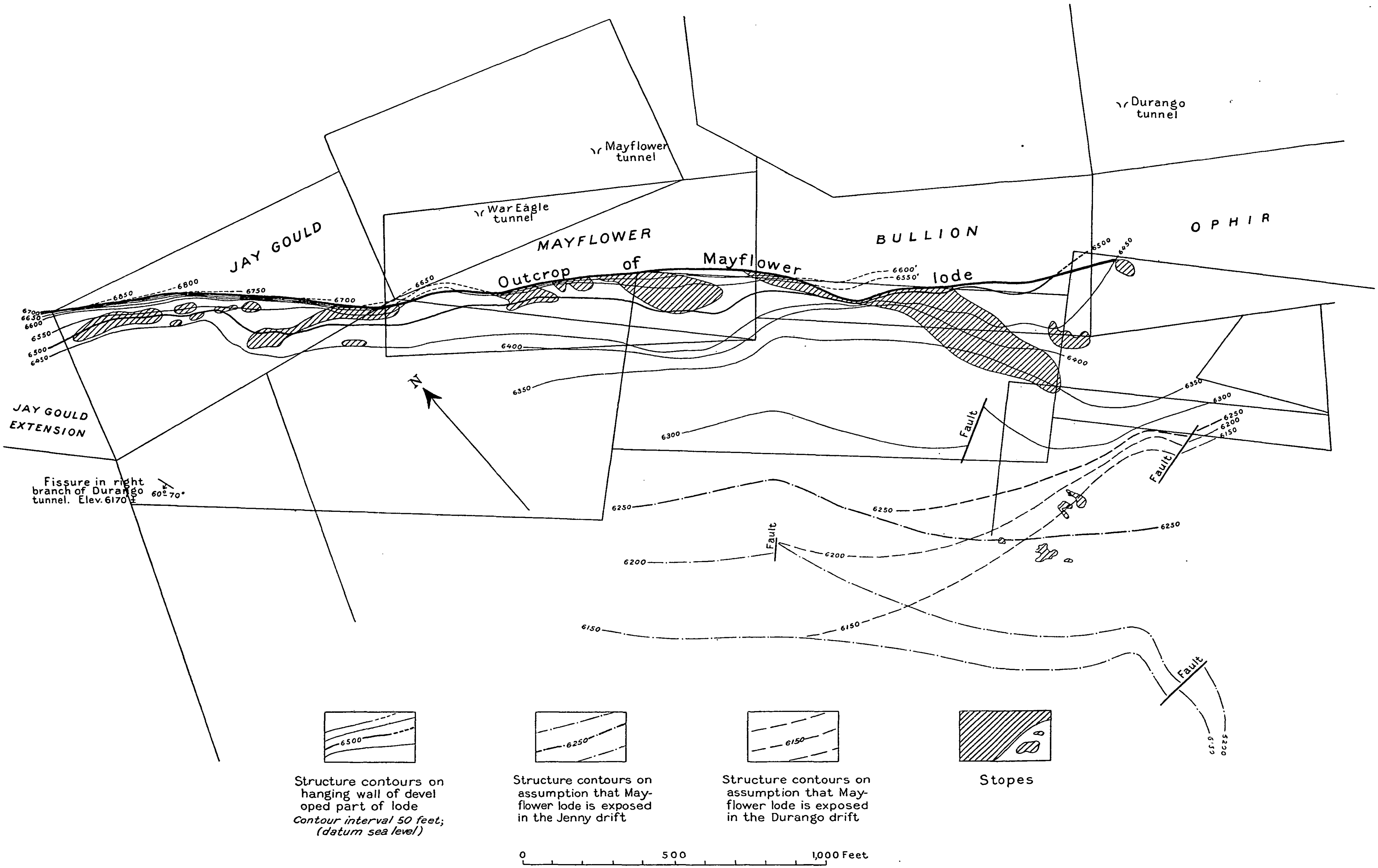
The stopes on the Mayflower lode are distributed along a definite horizontal zone of about 300 feet vertical extent, as shown on Plate 16. No ore bodies are known either above or below the stoped-out



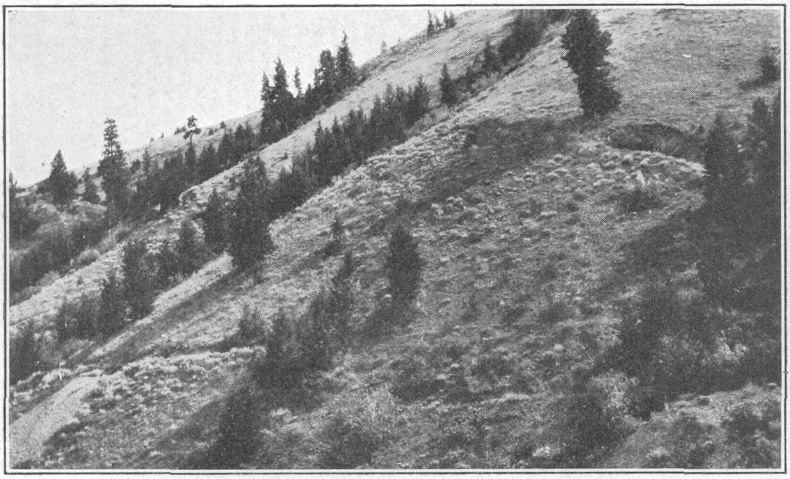
SURFACE MAP SHOWING THE RELATIVE POSITIONS OF THE MAYFLOWER, RED ELEPHANT, AND SUBSIDIARY LODES AND THE PRINCIPAL WORKINGS ON THEM



PLAN AND SECTION SHOWING PRINCIPAL WORKINGS ON THE MAYFLOWER LODE

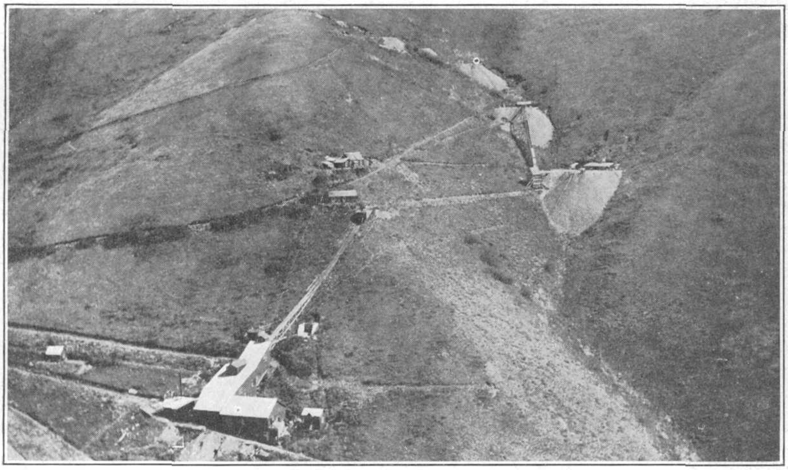


DIAGRAMMATIC STRUCTURE CONTOURS ON THE MAYFLOWER LODE



A. OUTCROP OF MAYFLOWER LODE, SHOWING STOPES WORKED TO THE SURFACE

Note almost complete lack of surface exposures of this large lode.



B. INDEPENDENCE MINE AND OLD MILL

The upper dumps mark the course of the lode.

ore shoots. The shape of the old stopes shows that the ore occurred in elongated lenticular bodies, which in the Bullion and Mayflower mines pitched southeast. On the Jay Gould one ore body pitched northwest, and the others appear to have been essentially horizontal. Five principal lenses, two each on the Mayflower and Jay Gould and one on the Bullion, and several smaller ones have been mined out. The lens in the Bullion mine, which is the largest one, had a pitch length of about 1,200 feet and an average breadth of about 100 feet. In several places the ore bodies were followed up to the surface, and the course of the vein is now plainly marked by a line of open stopes. Between these openings on the surface the lode is barren and most inconspicuous, as shown in Plate 18, *A*. On the Jay Gould claim, in particular, most of the lode is barren at the surface, and the longest stope is overlain by about 300 feet of ground that contains no known ore bodies, as is shown on Plate 16. This mine, however, according to the available maps, has been less extensively developed than the Mayflower and Bullion.

The country rock of the Mayflower and associated lodes belongs to the Wood River formation. Most of the rock in and near the principal workings is dark calcareous shale, with varying amounts of siliceous and calcareous material but without beds of sufficiently striking and constant characteristics to be useful as horizon markers. On the hill above the Durango workings there are contorted and brecciated limestone beds with calcite stringers above the shale, which here strikes N. 75° W. and dips 30° SW., and on the crest of the ridge there is massive light bluish-gray quartzite. On the Jay Gould and Mayflower claims the average strike is probably about N. 30° W., and the beds dip either to the southwest or more commonly to the northeast, at angles that average perhaps 45°.

Northeast of Bullion Creek dark-blue calcareous beds strike a little west of north and dip 25°–45° E. Here as elsewhere in the region it is difficult to decipher the details of the structure, but painstaking work would probably be successful and might yield data that would aid in understanding the factors that have governed the formation of the ore shoots in the Mayflower lode. Perhaps the distribution of the ore in the lode has been influenced by the presence of one or more beds in the sedimentary series that were particularly susceptible to replacement by the mineralizing solution. This idea can not be tested, nor is it of any value in the search for new ore bodies without much more complete information in regard to the local stratigraphy and structure than is at present available. Some have sought to explain the failure of the ore bodies at about the same level in different mines on the basis of possible faulting. As more fully discussed below, this explanation does not seem to accord with observations made on the lower levels, and it clearly can not account for the apparent absence of ore bodies in the unfaulted upper part of the lode. The relations can not be explained as results of concentration by supergene processes, for the portions of the lode outside the ore shoots are almost barren of mineralization, and much the greater part of the ore mined was typical hypogene material. It consisted chiefly of galena intergrown with considerable tetrahedrite and sphalerite in a gangue of siderite, quartz, and altered country rock, with calcite in some places. The first-class ore contained 50 to 65 per cent of lead and 90 to 125 ounces of silver to the ton. The early operators are reported to have found sand carbonate (cerusite) and iron and manganese oxides in stopes near the surface. These deposits, like similar ones elsewhere in the region, were formed through replacement by solutions that rose from greater depths. It seems only reasonable to conclude from available evidence that other lenses of ore should be found deeper on the shear zone, or else the conclusion must be accepted that at the time of deposition the requisite relation of temperature and pressure was so nicely adjusted that replacement was possible only in one particular zone about 300 feet in vertical extent. The dip of the shear zone may have had an effect which can not at present be evaluated. In the Independence mine, which has numerous points of similarity to those here described, the best ore was found in the steepest parts of the lode, and the mine was abandoned when the lode flattened. The Mayflower lode has flattened notably in the lowest levels on which it has been explored. On the other hand, as shown on Plate 17, the old stopes are in the more gently inclined parts of the developed portion of the lode.

The part of the vein in the Jay Gould and Jay Gould Extension claims is now largely inaccessible. According to Lindgren,[26] the Jay Gould tunnel crosscuts the vein 1,800 feet from the portal and then follows it into the Extension ground. The calcareous shale in the tunnel dips 50° NE. In places no distinct walls are exposed, and the lode was followed chiefly by the calcite, siderite, and pyrite distributed along it.

The Mayflower tunnel crosses a crushed zone 720 feet from the portal. This is apparently the lower extension of the lode mined in the upper levels. This zone has been followed by drifts for about 400 feet to the northwest and 300 feet to the southeast, with several short crosscuts off the drifts. The zone dips 25°–45° SW. and shows abundant evidence of considerable movement. The hanging wall is sharp and vertically striated, but the footwall is much crushed for 4 or 5 feet back from a 6-inch clay selvage that did not show evidence of mineralization. A raise from the southeast drift is re-

[26] Lindgren, Waldemar, op. cit., p. 201.

ported to lead up along the plane of movement and opens into overlying stopes. No ore has been found on this level.

Most of levels 4 and 5 of the Bullion mine were accessible in 1923. Almost all traces of metallic minerals have been removed from the old stopes. The lode ranges in width from a few inches to over 10 feet and is defined on one or both sides by clean-cut walls, which in places are grooved up the dip. There is some tendency for the lode to narrow both above and below the stopes, but in no place where it is exposed does it pinch out entirely. It would seem that ore bands terminated abruptly, with blunt ends and without apparent cause, just as they do in some of the less completely worked out mines in the district. The lode beyond the limits of the stopes is merely a zone of crushed rock with calcite veinlets, bands of gouge, and in places limonite stains. A number of slips intersect the lode at different angles, but none of those seen appear to have caused much displacement.

Much of the work on the Boggs level has been done in the last few years. In the westernmost drift there is a zone of crushed rock that appears to represent the lode on this level. This zone is rolling but in general is inclined at low angles to the southwest. It is cut by calcite stringers and by a few slips that dip at higher angles. In the footwall there are in places exposures of a soft rusty rock that when examined microscopically proves to be an altered granodiorite or similar rock containing a little pyrite. It is probably a dike related to the large mass of granodiorite exposed farther north. Yellow soft material of similar appearance is present in the footwall of the lode on the upper levels, and in places it is sufficiently fresh to be recognized as igneous rock similar to that on the Boggs level. East of the dike on the Boggs level the main drift trends southwest for about 200 feet. There are several slips roughly parallel to this portion of the drift, of which the strongest dips about 55° NW., though flattening above. This zone of slips is interpreted by the company's engineers as a transverse fault that displaces the lode horizontally 150 feet or more. This displacement is greater than that of any other known fault that cuts the Mayflower lode.

When the raise connecting the Durango workings with the Boggs level was driven a few fragments of galena were found in yellow material similar in appearance to the altered granodiorite just mentioned in the footwall of the lode a short distance east of the fault. In a drift northeast of this place some narrow streaks of ore are exposed. In the irregular drifts in the eastern part of the Boggs level the rock is altered and broken in a number of places, and there are several slips. A little ore is reported to have been exposed in a raise above the first drift off the Durango tunnel, which is now inaccessible. The extensive work on the Durango tunnel level, which is 160 feet vertically below the Boggs level, has failed to disclose any ore of commercial value.

The Durango drifts that branch off the tunnel 1,175 feet from the portal reveal a zone of sheared and brecciated rock with some gouge and limonite stains. There are slips with various attitudes, but most of the well-marked ones strike N. 50°–70° W. and dip 60°–70° SW. One strongly marked slip strikes N. 30° W. and dips 35° SW. A slip with some rusty material on it, striking N. 75° E. and dipping 65° S., is exposed in the main tunnel 310 feet farther in. At the turn in the tunnel is another slip, which strikes N. 80° E. and dips 50° S. Beyond this turn 185 feet of drifts, called the Jenny drifts, lead from both sides of the tunnel on another zone of shearing. In the drift to the west there are irregular stringers of gray gouge, which appear in general to dip about 30° S. In the first part of the other drift the shearing strikes about N. 20° E. and dips 40° NW. Some of the gouge here superficially resembles the yellow altered igneous rock on the Boggs level, but under the microscope this material has a distinctly different appearance. It is probably altered calcareous sedimentary rock. Beyond this place the drift turns on a slip that strikes nearly east and dips 45°–50° S. This slip offsets the zone of shearing about 50 feet horizontally. Beyond it the zone continues with about the same average strike as before. The dip is 35° NW. where the zone is first struck again and steepens to over 55° near the end of the drift.

A sample collected in this drift is reported to have assayed 4 ounces of silver to the ton.

The main tunnel continues 300 feet beyond the drifts and 180 feet beyond them exposes a calcite-lined slip that strikes N. 25° E. and dips 45° NW. There are minor slips in several places along the Durango crosscut, but they are strongest and most abundant along the part of the crosscut about 500 feet from the fork near its end and in the curved drifts in this vicinity. The slips here range in strike from nearly north to nearly east and in dip from vertical to horizontal. The westernmost drift, which terminates only about 32 feet short of rejoining the main crosscut, exposes a rolling, nearly flat zone of brecciated and altered rock with thin stringers of calcite.

Near the face of the right branch of the Durango crosscut there is a zone of brecciated and sheared rock with considerable calcite lining the fracture surfaces. The slips differ in strike and dip, but the general trend appears to be N. 10°–20° W, and the dip is 60°–70° W. The position of this zone is shown on Plate 17. From this drawing it can be seen that the zone of shearing might be considered a barren downward extension of the lode below the Jay Gould workings. Parts of the lode between stopes in the Mayflower workings are quite as barren-looking as this shear zone, but the strike is so much at variance with the average strike of the Mayflower lode that it seems unlikely that the zone is a continuation of that lode. An alternative explanation, which is fully as probable, is that this zone is the result of movements unrelated to and perhaps later than the mineralization. Under this hypothesis the calcite would be derived from leaching by ground water from the surrounding calcareous sedimentary rocks.

In a drift off the left branch of the Durango crosscut is exposed the only vein containing galena that was encountered in the course of the development along the crosscut. This drift, which is shown on Plate 16, follows the irregularities of a winding zone of shearing that has an average trend of about N. 60° W. There are numerous slips at various angles. Pyrite is scattered through the rock, and calcite is abundant, lining fracture surfaces and in irregular veinlets. The country rock is calcareous sandstone of the Wood River formation. It has been bleached nearly white along some of the slips but elsewhere is stained by oxidation products of the pyrite. Fine-grained galena is present in places. It has formed by replacement along fractures in the rock. At one place a bunch of galena ore 8 inches wide was found. This ore is reported to have assayed 4 ounces to the ton in silver and 8 per cent of lead. The mineralized shear zone extends southward into the Red Elephant ground. It is presumably a segment of the Red Elephant lode or of some branch of that lode.

The recent development work on the Durango tunnel level was done on the assumption that the Mayflower lode had not yet been encountered on this level and that the altered yellowish igneous rock in the footwall on the Boggs level marks a fault which has cut the lode and thrown its lower segment off to the southwest at a low angle. In view of the fact that this dike rock is mineralized and altered it was probably intruded into essentially its present position before the formation of the lode, a conclusion which is in accord with the general geology of the region. The Durango tunnel and crosscut explore the ground for more than 1,100 feet horizontally southwest of the Boggs level in the direction of the dip of the lode, and the Boggs level is only 160 feet vertically above them. Great flattening in the dip of the lode or a fault of large throw would be necessary to displace the lode to the southwest so far that it would not be exposed in either the tunnel or the crosscut. It is conceivable that the throw of the fault was such as to displace relatively the lower segment of the lode to the northeast instead of to the southwest, but it should then crop out in or near Bullion Gulch. On either hypothesis the trace of a strong fault without mineralization should be visible in the mine workings.

A hypothesis which seems much more probable is that one or the other of the two zones of shearing explored by the drifts from the Durango tunnel is the prolongation of the Mayflower lode on this level. There is quite as much obvious evidence of mineralization in these zones as there is in some parts of the lode between and above the stopes on the levels above. Another possibility is that the Mayflower lode has split and that the two zones of shearing cut by the Durango tunnel are both branches of the lode. The rolling zone of sheared rock in the drift near the Durango crosscut may perhaps represent the continuation of the lode in this region. In Plate 17 the structure contours drawn on the lode as indicated by the workings shown in Plate 16 are projected downward as far as the Durango level in accordance with the assumptions just suggested. It will be seen that the correlation of the zone in either set of drifts with the lode leads to a result which fits the known facts, and the idea that the two zones are both branches of the lode is also plausible.

The Durango crosscut has explored much of the ground between the Bullion and the Red Elephant mines but without conclusive results. In order to prospect for the continuation of the Mayflower lode on the basis of the hypothesis suggested above, it would seem advisable to carry farther the work in the neighborhood of the drifts from the tunnel. This work might be done by extending the drifts both ways and by sinking winzes on the dip of the shear zones. Another method, which would seem to have several advantages, would be to put in diamond-drill holes horizontally from the drifts and the Durango crosscut and also up and down on the average dip of the shear zones in both sets of drifts.

RED ELEPHANT MINE

The Red Elephant mine is 6½ miles a little south of west of Hailey and 1 mile west of the old town of Bullion, in secs. 15, 16, 21, 22, T. 2 N., R. 17 E. The claim lies on the steep south slope at the head of Red Elephant Gulch and extends from an altitude of perhaps 7,000 feet up to 8,000 feet. The deposit was worked during the early period of mining activity in the region but made its principal production between 1890 and 1898; more recently it has been worked by lessees but with only moderate success, and in 1923 it had been shut down for several years. The mine was reopened in 1926. The total production is roughly estimated at $1,400,000, including that from tailings reworked for zinc. The production so far as known is shown in the tables below.

Production of Red Elephant mine, 1882–1900

[From records of E. Daft and the Ketchum smelter]

Year	Ore	Gold	Silver	Lead	Copper
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1882	14.4		1,253.2	17,864	
1883	22.2		1,900.4	24,103	
1884	27.1		2,309.7	31,087	
1885	93.7		10,051.8	58,296	
1886	1.6		148.2	1,406	
1887	7.5		1,020.6	7,088	
1888	299.4		40,618.4	305,067	
1889	267.9	5.370	31,385.7	272,846	
1890	476.2		51,359.6	463,038	62,074
1891	829.3		74,939.2	753,523	129,405
1892	1,470.9	2.839	161,870.0	1,381,298	161,277
1893	1,384.7		137,295.9	1,439,751	153,509
1894	1,795.2		175,814.0	2,154,876	183,998
1895	801.5		73,734.7	853,509	91,180
1896	286.4	1.242	25,885.2	327,479	
1897	267.4		23,303.4	311,384	
1898	122.0		15,460.7	152,074	
1899	51.2		4,902.2	56,164	
1900	12.4		1,348.7	13,078	
	8,231.0	9.44	834,601.6	8,655,493	781,443

Production of Red Elephant mine, 1904–1918

[From records of U. S. Geological Survey]

Year	Ore sold or treated	Crude ore shipped to smelter	Ore milled	Concentrates produced	Metals recovered				
					Gold	Silver	Lead	Zinc	Copper
	Tons	*Tons*	*Tons*	*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*	*Pounds*
1904	350		350	24		10,393	111,900		
1905	1,445	289(?)	1,156(?)	289	9.132	24,743	232,349	34,689	2,312
1907	1,084	168	916	229	9.54	36,790	202,602		1,240
1908	1,334	26	1,308	327	11.32	33,797	212,075		2,712
1909	62	10	72	18	1.15	3,084	18,596		
1913	1,748		1,748	470	10.82	11,800	41,946	135,926	1,161
1917	868	8	860	37	.60	3,552	31,010		
1918	36	36				940	2,931		

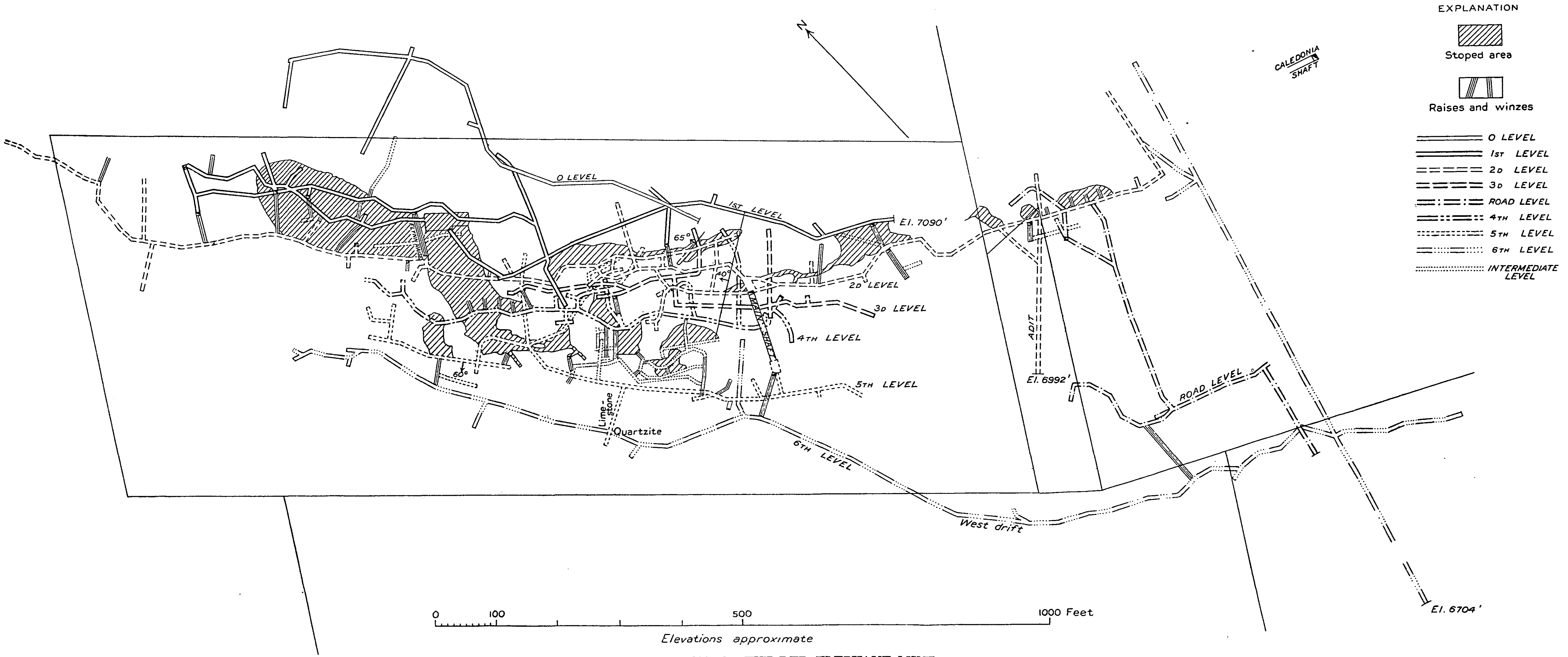
The developments comprise about 9,000 feet of workings on six levels, three of which are turned from an inclined shaft that starts from level 2 at a point about 1,000 feet from its portal. The principal developments are shown on Plate 19.

Most of the ore has come from above level 2, and none has been found to extend below level 5. On the upper levels ore has been found much farther to the east and west than on the lower ones. Thus the ore-bearing portion of the fissure has roughly the form of a blunt wedge pointing downward. Five fairly distinct ore bodies have been worked out from level 2, and the old stopes on three of them were partly accessible in 1913. Small stopes were made both east and west of the point where the tunnel first intersects the vein, but these have not yielded much ore. About 300 feet west of the intersection is the Hard Rock shoot, which yielded about $80,000. This lens of ore bears more to the west than the others, and at a point 40 feet west of the shaft it terminates against a fault that trends northeast and dips 40° NW.

About 90 feet north of the point mentioned, on the opposite side of the fault, is the Coeur d'Alene shoot, which extends westward. Minute fragments of crushed ore may be panned from the fault gouge along that part of it between the two ore bodies, showing that the Hard Rock and Coeur d'Alene shoots are segments of a once continuous mass that have been separated by a transverse displacement. A short distance below the tunnel level the Hard Rock shoot was cut off by a strike fault with dip of 45° NE. This fault caused an offset down its dip of about 40 feet. Two other faults parallel to it occur between the 300 and 400 foot levels. They offset the vein 15 and 4 feet and are well exposed near the shaft in the crosscuts from levels 3 and 4. The Coeur d'Alene shoot is about 100 feet long and on the west is cut off by another transverse fault that strikes N. 80° E. and dips 65° NW. It throws the vein about 30 feet east, whence it continues westward as the Silver Chamber shoot. This ore body showed solid galena as much as 12 feet wide and with minor offsets by strike faults that continued down nearly to the 500-foot level. About 100 feet west of it is the Flynn shoot, the largest in the mine, apparently an entirely distinct shoot, although it is in the same vein. In one place in it ore of excellent grade is said to have been 50 feet in width. Its stopes were not accessible in 1913 or 1923, but they are shown on the company's maps as being continuous from a point a little above level 1 down nearly to level 5.

The largest fault in the mine is one that shows clearly both on the surface above the mine, where quartzite and black shale are in juxtaposition, and in the workings, where it is followed by the 500 and 600 foot levels. Its average strike seems to be about N. 30° W., with a dip of 60° SW. Striations exposed on the walls in level 5 suggest that for each drop of 100 feet the hanging wall has shifted about 25 feet to the southeast. The vertical displacement could not be accurately determined, because the relative positions of the shale and quartzite beds in the normal section are not known, but it is probably several hundred feet.

As seen beneath the surface a gouge seam ranging from 2 to 6 feet in width follows the fault next to the hanging wall, which is sharp and in contrast to the gradational footwall. This seam is locally known as the "mud vein." Farther southeast it is recognized in the Look Out and O. K. workings. A point of particular economic interest is that only one of the ore bodies is known to be cut by this fault. The large shoots, which are not now accessible, are said to have terminated well back in its footwall. The one ore body which it truncates is a small lens near the west end of level 5. A tunnel to explore the hanging-wall country rock has been started well down the gulch at an altitude of about 6,235 feet. This tunnel is known as the Red Elephant Consolidated Tunnel, from the name of the company that



LEVEL MAP OF THE RED ELEPHANT MINE

did the work on it. At the time of Umpleby's visit it was in 1,280 feet on a course N. 55° E. Here, as in the upper workings, the country rock consists of shale, sandstone, and siliceous limestone of the

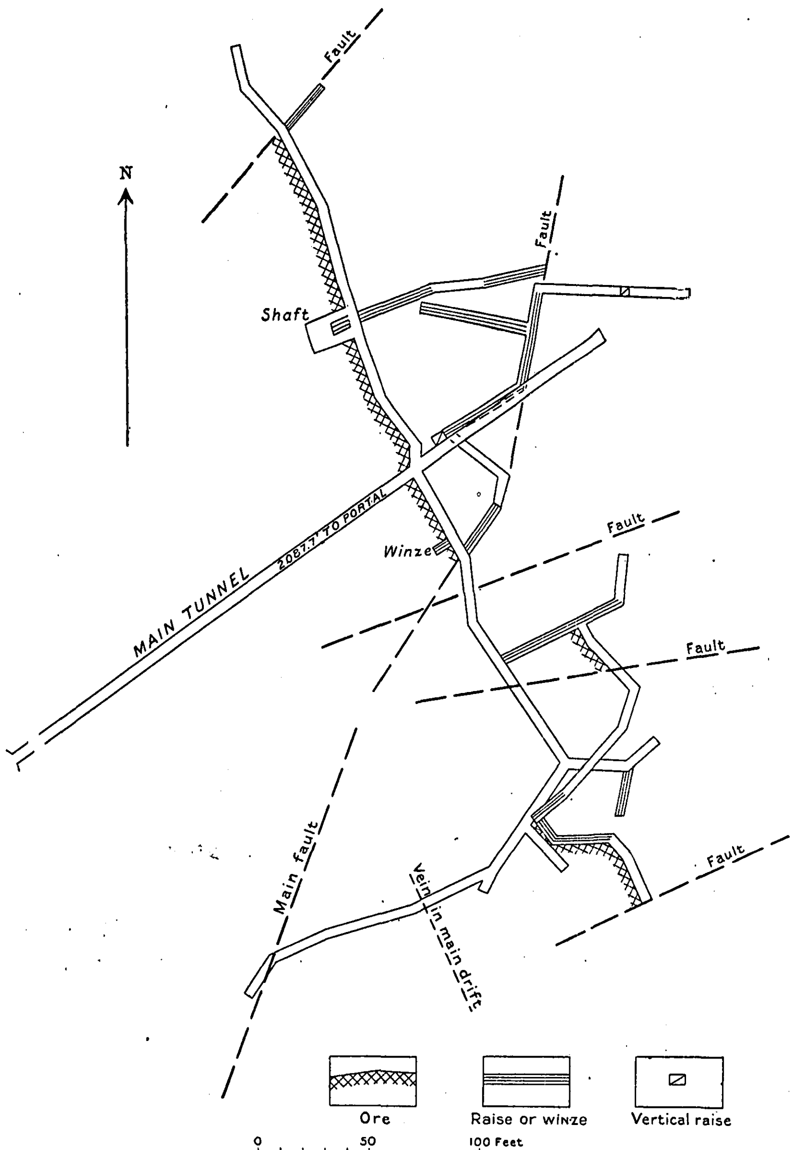


FIGURE 10.—Map of Red Elephant Consolidated Tunnel

Wood River formation. Locally this is rather intensely metamorphosed, being impregnated with fibrous wollastonite and tremolite and containing minute crystals of diopside. According to a map prepared in 1919 (fig. 10), this tunnel then had a length of over

2,000 feet and had cut a vein carrying ore. The vein was drifted on both ways from the tunnel, and several raises and winzes were driven from these drifts. No work has been in progress here for some time. The Durango crosscut, driven by the Bunker Hill & Sullivan Mining & Concentrating Co., was originally intended to connect with the Red Elephant Consolidated Tunnel but was stopped before this was accomplished. The ore found in one branch of this crosscut may be in a segment of the Red Elephant vein or of an offshoot of that vein.

The ore from the mine consists of galena, zinc blende, and pyrite, with a little tetrahedrite, in a siderite-quartz gangue. Most of the silver is in the galena, although the other ore minerals and siderite are known to contain some of it.

The ore bodies present abundant evidence of replacement along a pronounced movement zone, but the feature of paramount interest to anyone attempting to work the deposit consists of the three systems of faults, one transverse to the vein and the other two parallel to it, one of them with dips to the northeast and the other with dips to the southwest. The relative age of these faults is not shown in parts of the workings accessible at the time of Umpleby's visit, although there is some suggestion that the one which follows levels 5 and 6 is the most recent.

NEW YORK-IDAHO EXPLORATION CO. PROPERTY

The camp of the New York-Idaho Exploration Co. is on Bullion Creek about half a mile north of the old town of Bullion, near the center of T. 2 N., R. 17 E. The property includes the old Eureka, Whale, Idahoan, Bay State, Garfield, and King of the Hills mines. These mines are all on the same lode system and may conveniently be considered together. They were all active in the early eighties. According to data furnished by E. Daft, they produced between 1880 and 1887 ore of the following gross values: Eureka, $141,162; Whale, $10,476; Idahoan, $899,525; Bay State, $25,219; Garfield, $1,909. Mr. Daft does not record the production of the King of the Hills. Lindgren[27] gives estimates of total production up to 1900 of at least $75,000 for the King of the Hills and about $100,000 for the Bay State.

Compilations made from Mr. Daft's records indicate that from 1883 to 1891 the Eureka produced 1,079 tons of ore and concentrate containing 82,733 ounces of silver and 1,199,356 pounds of lead and that from 1882 to 1906 the Idahoan produced 9,147 tons of ore and concentrate containing 591,547 ounces of silver and 10,548,390 pounds of lead, the Whale produced 253 tons of ore and concentrate containing 27,410 ounces of silver and 311,089 pounds of lead, the Bay State

[27] Lindgren, Waldemar, op. cit., p. 204.

produced 197 tons of ore containing 29,610 ounces of silver and 216,038 pounds of lead, the Garfield produced 37 tons of ore containing 4,053 ounces of silver and 43,003 pounds of lead, and the King of the Hills produced 47 tons of ore containing 4,175 ounces of silver and 59,285 pounds of lead. If Lindgren's estimates are correct these figures are not complete for some of the mines, especially the King of the Hills.

According to the annual volumes of Mineral Resources of the United States and the annual reports of the State mine inspector, work has been in progress at the Eureka mine intermittently since 1905, when the Eureka Development Co. was organized, and considerable

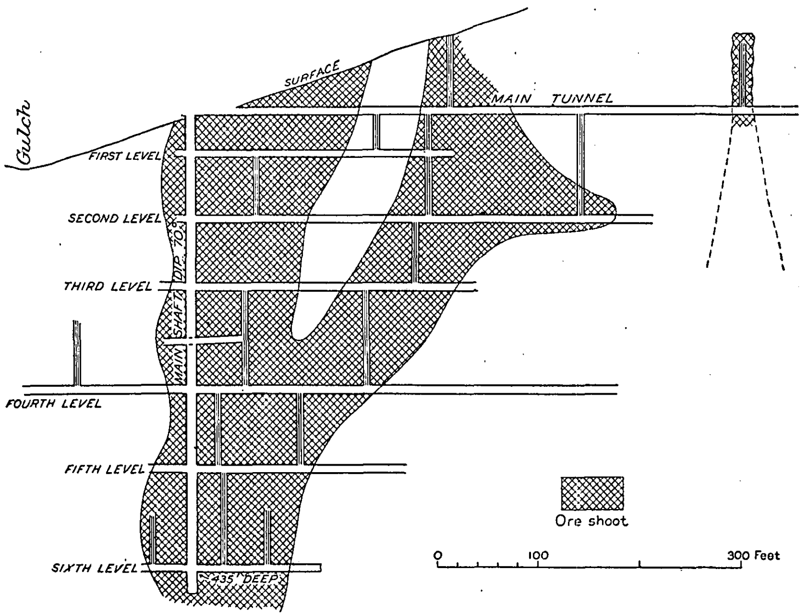


FIGURE 11.—Section through the Eureka shaft

ore has been shipped from it. Recently, however, only a few lessees have been at work. In 1923 the New York-Idaho Exploration Co. acquired the group of mines. In the summer of that year this company was actively engaged in erecting new buildings and in mapping preliminary to reopening the mines. A few men were employed in the Whale tunnel. One car of concentrate is reported to have been shipped in December, 1923. Early in the summer of 1924 the New York-Idaho Exploration Co. ceased operations at the mine, and little has been done since.

