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ORE DEPOSITS IN TERTIARY LAVA

IN THE SALMON RIVER MOUNTAINS, IDAHO

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by

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C O N T E N T S

ILLUSTRATION

ORE DEPOSITS IN TERTIARY LAVA IN THE SALMON RIVER MOUNTAINS, IDAHO

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INTRODUCTION

The deposits of gold and silver ore in Tertiary volcanic rocks in Idaho have attracted less attention in recent years than the deposits of lead-silver ore in the older rocks, yet in the early days they yielded bonanza ore. As will be seen below, the possibilities of these deposits are far from exhausted. In the last 12 years almost no mining has been done in any of them but in the summer of 1926 there was a slight revival of interest in the Yankee Fork district, Custer County, one of the best known of the districts. All the known ore deposits in Tertiary lava in Idaho, except those in