In recent years the Eureka group has produced 9,200 tons of ore, from which about 20 ounces of gold, 114,962 ounces of silver, 1,755,151 pounds of lead, and 12,268 pounds of copper have been recovered.

The development at the Eureka mine comprises a main tunnel about 1,100 feet long, with over 300 feet of crosscuts leading from it, and an inclined shaft to a vertical depth of 435 feet, with six levels, aggregating perhaps 2,000 feet of workings, turned from it. The tunnel is shown on Plate 20, and a sketch section of the shaft and workings off it is shown in Figure 11. The shaft is now partly caved and inaccessible. There are also some short tunnels, as shown on Plate 20. The Whale tunnel is over 1,600 feet long, with crosscuts and stopes off it, and there are several other tunnels on this claim. In the Idahoan there are two tunnels, each about 230 feet long, which can still be entered, and some others that are inaccessible. Above one of the tunnels is a large stope. The shaft from which the principal workings extended is now completely caved. There are reported to have been eight levels. A shaft was sunk on the vein to a depth between 300 and 400 feet. About 500 feet northwest of the bottom of this shaft sinking was resumed. The total depth attained on the vein was about 700 feet.

The accessible part of the Bay State workings comprises two crosscut tunnels, 350 and 120 feet long connecting with a drift about 520 feet long with stopes above it. As can be seen from Plate 20 there are numerous other tunnels on the company's claims.

Plate 20 shows in detail the geology of this group of claims, as well as the workings on them. It is the result of the painstaking work of R. W. Landwehr and his assistants, acting under the supervision of J. J. Beeson, consulting geologist for the company, in an attempt at subdivision of the Wood River formation with a view to working out the details of its structure. The formation contains few persistent beds sufficiently characteristic in appearance to be safe and convenient horizon markers. Landwehr's subdivisions appear to have been made strictly on lithologic grounds. From study of the map it seems likely that the two limestones with interbedded shale mapped by him should be correlated with each other stratigraphically and that the two quartzites are likewise stratigraphically equivalent to each other. The group of beds consisting principally of shale would then be the youngest strata exposed, the limestones would be the oldest, and the prominent quartzite beds would be at or near the contact between the limestones and the shales. It should be emphasized that all these groups of rocks resemble each other more or less. They are dark sedimentary rocks containing varying amounts of siliceous, argillaceous, and calcareous material. Lenses of fairly pure crystalline limestone and of moderately pure quartzite are present, but they are small and discontinuous.

On the basis of the stratigraphic correlation suggested above structural features can be worked out that accord with the strikes and dips plotted on the map and with what is known of the general structure of this part of the Hailey quadrangle. An anticlinal axis appears to cross Bullion Gulch just below the southwest side line of the November claim and terminates near the northwest end of that claim. Most of the rest of the strata represented on the map slope northeast at moderately high angles. The trend of the major structural features is roughly N. 40° W. There are numerous irregularities in the folds, and the structure is further complicated by faults, many of which are indicated on the map. A part of the mass of quartz monzonite that crops out over a wide area in this vicinity and dikes of similar rock and of aplite are also shown on the map. A quartz monzonite dike is cut by the lode in the Eureka tunnel and is somewhat altered. The intrusion of the igneous rock has resulted in extensive but rather inconspicuous metamorphism of the strata. Lindgren [28] reported that the rocks near the large mass of quartz monzonite were "very intensely altered for several thousand feet from the contact." He also stated that the limestone contains abundant white pyroxene, probably malacolite, and fibrous wollastonite and that the shale is recrystallized and contains much andalusite. The properties here described lie in this area of metamorphism. The sedimentary rocks have been more or less recrystallized and some contain white pyroxene and other metamorphic products, but many are not sufficiently altered to be distinguishable in the field from similar rocks elsewhere unaffected by the metamorphism.

The lodes on the Eureka and adjoining properties appear to belong to a single lode system. The Idahoan, Eureka, and Whale workings are probably all on the same lode. This lode has several offshoots and is cut by numerous faults, none of which have a large displacement. Subsidiary lodes are exposed on the Mormon Girl, Garfield, Homestake, and November claims. The Iris and Arizona claims are also on deposits belonging to the same system. To the northeast are the lodes on the Chicago, Thanksgiving, Bay State, Monarch, and other claims.

These lodes have the same characteristics as most of those in the vicinity of Hailey. They are shear zones which in some places show little evidence of mineralization and elsewhere contain shoots of excellent lead-silver ore. In the Eureka mine ore was followed in a gradually shortening shoot from the surface to the sixth level, as shown in Figure 11. It occurred along a fault plane between fairly distinct walls from 4 to 10 feet apart. The ore consisted principally of low-grade material averaging about 8 per cent of lead and 9 ounces of silver to the ton, but about one-fourth of it ran from 50 to 60 per cent of lead and 60 to 65 ounces of silver to the ton. There were numerous small lenses and bunches of ore in unfractured rock at a distance from the fissure and hence clearly formed by replacement. The

[28] Lindgren, Waldemar, op. cit., p. 195.

stopes from the Idahoan tunnels indicate that the shoot mined here was even larger than that in the Eureka shaft. Much ore was also obtained from the workings leading from the Idahoan shaft several hundred feet below the tunnels. The best ore is reported to have been found on the 400-foot level, where a body 26 feet wide was worked. There are several other shoots that have yielded considerable ore. The metallic minerals noted are galena, sphalerite, and pyrite in a gangue of altered country rock, quartz, siderite, and calcite. Hisingerite occurs on joint planes in the Whale tunnel. The small amount of copper stain present on some weathered specimens may be derived from tetrahedrite.

ARIZONA GROUP

The Arizona group, comprising the patented claim of that name and ten others, lies largely in sec. 23, T. 2 N., R. 17 E., about three-quarters of a mile east of Bullion. The property is owned by the estate of Mrs. Charles Cuneo and when visited in 1923 was held under lease and bond by the Plata Mining Co., which started development in 1922.[29] The Arizona claim was patented during the early boom days in mining in the region, but the development on it was small. The records of E. Daft show the following shipments from this group:

Early shipments from Iris and Arizona claims

[From records of E. Daft]

Year	Ore	Silver	Lead	Year	Ore	Silver	Lead
Iris	*Tons*	*Fine ounces*	*Pounds*	*Arizona*	*Tons*	*Fine ounces*	*Pounds*
1888	1.9	145.0	2,368	1900	2.5	195.32	3,036
1890	.5	32.3	534	1901	2.3	120.51	1,843
Total	2.4	177.3	2,902	Total	4.8	315.83	4,879

In 1915 to 1918 Charles Cuneo worked on the Arizona and the adjoining Iris claim and made some shipments of ore from an open cut in the Arizona and a tunnel and shaft, now caved, on the Iris. According to Mark King, one of the present owners, the value of the ore shipped by Cuneo and others is $20,000. The only recent shipments of which record is available are one in 1917 of 22 tons containing 1,345 ounces of silver and 20,699 pounds of lead, and another in 1918 of 43 tons containing 2,292 ounces of silver, 36,911

[29] Campbell, Stewart, op. cit., p. 40.

pounds of lead, and 58 pounds of copper. A tunnel with its portal on the Iris claim exposed the vein under the Arizona open cut, and there are several other small tunnels on the two claims. The Plata Mining Co. has confined its efforts so far to driving a crosscut tunnel which is intended to cut the Arizona vein at depth. The portal of this tunnel is some distance down the gulch to the southeast of the old workings. On July 27, 1923, the tunnel had been driven somewhat more than 380 feet with a trend of N. 28° E. and two short drifts to the northwest had been opened from it. Soon after this date operations were suspended.

The country rock belongs to the Wood River formation and is principally dark siliceous and calcareous shale. The strata are steeply inclined, nearly vertical in a number of exposures, and vary widely in strike. They have been both folded and faulted. In one of the tunnels on the Iris claim there is a dike of granitic rock.[80] The Arizona vein strikes about N. 30° W. and dips very steeply to the southwest. The drift in the new tunnel nearest the portal follows a slightly mineralized slip that strikes N. 40° W. and stands vertical. The other is near the tunnel face and is on a similar slip that strikes N. 50° W. The banded calcareous shale near the portal of the tunnel stands nearly vertical and strikes N. 30° W. According to Mark King two veins have been struck in work done since the property was visited, and development is proceeding steadily.

RED CLOUD MINE

The Red Cloud mine is 1½ miles northwest of the Red Elephant mine, in sec. T. 2 N., R. 17 E., at an altitude of about 7,500 feet. Only the lowest level was accessible in 1913, and in it most of the side drifts were flooded. Except for the account of the work on the tailings in progress in 1923, the following description is compiled from the published descriptions by Lindgren [81] and Turner [82] and from the observations of Umpleby in the small part of the workings accessible to him. Between 1880 and 1902 the Red Cloud mine produced ore of a gross value of $815,802. The period of greatest activity was between 1888 and 1898. The tailings dump was reworked in 1906, and there has been intermittent mining since then.

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[80] Landwehr, R. W., personal communication.
[81] Lindgren, Waldemar, op. cit., p. 204.
[82] Turner, H. W., Faulting in the Red Cloud mine: Min. and Sci. Press, vol. 95, pp. 747–748, 1907.

The following tables give all available data on the production of the Red Cloud mine:

Early production of Red Cloud mine

[From records of E. Daft and the Ketchum smelter]

Year	Ore	Gold	Silver	Lead	Copper
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1884	10.8		788.1	15,394	
1885	65.99		4,464.7	85,656	
1886	100.4		6,731.5	121,109	
1887	38.3		2,874.8	36,282	
1888	11.2		8,188.5	146,566	
1889	95.0	18.22	5,228.8	100,453	
1890	412.1	.43	27,983.9	545,086	
1891	1,766.9	253.15	114,450.0	2,267,914	
1892	2,098.1	305.25	134,373.9	2,705,336	
1893	1,164.7	252.56	70,254.5	1,439,651	
1894	431.0	91.80	25,023.3	525,259	
1895	102.7	24.56	5,869.9	118,622	
1896	51.6	13.398	2,055.4	386,371	
1897	2.4	1.07	93.7	2,213	
1899	605.0	123.83	28,933.7	596,728	73,671
1900	1,338.8	431.36	51,591.3	1,100,796	
1901	68.2	29.73	2,256.8	49,065	5,263
1902	1.7	100.3	2,278		
1905	19.2	10.6	350.8		3,162
	8,384.0	1,656.0	493,791.6	13,213,227	82,096

Production of Red Cloud mine, 1906–1918

[From records of U. S. Geological Survey]

Year	Ore sold or treated	Crude ore shipped to smelter	Ore to mill	Concentrates produced	Metals recovered			
					Gold	Silver	Lead	Copper
	Tons	*Tons*	*Tons*	*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1906	3,200		[a] 3,200	320		10,030	89,600	
1911	33	33			7.46	1,599	37,998	
1917	69		69	23	9.36	249	3,730	140
1918	51	40	11		22.27	414	7,100	
	3,353	73	3,280	343	39.09	12,292	138,428	140

[a] Old tailings re-treated.

The property has been extensively developed on 10 levels, opened by tunnels and shafts, and there is a still deeper tunnel which with its various branches has a total length of 5,000 feet. This tunnel is nearly 1,100 feet below the outcrop of the lode. It runs N. 88° E. for 1,825 feet and then extends several hundred feet southward with long drifts to the east and west at several places. About 500 feet from the turn is a raise to the upper workings.

The country rock is limestone and calcareous shale of the Wood River formation. The main vein strikes about N. 23° W. and dips steeply southwest, and a branch of it, known as the hanging-wall vein, strikes about N. 46° W. and dips more than 60° SW. Nearly all the ore was mined from stopes above level 9, which is 706 feet below the surface at the portal of No. 1 adit.

The veins are broken by a number of faults, some of the larger of which are shown in the two sections in Figure 12. According to Turner (fig. 12, B), the fault of greatest displacement is that between levels No. 5 and No. 6. Here an ore body has been displaced 240 feet along a slip which dips only about 8° NW. At about the No. 9 level there is a fault which dips about 15° NE. and displaces the vein 90 feet. This fault may correspond to one above the No. 8 level shown in Lindgren's section (fig. 12, A), which is presumably taken through a different part of the mine from that given by

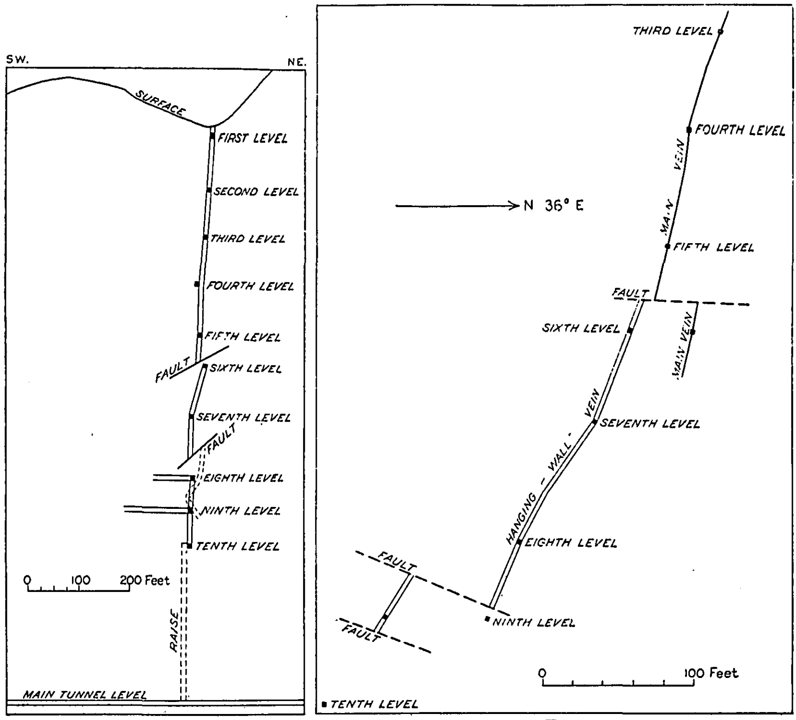

FIGURE 12.—Vertical sections of the Red Cloud vein. (After Waldemar Lindgren and H. W. Turner)

Turner (fig. 12, B). Below it is another slip, which Turner interprets as a parallel fault. The vein has not been identified below this slip, although several zones of fracture showing some mineralization are exposed in the lowest tunnel and the drifts from it. A few tons of silver-lead ore has been mined from one of these drifts. A vein with prominent outcrops but of very low grade is exposed a short distance east of the mine, and this may correspond to one of the fracture zones on the lowest level. At the turn in this lowest tunnel there is a zone of shattered rock devoid of mineralization which may represent the continuation of the main vein mined above. That this crushed zone represents the vein fissure is indicated by its relation to a barren cross vein recognized throughout the mine.

The ore as seen on the lower dump and near the old mill consists of sphalerite, galena, pyrite, arsenopyrite, and small amounts of tetrahedrite and chalcopyrite in a siderite-quartz gangue. In this ore, as in that from the North Star mine, the sphalerite and siderite have been extensively brecciated and cemented, largely by pyrite and arsenopyrite. The ore contains many partly replaced inclusions of the limestone wall rock. Although worked for the lead and silver it contained, the ore carries a noteworthy amount of gold.

This mine has now been shut down for some time, and most of the workings are inaccessible. In the summer of 1923 M. G. Smith was setting up jigs and tables at the mouth of Red Cloud Gulch to treat tailings from the old mill. He planned to operate his machinery with water power from a ditch out of Wolf Tone Creek and to sluice the tailings down to his plant with water from one of the mine tunnels. He intended to make pyrite, lead-silver, and zinc concentrates but expected to derive most of his profit from the pyritic concentrate. He estimated from his own samples and assays that the clean pyrite here carries an average of an ounce of gold to the ton.

PASS GROUP

The Pass group is 1½ miles northwest of Bullion, about the head of Narrow Gage Gulch, a tributary of Deer Creek, in sec. 9, T. 2 N., R. 17 E. It lies within the area of sedimentary rocks a few hundred yards back from the quartz monzonite. The principal development is on the Argent claim, which was worked for many years prior to 1900 and is credited with a production of about $160,000. A little ore has been produced since then. The following tables give the available data on the early production. Presumably the production credited to the Pass mine came from claims of this group other than the Argent. The records of the United States Geological Survey show that 1 ton of ore yielding 99 ounces of silver and 1,571 pounds of lead was shipped in 1911.

Early production of Pass mine

[From records of E. Daft and Ketchum smelter]

Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*
1885	28.5		3,997.8	37,124
1886	74.5		7,496.0	92,228
1887	6.5		571.2	9,015
1897	19.8		1,515.6	23,260
1899	69.0	0.14	4,675.0	80,745
	198.3	.14	18,254.7	242,372

Early production of Argent claim

[From records of E. Daft and Ketchum smelter]

Year	Ore	Silver	Lead	Year	Ore	Silver	Lead
	Tons	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Pounds*
1885	94.5	10,582.6	112,419	1893	50.2	4,590.0	49,823
1886	78.0	7,565.3	78,986	1894	53.1	2,267.1	37,802
1887	9.6	787.2	11,672	1895	55.0	4,040.5	64,855
1889	3.1	292.9	4,326	1896	14.6	981.6	16,736
1890	14.7	1,185.5	18,165				
1891	4.6	355.6	5,546		394.6	36,987.7	449,965
1892	37.2	3,938.9	49,635				

The group is developed by four principal tunnels, only the lower one of which, at an altitude of 7,300 feet, was accessible in 1913, when visited by Umpleby. It was not visited during the examination made by Ross in 1923. Several shoots of ore extend upward from this level, but little ore is now in sight. Between the shoots the roof of the tunnel shows a clay gouge as much as 6 feet wide, which locally is partly replaced by vein quartz studded thickly with pyrite and sparsely with galena and sphalerite. Clean walls with an average strike of N. 20° W. and a dip of 60° NE. border the gouge seam. This vein is crossed by another that strikes more westerly; the principal ore body, an irregular curved mass, roughly followed their intersection. Lindgren reports that on level 6 (presumably next above the one accessible in 1913 the principal ore shoot contained chiefly galena and that a shoot of gray siderite was found near the face of the tunnel.

AJAX MINE

The Ajax mine is in sec. 30, T. 3 N., R. 17 E., on one of the tributaries of Deer Creek a little more than 10 miles by road northwest of Hailey. The property is owned by William Barrett, Leo B. Rember, and William Rember and comprises four unpatented claims developed by three tunnels and some cuts. More than $15,000 worth of lead-silver ore is reported to have been produced. Most of this came from a hole near the uppermost or No. 1 tunnel, which is now caved. Ore to a value of several thousand dollars was taken from stopes above No. 2 tunnel, which is about 45 feet below No. 1 and connected with it by a raise.

The country rock is black quartzitic and calcareous shale belonging to the Wood River formation. No. 2 tunnel follows a shear zone striking about N. 30° E. A granite dike partly sericitized and containing pyrite grains is exposed in this tunnel. In two branch drifts there are mineralized bodies. One of these bodies is a vein which has been mined by means of small stopes. The other drift exposes irregular bodies containing pyrite, sphalerite, galena, and calcite formed by replacement and filling of small fractures in the shale. No. 3 tunnel, which is roughly 200 feet vertically below No. 2, was driven to cut at depth the ore exposed in No. 2, but this object was not accomplished. The tunnel was driven on a winding course into the hillside until a fault was encountered. Pyrite and sphalerite are reported to have been found in the drag on this fault. The tunnel follows the fault a short distance, then leaves it and stops.

BIG MINT GROUP

The three unpatented claims of the Big Mint group, owned by Frank Plughoff and Joe Tehee, cross the corner where secs. 31 and 32, T. 3 N., R. 17 E., and secs. 5 and 6, T. 2 N., R. 17 E., meet. There are five tunnels, three of them caved, and several cuts on the property. The two accessible tunnels are both on the Big Mint claim, the southernmost of the three. Most of the old workings are on the next claim to the northwest, known as the Big Mint Extension. Ore is reported to have been mined from these workings. In 1923 the property was being worked under lease by W. P. Fowler, John Lindstrom, Ollie Nelson, C. E. Lind, and James Laughlin, who were exploring in the lowest tunnel in search of the vein found in workings farther up the hillside. This tunnel is over 300 feet long. Most of it trends about N. 66° W., and there are two short drifts from it trending somewhat west of north. In the drift nearer the portal is a slip lined with gouge and red iron oxide, which strikes about N. 55° W. In the other drift are some poorly defined slips of similar strike with a little pyrite along them. The other tunnel that is still open is 230 feet vertically farther up the hillside and is about 140 feet long.[33] It exposes a shear zone in black shaly beds of the Wood River formation. Near the portal this zone is about 3 feet wide, strikes N. 35° W., and dips 60° NE. Farther in it splits up and swings more to the west. This zone contains soft altered country rock, pyrite, and lenses of quartz. A sample from the tunnel is reported to have assayed $4.85 worth of gold to the ton. The two old caved tunnels are 130 and 155 feet above this one.

BONNIE AND BARIUM SULPHATE GROUPS

The Bonnie group is in sec. 31, T. 3 N., R. 17 E., and the unsurveyed section west of it, on the ridge between Ajax Creek and the North Fork of Deer Creek. It is at present held by the Bunker Hill & Sullivan Mining & Concentrating Co., which in the summer of 1923 was engaged in extending the tunnel driven by John Dockwell, the original owner, and consequently called the Dockwell tunnel.

[33] These and similar figures are taken from a map prepared for the owners by C. C. Carhart in May, 1922.

The object of the work was to search for the downward extensions of bodies of lead-silver ore and of barite that had been found at the surface. A carload of barite mined from a shallow open cut was shipped in 1922.

The country rock belongs to the Wood River formation and in general strikes N. 50° W. and dips 50° SW., with many variations. A series of prominent white outcrops of barite crosses the crest of the ridge at an altitude of about 7,500 feet above the sea west of the middle of the west boundary of sec. 31, T. 3 N., R. 17 E. Some exposures of the barite are shown in Plate 11, *B*. There are similar outcrops on the Ajax Creek side of the ridge, near the middle of the S. ½ sec. 31, on the claims of the Barium Sulphate group. The barite is for the most part white, more or less distinctly banded, and nearly free from visible impurities but is somewhat iron-stained in places from the oxidation of small grains of pyrite, some of which remain unaltered. At the open cut on the Bonnie group the deposit is over 50 feet thick. The banding in it strikes N. 32° W. and dips 75° NE. The trend of the outcropping mass appears to be parallel to the banding. The attitude of the inclosing calcareous strata could not be ascertained. The outcrops on the Bonnie and Barium Sulphate groups lie in a general zone trending southeast from that in which the open cut has been excavated but are by no means in close alinement. There is probably a series of lenticular masses inclosed in the sedimentary strata, which have been broken and displaced by earth movements.

The Dockwell tunnel had in July, 1923, a length of 840 feet. Near the portal hard black quartzitic and calcareous strata are exposed. Farther in the rocks are comparatively light gray, soft, and more or less fractured and altered. About 660 feet from the portal there is a cut on the right side of the tunnel which discloses light-gray rock containing cinnabar in scattered grains and narrow discontinued veinlets. It is reported that John Dockwell found native mercury here. A short distance farther in barite with a maximum width of about 20 feet is exposed in the roof of the tunnel. At the face there is gray limestone that contains a little pyrite, sphalerite, and quartz. The three types of mineralization whose effects are observable in this tunnel do not appear to have had any direct genetic relations with one another.

NAY-AUG MINE

The Nay-Aug group, comprising six patented claims said to have produced about $150,000, is 2½ miles west of Clarendon Hot Springs, in a valley tributary to that of Deer Creek, in secs. 27 and 28, T. 3 N., R. 17 E. As the tables below show, the mine was worked during the early days, but its period of maximum production was from 1904 to 1916. It has not been worked in recent years.

Early production of the Nay-Aug mine

[From records of E. Daft and the Ketchum smelter]

Year	Ore	Silver	Lead	Year	Ore	Silver	Lead
	Tons	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Pounds*
1884	0.819	89.5	983	1891	33.7	2,254.0	40,964
1885	161.0	14,666.8	167,818	1892	45.4	4,651.2	65,165
1886	99.6	10,244.24	131,175	1893	24.1	2,098.3	32,179
1887	65.1	5,744.9	91,413	1894	16.3	1,534.0	24,725
1888	16.8	1,282.4	21,288	1895	4.9	406.0	6,487
1889	85.7	6,578.7	108,782				
1890	66.4	5,148.3	87,172		664.8	54,698.3	778,151

Recent production of Nay-Aug mine

[From records of U. S. Geological Survey]

Year	Ore sold or treated	Crude ore shipped to smelter	Ore to mill	Concentrates produced	Metals recovered				
					Gold	Silver	Lead	Zinc	Copper
	Tons	*Tons*	*Tons*	*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*	*Pounds*
1905	300	----------	-------	----------	70.59	12,733	196,039	55,449	--------
1906	545	545	-------	----------	190.75	28,885	485,050	----------	--------
1907	700	700	-------	----------	144.78	34,701	554,570	37,077	--------
1908	62	62	-------	----------	11.05	3,356	57,856	----------	--------
1909	868	868	-------	----------	338.90	44,105	686,380	----------	--------
1910	447	447	-------	----------	118.50	18,161	286,855	47,012	--------
1911	103	103	-------	----------	16.56	4,910	80,123	15,092	--------
1912	45	45	-------	----------	4.03	1,756	29,425	15,397	--------
1913	39	39	-------	----------	8.04	1,120	15,075	18,165	205
1914	158	158	-------	----------	36.77	11,789	192,277	----------	649
1915	2,636	146	2,490	415	148.17	23,508	352,398	112,434	286
1916	587	----------	587	70	20.88	3,340	42,762	18,170	426
1920	18	18	-------	----------	3.67	1,149	21,367	----------	--------
	6,508	3,131	3,077	485	1,112.69	189,513	3,000,177	318,796	1,566

The following description is based on an examination by Umpleby in 1913. The vein is of particular interest because it cuts directly across the contact between quartz monzonite and limestone. Two of the three ore shoots occur in the quartz monzonite, and the other passes from the limestone at the surface to the quartz monzonite in depth.

The mine is developed by seven tunnels to a depth at the face of the lowest one of nearly 600 feet. This tunnel, 2,400 feet in length, passes the east and middle ore shoots and lacks only 150 feet of reaching a point where the west one should be found. Beyond a point 280 feet from the portal it follows the lode continuously. The lode is marked in most places by clearly defined walls that stand from 4 to 6 feet apart and inclose a gouge of crushed quartz monzonite locally replaced by a band of ore, in most places next to the hanging wall but in the middle shoot on the seventh level next to the footwall. These bands of ore range in width from 2 to 18 inches, rarely to 3 feet. They are made up of galena, pyrite, sphalerite, chalcopyrite, and a little arsenopyrite in a quartz-siderite gangue. The ore streak in most places is exceptionally clean, with a little concentrating ore alongside. The better ore is said to contain 40 to 50 ounces of silver to the ton.

The limits of the shoots are rather indefinite, and it has been possible to work only portions of them at a profit. In general, however, the stope length of the middle and east shoots as exposed on level 7 may be considered to be 300 and 150 feet respectively. The west shoot, the largest and most persistent of all, is about 600 feet long on level 5, but this figure includes many barren segments of irregular shape and unequal size. Above level 7 the east and middle shoots have been largely worked out, and above level 5 the west shoot has been mined. Between the shoots the fissure may be indicated by slight iron stains but does not otherwise show evidences of mineralization.

The vein strikes northwest and dips steeply southwest. It is offset by six transverse faults, each of which dips northeast and causes a horizontal displacement of the fissure of 6 to 30 feet.

WAR DANCE AND JOLLY SAILOR MINES

The War Dance and Jolly Sailor mines, now consolidated under the ownership of James Burns and associates, are in secs. 28 and 29, T. 3 N., R. 17 E. The Jolly Sailor lies west of the War Dance. Its workings have long been abandoned, little of value having been found in them. The only production from the Jolly Sailor recorded by Daft is 0.47 ton containing 58 ounces of silver and 518 pounds of lead, mined in 1882. The War Dance yielded lead-silver ore of a gross value of $126,018 in the eighties, and intermittent work has been done on it since them. In 1913 and 1914 material from the dumps was jigged for zinc by using water from one of the tunnels, and mining has been continued intermittently since then. The available data on production are given in the tables below.

Early production of War Dance mine

[From records of E. Daft]

Year	Ore and concentrate	Silver	Lead	Copper	Year	Ore and concentrate	Silver	Lead	Copper
	Tons	*Fine ounces*	*Pounds*	*Pounds*		*Tons*	*Fine ounces*	*Pounds*	*Pounds*
1888	292.9	25,409.0	361,977		1894	14.0	1,282.9	18,793	373
1889	126.6	10,765.9	164,497		1895	10.3	709.2	11,612	
1890	289.3	24,907.8	394,537		1899	.2	28.9	337	
1891	181.9	15,557.4	229,763		1902	6.0	479.8	7,727	
1892	93.6	8,056.6	133,632		1903	5.8	370.7	6,087	
1893	10.5	932.8	14,110	527		1,031.10	88,501.00	1,342,619	900

Production of War Dance mine, 1904–1918

[From records of U. S. Geological Survey]

Year	Ore sold or treated	Crude ore shipped to smelter	Ore milled	Concentrates produced	Metals recovered			
					Gold	Silver	Lead	Zinc
	Tons	*Tons*	*Tons*	*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1904	[a] 27	27				120	4,455	26,125
1905	191			108	1.20	638	6,960	70,260
1911	100			20		60	1,200	14,722
1912	500		500	78		597		63,437
1913	68	14	54	27		1,185	18,382	22,399
1914	189		189	63				51,505
1916	41	41				410	3,280	29,274
1917	36	36				60	808	28,055
1918	2	2			.04	142	1,847	
	1,154	120	743	296	1.24	3,212	36,932	305,777

[a] Mined 3,000 tons.

Late in 1923 a vein of arsenic ore was found on the War Dance ground. It has been exposed in a number of shallow cuts on the hillside northwest of the Jolly Sailor tunnel. The ore contains arsenopyrite partly oxidized to scorodite and other minerals. In the winter of 1923–24 R. B. French, working under lease, drove a short crosscut and short irregular raises from the Jolly Sailor tunnel under the old War Dance workings.

The underground workings in the War Dance mine are estimated by Campbell[34] to exceed 10,000 feet. There are six tunnels, only the lower two of which are now open for any considerable distance. The principal work was done from a drift to the north from No. 5 tunnel and from drifts on two levels below and connected by winzes with this drift. In recent years a sixth tunnel, 1,300 feet long, starting on the Jolly Sailor ground, and a raise connecting this with the old workings just mentioned have been driven. Much of the old workings is now inaccessible, but there are small stopes on the fifth level, the two intermediate levels below it, and probably also on the upper levels. The principal production is reported to have come from a stope on a lens-shaped mass 16 feet wide, 30 feet high, and 40 feet long.

Both properties are in a rather dark phase of the quartz monzonite a short distance southwest of the contact with the Wood River formation. In places along the main drift on the fifth level, especially on the hanging-wall side of the vein, there are blocks of dark fine-grained altered rock of sedimentary origin, containing irregular veinlets and small masses of a zeolite, probably laumontite.

[34] Campbell, Stewart, Twenty-fourth annual report of the mining industry of Idaho, for the year 1922, p. 41, 1923.

The principal vein in the accessible part of the drift on the fifth level of the War Dance mine strikes north and dips about 45° W. Beyond this part the drift appears to swing to the west. A short distance south of this turn another vein branches off on the hanging-wall side with a strike of about N. 60° W. The small stopes on the two levels below are probably on this vein. On these levels there are short crosscuts that extend east to another vein, presumably the one followed by the main drift on the fifth level. The quartz monzonite between these two veins is sheared and somewhat altered. No ore has been found on the sixth or Jolly Sailor level, but a narrow zone of crushed and somewhat mineralized rock is exposed. This zone may be a continuation of a vein that crops out on the hillside above, which in turn is supposed to be an extension of the vein that was prospected unsuccessfully in the old Jolly Sailor workings. The exposures on the hillside show banded quartz with a few grains of arsenopyrite and faint copper stains on cracks.

The ore on the dumps and in piles underground is all of the same general character and evidently came from the two veins in the War Dance workings. Much of it is distinctly banded. The minerals noted are quartz, galena, sphalerite, and pyrite.

NARROW GAUGE MINE

The Narrow Gauge mine, which comprises two claims, is near the creek level in the upper part of Narrow Gage Gulch, at an altitude of 6,750 feet, in sec. 9, T. 2 N., R. 17 E. It lies near the quartz monzonite contact with Pennsylvanian rocks (Wood River formation), which here consist of massive fine-grained sandstone and black calcareous shale. The mine is credited with an estimated production of $200,000 prior to 1898; it has been worked but little since. The available data on early production are given below.

Early production of Narrow Gauge mine

[From records of E. Daft and Ketchum smelter]

Year	Ore and concentrate	Gold	Silver	Lead	Year	Ore and concentrate	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1883..	408.7	....	37,547.2	468,011	1895..	1.46	....	47.3	953
1884..	306.3	....	32,693.2	372,642	1896..	7.6	....	490.2	9,230
1885..	417.8	....	34,411.7	432,915	1897..	1.2	....	99.3	1,479
1887..	43.4	....	3,952.2	46,749	1898..	22.3	....	1,933.6	31,705
1888..	30.4	....	1,697.5	23,737	1899..	18.6	....	1,328.6	23,999
1889..	11.6	....	649.0	16,491	1900..	5.4	....	355.4	4,991
1890..	.7	....	37.4	829	1901..	.6	0.019	48.2	867
1891..	6.8	....	608.4	8,037	1903..	1.3	....	91.2	1,601
1893..	15.7	....	1,467.1	18,371					
1894..	6.5	....	505.7	7,991		1,306.3	.019	117,963.2	1,470,598

In 1913 tailings from the old mill were being hand-jigged for zinc. Some small shipments made since then are listed in the following table:

Production of Narrow Gauge mine, 1914–1918

Year	Ore sold or treated	Crude ore shipped to smelter	Metals recovered		
			Gold	Silver	Lead
	Tons	*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1914	16	16	0.49	935	9,958
1915	12	12	.45	483	3,755
1916	7	7		129	1,782
1918	[a] 14			414	4,155
	49	35	.94	1,961	19,650

[a] Tailings.

The vein, a narrow fissure that strikes northwest and dips 85° SW., is developed by two shafts and several tunnels, nearly all of which are now accessible. As described by Lindgren the ore consisted of galena, zinc blende, and a little chalcopyrite and occurred as streaks and bands in a siderite gangue. The main pay shoot was found above the lowest tunnel on the south claim.

LE DESPENCER MINE

The Le Despencer mine, owned by Mrs. Edward Flannery, of Clarendon Hot Springs, is on the north side of Deer Creek somewhat less than a mile upstream from Clarendon Hot Springs. It is developed by two tunnels and a few other shallow workings. The lower tunnel is about 275 feet long but was full of water when visited in 1923. The other tunnel is 190 feet long and has a shallow winze 70 feet in from the portal and a small stope just beyond the winze.

The rock in the vicinity of the mine is rather coarse grained granite, a silicic facies of the quartz monzonite. The upper tunnel follows a fairly well defined slip from a place near the portal to about 30 feet beyond the winze. The inner portion of the tunnel exposes several small slips which differ in attitude and are lined with rusty gouge and a little pyrite. The slip on which stoping has been done strikes N. 80° W. and dips 45° N. Specimens from the dumps of the tunnels show that the ore mined contained galena, sphalerite, pyrite, quartz, and calcite in somewhat altered granite. Specimens in which vein minerals are abundant consist largely of rudely parallel and indefinitely bounded layers. Some layers are composed of quartz and pyrite and others of coarse-grained sphalerite and galena or of sphalerite alone. The calcite fills small, irregular fissures in the other minerals. Some of the quartz is in small prismatic crystals. The altered granite adjoining the ore contains rather well formed crystals of pyrite.

OTHER PROSPECTS NEAR DEER CREEK

There are a number of prospects in the valley of Deer Creek that were not visited by either Umpleby or Ross. Among these are the Blumite, Rattler, Black Hawk, Bullwhacker, Snow Fly, Montana, Silver Moon, and Davitt. Most of these prospects have been inactive for a number of years, but assessment work is maintained on some of them. Their location is shown on Plate 9, and such data as are available are given below. The following tables give the data in the records of E. Daft and the Ketchum Smelter on production at these properties.

Production of Snow Fly mine

Year	Ore	Gold	Silver	Lead	Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1883	4.5		418.8	6,042	1892	5.5		555.6	7,914
1884	45.0		2,997.9	54,022	1893	4.5		327.4	5,147
1885	29.6		871.7	14,874	1903	9.2	0.278	676.2	10,763
1887	83.7		5,999.6	101,546	1905	.8		68.9	1,246
1888	42.4		2,991.4	58,295					
1889	41.5		2,888.9	57,711		265.7	.278	17,796.4	317,560

Production of Bullwhacker mine

Year	Ore	Gold	Silver	Lead	Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1883	0.8		62.1	907	1895	3.5		328.7	5,157
1884	5.4		556.9	7,420	1896	1.1		77.4	1,323
1885	50.6		3,165.2	47,382	1897	.8		52.3	840
1887	8.0		794.3	11,229	1900	2.3	0.094	162.5	2,117
1888	7.1		711.5	9,644	1901	.6		51.4	701
1890	1.1		114.2	1,499	1905	.8		39.2	539
1891	1.8		173.8	2,544					
1892	8.1		830.0	11,400		95.1	.094	7,441.4	107,337
1893	3.2		321.9	4,635					

Production of Montana mine

Year	Ore	Silver	Lead	Year	Ore	Silver	Lead
	Tons	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Pounds*
1882	40.0	6,526.29	46,460	1888	7.2	785.9	3,990
1883	13.5	1,768.7	15,423	1891	2.9	393.6	2,467
1884	.9	92.5	440				
1885	33.6	3,421.8	20,774		114.0	14,953.8	101,206
1887	15.9	1,965.1	11,652				

Production of Davitt mine

Year	Ore	Gold	Silver	Lead	Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Pounds*	*Pounds*		*Tons*	*Fine ounces*	*Pounds*	*Pounds*
1883	461.6		37,020.4	580,950	1896	0.9		29.8	585
1884	139.6		10,263.5	143,839	1906	.9		29.1	572
1885	2.5		141.3	2,277					
1892	8.9	0.580	3,287.2	11,964		614.40	.580	50,771.3	740,187

Production of Rattler mine

Year	Ore	Silver	Lead
	Tons	*Fine ounces*	*Pounds*
1884	2.0	155.7	2,511
1885	.9	29.2	492
1888	.2	18.7	320
	3.1	203.6	3,323

The Blumite or Blomide mine near Clarendon Hot Springs, is owned by J. G. Arkoosh. Over 500 feet of development work has been done, principally in three tunnels. The country rock belongs to the Wood River formation.

The Rattler group of three claims is south of Clarendon Hot Springs and is one of the more recently opened prospects in the district. The following data were furnished by the owner, Alexander McKibbin. There are a number of short tunnels and a shaft 30 feet deep, a total of about 500 feet of developments. From one small ore body at shallow depth 8 tons of ore was mined and yielded 70 per cent of lead and 130 ounces of silver to the ton. A shipment of 3 tons from the bottom of the shaft contained 70 per cent of lead and 100 ounces of silver to the ton. The workings are all in quartz monzonite.

Probably none of the other properties mentioned above except the Bullwhacker have been worked in recent years. The Black Hawk and Bullwhacker are in the Wood River formation and the others in quartz monzonite.

IMPERIAL GROUP

The Imperial group, owned by the Hailey Bonanza Mining Co., is on one of the tributaries of Greenhorn Creek near the common corner of secs. 14, 15, 22, and 23, T. 3 N., R. 17 E. Small shipments were made from this property in 1919 and 1920, and some work has been done since then. There was no one at the mine when it was visited in July, 1923. In 1924, however, a new company took over the property, did considerable development work, and started to build a mill, and since then this company has mined and milled some ore. There are a number of cuts and tunnels on the property. The longest tunnel has a length of over 200 feet, and there are probably nearly 1,000 feet of workings in all. Most of the ore mined evidently came from a stope above the longest tunnel, which is in a branch gulch on the east side of the stream above the camp. The principal development work done in 1924 consisted in extending the long tunnel and putting up raises from it in search of the continuation of the ore mined above.

The country rock belongs to the Wood River formation. It strikes in general west of north and dips steeply to the east. There are a number of lodes. The one that has been stoped strikes in general a little west of north and stands nearly vertical. It has a horse of barren material in the middle. The following data regarding recent shipments from this property are extracted from a report by A. E. Ring, of the Federal Mining & Smelting Co.

Shipments from Imperial group

Date	Dry ore	Gold	Silver	Lead	Copper	Insoluble	Zinc	Sulphur	Speiss	Iron
	Tons	*Fine ounces per ton*	*Fine ounces per ton*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Dec. 12, 1919	27.8	0.075	56.6	48.2	0.4	19.2	4.0	1.5	4.5	3.0
Sept., 1920	22.2	.013	47.0	38.65	.3	27.7	7.7	.45	1.6	3.3

The following table shows shipments credited by Daft to the "Imperial." Presumably they are from this property.

Production of Imperial mine

[From records of E. Daft]

Year	Ore	Silver	Lead	Year	Ore	Silver	Lead
	Tons	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Pounds*
1883	50.6	3,007.8	52,419	1889	0.6	28.81	745
1884	4.3	523.5	4,136	1890	1.2	84.4	1,496
1885	15.6	816.7	16,482				
1886	13.4	901.7	17,276		89.50	5,584.6	97,171
1887	3.8	221.7	4,617				

There are several short tunnels on the northwest side of the main gulch. These tunnels follow lodes that have an average strike of about N. 25° W., with considerable variation, and dip steeply to the west. The lodes consist of sheared and brecciated country rock that contains layers of white quartz with massive calcite in places. The calcite weathers somewhat rusty. In places there are exposures of subparallel quartz stringers an inch or more wide. Much of the quartz in these stringers is in the form of tiny prismatic crystals in radiating clusters that line the sides of small cavities. Limonite and a little copper stain is associated with the quartz, and unaltered pyrite can be discerned in some specimens. The stringers strike nearly east and dip steeply north. Some of them cut the lode that strikes northwest, but other terminate against it.

DEMOCRAT MINE

The Democrat mine, also known as the Idaho-Democrat, is near the head of Democrat Creek, in sec. 11, T. 2 N., R. 17 E., 4½ miles in a straight line west of Hailey. The property comprises 11 patented claims, on which extensive development work has been done. There is a boarding house, a blacksmith shop, and other buildings. The mine is connected with the main highway at a point nearly 2 miles from Hailey by a fairly good road about 3½ miles long.

The principal activity at this mine was in the boom days of the Wood River region, over 40 years ago, and nearly two-thirds of the total production of lead-silver ore, with a gross value of perhaps more than $300,000, was obtained at that time. The following table shows available data on the production:

Early production of Idaho-Democrat mine

[From records of E. Daft and Ketchum smelter]

Year	Ore	Gold	Silver	Lead	Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1883	24.1		1,913.8	20,973	1894	49.9		5,007.6	71,857
1884	69.1		5,426.8	44,132	1895	35.2	4.4	4,640.8	50,432
1885	48.1		4,274.7	42,772	1896	131.8		15,713.6	187,858
1886	62.5		7,036.6	72,477	1897	110.3		13,594.2	160,151
1888	43.6		6,354.4	53,674	1898	326.5		39,463.5	463,983
1889	4.5		853.3	6,349	1899	278.8		33,025.3	353,622
1890	22.0		2,993.0	32,659	1900	246.2		28,881.2	317,945
1891	65.7		9,158.4	97,176	1901	287.2		34,566.8	382,535
1892	15.3		2,516.2	22,582					
1893	53.4		6,102.6	72,758		1,874.2	4.4	221,522.7	2,454,93[illegible]

In 1902 to 1910, according to the records of the United States Geological Survey, 1,689 tons of ore was mined, of which about 900 tons was concentrated. A total of 138,141 ounces of silver and 1,240,249 pounds of lead was obtained. The mine has been shut down since 1910 but was reopened in 1923. When visited in July, 1923, 2 of the 10 principal tunnels were being cleaned out and retimbered by A. W. Bartlett and his associates, who had a lease on the property. There are filled stopes above these tunnels, but ore had not yet been reached. It is reported that the mine was idle in 1924 but that work has since been resumed.

The principal workings of the mine are all in quartz monzonite, and the ore was probably all along a single shear zone. A short distance east of the lowest or No. 10 tunnel the quartz monzonite is in intrusive contact with impure Pennsylvanian limestone. A little oxidized ore has been found in limestone near the contact. The two tunnels where work was in progress at the time of visit are known as Nos. 7 and 10. No. 7, which is some distance up Democrat Creek above No. 10, is entirely in granodiorite. The first part of it is a crosscut, but most of it follows a rather poorly defined shear zone with variable northwest trend and dips of 60°–75° S. In the stopes above part of this tunnel the vein is reported to have been 6 to 8 feet wide with 4 inches to 3 feet of clean galena ore on the hanging-wall side. The first part of No. 10 tunnel is also a crosscut. A block of limestone is exposed near the portal, but most of the crosscut is in granite. The first mineralized material encountered is a vein in another limestone block that strikes N. 43° W. and dips 50° S. In the limestone the vein is a shear zone lined with a little gouge and showing some iron stains. The tunnel continues with several twists and in a short distance passes out of the limestone into mineralized quartz monzonite. One of the contacts between the two rocks is a fault slip, and there has also been movement on the other contact, but the limestone blocks were doubtless originally engulfed in the quartz monzonite during the intrusion of that rock. Farther in another vein is encountered in the quartz monzonite. This vein seems to be nearly in line with the vein in limestone and may well be a continuation of it. The rest of the tunnel follows this vein, which has been stoped above the tunnel in places. Much of the vein is merely a layer of gouge on the hanging-wall side of a shear zone in sericitized quartz monzonite. The strike ranges from N. 10° W. to N. 80° W., and the dip is 45°–65° S.

According to Lindgren [35] the ore contained galena, sphalerite, and tetrahedrite, and the sericitized quartz monzonite contained disseminated grains of pyrite, galena, and sphalerite. Vein quartz and siderite are associated with the ore. Mr. Bartlett states that smelter returns show that the ore shipped in the early days averaged 61 per cent of lead and 126 ounces of silver to the ton. The gold content was low.

LE GRANDE GROUP

The Le Grande group of six claims, owned by Floyd Wilson and his associates, is in sec. 2, T. 2 N., R. 17 E. It has been developed by three short branching tunnels and some shallow cuts. There are several irregular lodes in quartz monzonite near the contact with Miocene (?) lava. They range in strike from N. 30° E. to N. 25° W. and dip for the most part steeply to the east. The lodes contain banded quartz, galena, and pyrite. Some of the quartz was deposited after the sulphides and most of the quartz had been formed. One of the veins contains only quartz and rusty pyrite. A sample from this vein is reported to have assayed 9 ounces of gold to the ton. The following table gives the smelter returns on three small ship-

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[35] Lindgren, Waldemar, op. cit., p. 206.

ments of ore taken out in the course of development work and shipped in November, 1923:

Shipments from Le Grande group

Dry weight (pounds)	Gold	Silver	Lead	Insoluble matter	Iron	Sulphur
	Fine ounces per ton	*Fine ounces per ton*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
10,220	0.09	146.6	45.9	23.0	6.4	13.4
3,528	.09	204.6	58.2	12.5	4.4	14.8
5,390	.085	46.0	10.4	60.8	8.9	6.0

WOLFTONE MINE

The Wolftone mine is in secs. 18 and 19, T. 2 N., R. 17 E., about 13 miles by road west of Hailey. The deposits were found in 1883, and most of the ore produced from the property was mined in the succeeding few years. It is reported that in 1883 to 1887 700.9 tons of a gross value of $75,155.43 was shipped. The following table gives the production as recorded by Daft. As it accounts for only 262 tons it is presumably incomplete.

Early production of Wolftone mine

[From records of E. Daft]

Year	Ore	Gold	Silver	Lead	Copper
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1883	88.2		5,807.3	89,239	
1884	69.6		5,465.9	53,403	
1885	36.7		1,866.0	34,820	
1886	9.6		823.0	6,543	
1887	10.1		637.8	11,974	
1889	1.9		110.5	2,304	
1892	15.6		1,117.7	19,118	177
1893	11.7		581.8	9,403	
1895	4.8		261.6	3,373	
1897	5.8		437.3	5,293	
1898	8.3	0.130	729.9	9,113	
	262.3	.130	17,839.3	244,583	177

Since 1887 most of the work has been done by lessees. The last work in the Sweed tunnel, the longest on the property, was done in 1912. In August, 1923, W. T. Riley was at work clearing out one of the upper tunnels.

The property comprises five claims, three of which are shown in Plate 10. The Sweed tunnel, which has its portal on the Detroit claim, is the most extensive one on the property. This tunnel and the short drifts that lead from it have a total length of nearly 2,000 feet, but part of it is now caved. The tunnel in which work was in progress at the time of visit is about 90 feet vertically above the Sweed tunnel, and its portal is several hundred feet farther south on the

Wolftone claim. This tunnel is being reopened to reach a vein exposed in some of the old workings on the mountain side above. These old workings consist of several short branching tunnels which are now all more or less caved. None of them attained much depth, and nearly all the ore mined is reported to have come from close to the surface.

The rock that incloses the deposits belongs to the Wood River formation, but a short distance to the west a large mass of soda granite crops out. The Sweed tunnel crosscuts the Wood River strata, which here strike northwest and dip rather steeply southwest. Near the end of the accessible part of the tunnel, near the floor, several lenses and irregular stringers of quartz are exposed. In the space above the pile of caved rock that blocks the tunnel there is a well-defined slip that stands nearly vertical and has a northward strike. In the tunnel beyond this slip some granite containing a little sphalerite and other evidence of mineralization is reported to have been encountered. The vein sought in the tunnel that is being reopened strikes a little east of north and dips about 35° E. Some work was done on it in the past, and lead-silver ore was mined. One of the old tunnels above this one exposes a vein whose strike is N. 5° E. and dip 30° E. and which contains calcite and galena. In another there is a slip that strikes N. 30° W. and dips 20°–40° SW. Mr. Riley states that the old workings exposed two intersecting veins, only one of which contained commercial ore.

PROSPECTS ON KELLY MOUNTAIN

Kelly Mountain is in secs. 19, 20, 29, and 30, T. 2 N., R. 17 E. A number of prospects have been opened here, but except on the Wolftone, just described, there has been little production. The claims shown on Plate 10 indicate the general position of the group of prospects, although there are doubtless a number of unpatented claims not shown. Among the prospects may be mentioned the Black Barb, Carboniferous, Continental Kelly, and Field Mutual. No work was in progress on any of these prospects in the summer of 1923, and they were not visited. According to Campbell[36] the Continental Kelly Mining Co. holds six unpatented claims with total developments of about 600 feet, and the Field Mutual Mining Co. holds 14 unpatented claims with about 3,000 feet of developments. Lead-silver ore is sought on both properties.

The following table shows the available data on early production at the Black Barb. In addition a small shipment was made from this property in 1919.

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[36] Campbell, Stewart, Twenty-fourth Annual Report of the Mining Industry of Idaho, for the year 1922, pp. 37, 38, 1923.

Early production of Barb mine

[From records of E. Daft]

Year	Ore	Gold	Silver	Lead	Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1889	3.4	----------	148.7	2,628	1893	12.5	----------	1,076.8	17,826
1890	1.9	----------	106.8	1,616	1908	8.8	0.493	310.3	5,369
1891	2.7	----------	53.2	764					
1892	.8	----------	45.9	659		30.1	.493	1,741.7	28,862

INDEPENDENCE MINE

The Independence mine is on Independence Creek, a tributary of Elkhorn Creek, somewhat over 4 miles east of Ketchum, in sec. 23, T. 4 N., R. 18 E., and adjoining sections. The ore was formerly treated in a mill in Independence Gulch, shown in Plate 18, *B*, but while the Federal Mining & Smelting Co. was operating the mine the ore was sent through the Plummer tunnel to the North Star mill and concentrates were sent down the East Fork of the Big Wood River to the railroad siding of Gimlet.

The mine has been worked intermittently since 1883. In 1913 it made an estimated production of $100,000. The Federal Mining & Smelting Co. acquired the property late in 1917 and maintained operation continuously until the later part of July, 1923. The company's records show that from the beginning of 1919 to July 1, 1923, 131,883 tons of ore was concentrated. Besides this some high-grade ore was shipped direct, and a few hundred tons was mined by lessees. The available production data are shown in the tables below:

Early production of Independence mine

[From records of E. Daft and the Ketchum smelter]

Year	Ore and concentrates	Gold	Silver	Lead	Year	Ore and concentrates	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1884	1.3	----------	202.1	1,447	1897	8.9	----------	1,380.6	10,793
1885	24.4	0.50	2,234.6	11,072	1898	3.9	0.718	351.3	2,947
1886	35.3	2.033	2,347.0	18,853	1899	9.3	2.70	758.7	7,561
1890	3.9	.356	49.8	3,951	1905	7.3	1.46	1,444.4	8,702
1891	4.6	.845	567.8	3,942					
1892	6.7	1.222	988.62	6,790		273.5	30.792	27,128.3	221,016
1896	167.9	20.958	17,103.5	144,958					

Production of Independence mine, 1908–1922

[From records of the U. S. Geological Survey with revision by the Federal Mining & Smelting Co.]

Year	Ore sold or treated	Crude ore shipped to smelter	Ore milled	Concentrates produced	Metals recovered				
					Gold	Silver	Lead	Copper	Zinc
	Tons	*Tons*	*Tons*	*Tons*	*Fine Ounces*	*Fine Ounces*	*Pounds*	*Pounds*	*Pounds*
1908	24	24	-------	-------	3.31	4,432	33,140	-------	-------
1909	30	30	-------	-------	4.74	5,592	37,467	453	-------
1912	441	-------	441	147	29.19	10,933	87,222	448	-------
1913	200	-------	200	28	3.44	1,541	11,232	104	5,175
1914	2,200	-------	2,100	300	80.00	34,400	320,000	1,820	-------
1915	2,268	-------	2,268	318	55.23	30,548	28,892	666	-------
1916	2,541	-------	2,541	363	74.46	27,909	256,726	2,072	-------
1917	6,850	-------	6,850	722	159.80	72,486	576,937	4,446	-------
1918	10,342	545	9,797	1,750	373.60	161,943	1,180,023	-------	-------
1919	13,386	352	13,034	2,542	539.60	216,333	1,556,600	-------	-------
1920	13,048	556	12,492	1,740	457.00	226,961	1,713,580	14,023	-------
1921 [a]	37,522	1,114	36,408	5,322	968.00	545,388	4,392,360	23,000	-------
1922	44,432	549	43,883	5,232	802.44	442,437	3,441,301	24,675	-------
	133,284	3,170	130,472	18,194	3,550.81	1,780,903	13,875,470	71,707	5,175

[a] Including North Star.

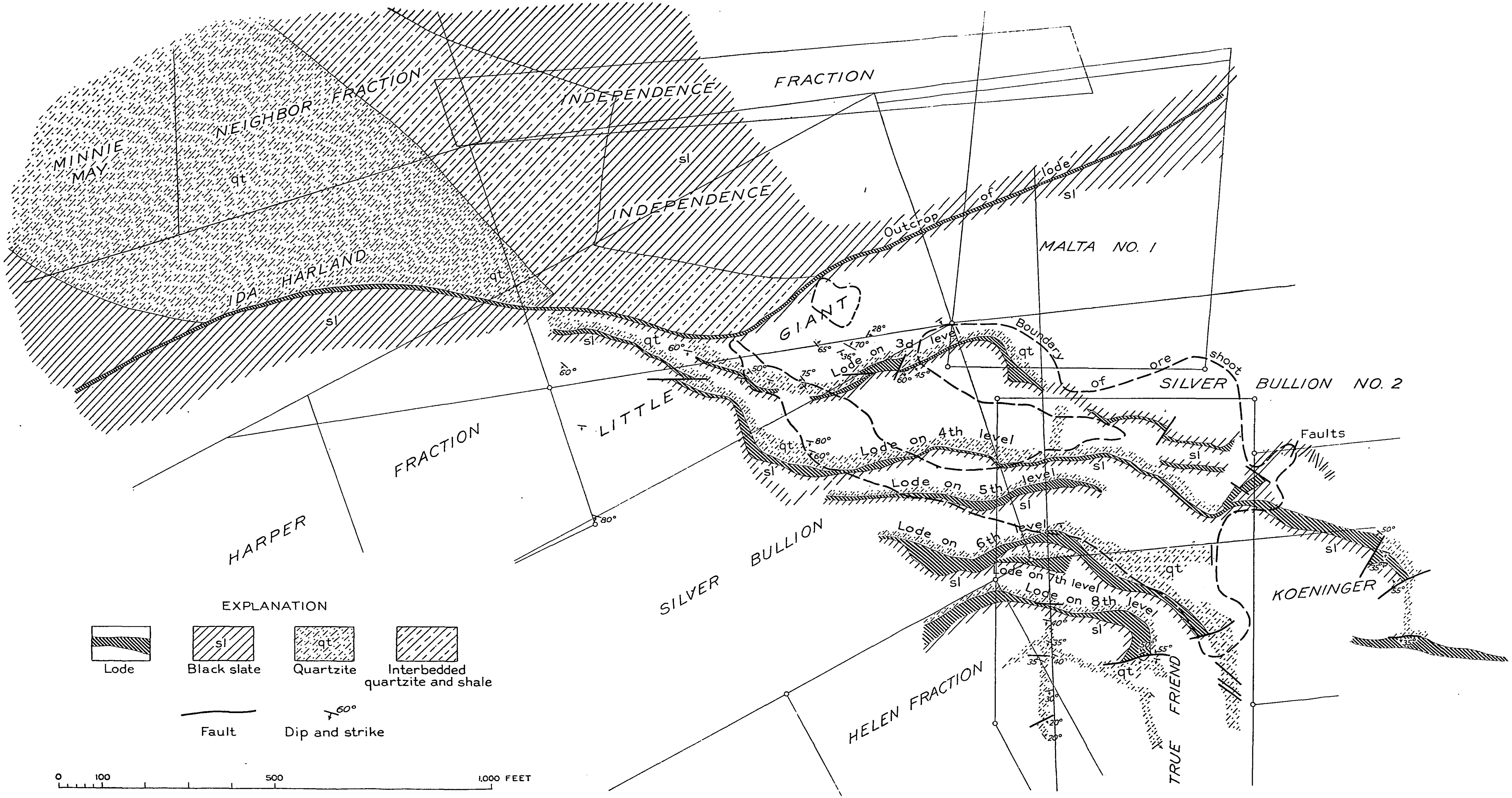
The North Star mill was remodeled and put in operation on ore from the Independence in 1920 and continued until 1923, when the mine was shut down because the known ore bodies had been practically exhausted. Ore and concentrates were hauled to the railroad by motor truck in summer and horse-drawn sleds in winter. The work was done by contractors, and the cost was about $2 a ton for motor haulage and $4 a ton when sleds were used.

The mine, as can be seen from Plate 21, has extensive drifts and crosscuts on nine levels. Four of the levels may be entered directly from the surface. The fourth level has tunnel entrances on both ends. Trains were hauled by mules on this level. Below all the levels is the Plummer tunnel, about 6,200 feet long, which emerges in North Star Gulch. After the raise from the tunnel up to the sixth level of the Independence was completed in 1920, the ore was sent down the raise and hauled through the tunnel on trains drawn by electric power. From the tunnel portal the ore was sent to the North Star mill, over 4,000 feet away, on an aerial tramway. The Plummer tunnel is connected by means of raises with the North Star workings above it and the Triumph workings below it. The relative positions of the three mines and the mill are shown in Plate 22.

The Independence mine is entirely in the Milligen formation, although as can be seen from Plate 1, erosion remnants of the Wood River formation crown some of the ridges on the property, and Porphyry Peak is capped with Tertiary lava and pyroclastic rocks. The Milligen rocks are largely black carbonaceous and more or less calcareous argillite. Some beds are composed of argillaceous quartzite, which is somewhat coarser grained than the argillite. Most of these beds are dark bluish or gray rather than black, although in many exposures the difference in color between the quartzite and the argillite is not marked. All the quartzite is somewhat argillaceous and calcareous, and no large mass was observed without interbedded argillite. Much of it is in layers a few inches thick alternating with argillite of similar thickness.

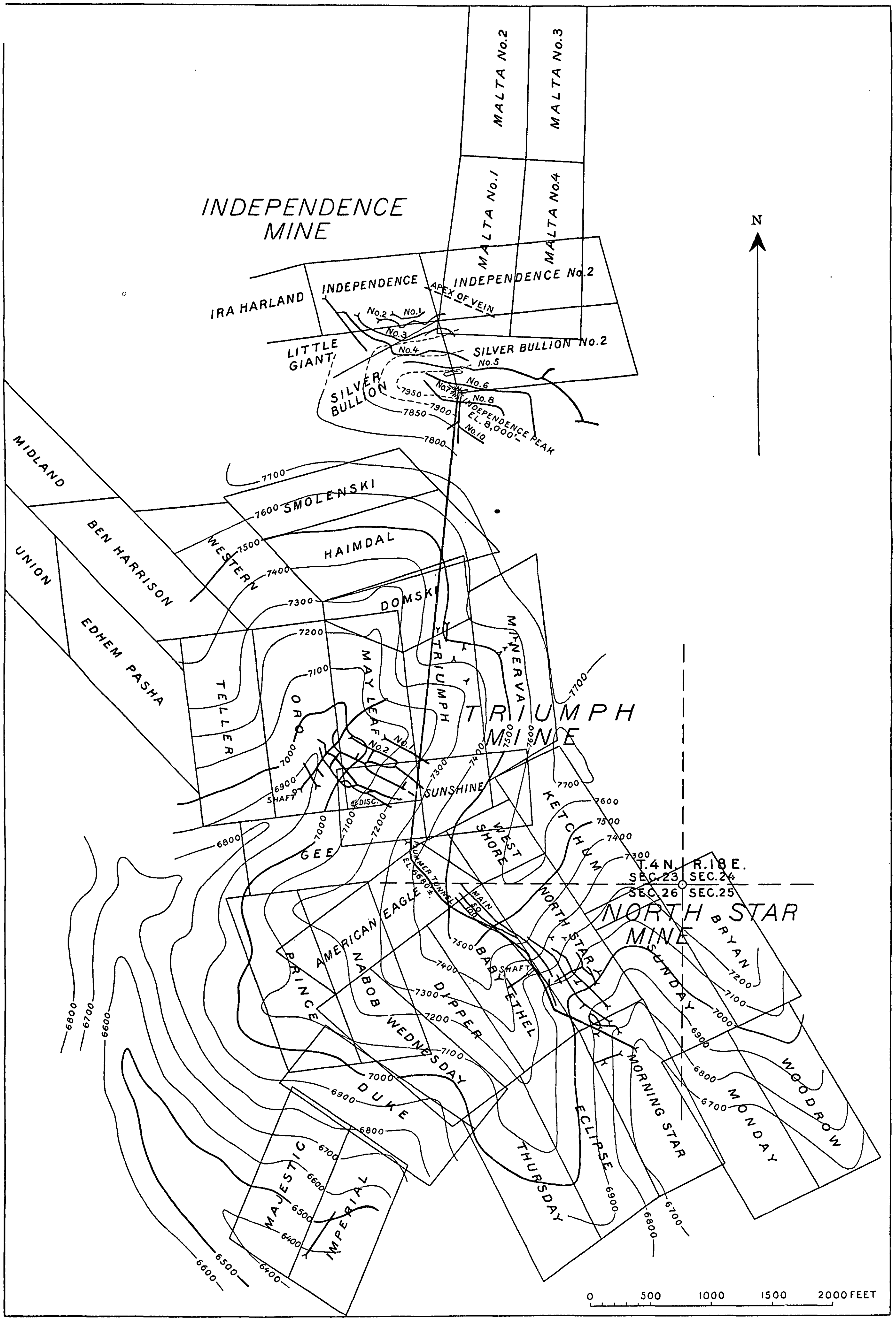
The Independence lode is a shear zone that has a general strike slightly north of west and dips south. The strike in different segments of the lode underground ranges from almost due west to N. 70° E., as is shown in Plate 21. Some parts strike about N. 25° W. As can be seen from Plates 21 and 23, the dip is steep in the upper part of the mine, flattens somewhat near level 3, and is again rather steep down to level 6, below which it flattens abruptly. The lode does not appear to have been encountered either on level 10 or in the Plummer tunnel. There is a rather poorly marked zone of fracturing in the Plummer tunnel which might possibly represent the extension of the lode, but it is unmineralized.

In the greater part of the workings the footwall of the lode is predominantly quartzite, and the hanging wall is argillite. The distribution of the two types of rock, as mapped by O. H. Hershey, is shown in Plate 21. These rocks have been greatly disturbed by minor movements, and consequently observed strikes and dips differ so much within short distances that an accurate idea of their general trend is difficult to obtain. It seems, in a broad way, that the rock on the footwall side of the lode strikes about N. 60° W. and dips southwest. The attitude of the shale on the hanging-wall side is even more difficult to determine, but this rock may lie more nearly parallel to the lode than the footwall quartzite does. In the Plummer tunnel the rock strikes roughly at right angles to the tunnel and dips in general at low angles toward the south. It is flexed into gentle folds, so that in places it lies horizontal or even dips northward. Much of the rock, especially in the northern part of the tunnel, is dark and shaly. Hershey, in his report to the company made in 1921, advances the idea that the Independence lode is on a reverse fault that has caused argillite belonging stratigraphically below the more quartzitic rock of the footwall to ride up on that rock. If his interpretation of the local stratigraphy is correct this theory is the most probable one. Reverse faults with similar trends are plentiful in the region, as has been shown by Westgate in his description of the structural geology of the Hailey quadrangle. The stratigraphic succession in the Milligen formation, however, has nowhere been accurately determined, and the rocks here are so similar to one another in appearance and the surface exposures are so poor that it is impossible to determine with certainty their stratigraphic or structural relations in detail.

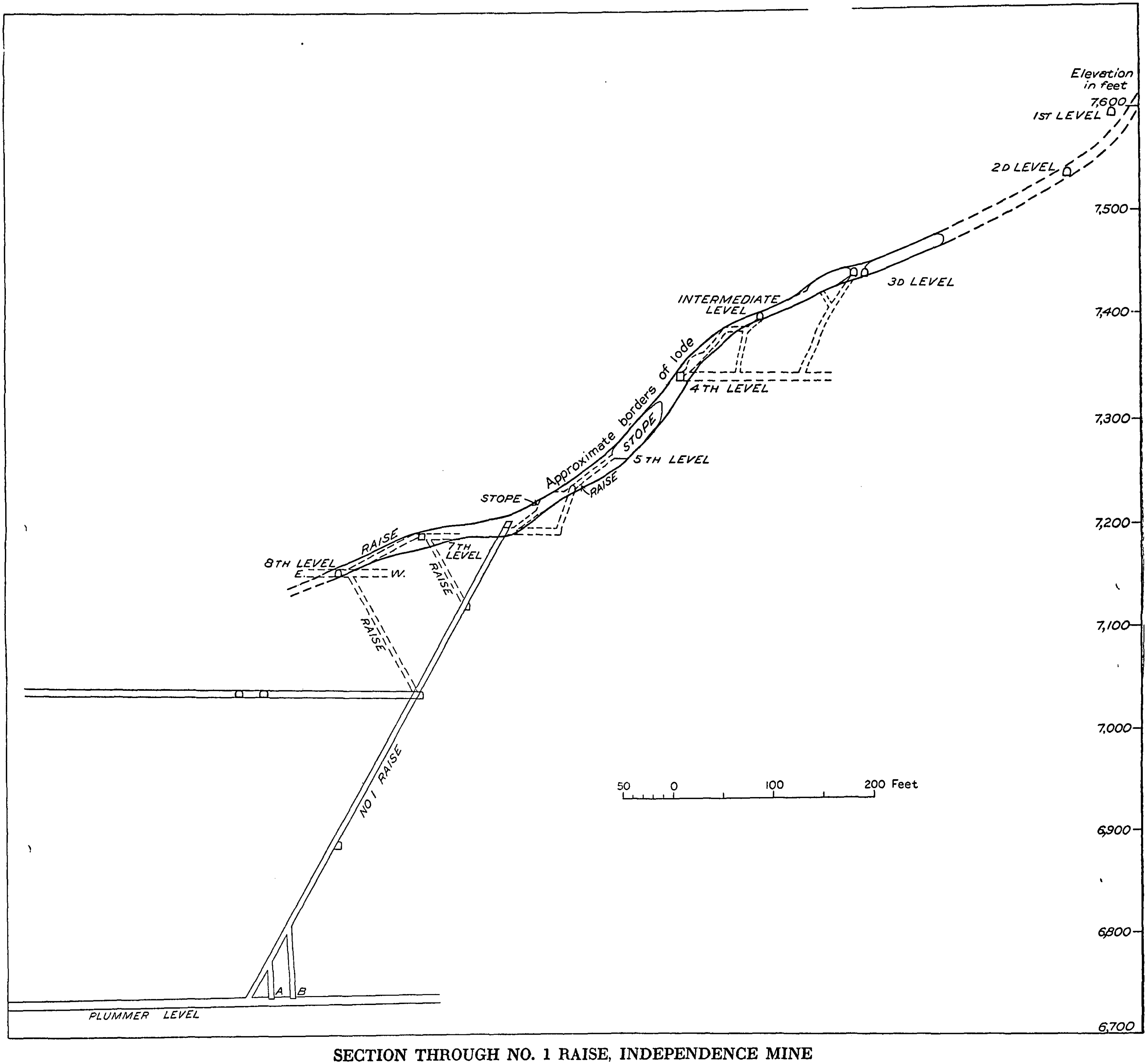


GEOLOGIC MAP OF THE INDEPENDENCE MINE

Showing the principal workings, the outlines of ore shoots, and the geology on the surface and underground as interpreted by O. H. Hershey.



MAP SHOWING THE RELATIVE POSITIONS OF THE INDEPENDENCE, NORTH STAR, AND TRIUMPH MINES



SECTION THROUGH NO. 1 RAISE, INDEPENDENCE MINE

Much of the disturbance of the rocks took place subsequent to the formation of the lode. The vein matter and ore have in many places been crushed, brecciated, and contorted to a marked degree. At a later period the lode was broken by numerous transverse faults. Many of these are indicated on Plate 21, but there are many others either so small or so poorly exposed that they have not been mapped. The southward swing of the eastern part of the lode may result from the cumulative effect of a series of small faults.

The distribution of the stopes and the content of samples recorded on the company's assay maps show that most of the ore lay in an irregular forked shoot, with two small shoots not known to be connected to the main one. The approximate outlines of the shoots are indicated on Plate 21. The principal shoot pitches downward to the east at an angle of about 37° to the horizontal in the plane of the lode. The line of stopes projected on a horizontal plane trends about S. 60° E. The ore body mined from level 1 may be regarded as a continuation of one fork of the principal ore shoot, but no connection between the two appears to have been found on level 2. There is, however, some lead and silver along level 2 for a distance of 140 feet from the portal. No stoping appears to have been done here. The ground left unmined between the exhausted stopes shows that the shoot outlined on Plate 21 did not contain ore of commercial grade throughout. The assay maps, however, show that most of it contained some lead and silver, and few samples containing these metals were taken outside its boundaries.

The greater part of the lode consists of a mass of more or less crushed rock, most of which appears to be altered carbonaceous argillite. The amount of crushing varies from place to place. Much of the lode material is soft and claylike. In general, the ore at any particular place occupied only a small part of the crushed zone. Most of it was found near the hanging wall. Small bodies of ore have been found in the soft crushed material, but it seems likely that these came into such positions as a result of later movements rather than original deposition. The steeper portions of the lode are reported to have yielded the larger ore bodies. Comparatively little ore has been found on the lower levels. All the known ore bodies have now been so nearly mined out that the company has ceased operations entirely. The little ore that remains is mostly in caved stopes and will probably be extracted by lessees. The comparatively unsatisfactory character of the lowest ore bodies found and the failure to pick up others in the Plummer tunnel or the crosscuts southward on the lower levels appear to have convinced the company's engineers that further development is not warranted. It has by no means been demonstrated, however, that other ore bodies do not exist. Such bodies may be present on the continuation downward of the pitch of the principal known ore shoot in ground considerably east of that explored by the Plummer tunnel and the crosscuts above it.

The metallic minerals of the ore include galena, pyrite, tetrahedrite, boulangerite, and stibnite, in a gangue consisting of crushed rock, quartz, and calcite. Much of the ore consists of layers of massive galena interstratified with layers of massive white quartz containing pyrite and in places tetrahedrite. The galena in places has the other metallic minerals listed above intermixed with it. Mr. Ring, the mine superintendent, states that masses of galena without gangue minerals were found in the hanging wall some distance from the lode. He considers that these masses are the results of redistribution of the lead by circulating waters after the lode had been crushed and faulted, but it would seem more probable that they were formed by replacement as one phase of the hypogene ore deposition. Stibnite, according to both Umpleby and Hewett, who visited the mine in 1913, occurred as radiating aggregates of needles on fracture surfaces. Much of the galena has been thoroughly crushed, and many of the ore lenses were highly contorted. Some of the larger masses of quartz are indicated on Plate 21, as mapped by Hershey. Much of the quartz contains almost no metallic minerals. There are lenses of calcite a few feet long in the black argillite. These lenses appear to be entirely free from metallic minerals and were noted at considerable distances from the lode. They probably result from concentration of the calcareous material in the shale by circulating water independent of the mineralization.

The grade of the ore mined may be judged from the following data kindly furnished by Mr. Ring. The average ore sent to the mill in 1921–22 contained 5 per cent of lead and 0.04 ounce of gold and 12 ounces of silver to the ton. The average shipping ore contained 50.5 per cent of lead and 0.15 ounce of gold and 132 ounces of silver to the ton. It will be noted that there is an average of more than 2 ounces of silver to each per cent of lead. This is a considerably higher ratio than is found in the vicinity of Hailey.

BALTIMORE MINE

The Baltimore mine, in the next gulch north of the Independence, yielded a considerable amount of high-grade ore during the early days of mining in the region. It has been shut down most of the time since then, and the old workings are largely inaccessible. In 1922 the Federal Mining & Smelting Co. had an option on the property; they drove a crosscut tunnel to the vein, drifted on it 274 feet, and put up some raises but found no ore. The mine was consequently again abandoned.

NORTH STAR MINE

The North Star mine is in North Star Gulch, a northern tributary of the East Fork of the Big Wood River somewhat over 5 miles above its mouth. It is in sec. 23, T. 4 N., R. 18 E., and adjoining sections. The mine was actively exploited during the decade next following 1883, and most of the ore available for treatment by usual methods found in the present workings was mined at that time. There remains in the mine, however, over 20,000 tons of refractory ore awaiting the development of a suitable method for its treatment. The total production of the mine up to 1915 is estimated at about $800,000. The Federal Mining & Smelting Co. acquired control of the property in 1916 and began development in April of that year. Some work was done at the mine in 1915. Ore was shipped by the Federal Mining & Smelting Co. in 1917 and 1918, but since then the mine has been idle. The available data of the production are shown in the following tables.

Early production of North Star mine

[From records of E. Daft and Ketchum smelter]

Year	Ore	Gold	Silver	Lead	Zinc
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1883	6.1	0.004	353.39	8,048	
1885	660.4	3.907	39,720.1	772,128	
1886	307.4	15,578.41	3,598.1		
1890	423.8	34.086	25,289.3	473,989	
1891	559.1	81.907	30,691.4	611,019	
1892	104.0	68.384	2,822.4	71,245	
1893	60.6	13.135	2,802.3	60,307	
1894	17.6	3.889	976.0	16,378	
1895	9.1	1.640	462.2	8,527	
1896	437.35	54.637	18,774.1	403,250	
1899	12.8	62.370	144.42	3,556	2,018
1901	45 2	6.132	1,861.6	42,475	4,665
1902	3.0		215.6	3,912	
1903	14.6		621.3	13,479	
	2,661.0	16,208.494	128,332.1	6,756,214	6,683

Production of North Star mine, 1905–1918

[From records of U. S. Geological Survey with revision by Federal Mining & Smelting Co.]

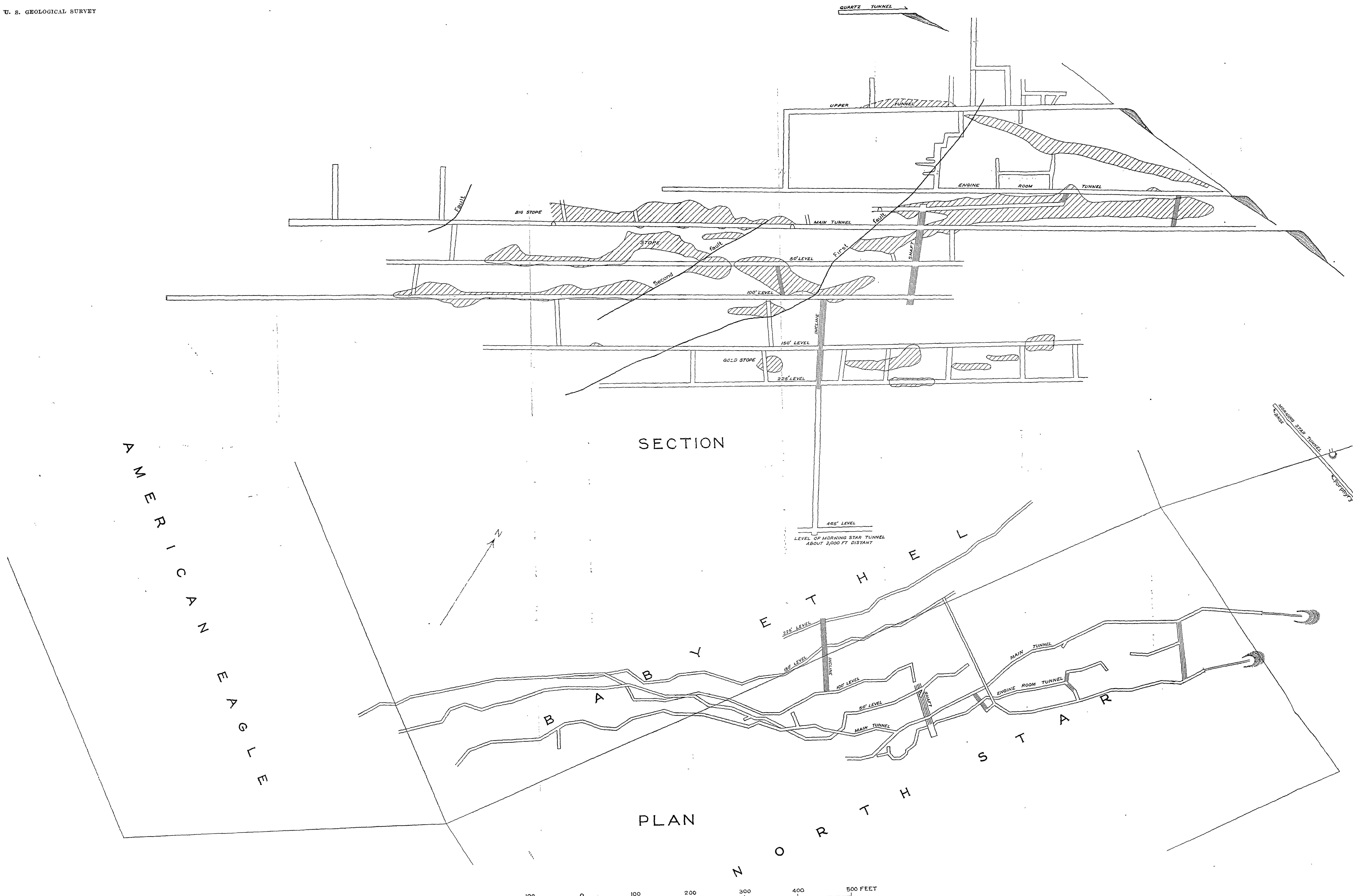
Year	Ore sold or treated	Crude ore shipped to smelter	Ore milled	Concentrates produced	Metals recovered				
					Gold	Silver	Lead	Copper	Zinc
	Tons	*Tons*	*Tons*	*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*	*Pounds*
1905	20					1,200	28,000		
1907	46	46			5.32	672	10,704	470	
1908	27	27			1.75	909	15,746		
1909	44	44				317	4,578		16,368
1910	43	43			.86	344			29,385
1916 [a]	650	29	621	69	7.24	1,316	22,821		27,440
1917	10,456	[b] 3,361	7,095	4,533	303	50,273	820,192		2,293,981
1918	9,400		9,400	2,363	133	31,952	550,909		1,010,498
	20,686	3,550	17,116	6,965	451.17	86,983	1,452,950	470	3,377,672

[a] Includes Triumph. [b] Old tailings.

The principal developments comprise two tunnels and two inside shafts, which follow the vein to a vertical depth of 225 feet below the lower tunnel. From one of the shafts drifts are turned at depths of about 50 and 100 feet, and from the other one, which starts from the 100-foot level, at depths of about 150 and 225 feet. Plate 24 shows most of the workings in plan and section, but as it is a composite drawing from several blueprints which do not exactly agree among themselves it is accurate only a general way. The tunnels enter on the strike of the lode, about N. 60° W., and the shafts follow its dip, which averages about 38° SW.

The country rock belongs to the Milligen formation. It is distinctly bedded in most exposures and is moderately hard. Much of it is a carbonaceous and calcareous argillite, but some of it is fine grained, more or less calcareous sandstone. Thin films of graphite are conspicuously developed along fracture planes in the argillite, and locally there are lenticular beds of almost pure graphite, perhaps as much as half an inch in thickness. They have been formed from the carbonaceous matter in the original shales. Near the portal of the Engine Room tunnel there is a narrow dike of intensely altered igneous rock, which has nearly the same strike as the vein but dips more steeply. It is too altered for definite identification but resembles the lamprophyre dikes that are widely distributed in this part of the Hailey quadrangle. The strike and dip of the strata are approximately parallel to those of the lode. In places, however, the lode appears to truncate the strata at small angles. The lode shows much less brecciation and shearing than that in the Independence mine. Crushed clayey material, such as is characteristic of the Independence deposit was observed in only a few places in the parts of the North Star visited in 1923. In many places between the stopes no indication of a lode is visible, but in others there are parallel layers of massive quartz, such as are found in parts of the Independence mine. As is shown on Plate 24, the lode is broken by two faults, which are found on most of the levels, and a third fault is exposed only in the main tunnel. The offsets on these faults are too small to present serious obstacles to mining.

Most of the ore has been obtained between the 100-foot level and the Engine Room tunnel, 160 feet above it. In this zone the ore occurs in lenses greatly elongated along horizontal axes, which in most of the ore bodies are from eight to fifteen times as long as the vertical axes. The smaller lenses stoped below this zone also lie nearly horizontal, but two large lenses in the upper workings, as shown on Plate 24, pitch to the east. One of the largest lenses in the one opened near the surface between the Engine Room and Main tunnels. This lens was stoped for a length of nearly 700 feet and an average height of perhaps 50 feet. The width, as shown by



PLAN AND SECTION OF THE PRINCIPAL WORKINGS OF THE NORTH STAR MINE stulls in the old stopes, ranged from 15 inches to 8 feet and averaged about 4 feet. This lens is said to have yielded $100,000 from ore that contained 22 per cent of lead and 22 ounces of silver and 0.3 ounce of gold to the ton. The lens mined in the Big stope above the west half of the Main tunnel was even larger, but its dimensions are not available. The richest lens in the mine was found on the 50-foot level, near its west end. This ore body, 4 feet in average width, yielded $127,000 from ore that contained 60 per cent of lead, 60 ounces of silver to the ton, and a negligible amount of gold. Above the Engine Room tunnel two large ore bodies were found, and below the 100-foot level seven small ones. One of these, known as the Gold stope, was a small isolated lens about 2 feet wide, which was reported to have averaged 6 per cent of lead and 6 ounces of silver and 15 ounces of gold to the ton. The ore in a few places contained over 40 per cent of zinc, and numerous assays are recorded of samples containing over 20 per cent of zinc. The refractory ore now remaining in the mine is said to average 8 per cent of lead, 17 per cent of zinc, and 10 ounces of silver and 0.03 ounce of gold to the ton. The average of 88 samples listed on a blue print furnished by the company is as follows: 4.9 feet width of lode, 0.232 ounce of gold and 6.08 ounces of silver to the ton, 4.4 per cent of lead, 13.3 per cent of zinc, 15.0 per cent of iron, 26.0 per cent of insoluble matter, and 18.7 per cent of sulphur. It will thus be seen that the character of the ore differs markedly in different parts of the mine. Some of the stopes are characterized by a comparatively large amount of gold, others by lead, others by zinc, and still others by zinc and arsenical iron.

The minerals of the deposit include galena, sphalerite, pyrite, arsenopyrite, quartz, and calcite and other carbonates. Aggregates of acicular crystals containing antimony are present in some of the ore. These crystals are probably largely boulangerite, but stibnite may also be present. The silver appears to be associated with galena, and the gold with pyrite. Some of the ore near the surface in the stope above the upper tunnel is reported to have been oxidized. The paragenesis of the minerals suggests several pulses of ore deposition, during each of which earlier lenses were reworked to a greater or less extent and new lenses were formed. Pyrite, sphalerite, siderite, and calcite formed early and were followed by galena, which replaced the carbonates and filled interstices in brecciated sphalerite. Later arsenopyrite, very abundant in some of the stopes and negligible in others, was deposited along with quartz. In many specimens a sphalerite-gelena-calcite mass has been brecciated and cemented with quartz and arsenopyrite in about equal amounts. An antimony mineral believed to be stibnite, which was the latest hypogene metallic mineral to form fills vugs and lines fracture surfaces in the quartz. Dolomite was apparently deposited at about the same time as the stibnite.

TRIUMPH MINE

The Triumph mine is south of the Independence mine, in secs. 14 and 23, T. 4 N., R. 18 E., about 7 miles northeast of Gimlet, the nearest railroad station. The deposit has been known for a long time. Much of the development work was done in the nineties and earlier, but a little work has been done at intervals since that time. Peter Snider,[37] who had charge of the mine in the early nineties, stated in 1912 that smelter returns showed that the Triumph had produced $40,000 worth of ore. The following table gives the data on the production contained in E. Daft's records. According to Mr. Snider's estimate, this table fails to show the total production.

Production of Triumph mine

[From records of E. Daft]

Year	Ore	Gold	Silver	Lead	Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1884	9.7		1,026.4	11,926	1893	8.7		997.2	11,313
1886	3.3		215.2	2,778	1894	5.5	1.668	411.4	5,171
1888	21.2		1,118.4	22,779					
1891	52.7	0.0317	4,020.7	80,679		171.1	5.477	11,381.7	193,980
1892	6.4	3.462	382.2	5,797					

The mine was inaccessible at the time of Umpleby's visit in 1913, and only part of the upper workings could be entered in 1923. The developments comprise a vertical shaft 275 feet deep with two levels from it, and three tunnels with crosscuts and drifts. The principal workings are indicated in Figure 13.

This mine was reopened in 1927 by the Triumph Development Co. A brief visit was paid to it by Ross in September, 1928. At that time it had been producing steadily for some time and development work was reported to be encouraging. The old workings had been unwatered and a winze sunk 75 feet below the lowest level. The management reports that the complex ore which presented so much difficulty to the early operators can be readily treated by modern methods of ore flotation.

The lode is probably either a continuation of that in the North Star mine, or parallels it a short distance away. It strikes N. 50°-60° W. and dips roughly 50° SW. As is shown by the plan of the workings (fig. 13), ore has been found at intervals over a width

[37] Unpublished letter to H. J. Allen concerning the Triumph mine, Oct. 20, 1912.

of roughly 100 feet across the lode with barren and little altered rock between. In the letter above cited, Mr. Snider refers to the "hanging wall," "footwall," and "iron" veins. It seems evident from the exposures in the main tunnel that these are all parts of the same lode. The rock between the ore masses, although of no commercial value, is fractured and more or less mineralized. Ore is exposed at several places in the accessible parts of the workings, and considerable bodies of it are reported to be present in the mine. Much of it is a complex mixture of sulphides similar to the ore of

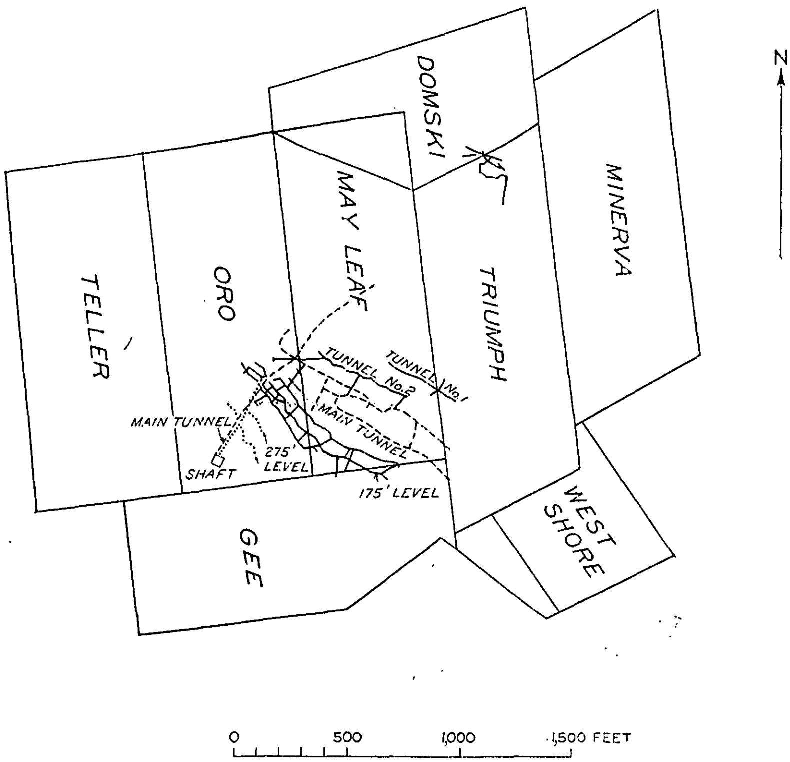


FIGURE 13.—Map of the Triumph mine

the North Star but is perhaps somewhat coarser grained. It may also have a lower average content of zinc. The ore thus presents essentially the same metallurgic problems that have prevented further development of the North Star ore bodies, although it is apparently a little easier to treat.

DUQUETTE PROSPECT

J. W. Duquette, of Idaho City, has a prospect on the west side of the mouth of Milligen Creek in sec. 24, T. 4 N., R. 18 E., and sec. 30, T. 4 N., R. 19 E. There are three short tunnels on the property, but the recent work has been confined to shallow cuts.

The country rock is black impure quartzite of the Milligen formation. The surface cuts expose veinlets of massive white quartz, with galena and its oxidation products in the quartz and near-by sedimentary rock. There are small amounts of oxidized copper minerals and probably some tetrahedrite. The evidence of mineralization is extensive enough to warrant further prospecting.

HOMESTAKE PROSPECT

The Homestake prospect adjoins the claims of the Independence mine on the east. It is on one of the branches of Milligen Creek in sec. 13, T. 4 N., R. 18 E., and adjoining sections. The property comprises 12 unpatented claims owned by John A. Nelson and Gus Johnson and worked since 1920 under bond and lease by W. F. MacGregor and F. Patton. All the underground development work is reported to have been done by these lessees. It consists of two tunnels, which with their branches have a total length of about 2,000 feet. This prospect should not be confused with the mine of the same name on Lake Creek.

The deposit being prospected is in a zone that contains numerous calcite seams in black Milligen argillite, which strikes in general eastward and dips 25° S. but shows considerable local variation as a result of fracturing and twisting. Layers containing pyrite and a little tetrahedrite occur in the argillite. In the bottom of a short winze in the lower tunnel a little galena and sphalerite in a gangue of quartz and calcite were found just before the time of visit in August, 1923. In several places in the lower tunnel there are lenses and small masses of an altered porphyritic igneous rock.

BROADWAY MINE

The Broadway mine is on the east side of the valley of Hyndman Creek about 3½ miles from its mouth. The property was worked by the Hiawatha Mining Co. about 1911 and 1912 but has been idle most of the time since then. It is now held by Fred Vancil. When examined in 1923 the workings consisted of a tunnel, which with its branches has a length of 330 feet, an inclined shaft 55 feet deep on the incline, and some minor cuts.

The country rock is carbonaceous argillite of the Milligen formation, which at the tunnel mouth strikes east and dips 15° S. Some of this argillite, especially near the stream below the mine, contains flakes of graphite. In the tunnel there are a number of gash veins of quartz from a few inches to more than a foot wide. The quartz contains in places pyrite, galena, and chalcopyrite. Some of the quartz has drusy cavities lined with small quartz crystals. Irregular pyritohedrons of pyrite nearly half an inch in greatest diameter were noted in shale included in the veins. Stibnite in sheaves of well-developed crystals is reported to have been found on the ridge above the Broadway mine. This mineral was not noted during the examination, but a number of quartz veins that were seen contain vugs lined with drusy masses of quartz crystals cementing together small fragments of the country rock.

PARKER MINE

The Parker mine is about 4 miles east of Ketchum in Elkhorn Gulch, in sec. 14, T. 4 N., R. 18 E. The deposit is reported to have been discovered August 3, 1883, by Eugene Gillenwater, who found fragments of ore near a badger hole and eight days later made his first shipment, a carload which netted $1,003. The table below, compiled from records in the office of E. Daft, in Hailey, shows that 1,552 tons of ore carrying 1,106,463 pounds of lead and 300,236 ounces of silver was mined up to the end of 1898. More than half of this was treated at the smelter at Ketchum, and the remainder was shipped to smelters in Utah. There has been no production in recent years. The mine is reported to have yielded up to May 10, 1886, a total of $283,811.50 over and above freight and treatment charges, which averaged about $2 a ton. In depth the ore abutted against a fault gouge, and persistent efforts to find the vein beyond the fault have failed. The last of these attempts was made in 1911 and 1912, when a large amount of tunnel and crosscut work was done on lower levels.

Production of Parker mine

[According to records of E. Daft and Ketchum smelter]

Year	Ore	Gold	Silver	Lead	Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1883	5.4		1,751.4	4,212	1889	13.6		3,271.9	11,339
1884	512.9		113,633.4	519.4	1890	.5		95.3	431
1885	955.2		172,604.8	304,123.7	1895	3.1		443.2	1,675
1886	40.7		5,551.6	26,950	1898	6.4	0.550	634.5	3,238
1887	2.7		556.3	3,297					
1888	11.6		1,693.4	9,255		1,552.1	.550	300,235.8	365,040

The vein conforms nearly to the bedding of the inclosing Milligen argillite, which dips about 30° SW. The rock is dominantly black calcareous argillite inclosing thin layers of bituminous limestone and has been intricately shattered. Along the fracture planes are films of graphite so pure that the hands are immediately soiled in touching unweathered material. In the mine all the tunnels contain "bad air," and in the absence of artificial ventilation a candle will not burn beyond a few score feet from the portals. Igneous rocks occur only as dikes, although a short distance to the west there is a large area in which contact-metamorphic minerals are abundantly developed. A specimen of dike rock collected from the roadside in the vicinity of the lower tunnel is vogesite, one of the lamprophyres, and another specimen found as float on the hillside near the blacksmith shop is a fine-grained graphite porphyry.

The vein material consists of galena, zinc blende, iron pyrite, tetrahedrite, and polybasite in a quartz-calcite-siderite gangue. Jenney[38] reports also a peculiar body of "graphitic anthracite" in the lower part of the mine. His description of this interesting feature follows:

In prospecting on the course of the ore channel below the point where the ore ceased, a deposit of graphitic anthracite was encountered, filling a fissure, lying almost flat. This body of coal varied in thickness from 2 to 6 feet, and as the explorations progressed an area more than 200 feet square with an average thickness of 3 feet, was developed. The coal was solid and massive, requiring blasting to remove it; in appearance it resembled anthracite which had been subjected to crushing and compression until all traces of structure were destroyed. The coal was full of slips and slickensided surfaces and the walls of the fissures were also polished in places. Small irregular veins of quartz intersected the coal in places and wound through the mass, but for the most part it is uniform in quality and appearance and free from any contaminating material. The following analysis of an average sample of this coal was made at the laboratory of the St. Louis Sampling & Testing Works:

Analysis of sample of coal from Parker mine

	Per cent
Moisture	1.72
Volatile matter	7.86
Fixed carbon	81.61
Ash	8.81
	100.00
Sulphur	0.79
Carbon	82.18
Hydrogen	4.10
Oxygen and nitrogen	3.09
Ash and loss	9.84
	100.00

Jenney concluded that this deposit of carbon was formed by distillation at the time of the intrusion of near-by dikes. The dikes, however, are probably younger than the contact-metamorphic deposits, which occur a short distance to the west, and Umpleby considers that it would be perhaps more reasonable to think of this concentration of carbon from the Milligen slates, which he believes to be certainly an adequate source, as a special phase of the contact metamorphism elsewhere expressed in an extensive development of garnet and associated minerals.

[38] Jenney, W. P., Graphitic anthracite in the Parker mine, Wood River, Idaho: School of Mines Quart., vol. 10, pp. 313–315, 1889.

Ross, however, considers that there are objections to any theory involving distillation. If a rock contained the requisite amount of volatile organic material it would be possible for this organic material to be distilled off under the influence of heat emanating during cooling from a body of igneous rock intruded near by. Under most conditions such distilled matter would tend to diffuse through the surrounding rocks. Only under special conditions would any considerable quantity of it be collected and condensed in any given place. It taxes the imagination to devise conditions under which a large mass of hydrocarbons could have been condensed in a single fissure in the rock which now contains the Parker mine.

Solid hydrocarbon material is frequently found concentrated in fissures in many regions. If the analysis of the material from the Parker mine was made from a clean sample without admixture of wall rock it is difficult to account for the presence of 8.8 per cent ash on the theory that the mass was produced by the metamorphism of such a body of solid hydrocarbons. It seems that the known facts could be most simply explained on the assumption that the mass termed by Jenney " graphitic anthracite " is merely a coal bed which has been metamorphosed. The composition indicated by the analysis quoted is in accord with this theory. Jenney's description indicates that the "graphitic anthracite" was in a fissure at an angle to the stratification of the inclosing rock. If so it can not be a coal bed, but the rocks in the general vicinity of the Parker mine have been so greatly folded and fractured that apparent discordances in the attitude of beds in different parts of the mine are to be expected. The part of the Parker mine containing the "graphitic anthracite" has long been inaccessible. Specimens collected by Ross from the dump are, however, essentially similar to material from the Evelyn prospect on Trail Creek. There is little doubt that the material in the Evelyn prospect is coal. (See p. 192.)

The ore shoot that afforded the mine's production is said by Jenney,[39] who was manager when the property was in operation, to have been about 75 feet long and to wedge out to a seam of calcite on the ends. It was followed down on the 30° dip of the vein for 500 feet and terminated against a steeply dipping strike fault. The fault gouge contained no drag ore, but the ore against it was smooth and striated, suggesting a slight postmineral movement along a premineral fault plane. No ore has been found beyond the fault. The ore averaged between 7 and 8 feet in width and was roughly banded. Next to the hanging wall was 8 inches of quartz and galena; then a band of massive galena from 3 to 4 feet thick, which carried about 200 ounces of silver to the ton; next was 2 feet 8 inches

[39] Oral communication to J. B. Umpleby.

of galena, gray copper, and polybasite, which carried from 1,000 to 3,000 ounces of silver to the ton; and between this band and the footwall was an 8-inch band of white quartz and gray copper containing from 100 to 500 ounces of silver to the ton. Sphalerite occurred only in the border portions of the vein. The common gangue in all the bands was quartz and calcite. At a distance of 3 to 15 feet from the main vein in the footwall a parallel vein of galena, narrow but exceptionally free from gangue minerals, was also worked.

QUAKER CITY MINE

Directly across the valley of Elkhorn Creek from the Parker mine is the Quaker City. It produced very rich tetrahedrite ore, some of it containing as much as 2,000 ounces of silver to the ton. The total production is said to have been about $50,000. Available data on production are given in the table below:

Production of Quaker City mine

[From records of E. Daft and Ketchum smelter]

Year	Ore	Silver	Lead	Year	Ore	Silver	Lead
	Tons	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Pounds*
1884	29.0	4,458.93	25,677	1889	5.3	1,522.8	3,122
1885	84.1	12,745.4	61,524	1890	4.0	678.4	4,432
1886	39.8	20,544.5	7,413	1[illegible]5	3.8	309.5	1,721
1887	2.5	459.2	1,665				
1888	2.4	520.88	2,884		170.9	41,239.5	108,438

The ore occurred in poorly defined lenses in a westward-dipping zone of crushed carbonaceous slate. The zone is developed by six principal tunnels, but most of the ore was found in the third level above the creek. Southward across the creek the zone continues in the Amicus deposit, but here a large amount of work has yielded very little ore.

BALD EAGLE PROSPECT

The Bald Eagle, a prospect opened a few years before 1913 but not active in 1923, is on the north side of Elkhorn Gulch, near the eastern margin of the area in which contact-metamorphic minerals are developed. It lies west of the Parker and north of the Starlight mine. The developments consist of about 600 feet of workings in two tunnels 130 feet apart vertically. In the lower tunnel copper ore was cut for 75 feet, and in a north crosscut from it copper occurs sparsely in the rocks for 75 feet farther. A section of the best ore 25 feet across along the course of the main tunnel averages 2 per cent of copper and 0.002 ounce of gold and 1.2 ounces of silver to the ton. The ore zone is inadequately developed but seems to strike northwest and to stand nearly vertical. On the margins it grades out into rock that contains much less copper. The copper mineral is chalcopyrite and occurs in veinlets of coarse-textured quartz and as blebs, patches, and disseminations in the metamorphosed country rock. In and close to the veinlets galena and sphalerite locally accompany the chalcopyrite and quartz, and with them siderite is sparsely developed. Pyrite and pyrrhotite accompany the chalcopyrite.

Near the face of the lower tunnel there is a dike of granite porphyry very rich in hornblende. The dike rock is locally traversed by minute veinlets of the ore minerals, showing that it is at least older than the final phases of the mineralization. As is shown in the general discussion, however, it is believed to be very little older and is probably an offshoot from the deeper-lying rock mass that caused the metamorphism and the accompanying deposition of the ore minerals.

This deposit seems to represent an intermediate phase of mineralization between that of the Parker, Quaker City, and Elkhorn on the east and the Starlight on the west. In the eastern mines there are few indications of contact metamorphism, but in the Starlight secondary lime silicates are abundantly developed. In rocks from the Bald Eagle such minerals are abundantly developed, but large individual crystals are lacking, and only when studied microscopically can they be identified. The most abundant mineral is a pyroxene, probably diopside, although augite, andalusite, epidote, garnet, and vesuvianite are present.

STARLIGHT MINE.

The Starlight mine is about 3 miles east of Ketchum near the level of Elkhorn Creek. It was in operation when visited in 1913 by Umpleby, but in 1923 had been closed down for a number of years and was consequently not visited by Ross. The principal tunnel was originally started in search of a downward continuation of the Elkhorn vein, which was thought to be faulted at a point almost directly above the inner Starlight workings. After considerable work had been done without finding the Elkhorn vein, it was discovered that the rock being penetrated contained gold, and the subsequent work was done for the purpose of mining this metal. When examined in 1913 the mine was developed by about 4,000 feet of tunnels and two 100-foot shafts. Most of the work had been done on what is known as level 3. From this level there is a long inclined raise with drifts from it at several places, and below level 3, near the portal, are two levels turned from a 100-foot vertical shaft.

The rock in the vicinity of the mine shows considerable contact metamorphism, but the only igneous rocks are narrow dikes of some lamprophyre, probably vogesite, and of granite porphyry. No igneous rock has been observed in the mine. The rock exposed in the workings is siliceous slate with intercalated beds of limestone and quartzite, standing nearly vertical and striking about N. 25° W. The limestone beds range in thickness from 2 to perhaps 30 feet and have been far more intensely metamorphosed than either of the other types of rock. The ore is in beds that have now been converted into a lime-silicate rock composed principally of aphanitic garnet, augite, diopside, and vesuvianite, with accessory amounts of apatite, wollastonite, and tremolite and with sphalerite, chalcopyrite, and pyrite disseminated through it. There is evidence of extensive faulting prior to the metamorphism, but only two minor displacements, both in the northern part of the mine, are believed to be postmineral. In many places beds of lime-silicate rock, where followed along their strike, abut against comparatively unmetamorphosed quartzite or slate. In the main tunnel a bed of lime-silicate rock has been followed southward to a point where it is cut off by a fault zone composed of three parallel planes which dip 60° N. and are vertically striated. South of the fault this bed has not been recognized, a fact which seems to indicate, as the beds stand vertical and the grooves on the fault planes are vertical, that there has been postmineral movement along a premineral fault. This bed constitutes a low-grade gold ore for 100 feet or so near the portal of the main tunnel, but farther south it becomes better in grade and in places has been stoped for 90 feet along the level. Shipments of 175 tons of ore, averaging 1.6 ounces of gold to the ton, had been made from these stopes before Umpleby's visit. In the course of mining this ore about 3,000 tons of ore, averaging $12 in gold to the ton, was also stoped. Other shoots are recognized in the mine, but none are equal in value to this one. About 1913 a small mill was erected for the concentration of the lower-grade ore, but it does not appear to have been operated more than a few years.

ELKHORN MINE

The Elkhorn mine, which is credited with a production of about $1,500,000, is 3 miles east of Ketchum on the divide between the two principal forks of Elkhorn Canyon, in sec. 23, T. 4 N., R. 18 E. The mine was in a deposit that was discovered about 1879 and was an active producer until the later part of 1885, when the ore body, which had been followed continuously from the surface, gave out at a vertical depth of about 300 feet. W. P. Jenney, in a report on the mine made in 1901, estimates that net returns from ore sales aggregated $1,275,000, to which at least 20 per cent should be added for freight and deduction for treatment in order to ascertain the gross output. The entire production came from beds within 300 feet of the surface. The production as recorded by E. Daft is given in the following table, but the data are evidently incomplete.

Production of Elkhorn mine

[From records of E. Daft]

Year	Ore	Gold	Silver	Lead	Year	Ore	Gold	Silver	Lead
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*		*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1884	223.7		22,765.9	213,731	1894	2.9	0.293	308.0	3,227
1885	926.2		57,460.6	517,408	1895	5.3	.536	639.6	6,642
1886	185.0		13,933.6	136,532	1900	8.6	2.371	1,221.8	9,261
1887	5.0		342.5	3,470					
1888	2.9		245.2	2,697		1,365.9	3.200	97,404.7	898,357
1890	6.3		487.5	5,389					

The vein is inclosed in carbonaceous slate that strikes northwest and dips steeply southwestward. It cuts obliquely across this structure, dipping 20° S. in the upper 100 feet and about 70° for the next 150 feet and thence continues nearly flat. The ore occurred in a shoot as much as 200 feet long and 12 feet wide, but in the lower, nearly horizontal part of the vein the ore is said to have been in lenses irregularly scattered along the fissure and more widely spaced with increased distance from the steeply dipping part. The ore was of excellent grade, averaging 30 to 45 per cent of lead and 80 to 150 ounces of silver and about 0.2 ounce of gold to the ton.

The vein is developed by a series of tunnels that enter along the course of the vein both from the east and the west sides of the ridge. It dips rather steeply in the upper part and then flattens abruptly. Beyond the flat part the vein may dip down again. There has been a large amount of exploration below the 300-foot or lowest productive level, but it has failed to reveal ore or a fissure definitely known to be the downward continuation of the productive one. Jenney [40] believed that the flat portion of the vein was filled from the steeper part and that the fissure or fissures along which the solutions rose are to be found below the steeper part. In 1913, when Umpleby visited the mine, it was almost wholly inaccessible, and it has not been reopened since, so that few data bearing directly on this problem were obtainable. It is believed, however, that the idea constitutes perhaps the most reasonable working hypothesis, both because of the large amount of work which has been done beneath the lower end of the nearly horizontal portion and because of the relations described below.

Some of this work is represented by a tunnel a short distance above the Starlight shaft. Here there is abundant evidence that the flat part of the vein occupies a fault along which movement has followed a N. 70° E. course. It was impossible to prove whether

[40] Oral communication to J. B. Umpleby.

the fault is premineral or postmineral, although the general distribution of unfractured pyrite sparsely through the firm gouge suggests strongly that it is older than the ore and has not displaced it. Rocks below this tunnel are explored from the opposite side of the ridge but without revealing evidence of mineralization. A feature that should be kept in mind in further exploration on the property is that the same general type of rocks which inclose the vein in the upper levels may be expected to continue for several hundred feet below the present mine workings.

EVELYN PROSPECT

The Evelyn prospect, owned by J. Hampton and Oscar Griffith, is in the NE. ¼ sec. 6, T. 4 N., R. 18 E. It is developed by three short tunnels, two of which are still partly open. The country rock is carbonaceous argillite of the Milligen formation. In the tunnels are two or more beds of metamorphosed coal. The largest is fully 10 feet wide. They stand nearly vertical, parallel to the bedding in the inclosing argillite. In one of the tunnels the rock next the ore is made up of alternating beds of black and light-colored material a few inches thick. Both coal and argillite are cut by small irregular veinlets of calcite. Galena and pyrite are reported to have been found. The coal is so much crushed and, where exposed to the air, is so softened that much of it can be dug out with the fingers. Below is an anlysis of a grab sample from the largest coal bed. The sample probably contained more than the average amount of hard material, high in ash, and is thus not accurately representative of the grade of the coal. Further work might result in finding bodies of coal distinctly lower in ash than the sample analyzed.

Analysis of grab sample from Evelyn claim, Trail Creek

[Analysis by U. S. Bureau of Mines]

	As received	Moisture-free	Moisture and ash free
Moisture	2.2		
Volatile matter	10.1	10.3	24.0
Fixed carbon	32.0	32.7	76.0
Ash	55.7	57.0	
	100.0	100.0	100.0
Sulphur	.5	.5	1.1
Calorific value:			
Calories	2,667	2,728	6,339
British thermal units	4,800	4,910	11,410

HOMESTAKE MINE

The Homestake mine is on Lake Creek in secs. 4 and 5, T. 5 N., R. 18 E., and unsurveyed land north of these sections. It is about 8 miles northeast of Ketchum by road. This property should not be confused with the prospect of the same name in sec. 13, T. 4 N., R. 18 E.

Ore has been shipped from this mine intermittently for many years and is estimated by the owners, J. J. Donovan and his brothers, to have a total value of $200,000. The Mineral Exploration Co. took over the property under option late in 1922 and began regular shipments in the summer of 1923. It ceased operations at the end of the year, and the mine was leased to a Mr. Johnson. The following tables show the available data on the shipments made up to the end of 1923. The data on early production appear to be incomplete, but those for recent years are probably accurate.

Early production of Homestake mine

[From records of E. Daft and the Ketchum smelter]

Year	Ore	Gold	Silver	Lead	Zinc
	Tons	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1885	68.2		3,162.7	62,623	
1886	44.9		2,112.8	50,404	
1887	.8		89.2	1,215	
1888	8.0		400.8	5,323	
1891	59.6		3,068.4	44,196	
1892	46.8		2,536.8	35,612	5,832
1893	53.1		1,966.5	31,074	
1895	80.1	1.271	2,802.8	54,341	
1897	12.6		631.1	11,537	
1898	8.3		373.0	7,294	
1900	.6		19.7	567	
1903	19.3	.58	813.2	17,349	5,150
	402.4	1.851	17,977.0	321,535	10,982

Recent production of Homestake mine

[According to Minerals Exploration Co.]

Year	Ore sold or treated	Crude ore shipped to smelter	Metals recovered			
			Gold	Silver	Lead	Copper
	Tons	*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1914	47	47		1,764	34,710	
1915	61	61		2,905	51,021	
1916	261	261		11,055	197,330	
1917	53	53		2,147	35,959	
1918	153	153		6,877	124,582	
1919	25	25		1,282	27,048	
1921	39	39		2,310	36,474	234
1922	14	14	0.21	805	7,382	183
1923	338	338		8,899	117,115	
	991	991	.21	38,044	631,621	417

The property comprises 14 claims. The development work includes over a dozen tunnels, with raises and stopes above some of them, and several cuts. The principal workings are shown in Figure 14. The total length of the tunnels is nearly 4,000 feet. The principal work in 1923 was in No. 5 tunnel, which in August, 1923, was nearly 1,600 feet long. There are 10 raises above this tunnel,

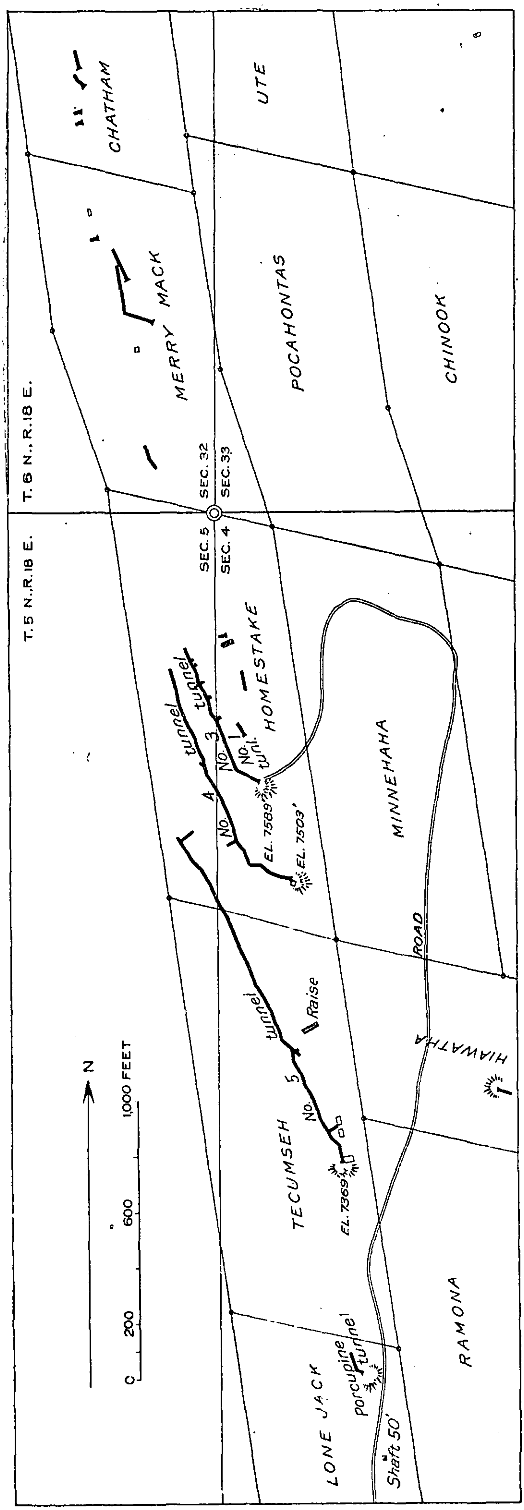


FIGURE 14.—Map showing principal workings of the Homestake mine

some of which connect with No. 4 tunnel. Most of the ore then being shipped came from one of these raises. The portal of No. 4 tunnel is 134 feet vertically above that of No. 5, and the portal of No. 3 is 86 feet higher. No. 4 is over 900 feet long, and No. 3 is nearly 600 feet long. The other tunnels are considerably shorter than those mentioned. In 1928 another tunnel was being driven on the vein below No. 5, but as yet had encountered almost no ore.

The country rock of the deposits is the nearly black siliceous and carbonaceous strata of the Wood River formation. The beds strike northeast and dip 20° and more to the southeast. On the slope below the workings are exposures of crumpled black shale which may belong to the Milligen formation. The lode has an average strike of about N. 25° W. and dips 45°–75° SW. It can be traced on the surface for about a mile and has walls several feet apart. The material between the walls is largely sheared country rock that has been mineralized for widths of a few inches to a few feet. Mineralization is most intense where the vein walls are farthest apart. Much of the ore which is being stoped is 1 to 3 feet wide, but in places the width is 6 feet.

G. M. Fowler, of the geologic department of the International Smelting Co., showed as a result of mapping the workings geologically that the rock where mineralization is most marked is softer and apparently more calcareous than that in the more barren parts of the vein. The ore consists of sheared country rock containing lenses of quartz, with more or less oxidized sulphides in both rock and quartz. The sulphides noted in the ore were galena, sphalerite, and pyrite. Some of the siliceous rock of the type not readily replaced by the ore contains sphalerite. Offshoots extend into both footwall and hanging wall of the lode. One of the best exposed of these offshoots is in one of the stopes above No. 5 tunnel. This offshoot has replaced a limestone bed and does not follow any zone of shearing. The tunnel on the Hiawatha claim appears to be on a branch of the main lode. It was cleaned out by sublessees in 1923, and some ore was obtained. There is more oxidation in this deposit than in most of the others visited. Much of that found in the earlier development contained little unaltered sulphide, and even some of that now mined, which comes from more than 200 feet below the surface, is somewhat oxidized. The following table, which was prepared from data furnished by W. H. Webber, of the Mineral Exploration Co., and by Mr. Johnson, who was in charge of the mine in 1923, will serve to indicate the character of the ore.

Shipments from Homestake mine

Date	Dry weight	Lead	Gold	Silver	Zinc	Iron	Sulphur	Insoluble
	Tons	*Per cent*	*Fine ounce per ton*	*Fine ounce per ton*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Aug. 27, 1915	22.3	26.8	0.30	32.00	28.2	1.5	1.0	4.20
Do	49.1	41.2	.30	47.20	10.4	3.9	1.4	21.5
Dec. 13, 1919	25.2	52.5		50.90	10.7	1.8	4.2	10.8
Nov. 15, 1921	26.8	49.3	.30	61.40	10.1	3.8	5.0	10.6
Jan. 4, 1923	9.4	24.0	.25	23.20	23.1	2.7	2.1	15.85
Do	14.2	26.2	.675	57.15	15.35	4.0	2.2	25.65
Mar. 19, 1924	38.4	20.2		26.30	22.8	2.0	1.2	27.0
June 3, 1924	49.1	22.6		26.95	21.6	2.53	1.25	26.27
July 2, 1924	43.5	27.75		29.5	19.4	2.15	1.65	25.6

ZINC PROSPECTS ON LAKE CREEK

About 8 miles northeast of Ketchum, on Lake Creek in secs. 8 and 9, T. 5 N., R. 18 E., there are two groups of claims with exposures of oxidized zinc ore. That on the north side of the stream is termed the

Lake Creek group and is owned by Robert Koeninger. That on the south side is called the Price group and is owned by Alonzo Price and his associates. Both groups were worked under lease by the Kusa Spelter Co. in 1917 and 1918. Over 1,000 tons of oxidized ore containing about 35 per cent of zinc was shipped at that time. In 1920 an additional 39 tons was mined, but it was not shipped until 1922. This shipment yielded 18,121 pounds of zinc. Much the greater part of the production came from the north side of the creek. There are shallow cuts and short tunnels on both sides. Development work was in progress on the Price group when it was visited in August, 1923.

The deposits are in the Wood River formation in and near the basal conglomerate. They have resulted from mineralization along irregular zones of brecciation, joints, and discontinuous fractures. No definite vein has been exposed, but the zone of mineralized fractures trends about N. 50° W. The deposits contain quartz, calcite, smithsonite, and calamine. Smithsonite is the most abundant zinc mineral. No sulphides are reported to have been found, but none of the workings have yet attained much depth. No lead minerals were observed, but according to a report on the Price property by A. E. Ring, of the Federal Mining & Smelting Co., some of the ore contains as much as 1 per cent of lead. His samples of picked ore contained over 40 per cent of zinc and a trace of silver.

MINES ON WEST FORK OF WARM SPRINGS CREEK

Three groups of claims on the West Fork of Warm Springs Creek about 5 miles west of Ketchum produced a considerable amount of ore between 1880 and 1885. The principal mines were known as the West Fork, the Moonlight about a mile north of it, and the Allen about a mile southeast of it. All are situated between altitudes of 7,000 and 8,000 feet. The West Fork produced about $50,000; each of the others somewhat less. In the West Fork group there was one eastward-trending vein cut by five westward-dipping, flat-lying faults, which caused offsets of as much as 100 feet. Most of the ore was mined within 100 feet of the surface. In addition to this vein there were two north-south veins. One of these cropped out at the surface for a distance of about 50 feet, and pillars now remaining in the stope show that the vein was made up of about 8 inches of clean galena ore bordered on the hanging-wall side by crushed limestone only slightly mineralized. The contents of recent shipments and three of the older ones are shown in the following table:

Production of West Fork mine

[From records of E. Daft and U. S. Geological Survey]

Year	Ore sold or treated	Crude ore shipped to smelter	Metals recovered			
			Gold	Silver	Copper	Lead
	Tons	*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1884	8.85	8.85		778.67		11,976
1885	18.26	18.26		1,501.61		19,439
1886	16.04	16.04		1,320.02		16,845
1915	21	21	0.48	1,828.00	14	25,981
1916	1	1		112.00		900
	65	65	.48	5,540.20	14	75,155

The Allen vein was similar in characteristics but somewhat less faulted. It was worked to a depth of about 150 feet.

The Moonlight workings were partly accessible at the time of Umpleby's visit in 1912, but no ore was seen in place. The mine is developed by several tunnels, which follow the strike of the vein, about N. 50° W. In the main tunnel small stopes and raises indicate that the ore occurs in lenticular masses that stand nearly vertical. Ore seen about the blacksmith shop is of the usual galena-siderite type.

NEW HOPE MINE

The New Hope mine lies at an altitude of 6,500 feet south of Warm Springs Creek, at a point about 1¼ miles from the west edge of the Hailey quadrangle. The deposit was discovered in 1905 and has yielded over $4,000. The following table gives data on the shipments of which the United States Geological Survey has record. Considerable additional ore was sold locally and shipped with other ore.

Production of New Hope mine, 1907–1913

Year	Ore sold or treated	Crude ore shipped to smelter	Metals recovered		
			Gold	Silver	Lead
	Tons	*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*
1907	30	30	3	1,800	36,000
1908	15	15	.30	844	13,500
1912	16	16	2.62	788	14,094
1913	20	20	.30	180	4,115
	81	81	6.22	3,612	67,709

The mine is developed by about 350 feet of tunnels and drifts. The vein, which averages about 8 inches in width, strikes N. 10° W. and dips 85° SW. The ore consists almost entirely of steel galena, which replaces and cements brecciated limestone. In 1923 none of the mines in this vicinity had been worked for about 10 years, and they were not visited.

MASCOT MINE

The property of the Consolidated Mascot Mines Corporation is on the East Fork of the Big Wood River, about 15 miles northeast of the railroad at Gimlet and 21 miles from Hailey. The company's camp is called Peter. The property comprises 6 patented and 55 unpatented claims, on 35 of which patent has been applied for. It is a consolidation of several prospects and mines. The principal workings are known as the Lydia, Silver Fortune, Paymaster, Iron Clad, Snow Clad, and P K, and the group as a whole is called the Mascot. Most of the claims are shown on Plate 9, but the topography, especially on and near the Paymaster claim, is not accurately shown on that map.

The Silver Fortune was originally located by a man named Tohill. It was worked intermittently from 1879 to 1908. The following data on the shipments made during these periods were compiled by T. A. Perkins [41] from the records of the Hailey Sampling Works and the Philadelphia & Idaho Smelter at Ketchum. The shipments listed as crude ore were probably largely cobbed material with the rock high in zinc discarded.

Shipments from Silver Fortune mine

Date	Character	Gross weight	Gold	Silver	Lead	Zinc	Iron	Silica
		Pounds	*Fine ounces per ton*	*Fine ounces per ton*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Aug. 20, 1886	Crude ore	2,946		23.60	60.00			
July 26, 1887	do	4,397		65.00	43.7			
Aug. 26, 1891	do	10,709		23.00	58.30			
Jan. 26, 1908	do	17,595	0.01	20.00	38.80	22.4	5.1	10.0
Sept. 2, 1908	Jig concentrate	6,120	.02	17.80	42.00	24.0	6.0	7.5
		41,767						

The Snow Clad is reported to have shipped a little high-grade ore, some of which contained as much as 82 per cent of lead and considerable silver. A little ore is reported to have been shipped from the Oregonian claim.

The Paymaster deposit was discovered in the late seventies, and high-grade oxidized ore was shipped in the eighties from shallow workings on the summit of the ridge west of Peter. It was sent down to the road along the East Fork on an aerial tramway. Some reports credit the mine with a production of $200,000 and with shipment of carload lots of ore containing 400 ounces of silver to the ton. The only available records of shipments are given below. The shipment of December 3, 1886, is credited to the Iron Clad but presumably came from the Paymaster.

[41] These and other early records given below are taken from a letter by T. A. Perkins to Dean F. A. Thomson, of the Idaho School of Mines, dated Dec. 27, 1922, with slight modifications based on Daft's records. The records are probably incomplete.

Shipments from Paymaster mine

Date	Weight	Lead	Silver
	Pounds	*Per cent*	*Fine ounces per ton*
July 17, 1884	[a]2,012	54.00	67.40
July 29, 1884	[b]1,928	55.75	67.93
Sept. 13, 1886	[b]2,254	34.20	29.00
Sept. 14, 1886	[b]1,416	60.00	55.50
Dec. 3, 1886	[a]1,476	54.60	58.40
	9,086		

[a] Gross weight. [b] Dry weight.

Considerable magnetite ore from the Iron Clad was shipped to the Pittsburgh & Idaho Smelter at Ketchum in the eighties for use as flux. This ore was sent down the tramway used for the Paymaster ore. Similar iron ore was mined on the Mars claim of the P K group, but no records of shipments are vailable. The iron ore from both the Iron Clad and the P K is reported to contain gold. That in the P K cut is said to average $6 to the ton, and one sample from the Iron Clad assayed $16 to the ton. A quartz ledge near the Iron Clad workings is reported to contain streaks of free gold. Prospecting for lead-silver ore was also done on this group in the early days.

Mr. Charles Peter, president of the Consolidated Mascot Mines Corporation, started work in October, 1914, and mining under his direction has continued with interruptions since that date. His first work was on the Silver Fortune. In 1917, according to the records of the United States Geological Survey, 23 tons of crude ore, which yielded 286 ounces of silver and 11,115 pounds of lead, was shipped from that mine. The net value of the two carloads was about $1,000. The Lydia tunnel, whose portal is near the west end of the Lydia claim, was started in 1918. The West Side tunnel in Mascot No. 1 and No. 7 claims was started in 1920. Work in both tunnels has been continued intermittently since then. The Iron Clad group was bought in the fall of 1921 and the Paymaster in 1922. A power plant was built in November, 1922. One carload of lead-silver ore from a raise above the Lydia tunnel was shipped in 1923, but the mine shut down in 1924. Some work is reported to have been done there in 1926.

The areal geology of the principal part of the company's property is shown in Plate 25, which is drawn from a map made by W. R. Landwehr under the supervision of J. J. Beeson, the company's consulting geologist. The rock exposures are unsatisfactory over much of the property, especially on the mountain slope east of the camp. As a consequence, many of the details can not be deciphered. The positions assigned to geologic boundaries on the Silver Fortune and adjoining claims are open to question, but they are based on careful work and accord with the available facts as closely as possible. The youngest sedimentary rocks belong to the Wood River formation, which is composed principally of impure blue limestone with thin beds of black shale, some impure quartzite, and lenses of reddish quartzitic conglomerate. The base of the formation is marked by conglomerate interbedded with quartzite and limestone. These basal beds are mapped separately on Plate 25. Below them is the black carbonaceous argillite with quartzitic and calcareous beds of the Milligen formation. The thickness of this formation exposed here is much less than the average thickness elsewhere, perhaps because of faulting. Below the shale are the limestone and quartzite of the East Fork formation. This formation may not be as continuous as is indicated on Plate 25. It was observed on the ridge west of the camp and also on the P K group but may perhaps be absent in part of the intervening area. The lowest formation exposed is the Hyndman, which here is composed principally of white to reddish massive quartzite. The boundary of the largest mass of granitic rocks in the Hailey quadrangle is 2 miles northeast of the camp, and dikes of quartz diorite porphyry and soda trachyte cut the sedimentary strata on the property.

In the open cuts on the Iron Clad and Mars claims and in outcrops and cuts on near-by claims there are masses of rusty material which appear to represent replacement of limestone and quartzite of the East Fork formation by magnetite, arsenopyrite, quartz, siderite, and probably other minerals. The exposures are so much oxidized as to make recognition of the minerals difficult. Some of the limestone near the Iron Clad deposit has been almost completely altered to actinolite, and this mineral is probably also associated with the iron ore on the P K group. Pyrrhotite is reported to have been found in ore from the P K. The presence of gold in the iron ore from both places has already been mentioned.

The old Paymaster workings are shallow cuts and irregular burrows on the crest of the ridge, as is shown in Plate 25. There are several rather poorly defined deposits, and the early miners merely gouged out the readily accessible more or less oxidized material near the surface and then ceased their activities. The minerals noted in the workings are limonite, smithsonite, and other oxidation products, galena, quartz, and calcite. The smithsonite was presumably derived from sphalerite. On the east slope of the mountain, on Mascot Nos. 2, 6, 7, and 8 claims, there are a number of outcrops and cuts showing mineralization. Galena, arsenopyrite, pyrite, magnetite, quartz, calcite, and siderite have been found here. The West Side tunnel has been driven in order to develop this ground. It is 1,000

A. THE "LEAD VEIN" IN A RAISE ABOVE THE LYDIA TUNNEL

Note the contortion and crushing of the quartz bands. Photograph by J. J. Beeson.

B. QUARTZ LENSES BROKEN BY A REVERSE FAULT, LYDIA TUNNEL feet long, and at its end a crosscut has been started with the intention of cutting the conglomerate bed exposed on the Paymaster and Mascot No. 8 claims, which at the surface shows evidence of mineralization at several places. When visited, a large part of this tunnel was in massive white quartzite. Since then it is reported that the last few hundred feet of work shown in Plate 25 has been driven and that a section similar to that of the East Fork formation a short distance to the north has been exposed. If the correlation is correct, the relation can best be accounted for, as suggested by Mr. Beeson, on the assumption that there is a thrust fault above the level of the tunnel. A mineralized zone 5 feet wide containing siderite, pyrite, and magnetite has been exposed in the crosscut 140 feet from the tunnel.

The Lydia tunnel and the workings from it constitute the most extensive developments on the property. The main tunnel is over 2,000 feet long and the drifts from it amount to nearly 2,200 feet. It is intended eventually to continue the tunnel all the way through the mountain in order to prospect this ground and to provide a convenient haulageway for ore from the P K group. Near the portal of the Lydia tunnel the rock is dark quartzite and impure limestone. Conglomerate occurs about halfway between the portal and No. 1 East drift, and this is overlain at a low angle by black carbonaceous argillite. There are several slips at and near the contact, but none of them have the appearance of faults of much displacement. A large part of the rock exposed east of here is black argillite, but quartzite and calcareous beds are also present, especially in No. 2 East drift and farther east and southeast. The rock near the portal, especially the conglomerate, resembles lithologically the Wood River formation, and the argillite apparently overlying the conglomerate looks like typical argillite of the Milligen formation. If this correlation is correct the apparently minor slips above the conglomerate mark a reverse fault of some magnitude. There is sufficient similarity between the rocks of the two formations, however, to make lithologic correlations in such small exposures somewhat uncertain. A number of reverse faults similar in general to that suggested exist in the region, and numerous small reverse faults marked by the displacement of quartz lenses are exposed in the Lydia workings. One of these is shown in Plate 26, *B*. The numerous small, irregular lenses of white quartz exposed in places in the workings are probably not related to the mineralization and may have been formed at a much earlier time. Quartz is, however, also one of the minerals of the ore deposits. Some of the small slips in No. 1 East drift have a little quartz and pyrite along them. In No. 2 East drift there are also veinlets that contain quartz and a little pyrite and galena. In the irregular workings from Nos. 1 and 2 West drifts a vein or shear zone is exposed at several places. This vein is referred to as the "lead vein." It is broken by what appears to be a normal fault with steep dip to the south and a displacement of over 250 feet to the west.

The only place in the mine where ore was exposed at the time of visit is in a short drift at the top of a 50-foot raise on this vein. The deposit consisted of subparallel stringers of quartz containing pyrite, galena, and sphalerite. The layers of quartz are nearly parallel to what appears to be bedding in the shale. There has been considerable crushing and movement subsequent to the mineralization, as can be seen from Plate 26, *A*, which shows the vein as it was when visited on July 20, 1923. The vein pinches out on what appears to be a fault in what was then the face of the drift. Late in 1923 a carload of high-grade ore was shipped from this drift and a neighboring raise. A mineralized zone which may be the continuation of the Silver Fortune vein is exposed in drifts north of the main tunnel and 600 feet west of its face. The apparent extension of the "iron vein" of the Silver Fortune mine is exposed in a drift about 500 feet from the face of the Lydia tunnel, as shown in Plate 25. Ore is reported to have been encountered early in 1924 in the Lydia tunnel nearly 2,200 feet from the portal. Vein siderite lies on the dump of the Lydia tunnel, but this mineral was not noted underground.

The old workings in the Silver Fortune mine were for the most part back filled and are consequently inaccessible. A shaft was sunk in 1914 to a depth of 165 feet. Good ore containing chalcopyrite and galena is reported to have been found in the bottom, but water came in so fast that the shaft was abandoned. There are over 2,000 feet of winding interconnected drifts now accessible, of which all but about 400 feet have been driven since 1914. Two lodes are exposed that appear to join in the western part of the mine. The one nearer the portal is called the Silver Fortune vein. It strikes about N. 55° E. and dips about 65° SE. It is a rather poorly defined shear zone, in places as much as 8 feet wide, which contains pyrite, galena, sphalerite, and layers and lenses of quartz. Jamesonite has been reported from the Silver Fortune claim, but from which lode is not known. The other lode in the mine is known as the "iron vein." The average strike is about N. 60° W., and the dip is steep to the southwest. At the east end, at least, this lode comprises two parallel mineralized zones separated by comparatively barren material. The ore contains mainly massive arsenopyrite, pyrrhotite, pyrite, a little siderite, quartz, and in one place a layer of galena.

BLUE BELL PROSPECT

Gus Johnson has three unpatented claims extending from a point opposite the mouth of Federal Creek, somewhat west of north of Sawmill Gulch. They are about 3 miles southwest of the Mascot Mine, as is shown on Plate 9. As the claims have not been surveyed their position on the map is merely approximately sketched. There are several short tunnels on the northernmost of the claims, which was the only one examined. The country rock is black argillite with interbedded quartzitic beds belonging to the Milligen formation. The beds have an average strike of about N. 40° W. and dip rather steeply to the southwest. The deposit is an irregular stockwork of quartz veinlets with a little galena and rusty vugs in some outcrops. The strike ranges from about N. 30° E. to N. 60° E., and the general dip appears to be steep to the north. In the lowest and longest tunnel there is a rolling slip inclined in general gently northward in shale that contains subordinate amounts of quartzite carrying seams of pyrite and stringers and lenses of quartz. The quartz veinlets are more abundant in the quartzite beds. The water in this tunnel has deposited a considerable amount of calcium carbonate on the floor.

PHI KAPPA MINE

The Phi Kappa mine is about a mile up and on the east side of Phi Kappa Canyon, which joins the Big Lost River Valley from the east at a point about 3 miles above the mouth of Kanes Creek. The deposit was first prospected about 35 years ago. In 1896 a small mill, long since dismantled, was built at the mouth of the canyon. The mill ran for about 30 days and afforded a few loads of concentrates. There has been intermittent work since then, most of it in the last 12 years. In 1911, 1912, and 1913 a tunnel was driven 500 feet for the Federal Mining & Smelting Co. at a contract price of $9.75 a foot. In 1917 and 1918 the Standard Coal Co. had control of the property and extended the tunnel to its present length. There are four claims, one of which is patented. The developments comprise a large number of open cuts, three tunnels, and a shaft 80 feet deep. The longest tunnel is that mentioned above and known as the "main tunnel." This tunnel with the short branch drifts near its end, comprises 1,155 feet of workings. The others are the Copper tunnel, 175 feet long with a drift 25 feet long leading from it, which is 600 feet south of the main tunnel, and the Clifton tunnel, 195 feet long with very short drifts from it, which is 340 feet north of the main tunnel. All three tunnels trend nearly east. They are shown in Figure 15.

The rocks on the property are calcareous quartzite and shale with beds of impure limestone. The beds strike a little west of north and have an average dip of 65° E. There are dikes of two kinds of igneous rock exposed in the workings and at the surface near by. Masses of monzonite or a similar granitic rock crop out on the west side of the canyon. On the south side of the Copper tunnel altered

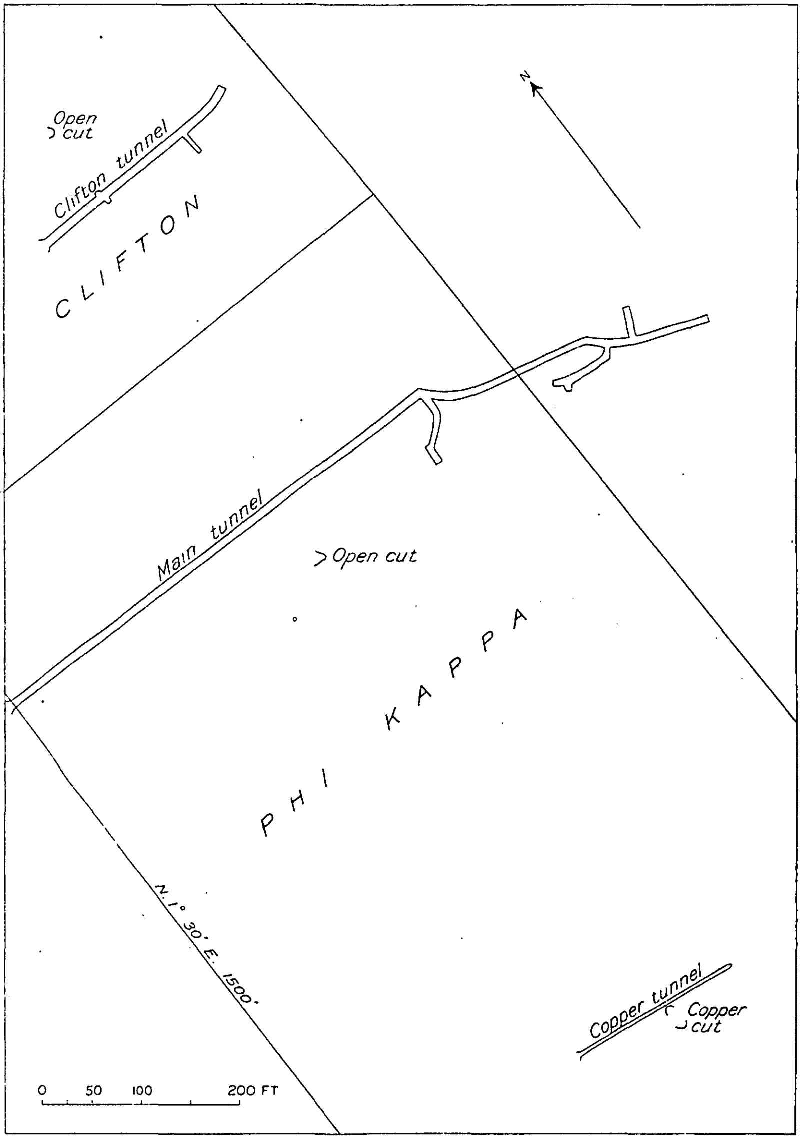


FIGURE 15.—Map of the principal workings of the Phi Kappa mine

granitoid rock is exposed for a distance of 36 feet. This rock may have had the composition of a monzonite, like others of similar appearance that crop out farther west, but it is too much altered for exact determination.

A dark dike is exposed in the face of a drift from the Clifton tunnel, and dikes of similar appearance cut the metamorphosed strata at the surface. They are composed of altered, rather fine grained gabbro, or a rock of similar composition.

The lode is exposed for a distance of about 6,000 feet and consists of contact-metamorphosed members of the sedimentary series, one of which was traced by Umpleby for the whole distance. To the north it has not been found beyond a normal fault that drops the strata on the north side about 200 feet, and to the south the mineralization gradually becomes less until none is observable. The lode as exposed at the surface consists of one or more calcareous beds that have been rather thoroughly replaced by contact-metamorphic minerals. Near the place where most of the development work was being done in 1913, when the property was visited by Umpleby, the principal bed is about 5 feet wide and is overlain by 10 feet of blocky argillite which separates it from a 4-foot bed of calcareous slate locally metamorphosed. Below is a dense, blocky siliceous slate of normal appearance. It is 18 inches thick and incloses a 2-inch white quartzite band about midway. Below this band is a dense fine-grained greenish-gray rock, generally diopsidized and locally containing metallic minerals. Several feet lower in the section is a similar bed, which presents about the same degree of alteration. About 600 feet to the north and an equal distance to the south only two intensely metamorphosed beds were observed.

In a shallow cut on the hillside above the Copper tunnel alternate bands of contact-metamorphosed limestone and shale containing oxidized copper minerals are exposed. In the tunnel there is a zone somewhat less than 10 feet wide containing galena, sphalerite, chalcopyrite, and pyrite, which may be the extension of that in the cut. Farther in the tunnel is in hard garnetized shale.

The main tunnel is driven in hard black siliceous shale. At one place in the tunnel there is a zone about 10 feet wide that contains contact-metamorphic minerals and some metallic sulphides. Similar garnetized rock, probably the continuation of this zone is exposed in the face of one of the side drifts, and the shale elsewhere shows some metamorphism.

The Clifton tunnel exposes dark shaly rock and the dike already mentioned. Little alteration was observed.

The intensely altered beds contain much garnet (grossularite) and lesser amounts of diopside, epidote, augite, calcite, quartz, magnetite, and prehnite. The sulphide minerals pyrite, chalcopyrite, galena, and a little sphalerite are scattered irregularly through the lime-silicate rock as bunches, lenses, and isolated grains. According to a statement made to Umpleby a sample taken from a segment of the outcrop of the main lode 16 feet in width assayed 10 ounces of silver to the ton, 5 per cent of lead, and 6 per cent of zinc. No ore body that seemed likely to be of this grade was observed by Ross during his examination in 1923.

The alteration which the rocks have undergone is that characteristic of contact metamorphism. A mass of granitoid rock is exposed in the workings, and it may well be an offshoot of a larger body lying a short distance below the surface.

BASIN GROUP

The Basin group, also known as the Alta Copper, comprises a portion of the north side of the open valley west of the Big Lost River near its head. The principal prospecting has been done at altitudes between 8,050 and 8,250 feet. The rocks in the vicinity are limy slate and clayey quartzite, in places intensely metamorphosed to a mass of lime-silicate minerals. The developments include several small pits and one tunnel 70 feet long that crosses garnet rock in which bedding planes that strike N. 30° E. and dip 30° SW. are faintly preserved.

The principal mineral of the deposit is birefringent garnet, which occurs as beautiful euhedral crystals that range from light amber to very dark amber in color and as minute grains of irregular shape that form a dense rock of peculiar greasy luster. Epidote (pistacite) is perhaps second in abundance. It occurs in irregular patches, locally several inches across, which are characterized by their grass-green color and brilliant reflections of light from numerous minute crystal faces. Prehnite, in radiating aggregates of tabular crystals, occurs in intimate association with all the other minerals. Wollastonite, diopside, augite, and fluorite, the last abundantly developed in one of the specimens, have been identified. Sericite occurs in part of the thin sections as minute shreds and felted aggregates locally intergrown with fluorite, one of the later minerals to form. Calcite and a little quartz occur interstitially. The predominant metallic mineral is galena, although pyrite and chalcopyrite appear in most of the specimens, and sphalerite and pyrrhotite are not uncommon.

The monzonite that caused the metamorphism crops out across the canyon of the Big Lost River and well up on the opposite side of the spur in which the deposits occur.

BLACK ROCK PROSPECT

The Black Rock prospect is a recently developed property at an altitude of about 9,000 feet on the west slope of Big Falls Creek. It was visited by Ross in September, 1927. At that time the developments comprised a tunnel over 100 feet long and a nearly completed road from the highway along the Big Lost River to the property.

The rock is somewhat calcareous slate of the Phi Kappa formation. There is marked variation in the attitude of the bedding, but near the prospect the average strike is a little east of north and the beds dip west at low angles. The ore has replaced the slate beds. In general the replacement followed the bedding, but in detail it was very irregular. The mass of ore that is being followed in the tunnel overlies a white bed that consists of coarse calcite and metamorphic minerals. The principal metallic minerals are galena, sphalerite, and pyrite. A little chalcopyrite is present in some specimens. Near the prospect tunnel there is an outcrop of slate cut by quartz veinlets that contain small amounts of arsenopyrite.

PROSPECTS ON LITTLE FALLS CREEK

Near the head of Little Falls Creek, at altitudes that range from 9,000 to 10,000 feet, there are several open cuts and short tunnels and one principal tunnel 300 feet long, which develop a vein that strikes N. 85° E. and dips 57° NW. The vein crops out as an iron-stained coarse honeycombed quartz, in which some of the cavities are lined with smithsonite and cerusite. In the main tunnel the vein is made up of overlapping lenses that average perhaps 6 inches in width and 50 to 75 feet in length. The inclosing rock, which strikes north and dips west, comprises sandstone, slate, and calcareous slate in alternating beds about 4 feet thick.

The ore consists of pyrite, galena, sphalerite, and chalcopyrite in a chalcite-quartz gangue that also incloses large amounts of wall rock as small and partly replaced fragments. Much of the pyrite is in the form of distinctly striated cubes, a few of which have cores of galena. The galena is of both the cube and the fine-grained or "steel" varieties. The sphalerite is very dark. The several sulphide minerals occur as complex intergrowths in bunches and lenses scattered irregularly through the vein.

ALTA GROUP

The Alta mine is on the west side of Kane Creek Canyon, 4 miles above its mouth, at an altitude of 8,000 feet. The workings were inaccessible at the time of visit in 1913, owing to a cave-in near the portal of the main tunnel. The developments comprise a shaft and two tunnels below, the upper one of which is apparently the principal opening, and represent possibly 1,000 feet of work. The rock at this place is a dark-blue quartzite in which bedding is rather well preserved. It strikes N. 60° E. and dips 40° NW. About 2 miles above the mine the granite, greatly sheared and jointed, crops out in the steep walls of the canyon.

The ore, as seen on the dump of the upper tunnel, is an iron-stained quartz-calcite material inclosing many fragments of the wall rock. The quartz comprises an assemblage of minute crystal grains arranged in roughly parallel bands, with here and there a small cavity lined with transparent hexagonal forms. Pyrite and its oxidation products are the principal metal-bearing minerals in the ore. The Red River and Columbus prospects and perhaps a few others are situated in this canyon, but little work is reported to have been done on any of them, and they have been idle for some time.

WILDHORSE CANYON PROSPECTS

The principal known prospects in the basin drained by Wildhorse Creek lie along Boulder Creek, the large tributary that enters from the west at a point 5 miles above the mouth of the main stream. Prospecting was started here over 40 years ago and has been pursued at long intervals since, but no ore has been shipped, and there is little activity here at present.

The country rock comprises slate, schist, and quartzite intruded by granodiorite. The ore occurs in veins inclosed in the sedimentary rocks, not far distant from their contact with the granite. The ore, as seen in a short tunnel near the creek bed and in a 40-foot shaft situated well up on the side of the canyon 1½ miles to the north, is a copper and iron stained coarse quartz carrying a little silver and free gold.

PART 3. GEOLOGY OF THE MINNIE MOORE AND NEAR-BY MINES, MINERAL HILL MINING DISTRICT, BLAINE COUNTY, IDAHO

By D. F. HEWETT

SCOPE OF WORK

During 1910, before the writer was a member of the United States Geological Survey, he was engaged privately to make a study of the Minnie Moore mine, in the hope that it would throw light on the fault problem that the mine had encountered. It seemed advisable, as a preliminary to this study, to record such local areal geologic features as might contribute to knowledge concerning the genesis of the deposits and structural history of the near-by region. Consequently four weeks was devoted to a study of the surface geology and the preparation of a geologic map. For the purposes of this report this map has been included in Plate 9.

Later, six weeks was devoted to the study of all the accessible underground workings of the Minnie Moore mine. Near-by mines were visited only where they might contribute to the problem at hand. When the district was revisited for 10 days in 1913 and for 4 days in 1926 the accessible mines west of the Wood River and south of Croy Gulch, as well as recent underground explorations in the Minnie Moore mine, were examined. As much of the deeper work in this mine is under water and caved beyond repair, many of the data here presented can no longer be observed. These statements summarize the critical details of the largest deposit of lead-silver ore in this region and one of the most interesting mines in the Western States.

GEOLOGY

SEDIMENTARY ROCKS

MILLIGEN FORMATION

There are at least 2,500 feet of beds under the basal Pennsylvanian conglomerate in this area to which the name Milligen formation has been given in this report. The beds include a wide range of fine-grained sandy and clayey sediments and limestone, as well as mixtures of these materials. Even where the beds are remote from the contact with the granitic intrusive rocks, they are highly indurated, and within a zone about 2,000 feet wide on the northeast side of the main intrusive mass typical contact minerals are developed. East of Bellevue, on the northwest spur of Lookout Mountain, at least 600 feet of beds are exposed that include gray calcareous shales, purplish and buff shales, and fine-grained bluish quartzite containing pyrite casts. At the Monday mine the country rock consists of gray and black shales, locally much contorted. Along the spurs north of Bellevue the beds are exposed only sporadically and the most common rocks are gray calcareous and sandy shales. North of Slaughterhouse Gulch, in the NW. ¼ sec. 30, T. 2 N., R. 19 E., a tunnel explores a zone of black shale. Probably the same zone is explored by another tunnel in the NE. ¼ sec. 23, T. 2 N., R. 18 E.

West of the Big Wood River the commonest rocks are gray shale, gray calcareous sandstone, and argillite. Here and there are beds of black chert and dark-gray limestone, but such materials are a small part of the total. At the mouth of Star Gulch thin-bedded gray sandy shale is highly contorted. During this examination attention was directed largely to the beds within 2,000 feet of the contact, in which most of the mines and prospects have been opened. As most of the details of this group of sediments were obtained in the study of the Minnie Moore mine, they are presented in connection with the description of that mine.

WOOD RIVER FORMATION

In the area south of the Hailey quadrangle rocks of the Wood River formation are best exposed along the western slope of Lookout Mountain, the conspicuous peak southeast of Bellevue, and in this area the following generalized partial section was measured. The succession of beds in the lower 500 feet is the basis for interpreting the faults in this region; where these beds are absent it is difficult to obtain any idea of the character and extent of the faults.

Generalized partial section of the Wood River formation on western slope of Lookout Mountain

	Feet
Crest of Lookout Mountain.	
Sandstone, calcareous, bluish gray	600+
Limestone, dark gray, no fossils; contains many white calcite veinlets, persistent	80
Sandstone, calcareous, gray	200
Sandstone, buff, no lime	150
Sandstone, coarse, calcareous, gray	240
Shales, buff	50
Sandstone, calcareous, bluish gray, with beds of buff sandy shale	300

	Feet
Sandstone, calcareous, bluish gray, veins of black calcite	50
Shale, sandy, buff	20
Limestone, siliceous, bluish gray, fossils	35
Limestone, white	12
Conglomerate, containing many lenses in which the pebbles range from 1 to 4 inches diameter; fossils are locally abundant in sandy layers	300
	2,037

The conglomerate at the base is a conspicuous bed in the high ridges east of Bellevue and is also present west of Bellevue. Where exposed in a belt that crosses Croy Creek west of Gilman it is highly silicified and crushed but is still recognizable. The base undoubtedly coincides with a notable unconformity in the section.

All the following fossils but one were collected from the conglomerate on Lookout Mountain; one brachiopod, *Productus costatus?*, was found in the bed north of the mouth of Croy Creek. The fossils were identified by Prof. Charles Schuchert, of Yale University.

Spirifer cameratus.
Spirifer rockymontanus.
Productus costatus?
Productus cora.
A terebratuloid (Dielasma?).

Four collections of fossils were made from the gray siliceous limestone that overlies the conglomerate in the exposures east of Bellevue. They included the following species:

Rhombopora lepidodendroides.
Syringopora multattenuata McChesney.
Polypora sp.
Fusulina secalica.
Zaphrentis excentrica.
Productus semireticulatus.
Productus sp.
Ambocoelia planoconvexa.
Crinoid stems.

The calcareous sandstone and shale that make up much of the upper part of the formation in the area studied by the writer are singularly devoid of fossils. No ore deposits occur in the Wood River formation near Bellevue.

IGNEOUS ROCKS

DIORITE

The surface exposures of diorite present only slight differences throughout the area. Where unweathered, it is a grayish granular rock in which biotite is very conspicuous and hornblende less so. The grains of the minerals commonly range from 1 to 3 millimeters in diameter, but locally the feldspars are larger. It weathers to light shades of brown. There are numerous joints, so that on high ground, in secs. 28, 29, 31, and 32, T. 2 N., R. 18 E., the surface is rugged. Five thin sections of the rock studied under the microscope show rather constant proportions of the minerals, roughly as follows: Labradorite, 70 per cent; biotite, 10 per cent; augite, 5 per cent; hornblende, 3 per cent; quartz, 10 per cent; magnetite, hypersthene, apatite, traces. It is noteworthy that no orthoclase or microcline has been found in the rock. As noted by Lindgren,[1] the rock is properly called quartz diorite, but in this report, as in Lindgren's description, it will be referred to as diorite.

Locally, near the contact with the underlying granite, as in the SE. ¼ sec. 29, there are roughly angular blocks of a somewhat similar rock in which hornblende is more abundant. These blocks are not segregations but appear to have been solid blocks carried upward in the diorite magma during the process of intrusion.

The diorite exposed in the Minnie Moore mine has the composition and texture given in the description of the rocks on the surface. The 5-foot sill exposed in the Allen shaft and near-by drifts and crosscuts, as shown by a specimen collected from the top of the Tweed raise, is a similar rock but probably contains more augite and hornblende than biotite and is slightly less coarse in texture. On the other hand, an 8-inch dike that adheres firmly to the adjacent contact rock in the 565-foot hanging-wall crosscut from the Allen shaft contains orthoclase, quartz, and labradorite with biotite but no augite or hornblende.

GRANITE

In the southwestern part of the district the diorite is underlain by granite. As the granite is much lighter in color, the contact may be traced clearly throughout the area except for a short distance southwest of the Croesus mine. It is coarser in texture than the diorite, and the lighter color is due to the smaller proportion of biotite, hornblende, and augite. An estimate of the mineral composition, based upon the examination of three thin sections, shows the following ranges: Potash feldspar (largely microcline), 30 to 45 per cent; plagioclase (andesine), 25 to 60 per cent; quartz, 20 to 35 per cent; biotite, 5 to 8 per cent; hornblende, none to 5 per cent; titanite, 2 to 3 per cent; muscovite, trace. Augite and magnetite are absent. In a strict sense, the rock is quartz monzonite, but, as in Lindgren's earlier report, it will be called granite.

In the granite, as in the diorite, there are sporadic small angular blocks of a darker rock. One specimen from the N. ½ sec. 5, T. 1 N., R. 18 E., is quartz monzonite of microgranular texture, as it contains, in order of abundance, green hornblende, microcline, plagio-

[1] Lindgren, Waldemar, op. cit., p. 195.

clase, quartz, biotite, and titanite. It is thus clear that the angular blocks in both the diorite and granite have some resemblances in composition to both rocks.

The contact between the diorite and granite is a smooth surface that dips 10° E. in the southern part of the area, is nearly horizontal near the Veta Grande prospect, and then progressively dips more steeply under the diorite until the maximum of 70° is attained in the northwestern part of the area. The granite is unaltered near the contact, but the dark minerals of the basal zone of the diorite, which is from 5 to 25 feet thick, are altered to chlorite over a large area.

The relations of the granite and diorite offer a chance for interesting speculation. There are enough similarities in mineral composition and texture to indicate that they were derived from a single magmatic source, but the sharp contact between them and the fact that the heavier rock lies above the lighter discourage the hypothesis that they segregated from a homogeneous mass in the place in which they are now found. The shape of the surface of contact indicates that the diorite was still viscous when the granite was intruded.

Broadly the bodies of diorite and granite, considered together, form a dike-shaped mass about 3 miles in width and at least 13 miles in length, of which about 6 miles lies southeast of Croy Gulch. At the southern border of the mapped area the rocks are covered by wash, so that the limit in that direction is not known. The limit on the northeast is a smoothly sinuous surface that dips 30°–50° SW. In both a general and a detailed way this surface cuts across the bedding of the stratified rocks in strike and in dip. The southwestern limit of the granite is similarly a smooth sinuous surface, roughly parallel to the other in strike but steeper in dip, which ranges from 70° SW. to vertical. Both surfaces appear to belong to a group of fractures that were formed during a period of folding before the diorite and granite were intruded. The relative age of the two rocks might be obscure if it were not for the presence of a few dikes and similar bodies of pegmatite and aplite that cut the diorite, especially near its contact with the granite. The hill southwest of the Croesus mine contains not less than 18 dikes of pegmatite arranged in three groups within which the dikes have parallel strike and dip. They range from 8 to 20 feet in thickness and most of them may be traced several hundred feet. The outcrops are conspicuous, and they present a distinctly banded appearance. Although the texture of some bands is coarse, and graphic intergrowths of feldspar and quartz are common, the texture of others is fine, and these fine-textured bands contain uncommon plumose aggregates of muscovite. Thin sections of the fine-grained rock show quartz and microcline, about 35 per cent each; plagioclase (andesine), 10 to 15 per cent; muscovite, 8 to 10 per cent; and garnet, 5 per cent.

In the W. ½ sec. 3, T. 1 N., R. 18 E., scarcely 100 feet above the granite-diorite contact, there is a rudely circular outcrop of coarse pegmatite, 150 feet in diameter, in which graphic intergrowths of orthoclase and quartz are common. Also there are two similar intrusive masses of aplite about 150 feet in diameter in the SW. ¼ sec. 27 and SW. ¼ sec. 28, T. 2 N., R. 18 E. Like the pegmatite dike, these masses are considered to be derived from the deeper part of the granitic magma and to have been intruded after the larger bodies were in place.

DIKES

The area of granite and diorite west of Bellevue contains many dikes, and the near-by sedimentary rocks contain a few sills. Dikes are most abundant in the high ridges at the heads of Galena and Lee Gulches, but only locally are they conspicuous. Several mines and prospects have encountered them underground (Minnie Moore, Edna, and others). In general the dikes occupy fractures parallel to near-by joints in the rocks, and they have produced little if any alteration of the adjacent rocks. The most persistent dike has been traced 1,500 feet, but it may be the same as others on adjacent ridges and be over 5,000 feet long. The maximum width is 60 feet. Most of the others are less than 20 feet wide.

The dikes show a wide range in color and mineral composition. The only rocks that resemble the diorite in composition are found in two sill-like bodies—one 500 feet north of the Star shaft, the other exposed in many places in the Relief tunnel and Allen shaft. The second is practically identical with the diorite; the first contains the characteristic minerals but is porphyritic. Probably both were intruded into the sediments soon after the main mass of the diorite.

The persistent northeastward-trending dike at the head of Lee Gulch is a gray andesite of common type. A thin section shows a groundmass of minute laths of plagioclase with a few conspicuous needles of hornblende, now chloritized. It contains accessory quartz, biotite, and magnetite. Part of this dike is very fine grained, and although it appears to be silicified it is not. The finer parts represent the material that was chilled at the contact with the inclosing rock. The most common dikes are dark and fine grained and rarely exceed 10 feet in width; some contain conspicuous biotite, others a few crystals of augite. Most of these are properly regarded as mica lamprophyres.

The relation of these dikes to the mineralization of the district is of great interest. This subject is discussed in greater detail in connection with the geology of the Minnie Moore deposit. It may only be stated here that the darker basic dikes occur in a number of mines and that some were undoubtedly intruded before the mineralization, as they are appreciably altered near the ore minerals, whereas at least one other is assuredly postmineral, as it fills a fracture along which a vein is faulted. W. P. Jenney[2] has written that these dikes are favorable places for the deposition of the ore minerals; certainly at one place in the Minnie Moore mine a part of the siderite of the ore shoot has replaced a basic dike. On the other hand, ore shoots are not coextensive with such dikes. Probably it is safe to say that fractures that permitted premineral intrusive magma to enter were readily accessible to ore-bearing solutions also.

SURFACE FLOWS

Within the area shown on Plate 1 there are four bodies of surficial volcanic rocks. The largest body continues several miles northwestward into the Hailey quadrangle, where it has been studied by Westgate (p. 54). The prominent hill in the NW. 1/4 sec. 19, T. 2 N., R. 18 E., is made up of greenish-gray augite andesite, now extensively altered by hot-spring action. The freshest rock shows many crystals of plagioclase and fewer of biotite and augite, the augite largely altered to chlorite, in a groundmass of minute feldspar crystals and glass. Here and there it is much fractured and zeolitized; stilbite crystals line druses along veins. Curiously, massive unfractured rock has resisted alteration, whereas rock that is minutely fractured is almost completely altered.

Zeolites have been found in several of the mines, and it is assumed that they are related to the period of intrusion of postmineral dikes and extrusion of flows. The stilbite of the Minnie Moore mine and the laumontite of the Bellevue King and Golden Bell mines are undoubtedly postmineral and related to the post-Miocene volcanic activity.

The spur in the SE. 1/4 sec. 2, T. 1 N., R. 18 E., is covered with a basalt flow. The spur in secs. 11 and 12 is covered first by a flow of rhyolite and then by one of basalt. In both localities the surface on which the flows rest dips about 10° eastward, toward the present valley; they appear to be the remnants of more extensive flows that once occupied valleys much like the present valley of the Big Wood River.

CONTACT METAMORPHISM

By contrast with recent sediments in many regions the bedded rocks of this area are highly indurated. The intrusion of the diorite and granite has had the effect of further hardening the near-by sediments and in a narrower belt adjacent to the contact

[2] Manuscript in the writer's hands.

has produced considerable change in their mineral and chemical composition. On the northeast side of the diorite the width of the belt in which changes have been observed ranges from 2,000 to 2,500 feet, but no precise limit can be drawn. The area southwest of the granite mass has not been closely studied to determine the nature and extent of contact metamorphism.

The new minerals that developed in the contact zone appear to have been determined by the original composition of the rocks and by the distance from the contact. The specimens that have been studied closely do not indicate that much material has been added to the sediments near the intrusive rock. The appearance of the altered rocks commonly gives little suggestion of the amount of change that has taken place, for almost all the details of lamination and color are still preserved in the rocks.

Only general statements concerning the changes will be presented here, as most of the detailed data were obtained underground at the Minnie Moore mine, and it seems best to give them in connection with the description of that mine. Much of the rock in the contact zone that appears to be fine-grained gray sandstone is shown by examination of thin sections to be largely diopside with small amounts of quartz. Commonly there are a few coarse crystals of diopside in a matrix of finely granular diopside. Here and there tremolite forms groups of radiating crystals. Some specimens are about half garnet (grossularite?), but this mineral is not common. In some specimens aggregates of garnet and diopside are bordered by blades of wollastonite and the three surrounded by calcite. Undoubtedly such rocks were originally calcareous sandstone; the proportion of grossularite was determined by the local presence of alumina, and the diopside and tremolite indicate that the carbonate mineral contained magnesia. Zoisite and vesuvianite were not observed in the coarsely crystalline rocks.

The changes in the fine-grained sediments depend roughly upon the distance from the intrusive rock. The specimens of hornstone collected within 1,000 feet of the diorite contact contain disseminated minute crystals of biotite (phlogopite?); one specimen contains a few crystals of brown tourmaline. Zoisite occurs on the borders of coarse quartz aggregates in some specimens. No rocks have been identified within 1,000 feet of the contact that were assuredly pure limestone at one time, although it is not impossible that some of the diopside rocks represent magnesian limestone to which some silica has been added. In the outer zone the purer limestone is practically unaltered.

In both coarse and fine sedimentary rocks lamination is shown by differences in color as well as size of grain. The color appears to depend upon the content of carbon, and no rocks are free from it. Near the diorite contact the grains of carbon are flat and highly lustrous and are therefore probably graphite.

Viewed broadly, the mineral composition of the sedimentary rocks near the diorite contact does not indicate profound contact metamorphism. Although carbon dioxide has certainly been set free by the combination of silica with calcium and magnesium oxides of the limestones, there is no evidence of great addition of new material to the sedimentary rocks nor of the absorption of elements from the sedimentary rocks by the diorite. As shown farther on, the contact minerals were developed before the minerals of the ore deposits were introduced.

STRUCTURE

The large features of the structure of this area are simple. Northeast of the Big Wood River the Paleozoic rocks dip generally eastward at inclinations that range from 18° to 70°; most observations range from 20° to 35°. Southwest of the river the beds dip generally westward at inclinations that largely range from 20° to 40°. It is thus clear that the sediments form a broad anticline, of which the crest almost coincides with the Big Wood River Valley. The arch is broken by faults, however, as will be explained below. West of the diorite and granite mass, near Gilman, the basal conglomerate of the Wood River formation trends north and dips steeply west. The underlying Milligen formation shows a wide range in local dip and strike. Undoubtedly the structure of these beds is complicated in detail, but exposures are too poor to permit even generalized interpretations. Where mine workings explore the Milligen beds along the ridges adjacent to the Big Wood River Valley, and here and there on the surface, the structure of the beds is locally complex. At the mouth of Star Gulch, in the Black Jack and Monday tunnels southeast of Bellevue, and in other prospects these beds are locally crumpled or closely folded. In general the thin-bedded Milligen strata are more highly folded than the Pennsylvanian (Wood River) beds, but this area does not yield any evidence as to whether this difference is due to the nature of the beds or whether they were folded before the Pennsylvanian beds were laid down.

There are many normal faults in the region, but in most places the determination of their displacement and precise location for any great distance is difficult if not impossible. The faults shown on Plate 9 were determined by offsets of the conglomerate and overlying limestone at the base of the Wood River formation. Most of the faults appear to fall into two simple groups—those east of the Big Wood River, which trend north and dip west, and those west of the Big Wood River, which trend northwest and dip northeast.

The character of these two groups is shown in Figure 16, A, B. The effect of the two groups is to drop the crest of the anticlinal arch from 2,200 to 3,200 feet.

There are reasons for believing that these faults are relatively recent. The present course of the alluvial valley of the Big Wood River is uncommonly straight and it does not deviate far from the trend of these faults, especially that of the group southwest of the river. Moreover, the facets of the bordering ridges are most accu-

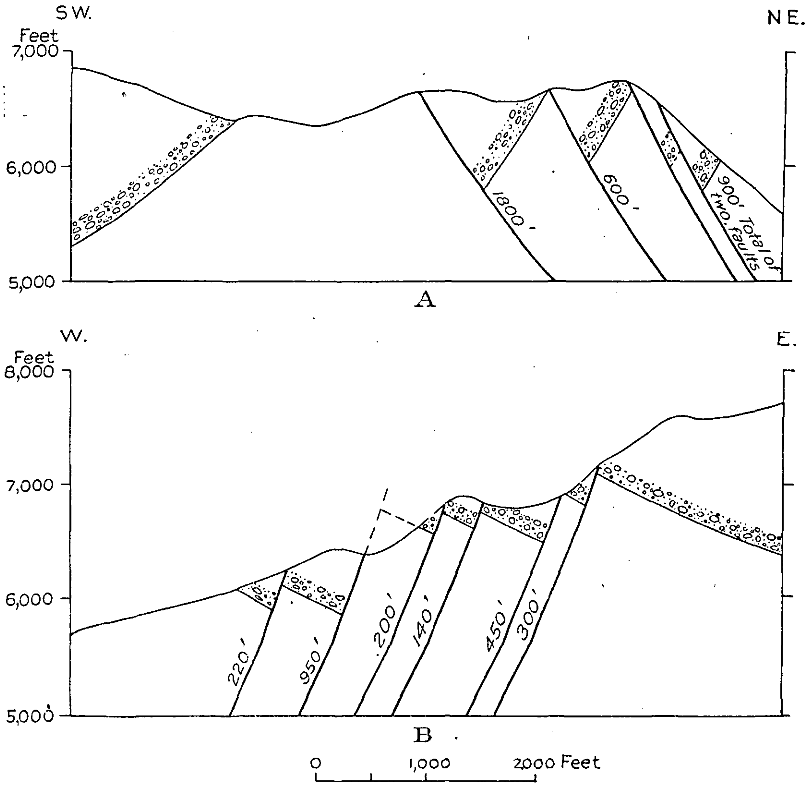


FIGURE 16.—Structural cross sections (A) N. 50° E. along ridge of Della Mountain west of Hailey and (B) S. 87° E. through Slaughterhouse Ridge, showing faults that displace conglomerate of base of the Wood River formation

rately alined for 7 miles or more south of Hailey. Owing to the differences in the rocks, as measuring their ability to resist weathering, one would scarcely expect to find such alinement. The suggestion arises that recent faults may limit the present valley, but there is a possibility that most of the normal faults shown on Plate 9 may be older.

Most of the mineralized fissures southwest of the Big Wood River trend northwest, but they dip southwest in the area where the normal faults dip northeast. There can be no doubt that some of the normal faults are later than the mineralized fissures and that movement took place after the minerals were introduced. Although there is a possibility that some of the normal faults that cross the fissures are premineral, the regional relations of the faults favor the conclusion that most if not all of the normal faults are postmineral.

SUCCESSION OF GEOLOGIC EVENTS

The evidence in this area yields the following summary of the structural and erosional history:

1. Deposition of Paleozoic sediments.
2. Development of open folds accompanied or closely followed successively by joints and fissures that later became (*a*) channels for intrusion of diorite and granite magma, (*b*) channels for circulation of ore-depositing solutions.
3. Intrusion of diorite.
4. Intrusion of granite and pegmatites.
5. Intrusion of andesite and lamprophyric dikes.
6. Deposition of ores.
7. Great erosion.
8. Development of two groups of normal faults.
9. Intrusion of lamprophyric dikes; extrusion of flows.
10. Great erosion to present forms.

DESCRIPTION OF MINES

MINNIE MOORE MINE

HISTORY

Inasmuch as the Minnie Moore mine has produced lead and silver ore of greater value than any other in the district, and as the successive events in the development of the mine are largely dependent upon geologic features of the deposit, a somewhat detailed account of its history is presented. In addition to published sources of information the writer is indebted to Mr. I. E. Rockwell, who was a part owner of the mine from 1902 to 1905 and later, to Mr. W. P. Jenney, a geologist who lived in the Big Wood River Valley from time to time between 1880 and 1900, and to Mr. Samuel H. Allen, a miner who worked in and knew many of the mines of the region before his death in 1922. The geologic features of the workings made since 1923 have been closely studied by R. T. Walker, geologist, of Salt Lake City, who prepared Plates 28–30. As the deposit explored in the Minnie Moore claim extends into the adjacent Relief claim and the two are now under single ownership, they are considered together.

The history of the mine is roughly separable into four periods. The first period extends from the discovery of the deposit in 1880 to the sale of the mine to Dent, Palmer & Co., of London, in 1884;

the second period, from 1884 to the cessation of work by that company in 1889; the third period, from 1900, when the mine was pumped out, to 1906, when it was again closed down; and the fourth period, from 1909, when it was pumped clear of water, until 1927, when it was again allowed to fill. The main shaft was pumped clear of water to the 1,000-foot level in 1909 and was kept open during prospecting in the footwall until 1913, when it began to cave seriously and was abandoned. In 1923 the mine was leased to the Federal Mining & Smelting Co., which pumped out the Minnie Moore shaft and sank the Allen shaft 300 feet deeper.

According to local report, galena was found in the waste from a badger hole by J. W. Moore in 1880. The discovery was made at a point about 200 feet east of the incline that later became the main shaft of the mine. W. P. Jenney,[3] who examined the deposit in November, 1880, states that "the only development was an open trench about 50 feet long and 8 to 10 feet high at the face, along which there was exposed a lens of galena 35 feet long and 2.5 feet thick." Later, in 1881, after a shaft had been sunk 45 feet and showed the lens to persist to this depth, a half interest in the claim was sold to Henry E. Miller for $10,000. From May 9 to November 30, 1881, 217 tons of ore averaging 101.62 ounces of silver to the ton and 67 per cent of lead was shipped.[4] On the date of sale to Dent, Palmer & Co., February 25, 1884, the principal workings consisted of the main inclined shaft, 160 feet deep, two levels eastward to a maximum distance of 205 feet, and three levels westward to a maximum distance of 80 feet. As there had been little stoping, it was clearly the purpose of the owner to explore the deposit rather than to ship ore. In an area 125 feet long and 100 feet wide the vein was estimated to contain 3,699 tons of ore averaging 100 ounces of silver to the ton and 68 per cent of lead. With the price of silver at $1.14 an ounce and of lead at $100 a ton, the gross value of the reserves was $673,329. In this condition the mine was sold for $450,000.

During the second period the mine was thoroughly explored to the old 900-foot level and yielded most of its total production. The period was not without its problems, however, for it is locally reported that early in 1886 there was so little ore on the 500-foot level that the mine was closed down. It is reported[5] that the ore shoot was cut off by a fault, probably that exposed in the Relief shaft and recently explored by drifts from that shaft. Later that

[3] MS. given to the writer.
[4] Report of the Director of the Mint for 1881, p. 183, 1882.
[5] U. S. Geol. Survey Mineral Resources, 1885, p. 58, 1886.

year lessees developed the large shoot on the 360-foot level west, and when the shaft was sunk to the 600-foot level, a new body of ore was found. The last ore removed by Dent, Palmer & Co. was taken from the body farthest west on the 800-foot level; no ore was found on the old 900-foot level. According to Jenney,[6] who saw the shoot on the 360-foot level west in 1887, it was a lens of massive galena 90 feet long on the level and was explored 60 feet up a raise. The thickness attained a maximum of 14 feet in the center but narrowed to 3 or 4 feet on the edges. The western part of the lens was troughlike, so that the level on it turned abruptly south, but whether the form was determined by premineral structural features or by postmineral folding is not known. There is an accurate record of the value of the output for the period 1886 to 1889 but not for 1884 and 1885. The net smelter return for these four years was $1,433,306.13, and, as the operating expense was $784,310.63, charges for new plant $16,454.74, and for mining claims $6,725, the apparent profit for the period was $625,865.76.

The mine filled with water and lay idle from 1889 to November, 1900, when I. E. Rockwell, C. R. Carpenter, and others, having purchased the property for $30,000, began to pump out the workings. Ore was struck in a raise from the south crosscut on the old 900-foot level in June, 1902, and from that time the lower part of the mine was vigorously explored. The Minnie fault was struck on the west end of the new 900-foot level in November, 1903, and later on in the successively lower beds. In July, 1904, 60 per cent of the stock in the Minnie Moore Mining Co. (Ltd.) was sold to C. M. Schwab, who operated it on company account until August, 1905. It was then operated under lease until two men were accidentally killed in the Singleterry raise in March, 1906. The mine was then allowed to fill with water. Most of the explorations beyond the Minnie fault, as well as the footwall crosscut on the 1,000-foot level, were made between July, 1904, and March, 1906.

During the period 1902 to 1906 mining operations below the old 900-foot level yielded about $1,100,000, net smelter returns. A small stope on the Singleterry vein above the 1,000-foot level yielded $31,000, net smelter returns.

In October, 1907, new pumps were installed, and by December 1, 1909, the 1,000-foot level was clear. Explorations during 1910 were confined to the Singleterry vein in the footwall. The Minnie Moore shaft began to cave in 1913 and soon thereafter was abandoned. During 1911 and 1912 crosscuts and drifts were opened on the 380 and

[6] Manuscript given to the author.

470-foot levels from the Allen shaft, and in 1923 that shaft was sunk to the 800-foot level. Three groups of operators made successive efforts to recover the ore shoot below the Minnie fault by exploring eastward on the 800, 900, 1,000, and 1,100-foot levels of the Allen shaft, but as these failed the mine was abandoned in May, 1927.

PRODUCTION

It is not possible to present a comprehensive summary of the production of the Minnie Moore mine. The most complete record is that compiled in 1902 by I. E. Rockwell, who, having access to the books of the Hailey sampler, which handled the ore during the early years, estimated the gross smelting returns at $7,316,600.12. Records from three sources are assembled below—the reports of the Director of the Mint for the period 1880–1887, the records of the Minnie Moore Mines Co. for the period 1902–1905, and the records of the United States Geological Survey for the period 1902–1926. Permission to publish the records was given by the owners.

Partial record of production of Minnie Moore mine, 1881–1886 [a]

Year	Ore	Lead	Silver	Year	Ore	Lead	Silver
	Tons	*Pounds*	*Fine ounces*		*Tons*	*Pounds*	*Fine ounces*
1881	217	290,780	22,047	1884	([b])	3,276,000	220,860
1882	([b])	([b])	([b])	1885	4,079	[c] 528,798	369,149
1883	([b])	([b])	([b])	1886	4,955	5,351,506	447,149

[a] Report of the Director of the Mint, 1881, p. 183; 1884, p. 258; 1885, p. 147; 1886, p. 190.
[b] Not recorded.
[c] Probably 5,287,980 pounds.

Production of Minnie Moore Mines Co., 1902–1905, as shown by records of the company

Class	Dry ore	Gold	Silver	Lead	Copper	Insoluble	Iron	Zinc	Sulphur	Arsenic
	Tons	*Fine ounces per ton*	*Fine ounces per ton*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
First-class crude	5,335	0.073	99.60	61.76	--------	--------	--------	--------	--------	--------
Second-class crude	511	.023	68.59	26.97	0.45	20.82	14.42	5.7	12.34	0.74
First-class concentrate	5,766	.73	83.94	60.10	--------	5.85	7.92	--------	--------	--------
Second-class concentrate	5,824	.31	39.80	11.36	.34	17.96	21.94	7.1	17.19	1.10
	17,436	--------	--------	--------	--------	--------	--------	--------	--------	--------

Net smelter returns at prices prevailing, $899,422.09.
Approximate gross value at prices prevailing, $1,595,000.

Production of Minnie Moore and Relief mines, 1902–1926

[As reported to U. S. Geological Survey]

Year	Ore mined	Shipments to smelter	Metals recovered			
			Gold	Silver	Lead	Copper
	Tons	*Tons*	*Fine ounces*	*Fine ounces*	*Pounds*	*Pounds*
1902	1,202	[a] 1,202	----------	107,779	1,337,662	----------
1903	6,295	[a] 6,295	----------	413,885	5,003,555	----------
1904	24,300	[a] 2,262 [b] 4,407	----------	469,538	5,373,583	----------
1905	14,580	[b] 3,645	----------	283,639	3,103,325	----------
1906	11,350	[a] 100 [b] 2,250	----------	72,500	530,000	----------
1907	[c] 386	[a] 36 [b] 120	----------	5,463	70,022	----------
1908	[c] 3,000	[b] 416	----------	8,320	54,912	2,496
1909	[c] 10,210	[b] 1,071	21.45	26,593	215,897	581
1910	[c] 8,728	[b] 1,627	20.53	40,238	315,250	----------
1911	[c] 1,790	[b] 179 [a] 159	5.40	4,234	33,782	1,069
1912	29	[a] 29	.30	947	13,348	153
1913	[c d] 15,206	[b] 2,255	3.30	42,152	448,220	3,060
1914	[c d] 3,144	[b] 786	3.23	11,769	132,817	1,598
1915	[c d] 2,709	[b] 387	.99	6,115	66,552	365
1916	[e] 50	[a] 50	.99	953	16,202	111
1917	[f] 34	[a] 34	.62	1,303	16,832	479
1918	[f] 18	[a] 18	----------	994	18,549	258
1919	[c] 10,000	[b] 1,665	30.80	28,503	184,276	6,974
1920	[c] 4,274	[b] 754	17.03	17,148	120,079	1,766
1921	509	[b] 72 [a] 77	.57	8,733	91,749	1,355
1922	303	[b] 101 [a] 33	2.00	3,030	23,032	477
1923	7	[a] 7	----------	535	8,171	45
1924	464	[b] 116	2.00	3,917	40,534	279
1925	1	[a] 1	----------	58	1,209	6
1926	43	[a] 43	.51	1,972	24,916	614

[a] Crude ore.
[b] Concentrate.
[c] Tailings treated.
[d] Tailings treated, probably largely from Queen of the Hills dump.
[e] Tailings treated from Queen of the Hills.
[f] Crude ore from Queen of the Hills.

ACCESSIBLE WORKINGS

Some conclusions concerning the relations of the Minnie Moore ore body can not be stated with great assurance, because practically all exposed ore has been removed and many levels are no longer accessible. Except for the 360-foot level east as far as the Singleterry rise, none of the levels from the Minnie shaft above the 500-foot level were open in 1910 or 1913. Fortunately most of the workings on the 1,000-foot and lower levels were open. The Relief shaft was open as far as the 400-foot level and nearly all the levels of the Allen shaft and Relief tunnel were accessible. The limits of accessibility in the workings in 1913 are shown in Plate 27 by a cross. All the workings opened between 1923 and October, 1926, were accessible during that month.

THE ORE DEPOSIT

General features.—At least three elements have played a part in controlling the distribution of lead minerals in this deposit—(1) the character of the sediments in which it is found; (2) the character, distribution, and succession of the igneous rocks that have invaded the beds; (3) the structure of the beds and the faults or disturbances that have affected them both before and since the minerals were deposited. In a broad way, other elements may have had a notable influence, such as the depth of the explored deposit below the surface at the time of deposition and the paragenesis of the minerals. It has not been possible, however, to draw very satisfactory conclusions concerning these matters, especially such as may affect the search for the downward or lateral extension of the deposit.

Sedimentary rocks.—The texture of the sedimentary rocks exposed underground is uniformly fine grained; in composition they range from calcareous rocks through claystone to siliceous rocks, and as they are close to the contact with intrusive diorite they have largely suffered considerable change before the lead and related minerals were deposited. To the unaided eye only a few types can be distinguished, and their appearance gives little clue to the degree of alteration they have undergone.

In order to understand the succession of beds and the relation of the deposit to them, particular attention was given to the zone in which the thickest section is well explored by workings. The section is that explored by the 1,000-foot level footwall crosscut and the Singleterry raise; it trends about N. 24° E. Along this section the lowest unit is 300 feet of dense nearly black argillite. In a thin section of a typical specimen (139)[7] lamination is shown both by size of grain and by distribution of carbon. The specimen is composed largely of microcrystalline quartz, but some layers contain considerable biotite. Here and there augen of quartz and scapolite (?) are bordered by large flakes of biotite and tourmaline. The rock is cut by minute veinlets of quartz and a carbonate (siderite?), which contain grains of pyrite. Such material is clearly a fine-grained siliceous rock that, at a distance of about 900 feet normally from the diorite contact, has received little new material but has been appreciably recrystallized.

A similar rock (149) occurs 520 feet from the top of the Allen shaft, between a sill of quartz monzonite and the main mass of diorite, but it is above rather than under the extension of the Minnie Moore vein zone. It appears to be a hard black shale but is made up of minute uniform grains of quartz in which lamination is indicated by flakes of carbon (graphite?) and sporadic grains of pyrite. It contains sparse patches of calcite and crystals of zoisite.

The second unit, about 100 feet thick in the cross section, is gray and of coarser texture, resembling fine-grained sandstone. Two thin sections of representative specimens differ only in that one (138) is made up largely of radial aggregates of diopside crystals with traces of quartz and calcite, whereas the other (140) is made up

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[7] Numbers correspond to those shown on Plate 27.

largely of similar radial aggregates of tremolite, with minor amounts of diopside, and quartz as a matrix. In both sections pyrite is sporadically distributed, garnet is absent, and lamination is shown by size of grain. Little material appears to have been added, although carbonic oxide has been lost by the combination of silica with the calcium and magnesium of the original carbonate minerals. Another specimen (106) from a point on the 1,000-foot level east hanging-wall crosscut, below the Minnie Moore fault and 200 feet distant from the diorite but probably from this unit, contains garnet, 50 per cent; calcite, 25 per cent; wollastonite, 10 per cent; quartz, 10 per cent; and diopside, 5 per cent. Before the alteration induced by the intrusion of diorite, these rocks were impure limestones.

The third unit, about 120 feet thick, resembles the first but is lighter in color and is probably nearly pure quartzite. No specimens have been examined under the microscope. In the eastern part of the mine it is overlain by the Minnie Moore ore zone.

The fourth unit attains a maximum thickness of 400 feet over the mine workings. It appears to be this group of rocks that is explored in the recent work south of the Minnie fault. In outward appearance, color, lamination, and size of grain the rocks closely resemble those of the second unit but in addition contain two beds of only slightly altered limestone 40 and 130 feet thick. A specimen (120) from the lower part of this unit, within 20 feet above the ore shoot, on the 1,000-foot level east of the 1,000–1,200 foot shaft, is a fine-grained quartzite with sporadic patches of very fine grained quartz. It contains a little feldspar (microcline and plagioclase) that undoubtedly has been introduced from the intrusive rock, which is scarcely 10 feet distant. Biotite and probably diopside are present but appear to have been decomposed, probably by ore-depositing solutions after the contact effects were completed. A specimen (95) collected on the surface south of the Minnie Moore shaft, 10 feet distant from the diorite, is composed largely of radiating crystals of diopside in a groundmass of granular diopside and a little quartz.

No other part of the mine workings offers so good an opportunity to interpret the succession of sediments as that described above. The 500-foot footwall crosscut from the Allen shaft explores a section that is about 135 feet thick. The upper 80 feet is largely in fine-grained gray diopside rock with a little calcite, and the lower 55 feet is in dense gray argillite. The footwall crosscut from the bottom of the Tweed raise on the 280-foot level passes through the same rocks. A rock at the top of the Tweed raise in the Relief Tunnel which appears to the naked eye to be a gray calcareous sandstone, is shown in thin section (127) to be made up of diopside grains, 95 per cent, and a trace of quartz. Although collected within 20 feet of the diorite contact it contains no feldspar or garnet. A similar rock (150) from nearly the same stratigraphic position, collected under an 8-foot sill 460 feet from the top of the Allen shaft, contains diopside, 90 per cent; garnet, 3 per cent; calcite, 2 per cent; carbon flakes, 2 per cent; quartz and pyrites, traces.

As far as the sedimentary rocks in the upper part of the mine have been studied closely, only three units can be separated—a lower unit of dense hard black argillite 200 feet thick, a middle unit of gray diopside rock 200 feet thick, and an upper unit of alternating fine gray quartzite and diopside rock 400 feet thick. The vein zone near the Minnie shaft closely follows the base of the upper unit. Unfortunately, in the region west of the Relief shaft, it is impossible to discriminate confidently between the middle and the upper units. In the 280 and 475 foot crosscuts from the Allen shaft the lenses of siderite, which appear to be the western extension of the Minnie Moore ore zone, seem to lie about 200 feet lower in the section.

In recent explorations for ore below the Minnie fault it has been difficult if not impossible to interpret the displacement of the faults there encountered, because there is some lack of distinctive beds and because the beds can not be definitely correlated with the beds above the Minnie fault. Lenses of siderite have been struck that closely resemble those in the upper ore zone, but as their stratigraphic position can not be confirmed, doubt remains whether they are the faulted extensions of the upper shoots.

Mr. R. T. Walker, geologist of the United States Smelting, Refining & Mining Co., has kindly permitted the publication of detailed geologic maps and cross sections of these new workings. (See pls. 28–30.) He attempted to record the distribution of five classes of sedimentary rock, but for present purposes it seems best to reduce these to two, argillite and calcareous rocks, some of which are largely altered to diopside.

The foregoing descriptions show that the rocks in the zone explored by the mine workings were considerably altered by the intrusion of the diorite. The alteration appears to have been accomplished by a recombination of the substances already present in the rock without the introduction of much new material. Apparently the minerals that were formed depend largely upon local variations of the content of silica, magnesia, and lime. The degree of alteration varies almost inversely with the distance from the contact, those nearest the contact being most altered.

Intrusive rocks.—There are three groups of intrusive rocks in the Minnie Moore mine—(1) the principal intrusive mass of diorite and related dikes of quartz monzonite; (2) thin dikes of fine-grained dark rocks that were undoubtedly intruded before the ore minerals were deposited; (3) thin dikes of fine-grained dark rocks that assuredly were intruded after the ore minerals were deposited.

The principal mass of diorite was first encountered on the new 900-foot level west and lower levels, where the contact with the sediments dips 35°–40° S. Later it was explored on the Relief 400-foot level and 800-foot level west. Recent work, since 1923, has explored the contact on the 800, 900, 1,100, and 1,150 foot levels below the Minnie fault. Explorations above the Minnie fault indicated that the form of the surface of contact with the sediments was very simple, but the deeper work has shown that it is locally very irregular. This change is unfortunate, as it hampers confident use of the surface in solving the complicated faulting. The great inward bulge in the contact explored near the Boericke winze is probably largely due to postmineral faulting rather than to original form. Generally a thin gouge separates the diorite from the sediments, but in many places, such as the hanging wall crosscut on the 1,000-foot level, the rocks do not separate readily but merge so that the precise limits can not be drawn.

In the western part of the mine there is a dike that outwardly resembles the diorite but differs in that it contains microcline and no hornblende. This dike is especially well shown in the Tweed raise and Allen shaft. It is properly called quartz monzonite and was probably intruded later than the diorite. In the Tweed raise it is 30 to 48 inches thick, and there is 12 feet of shaly material between it and the main contact. In the Allen shaft the dike is 4 feet thick. In the 565-foot hanging-wall crosscut south from the Allen shaft there are two similar dikes that range from 8 to 20 inches in thickness.

From his studies of the deeper levels of the mine during 1904 W. P. Jenney [8] concluded that siderite and galena replaced dike material over a large area. He collected many specimens, which he sent to Columbia University and which the writer has been able to examine. One of the specimens collected from the 1,000-foot level west certainly confirms this conclusion. The dike rock is dark olive-green and fine grained and is locally replaced by siderite. On the other hand, during the writer's examination dikes of fine-grained dark rock parallel to the vein zone were found in only four localities, and though the relations at two localities were inconclusive (565-foot level west from Allen shaft and Relief tunnel 100 feet from entrance), at the other two (Relief winze and 300-foot level east of the Relief

[8] MS. submitted to the writer.

shaft, fig. 17) the dike appeared to be later than the siderite which inclosed it. In the locality shown in Figure 17 the dike cut a lens of siderite obliquely and was overlain by a veinlet of galena in the siderite. Here it appears that the dike was intruded after the vein of siderite was deposited but was cut by a bedding-plane fault similar to that which overlies the vein. The relative age of the galena is obscure. None of these rocks have been examined in thin section.

The only dike that occupies a northward-dipping fault which displaces a vein in this mine is found on the 360-foot level northeast, 38 feet below the top of the Singleterry raise. The dike is 44 inches thick, trends N. 70° W., and dips 45° NE. Along it the Singleterry vein is dropped 10 feet. It may be noted that this fault is similar in strike, dip, and displacement to that against which the Minnie Moore ore shoot ended in the lower levels. A thin section of the rock shows a few coarse crystals of augite in a groundmass composed of minute blades of plagioclase, augite, biotite, and a chloritized mineral. The rock may be considered an augite lamprophyre. The

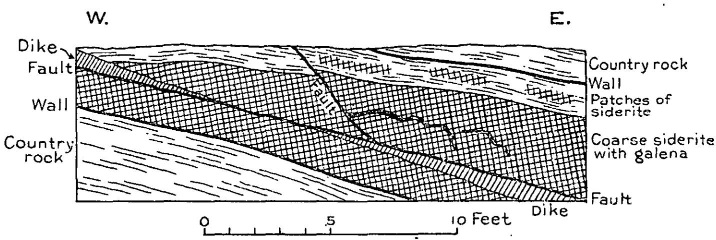
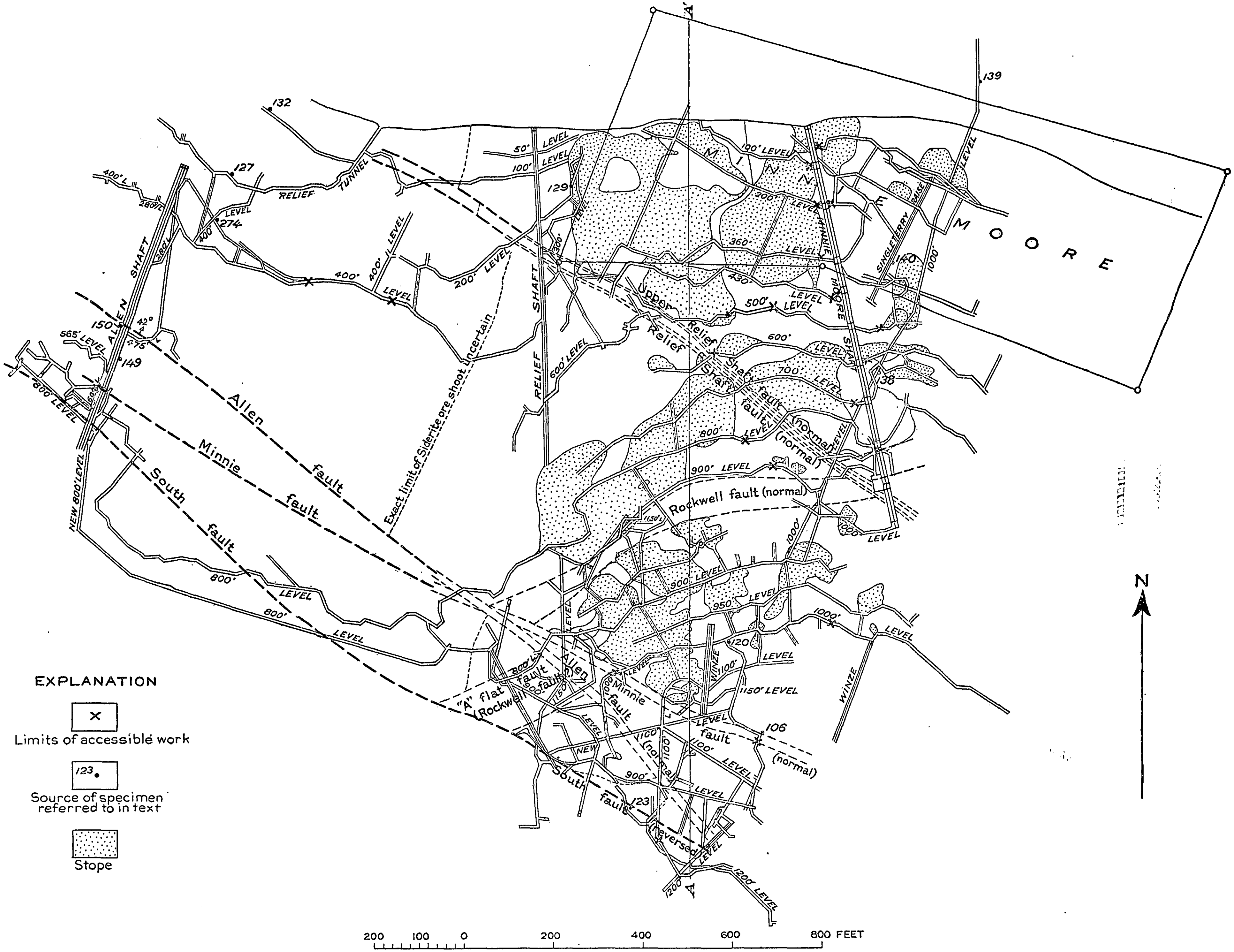


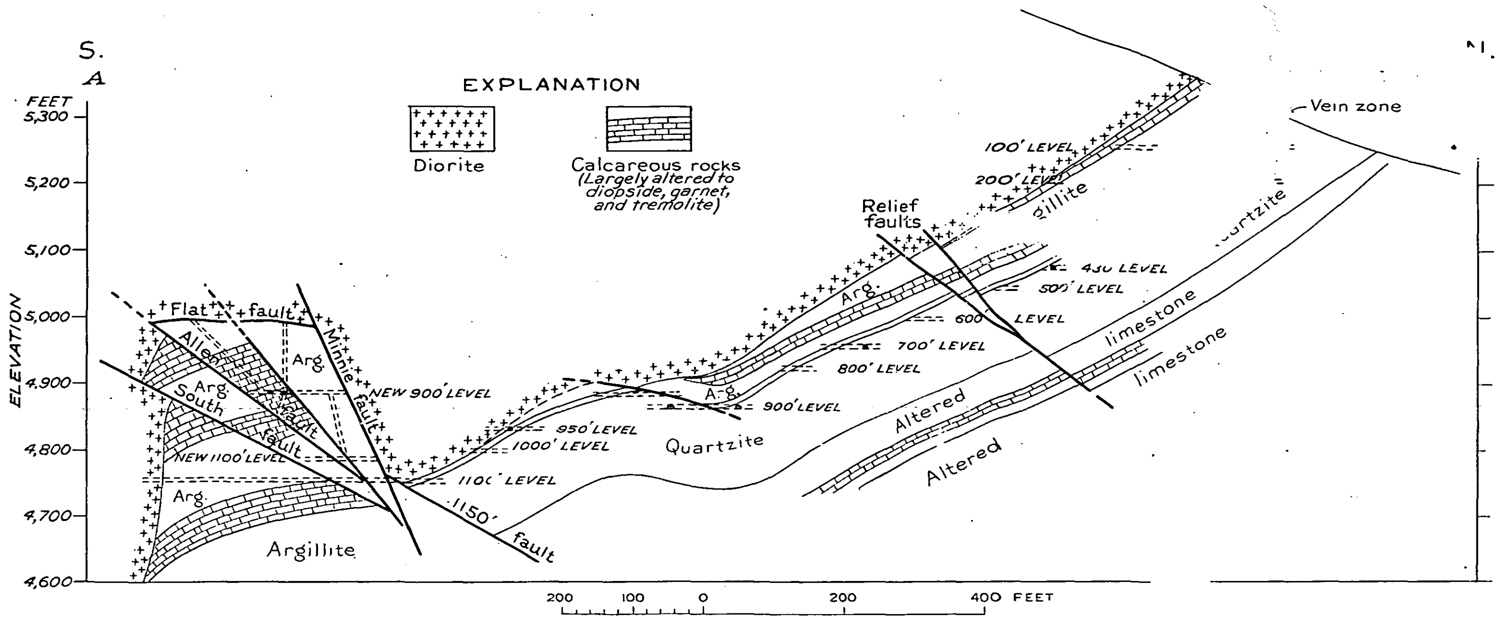
FIGURE 17.—Sketch showing Minnie Moore vein exposed along 300-foot level east of Relief shaft

texture is coarser than that of the dikes in the vein zone. There is no room to doubt that this dike is younger than the Singleterry vein, and it is probably younger than any of the other dikes. The dike produced little change in the near-by rocks or vein materials.

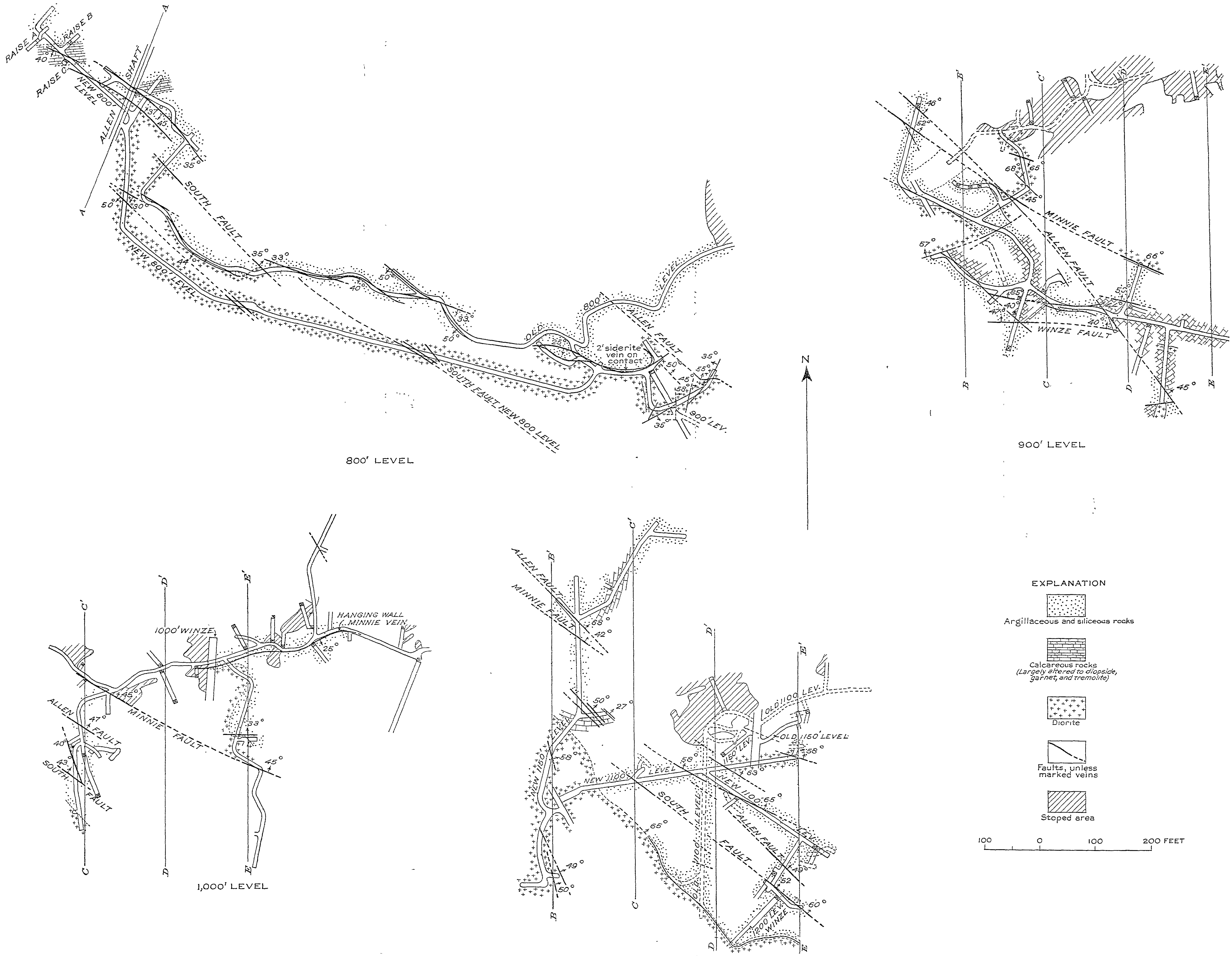
Structure of the beds.—In a general way the beds in the Minnie Moore mine strike northwest and dip gently southwest; locally, there is considerable range in strike and dip. In the eastern part of the mine the trend of the levels, each of which is arc-shaped and concave southward, conforms generally with the strike of the beds. As the deeper mine workings are near the contact with the diorite, which here has the form of a large protuberance from a generally smooth and simple surface, the trend may be partly due to this feature. Farther west, in the Relief and Allen shafts, the beds turn from west to northwest again. The accessible exposures indicate that some of the beds near the diorite contact in the eastern portion of the mine, a part of those which make up the fourth or uppermost unit, end westward against the contact.



MAP OF THE UNDERGROUND WORKINGS OF THE MINNIE MOORE MINE

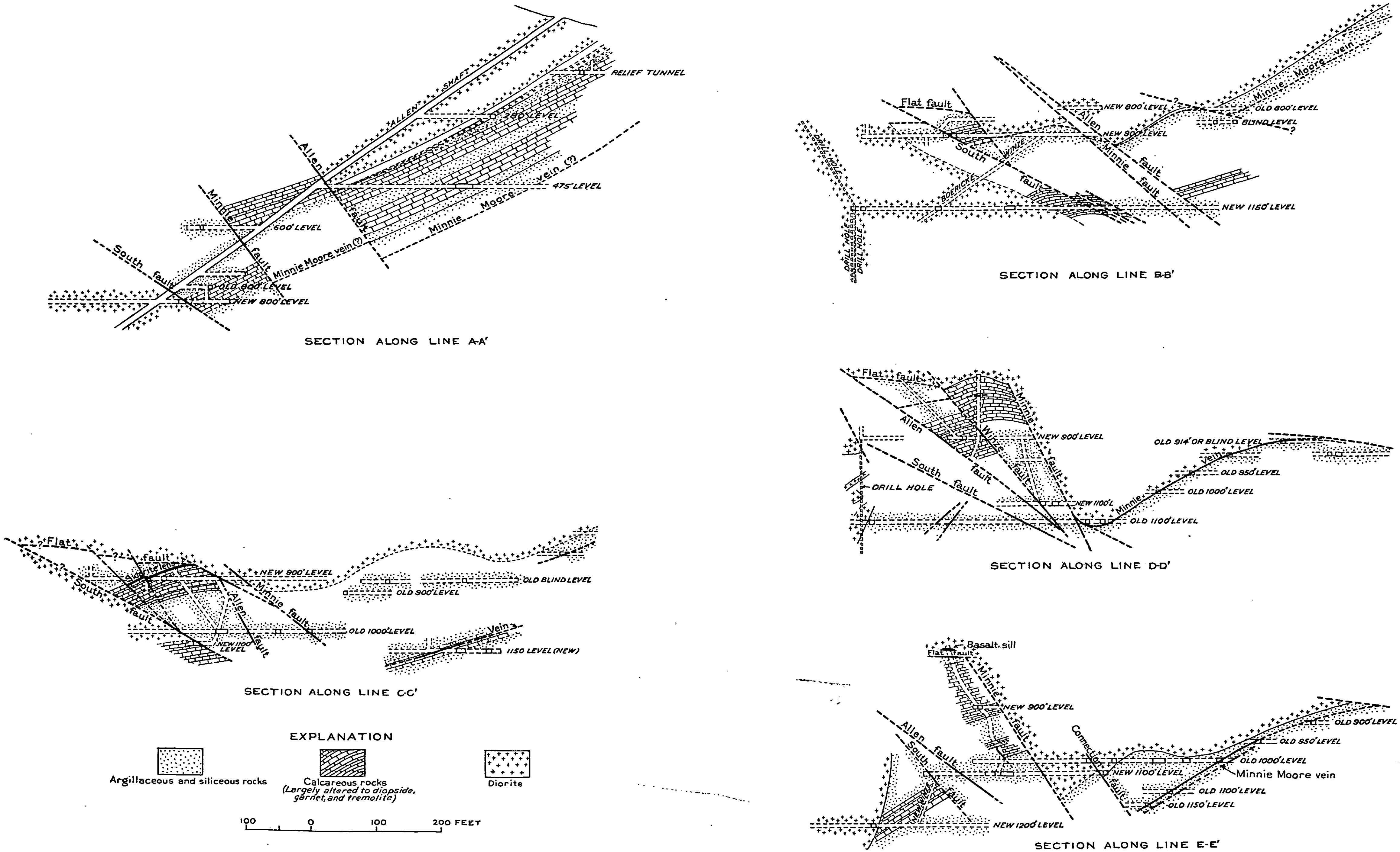


GEOLOGIC CROSS SECTION OF THE MINNIE MOORE MINE



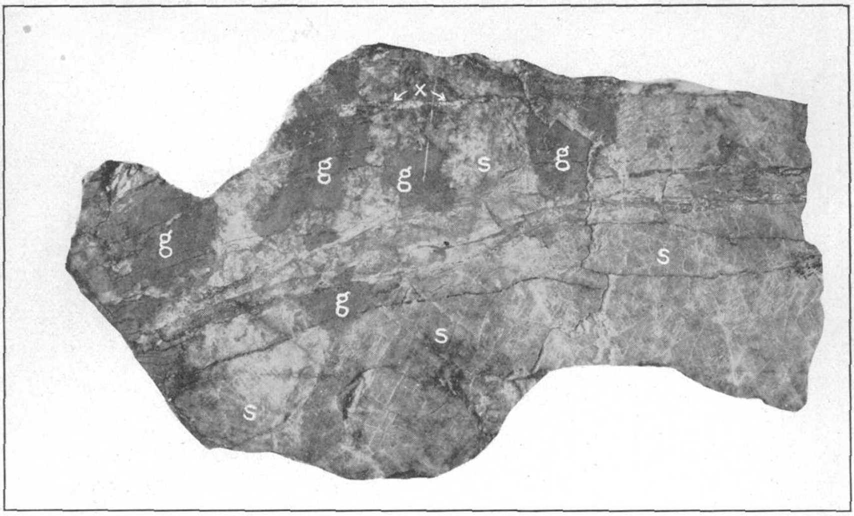
DETAILED GEOLOGIC MAPS OF LOWER WORKINGS OF THE MINNIE MOORE MINE

Geology by R. T. Walker.



DETAILED GEOLOGIC CROSS SECTIONS OF LOWER WORKINGS OF THE MINNIE MOORE MINE

Geology by R. T. Walker.

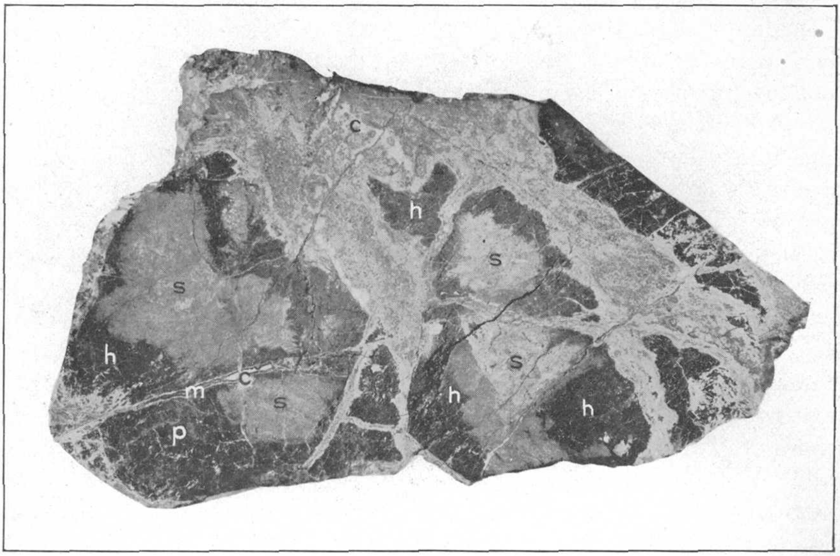


A. SPECIMEN OF ORE FROM THE 300-FOOT LEVEL EAST, RELIEF SHAFT

s, Siderite; g, galena; x, quartz veinlet. Natural size.

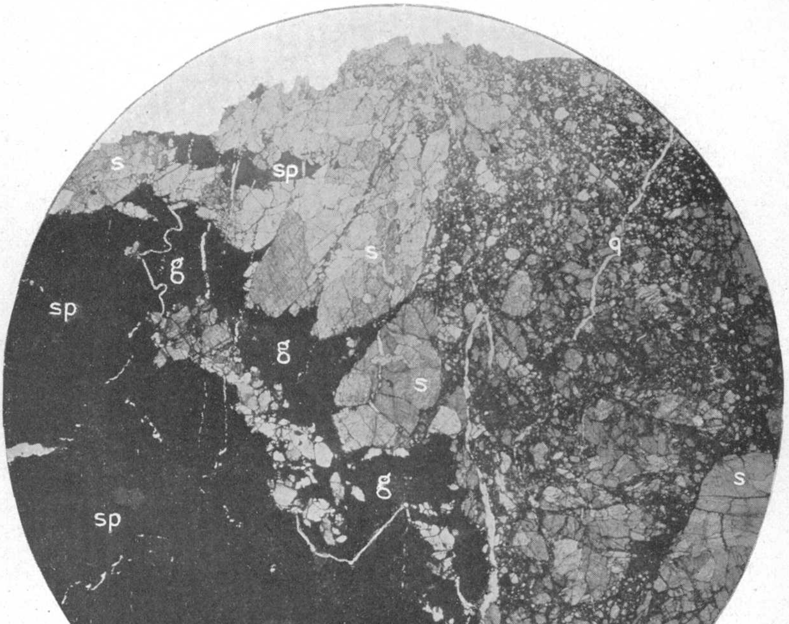
B. QUARTZ-BEARING SIDERITE ROCK, RELIEF TUNNEL

s, Siderite; q, quartz. Enlarged about 26 diameters.



A. SPECIMEN OF SIDERITE AND HISINGERITE, 470-FOOT LEVEL, ALLEN SHAFT

s, Siderite; h, hisingerite; m, marcasite; c, calcite. Natural size.



B. THIN SECTION OF ORE FROM THE 200-FOOT LEVEL EAST, RELIEF SHAFT

s, Siderite; sp, sphalerite; g, galena; q, quartz. Enlarged about 26 diameters.

In depth much the same situation exists. As shown in Plate 28, the dip in the deeper northern workings, well shown on the 1,000-foot level footwall crosscut, increases progressively southward from 10° to about 30°, then decreases to 0, then increases to 40° again. The folds thus indicated in the beds have the effect of bringing progressively lower beds against the deeper parts of the diorite contact. These relations accord with those observed elsewhere farther north and show that the surface of contact of the diorite with the sediments cuts across the bedding.

Minnie Moore vein.—The distribution of mined material in the Minnie Moore vein is shown by the stopes mapped on Plate 27. These stopes indicate a shoot about 900 feet in stope length and 1,500 feet in pitch length measured on the surface of the vein to the point where it was cut off by the Minnie fault. The stopes commonly range from 3 to 6 feet in width but locally attain 12 to 15 feet. The pitch of the shoot almost coincides with the direction of dip. In detail, the shoot may be considered as made up of three parts separated by barren areas, each part being that exploited during one of the successive campaigns of operation. Practically every specimen of galena-bearing material has been removed from this shoot, and most of the stopes above the 1,000-foot level were caved at the time of the writer's examination in 1910, so that some conclusions concerning the relations of the ore minerals can not be stated with great assurance.

The exposures in the accessible parts of the mine indicate that there was a persistent hanging wall above the ore, which limited the zone in which lenses of ore occurred. Throughout the mine the lenses broke freely from adjacent country rock. In a broad way, the hanging wall coincides with the bedding of the sediments in the productive area; locally, in the productive area and along the western edge of the shoot, the wall departs from the bedding in both strike and dip. On the 100 and 200-foot levels, east and west from the Relief shaft, there is a persistent hanging wall over a lens of siderite, but the strike differs as much as 70° from the local bedding. In the Minnie Moore shaft, which closely follows the hanging wall over the ore shoot as far as the 900-foot level, the hanging wall departs from the local dip of the beds as much as 20°. The discordance between the hanging wall and the bedding is also shown by slight local differences in the character of the rocks on the walls. Above the old 900-foot level the average strike of the hanging wall is about due west, but on the western border and lower levels it turns to S. 60° W. The average dip above the old 900-foot level is about 29° S., but south of that level the wall and underlying ore become flatter and then below the new 900-foot level dip south again at an average of 39°. (See pl. 28.)

As so much of the stoped ground is inaccessible, it has not been possible to establish a close relation between the local distribution of ore and the character of the sediments. When the mine was revisited in 1913, after the wall rocks had been closely studied, the conviction was reached that there may have been a close relation between local shoots of ore and the coarse sediments. The ore shoot occurs near the base of a zone of coarse altered sediments that is underlain by very dense fine-grained argillite.

Toward the west on the upper levels, the hanging wall was cut off by a zone of fracturing that trends north and dips west (100-foot level, Relief shaft), and although walls resembling the main hanging wall were met west of this zone, in the workings of the Relief tunnel and Allen shaft, there is no assurance that these are actually parts of the main hanging wall.

On the surface the hanging wall was 400 feet normally below the diorite contact, but below the 900-foot level the wall merged with the contact, so that in the lower 150 feet of the shoot the ore lay against the diorite.

The hanging wall is clearly a fracture along which there has been movement. On such a fracture, which in part follows the bedding and in part cuts it obliquely, the overlying block must have moved relatively upward rather than downward, and the movement is thus analogous to that encountered in thrust faulting. Probably it occurred during the folding that preceded intrusion of the diorite and granite.

Mineralogy.—The number of minerals in the ore is small, and their relations are rather simple. Galena is the principal sulphide; sphalerite is less abundant but apparently persistently present. The several specimens of galena-bearing material that have been polished and examined carefully contain a little tetrahedrite; probably it was uniformly present throughout the mine, for most of the shipments showed 0.3 to 0.4 per cent copper. Most of the galena is finely crystalline, so that the fracture resembles that of steel. In some of the upper parts of the mine cleavage cubes of galena broken from large masses attained an inch or more in diameter but showed a peculiar lamellar twinning, which has been studied by Cross.[9] The relation of the galena to the adjacent minerals, as well as to those embedded in it, indicates that the finely crystalline texture, as well as lamellar twining, are due to pressure after deposition. Chalcopyrite is also present here and there but much less commonly than

[9] Cross, Whitman, Note on slipping planes and lamellar twinning in galena: Colorado Sci. Soc. Proc., vol. 2, pp. 171–174, 1888.

tetrahedrite. Pyrite is present but is not abundant. A similar sulphide that is associated with hisingerite has been locally identified as marcasite. The writer identified needles of stibnite in hisingerite on fractures in the ore from the 1,000-foot level west.

According to local report, the high-grade lead ore from this mine contained about 2 ounces of silver to the ton for each per cent of lead, which was more than that in most of the lead deposits of this region. Low-grade material commonly contained more silver, as much as 3 or 4 ounces to the ton for each per cent of lead. Probably the silver was a constituent in the tetrahedrite. The gold content of the ore was consistently low, rarely more than 0.03 or 0.04 ounce to the ton.

Among the gangue minerals siderite is the most common. According to local report, no galena was found in the Minnie Moore vein that was not intimately associated with siderite. In the ore shoot the siderite is as a rule coarsely crystalline, but with increasing distance from the shoot along the strike the siderite becomes progressively finer grained. In the footwall drifts from the Allen shaft there are lenses of moderately crystalline siderite 3 to 5 feet thick, and the near-by country rock is locally sideritized, but no galena is present. The character of the material from the ore shoot is shown in Plates 31, *A*, and 32, *B*. By analysis, this siderite contains ferrous oxide, 42.19 per cent; manganous oxide, 13.50 per cent; lime, 0.92 per cent; insoluble matter, 4.39 per cent. A thin section of fine-grained quartz-bearing siderite is shown in Plate 31, *B*. An analysis of similar material collected from a deeper zone on the 470-foot level of the Allen shaft shows ferrous oxide, 21.17 per cent; manganous oxide, 6.05 per cent; lime, 15.38 per cent; insoluble matter, 26.03 per cent. In these analyses the relation of iron carbonate to manganese carbonate is nearly the same. In the siderite from the ore shoot the lime was less than 1 per cent, but in that remote from the shoot it was 15.38 per cent but probably lower than the original diopside rock from which it was formed. The unmilled second-class ore commonly contained 18 to 27 per cent of iron, which was undoubtedly largely present as siderite. Those specimens of siderite from the ore shoot that have been carefully studied after polishing and etching consistently show much brecciation. (See pl. 32, *B*.) In some of the specimens the galena clearly has been introduced after such brecciation, although it is fine grained itself, as if by late crushing. The cement of the crushed siderite is siderite also.

Quartz is present in the vein zone as crystals in the siderite and on its borders, as locally silicified country rock, and as veinlets that cut the siderite and galena. (See pl. 32, *B*.) In the massive siderite it is not conspicuous, but the persistent presence of 8 to 35 per cent of insoluble material in the shipments indicates that it is rather uniformly present.

The minerals described above are considered to have been deposited in the vein zone after the intrusion of the diorite and granite and the related monzonite dikes. They represent the primary mineralization in the vein, before a considerable thickness of overlying rock was removed by erosion. The minerals described below are considered to be later deposits.

Many parts of the Minnie Moore mine, especially the 1,000 and 1,100 foot levels west, the 475-foot level footwall crosscut from the Allen shaft, and drifts from the Relief tunnel, contain hisingerite, a hydrous ferric silicate, which coats fractured masses of siderite, and both minerals are cut by veins of marcasite and calcite. (See pl. 32, *A*.) On the 1,000-foot level west needles of stibnite occur in hisingerite along fractures. The zeolite stilbite was found on fractures at three localities in the mine—the drift on the Grey Copper vein eastward from the 1,000-foot level footwall crosscut, the 565-foot level hanging-wall crosscut, and the 565-foot level drift west from the Allen shaft.

There is no record of the extent of oxidized minerals in the vein. Galena is recorded in the float that led to the discovery of the deposit. Traces of limonite were found on the 200-foot level east from the Relief shaft, but the galena is unaltered. Probably some carbonate and sulphate of lead were present in the workings above the 200-foot level.

Paragenesis of the minerals.—The general succession of vein minerals established by this investigation is as follows: (1) Siderite and quartz, (2) sphalerite and tetrahedrite, (3) galena, (4) quartz. The succession siderite, sphalerite, and galena appears to be invariable; quartz has certainly been deposited at several stages and possibly throughout the period of vein deposition. The siderite has uniformly replaced the country rock, in which diopside is generally the most abundant mineral, although tremolite, garnet, and wollastonite are also common. Generally sphalerite has replaced the siderite, but here and there it may have cemented siderite breccia. Undoubtedly galena also has generally replaced siderite, but more commonly than sphalerite it also cements siderite breccia. (See pl. 32, *B*.) The brecciation of the minerals previously mentioned indicates movement along the walls throughout the period of ore deposition. There is good record of widespread crushing of the siderite and sphalerite before galena was deposited, as well as the later shearing of the galena which produced the characteristic texture.

The relations of the fine-grained dikes to mineralization may also be summarized. At one place a dike is sideritized; at another a similar dike probably followed deposition of siderite but is itself sheared by movement in the vein parallel to the walls. These relations may indicate two periods of dike intrusion or a single period of dike intrusion in a zone where siderite was being deposited more or less continuously over a long period. To the writer the evidence favors the first conception. There appear to have been two periods of dike intrusion—(1) fine-grained dikes in the vein zone early in the period of ore deposition and (2) coarser dikes in the vein zone and in crosscutting faults after ore deposition.

The alteration of siderite to hisingerite and the associated deposition of marcasite, stibnite, and calcite are assigned to the period of late Tertiary igneous activity. It is concluded that here, as elsewhere in the region, the same waters that formed hisingerite in contact with siderite deposited zeolites remote from the vein zone. Hisingerite is not an uncommon mineral in the zone of oxidation of iron deposits, but so far as the writer can learn this is the first record of its occurrence under circumstances that indicate its hypogene origin. It is interesting that hisingerite has formed extensively here, in association with marcasite and stibnite, at least 500 feet vertically below any other evidence of surface oxidation. Chemically it indicates also that a ferrous carbonate is altered to a hydrous ferric silicate, which in turn is followed by a ferrous sulphide marcasite.[10]

Contact vein.—The drift along the diorite contact on the 280-foot level, Allen shaft, explores several shoots of sulphide minerals. The most extensive, known as the Contact vein, shows for 300 feet. This vein has a maximum width of 8 feet, of which 4 feet is occupied largely by sulphides, about 50 per cent pyrite and 20 per cent sphalerite; galena is present in traces only. The gangue is largely quartz, and if siderite is present it is inconspicuous. The lens thins to 6 inches at the west face of the drift and at the east end near the Tweed raise. The 400-foot level west, Relief shaft, follows the contact for 600 feet but reveals no continuation of this vein. The downward extension of this vein contained a little galena on the 470-foot crosscut, Allen shaft. In contrast with the Minnie Moore vein, this part of the vein contained less than 1 ounce of silver to the ton for each per cent of lead.

Where the footwall of the Contact vein is explored from the 475 and 280 foot levels of the Allen shaft, as well as the 100-foot level west from the Relief tunnel, the rocks have been considerably sideritized locally, and in several places there are veins of siderite that is rather coarsely crystalline. None of these veins show any galena, however.

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[10] Hewett, D. F., and Schaller, W. T., Hisingerite from Blaine County, Idaho: Am. Jour. Sci., 5th ser., vol. 10, pp. 29–38, 1925. See also Ross, C. P.; The Vienna district, Blaine County: Idaho Bur. Mines and Geology Pamphlet 21, pp. 11, 14, 1927.

Singleterry vein.—The Singleterry vein was first exposed at the surface in the early days. Later it was cut on the 1,000-foot level footwall crosscut; a raise was driven upward on the vein to the 360-foot level, and a winze was sunk 90 feet. In 1906 ore that is reported to have yielded $31,000 net smelter returns was stoped over an area 30 by 80 feet. For most of its length the vein is from 1 to 3 feet thick, but sulphide minerals are largely confined to a zone 2 to 12 inches thick. A carload of first-class ore from the stope contained 46 per cent of lead, 5.5 per cent of zinc, 4.3 per cent of iron, which was probably present largely as pyrite rather than siderite, and 61 ounces of silver to the ton. Concentrate from similar but lower-grade material contained 15 per cent of lead, 8.6 per cent of zinc, 15.6 per cent of iron, and 30 ounces of silver to the ton.

The vein is particularly interesting because, unlike the Minnie Moore, it lies between two walls that dip 52° S. and hence cut the bedding throughout. In its explored pitch length of 500 feet it passes successively from dense siliceous shale on the 360-foot level through gray calcareous sandstone (diopside rock?) in the vicinity of the stope above the 1,000-foot level into dense hornstone below the 1,000-foot level. In the dense siliceous rocks sulphide minerals occur either as narrow veinlets parallel to the walls or as narrow lenses oblique to the walls and roughly parallel to the bedding, which dips about 30° SW. Where the country rock is coarse grained, the lenses of sulphide and gangue minerals replace it and attain the maximum width, but where the country rock is fine grained and hard, the minerals tend to develop crustification.

Polished sections of the sulphide veinlets show a border zone of pyrite, then sphalerite with tetrahedrite, and a central zone of galena and quartz. The galena is fine grained and contains rows of angular fragments of tetrahedrite and sphalerite. The conclusion is reached that the vein material has been crushed and sheared after deposition.

Gray Copper vein.—At a point 250 feet horizontally north of the Singleterry vein the Gray Copper vein is cut by the 1,000-foot level crosscut. It contains pyrite, sphalerite, and quartz and ranges in width from 3 to 10 inches. Like the Singleterry vein it fills a fracture that cuts across the bedding of the lowest zone of hornstone.

Faults.—When the writer concluded field work in this region in 1913, observations in the Minnie Moore mine were largely confined to the old workings above the Minnie fault in the lower mine levels, the Relief and Allen shafts. Below the fault only the 1,100-foot level hanging-wall crosscut was open. From the study of these workings the conclusions were reached that the Minnie fault, as well as others in the upper workings, was postmineral and that its principal component was horizontal rather than vertical. In revisiting the mine in 1926, the writer was fortunate in being able to examine the work done since 1923 with R. T. Walker, geologist, of Salt Lake City, who had recently made the geologic maps and cross sections here reproduced as Plates 29 and 30. Mr. Walker's work showed that there were more faults in the lower workings than those indicated above and that their history was more complex than had been suspected. He also had concluded that the Minnie fault was postmineral. The following summary, although written by the author of this report, contains the conclusions of Mr. Walker, because the most essential observations were confirmed by joint study. The author acknowledges with gratitude the cordial spirit of cooperation shown by Mr. Walker and his permission to reproduce the maps.

The only premineral fractures recognized in the mine, apart from the surface of contact of the diorite and sediments, are those along which either galena or siderite has been deposited. Some of these fractures nearly follow the bedding (Minnie Moore), and others cut the bedding, slightly in plan but considerably in dip (Singleterry and Gray Copper veins). All fractures except those containing galena or siderite appear to be postmineral.

The postmineral fractures may be considered in three groups, distinguished principally by their relations at intersections. In areas of complicated faulting this criterion, if unsupported by other evidence, must be used cautiously, but it appears to be a safe guide in this mine. Most of those in each group have similar strike and dip. The earliest group is represented by a fault encountered in the workings above the new 900-foot level from the Boericke winze. (See sections B–B′, C–C′, D–D′, pl. 30.) Although broken by faults of the second group, it seems to have been a persistent surface of southwest strike and gentle northwest dip. It cuts lenses of siderite and contains large round and small angular fragments of coarse siderite. Apparently the overlying block moved northward down the dip, possibly as much as 200 feet. There is a possibility that the Minnie Moore vein ended against this fault or a similar one on the old 900-foot level, where the ore shoot was lost in 1889.

The second group of faults trends northwest and dips northeast. Near-by minor faults with parallel strike and opposed dip may belong to a complementary set formed at the same time. The outstanding fault of this group, the Minnie, is that which cut off the ore shoot on the 900 and 1,000 foot levels and has been confidently traced westward to the Allen shaft and downward into the recent workings. With it are associated the Allen and South faults of similar strike and dip. The two faults observed in the Relief shaft near the 300-foot level and in the Relief winze belong to this group. The fault that contains a basic dike near the top of the Singleterry raise is probably contemporaneous. Striae and grooves as much as 12 inches deep on the Minnie fault plunge about 30° SE. and indicate that the strike component is greater than the dip. The actual movement along the faults of this group is difficult to determine owing on the one hand to the lack of distinctive beds in the section and on the other to proved irregularities in the form of the diorite contact. If the apparent offset of the stopes along the Relief faults is taken as a guide, the northern or upper blocks have moved northwest with reference to the lower blocks. (See pl. 27.)

The most plausible explanation of the great block of sediments included in the inward bulge in the general diorite contact below the Minnie fault demands considerable horizontal movement on the limiting faults (Minnie and South) but a movement of slightly different pitch. The principal objection to the hypothesis of the general movement indicated above lies in its regional setting. Along all

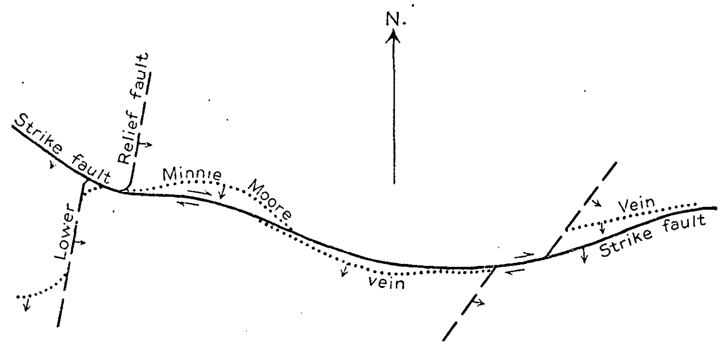

FIGURE 18.—Sketch showing relations of two faults to Minnie Moore vein on lowest level east of Relief winze. Minnie Moore vein (dotted) represented by lens of siderite, displaced first by Lower Relief fault and second by a strike fault. Geology by R. T. Walker

the northwest faults on both sides of the Wood River Valley (see pl. 9 and fig. 18) the upper blocks seem to have moved down the dip toward the valley. However, the recent underground work in searching for the downward extension of the Minnie ore shoot, though based upon this hypothesis, seems to have proved it incorrect. If, as stated above, the lead ore shoot merges westward with thick lenses of massive siderite, such as that encountered on the new 900-foot level, the only area that may now contain a downward extension of the ore shoot lies east of the recent work on the 1,100-foot level and below the South fault.

The third and youngest group of postmineral faults is represented by a fault almost parallel to the Minnie Moore vein in the workings near the Relief shaft. The relations of this fault, as exposed on the lowest level east of the Relief winze, are shown in Figure 18. This sketch, taken from observations by R. T. Walker, confirmed by the writer, shows that the vein was first broken by the lower Relief fault and that later both were displaced by a fault almost parallel to the vein. Like the second group of faults, the horizontal shift along it is appreciable. A similar fault is shown on the higher levels, such as the 300-foot level east of the Relief shaft. At this place the fault has broken the postmineral basic dike that roughly follows the vein.

The structural events that are recorded in the Minnie Moore mine may be summarized as follows:

1. Development of joints or persistent fractures.
2. Intrusion of diorite and granite.
3. Intrusion of fine basic dikes.
4. Ore deposition.
5. Flat faults of first group.
6. Faults of the Minnie group.
7. Intrusion of postmineral basic dikes.
8. Strike faults roughly parallel to the Minnie Moore vein.

QUEEN OF THE HILLS MINE

Records show that the Queen of the Hills mine shipped some ore in 1881, but the quantity and grade are not stated.[11] In 1884, according to reports, the mine contained 3,000 feet of tunnels and drifts and was equipped with a mill capable of producing 10 tons of concentrate daily from 40 tons of crude ore.[12] According to W. P. Blake,[13] who examined the mine in 1890, there was considerable exploration from the fifth level of the inclined shaft. He records the following shipments:

Shipments from Queen of the Hills mine

Year	Ore	Gross value	Freight, smelting, and other charges	Net value
	Tons			
1884 [a]	1,032	$153,714	$61,820	$91,894
1885	3,602	303,516	72,730	230,786
1886	3,128	390,321	94,848	295,473
1887	2,361	270,366	77,332	193,034
1888	1,067	127,691	35,733	91,958
1890 [a]	187	[b] 20,000	7,000	13,000
	11,377	1,265,608	349,463	916,145

[a] Incomplete. [b] Estimated.

In 1892 explorations ceased and the workings filled with water. During 1903 and 1904 the main tunnel was extended 300 feet under an adjoining claim, but no ore was mined. The mine was reopened in 1913, and the shaft was pumped clear of water in 1915. The

[11] Report of the Director of the Mint for 1881, p. 184, 1882.
[12] Idem, 1884, p. 258. 1885.
[13] MS. report submitted to writer by I. E. Rockwell.

workings below the Lusk tunnel were not unwatered when the writer examined the mine in October, 1913.

Early in the history of the mine a mill was erected below the mouth of the Lusk tunnel. In 1907 a new mill, using the Sutton, Steele & Steele system of dry concentration, was built to treat the tailings dump.

As shown in Figure 19, the Queen of the Hills mine has two tunnels—the Moulton tunnel, 750 feet long and inaccessible in 1913, and the Lusk tunnel, 2,475 feet long, 738 feet from the mouth of which there is an inclined shaft with drifts east and west on the vein at five levels. The shaft has an inclination of 62° and attains a vertical depth of 354 feet. Only the Lusk tunnel and some of the stopes were accessible in 1913.

The Lusk tunnel essentially follows for its entire course a clean wall which trends on the average N. 70° W. and dips about 62° SW. This wall is the hanging wall of the Queen vein. There is no definite footwall, but the shoots appear to have been lenses limited by local fractures that merged with the hanging wall. For most of its distance the Lusk tunnel, as well as many short crosscuts, is in hard black hornstone, a rock which closely resembles that encountered for most of its distance by the 1,000-foot level footwall crosscut of the Minnie Moore mine. Over large areas it is rather massive, and the bedding is obscure. The inner 500 feet of the tunnel is largely in dark carbonaceous shale with some beds of hard hornstone. For 2,000 feet the bedding of this hornstone does not deviate greatly from N. 40°–50° W. and the dip largely ranges from 25° to 35° SW. The shale shows great diversity of strike and dip and is clearly crumpled in a zone overlying the hornstone. The conclusion is clear that the Queen hanging wall cuts across the bedding of the rocks in strike and dip throughout its explored course.

About 280 feet west of the Queen shaft there is a crosscut 105 feet long to a footwall vein 1 to 6 inches wide that has been locally explored by drifts and raises. It contains siderite, pyrite, galena, and sphalerite with traces of tetrahedrite, and like the Queen vein it cuts the bedding of the hornstone at a low angle.

The principal shoot on the Queen vein, the source of practically all the ore shipped, has a stope length of nearly 500 feet and, according to Blake, was made up of a series of lenses of metallic sulphides that commonly ranged from 2 to 4 feet but attained a maximum width of 6 feet. Along the western limit of the present stopes it is largely siderite and quartz, 20 to 30 inches wide. The inner 1,000 feet of the tunnel shows two smaller shoots that contain lenses of siderite, calcite, and quartz with minor galena and sphalerite. The only record of structural conditions on the lower levels is the report by Blake and a statement by I. E. Rockwell that was based on observations made

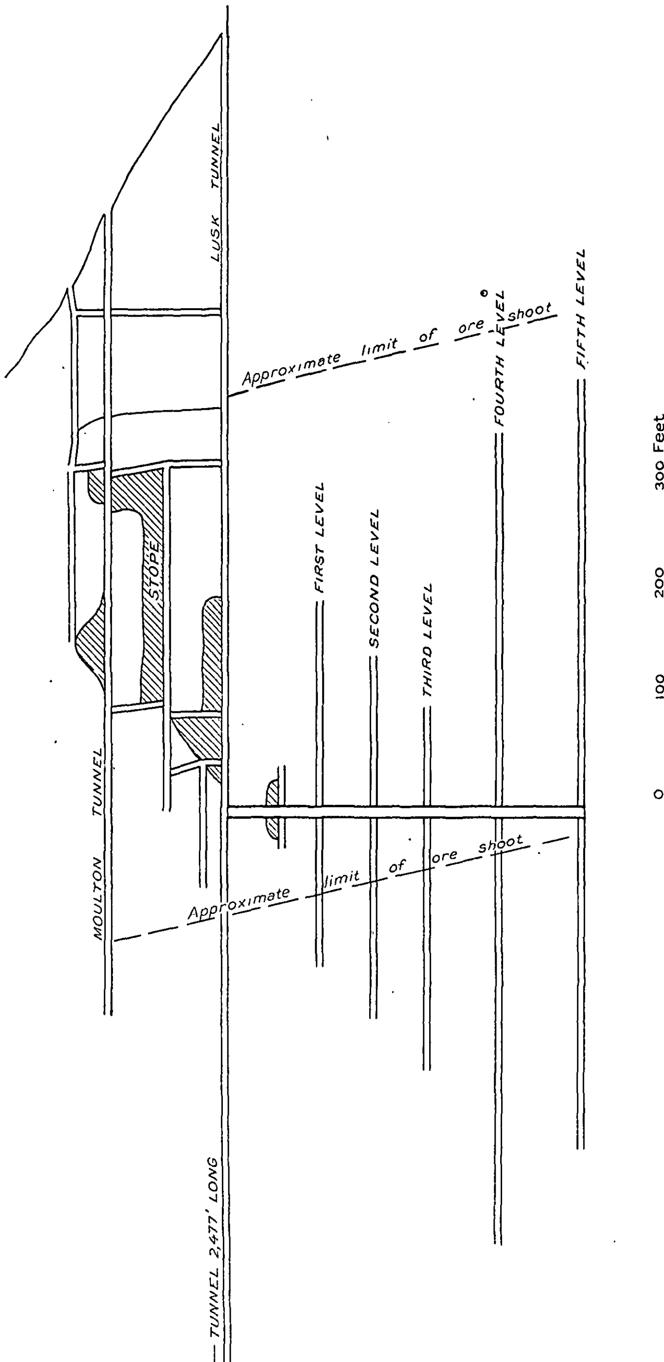

FIGURE 19.—Longitudinal cross section, Queen of the Hills mine

when the shaft was pumped out in 1915. According to Blake, in 1890 the vein was extensively stoped to a depth of 50 feet below level 3, and although lenses of gangue minerals were found on the lower levels they contained less galena. Early explorations on level 5 brought confusion, but later it appeared that the beds, which dipped 40°–50° SW. in the higher levels, had become horizontal below level 4 and then had become steeper again on level 5. Such a fold would correspond closely in depth to the fold in the beds between the Minnie Moore 900 and 1,000 foot levels. It has not been established whether the hanging wall of the Queen vein persisted to level 5. Two veins were explored and locally stoped on this level, but it was never certain which one was the lower extension of the vein worked higher up.

The following statements concerning the ore minerals are based upon an examination of the stopes above the Lusk tunnel and a study of specimens collected on the dump. Quartz is the most abundant gangue mineral, siderite is common, and calcite forms veinlets in the ore as well as in the walls. Dark-brown sphalerite is more abundant than galena, and tetrahedrite is commonly associated with it. Pyrite forms grains in quartz, and a similar sulphide, probably marcasite, forms films on the sphalerite. The masses of sulphides, carbonates, and quartz fill fractures in the hornstone, and no tendency toward replacement was seen. Plate 33 represents a specimen collected from the footwall vein that seems to epitomize the deposition of the minerals in the Queen vein. Angular fragments of hornstone are unreplaced by either gangue or sulphide minerals but are surrounded by a border of siderite. Next to this is a zone of sphalerite with sporadic tetrahedrite, quartz, and minute grains of pyrite. Galena occupies a central zone and locally cements a breccia of the preceding minerals; it is clearly the latest mineral to be deposited except marcasite, which was probably deposited by descending waters during recent weathering. The relations of calcite in the Queen vein were not determined.

The average percentage of lead in the crude ore can only be guessed. Most of the ore was milled, and as the concentrate contained 60 to 65 per cent of lead the crude ore probably contained 15 to 25 per cent.

No igneous rocks were found in the workings of the Queen of the Hills mine.

GOLDEN BELL MINE

The Golden Bell claim lies near the head of Galena Gulch. It is owned by Charles Sheehan, of Bellevue, but from 1911 to 1915 it was operated under lease by the Jewell Princess Patricia Mining Co. During this period 173 tons of ore was shipped; it contained 156 ounces of gold, 182 ounces of silver, and 3,340 pounds of copper.

SPECIMEN OF ORE, QUEEN OF THE HILLS MINE

h, Hornstone country rock; s, siderite; sp, sphalerite; t, tetrahedrite; g, galena. Enlarged 2 diameters.

In 1913 the workings included an upper tunnel, of which the first 78 feet was a crosscut southwest to the vein and the remaining 290 feet a drift northwest along the vein. The drift and some stopes explored a vein of sulphide minerals whose width ranged generally from 10 to 20 inches, although a maximum width of 4 feet between the walls is reported. At one point the vein is cut by a postmineral basic dike that trends N. 70° W. and dips 40° NE. A lower tunnel is also a crosscut southwest and is 645 feet long. The vein is struck at 278 feet within this crosscut and followed northwest 238 feet. Near the crosscut the vein is offset 55 feet north by a fault that trends N. 5° E. and dips 65° W. On this level there are two well-defined walls that trend northwest, dip 40° SW., and are from 4 to 6 feet apart. Within this zone, but commonly next to the foot-wall, occur veins of pyrite, arsenopyrite, quartz, and calcite that commonly range from 3 to 10 inches in width.

On both levels the vein minerals, named in order of abundance, are pyrite, arsenopyrite, and chalcopyrite. These sulphides commonly show zonal deposition along the walls, and the central zone is filled with radiating crystals of quartz and massive calcite. The decomposed diorite between the walls commonly contains disseminated crystals of pyrite, but here and there the rock is replaced by siderite and quartz around irregular patches of pyrite and arsenopyrite. The metal of greatest value is gold, of which the heavy sulphides carry about 0.90 ounce to the ton, but the decomposed diorite contains only from 0.20 to 0.40 ounce.

The sulphide minerals are largely decomposed to iron oxides nearly to the upper tunnel level, and below that level scorodite (hydrous iron arsenate) is abundant. The zeolite laumontite is present on fractures that cut the vein in the lower tunnel.

BELLEVUE KING MINE

The Bellevue King mine is in the diorite on the ridge south of Lee's Gulch, in the N. ½ sec. 3, T. 1 N., R. 18 E. It is owned by Mike Brown, of Bellevue. Although the production is not known, it probably has not exceeded several thousand dollars' worth of silver and copper. Particular interest is attached to the deposit, because here the relation of zeolites and hisingerite to the ore minerals is well shown.

The workings are largely confined to one level, although a winze is sunk 40 feet lower, and a raise with some stopes extends to the surface, 80 feet higher. Only the inner workings near the ore shoot are shown in Figure 20. No rocks other than the local diorite were observed underground. In the workings remote from the shoot the diorite is dark olive-green and apparently quite unaltered. In an area about 100 feet in diameter it is dull brownish green, and the feldspar, mica, and hornblende are considerably altered, probably to sericite and chlorite.

From what could be seen in 1913, only two veins appear to have been found, and most if not all of the material shipped has come from one of them only. This vein has been explored by the 40-foot winze and stopes above. In the winze, within a zone about 5 feet wide, there are at the most five veinlets of siderite that range from

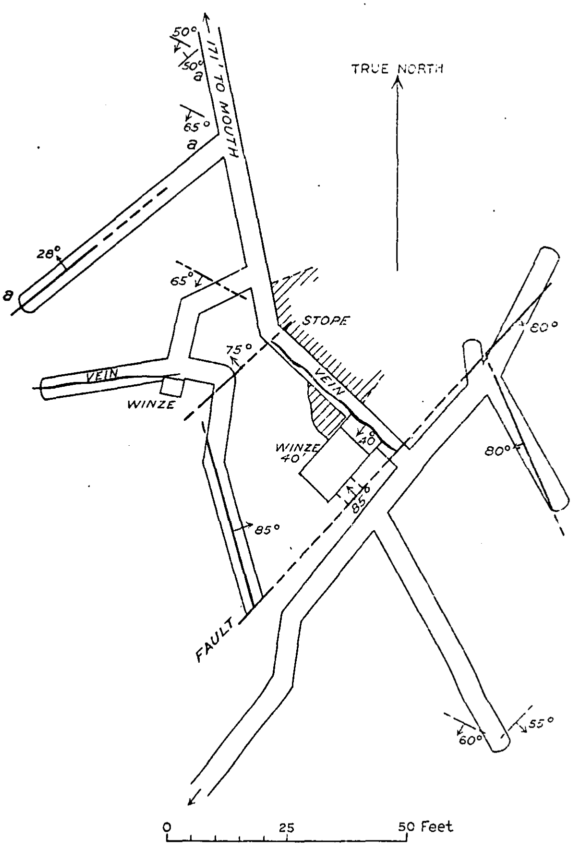

FIGURE 20.—Plan of part of underground workings of Bellevue King mine. *a*, Locality where laumontite is abundant

1 to 5 inches wide. These veinlets locally contain irregular patches of argentiferous tetrahedrite and chalcopyrite. One specimen of this material, assayed by the Boise Chemical Institute, contained 13.6 per cent of copper and 1,184 ounces of silver to the ton. Another vein, which was explored in a drift farther west, ranged from 1 to 4 inches in thickness and contained siderite and disseminated pyrite, arsenopyrite, and chalcopyrite but is reported to contain little silver. Close examination of a number of polished speci-

mens of the sulphide-bearing siderite shows that the siderite is generally coarsely crystalline but locally is much broken into angular fragments and recemented by a similar carbonate; the tetrahedrite locally possesses crystal outlines but generally is irregular in shape, some masses are fractured, and the fractures contain siderite powder; and chalcopyrite is confined to many minute veinlets that cross the tetrahedrite and extend beyond into the siderite, but only rarely is tetrahedrite in contact with siderite.

The conclusions from these observations are that the siderite was the first mineral to be deposited, that it was closely followed by tetrahedrite, and that the development of chalcopyrite followed the crushing of the earlier minerals. Probably all these processes followed in close succession and were accomplished before later alterations, which will be described below, took place.

It should be noted here that the mineral-bearing fissures are not persistent or well marked by walls but are distinctively minor fractures that are limited in strike by much more impressive faults. In fact, thus far, no siderite or copper sulphide minerals have been found southeast of the persistent wall that trends N. 42° E. near the 40-foot winze. Furthermore, this fault displaces all joints and fractures that meet it.

The zeolite laumontite, a hydrous silicate of calcium and aluminum, is abundant in fractures that trend northeast and dip northwest along the tunnel and first drift southwest. None was observed in the vicinity of veins of siderite. On the other hand, in the 40-foot winze the siderite vein is much fractured, and fragments are superficially altered to hisingerite, a hydrous ferric silicate. In places the siderite is cut by veins made up of angular fragments of hisingerite cemented by crusts of quartz and calcite. The spatial distribution of laumontite and hisingerite and their chemical relations to near-by minerals justify the conclusion that the waters which altered ferrous carbonate to hydrous ferric silicate and deposited silica and calcite at one locality were the same that deposited laumontite and calcite at the other localities. The formation of both groups of minerals is attributed to the circulation of hot waters associated with the late Tertiary period of intrusion of postmineral dikes and extrusion of surface flows.[14]

There is no trace of the common products of oxidation by weathering near the ore shoots on the tunnel level.

[14] Hewett, D. F., and Schaller, W. T. Hisingerite from Blaine County, Idaho: Am. Jour. Sci., 5th ser., vol. 10, pp. 29–38, 1925.

QUEEN BESS MINE

The Queen Bess mine lies in the NE. ¼ sec. 27, T. 2 N., R. 18 E., north of the mouth of Mammoth Gulch. It has been worked intermittently in a small way for a number of years. According to local report, it has yielded lead-silver ore that had a gross value of about $60,000. In 1913 there was a lower tunnel, which was caved 60 feet from the entrance. An upper tunnel, 40 feet higher, is 282 feet long to the face. Two other newer and shorter tunnels, 100 feet south, explore a different zone.

The principal tunnel trends about N. 85° W. and follows a well-defined hanging wall which overlies a succession of crushed zones. The country rock is fine-grained sandstone, the strike of which ranges from N. 10° W. to N. 50° W. and the dip from 20° to 32° SW. A stope that appears to have maximum dimensions of 40 by 60 feet in plan by 2 to 3 feet in width extends from the lower to the upper tunnel near its mouth. Apparently silver-bearing galena was the principal ore mineral.

LARK MINE

The Lark claim is situated on a low ridge in the diorite 2 miles southeast of Bellevue. It was located early in the activity along Wood River and has been owned by the H. E. Miller estate for many years. In 1913 it was worked under lease by Reed & Plughoff, of Hailey. It was reopened in 1919 and produced several hundred tons of ore before 1923.

The only development in 1913 was a shaft 80 feet deep, with levels at 30, 36, 65, and 80 feet. The shaft explores a vein with well-defined walls that trend N. 80° W. and dip 85° N. In the shaft the average width between the walls is 4 feet, but the vein was narrower near the end of the drifts, 25 to 60 feet distant from the shaft. The vein is made up partly of lenses of altered diorite and partly of lenses of galena, sphalerite, and quartz. The lenses that contain sulphide minerals range from a few inches to as much as 20 inches in width and 15 to 25 feet in stope length. When considered together they indicate a shoot about 50 feet in stope length.

In mineralogy and structural associations the vein resembles several others in the diorite near the contact with the sediments, such as the Overland. The galena is fine grained and undoubtedly has been crushed. Sphalerite appeared at the 80-foot level for the first time. Tetrahedrite forms grains distributed through the galena. Cerusite is abundant as far as the 80-foot level. No siderite was found underground. Assays of selected ore show about 55 per cent of lead and 100 ounces of silver to the ton.

SUMMARY OF THE LOCAL ORE DEPOSITS

As in many other mining districts, the deposits of the area offer many bases for comparison and classification. Several of these features will be summarized briefly.

Most of the ore deposits are veins of silver-bearing galena (Minnie Moore, Queen of the Hills, Overland, Queen Bess, Star, and others); a few are silver-bearing chalcopyrite (Bellevue King); and a few are gold-bearing pyrite, chalcopyrite, or arsenopyrite (Croesus, Golden Bell, and others). Veins of the first group occur both in the granitic rocks and in the sediments, but most of them are localized near the contact of these rocks, although the actual contact has not been very productive. In strike and dip the veins are roughly parallel to the contact. Of the gangue minerals manganiferous siderite is abundant in most of the veins, especially near the contact of the granitic rocks and sediments. Quartz is insignificant in the siderite veins but is conspicuous in the veins in the sediments remote from the contact (Black Jack).

In structure the veins either follow simple fissures in the granitic rocks (Croesus, Golden Bell, Lark, and others), or fractures that cut the bedding of the sediments (Queen of the Hills, Queen Bess, Climax, and others), or else they follow fissures that nearly parallel the bedding of the sediments (Minnie Moore).

If production up to the present time is considered a criterion, the veins that offer the principal promise in the area are those that lie in the sediments close to the contact with the granitic rocks, like the Minnie Moore, or those that occur in the coarser, even though altered sediments in which replacement by siderite or sulphide minerals may have been effective. Simple fissures in dense resistant rocks, remote from the contact, do not offer promise of large production.

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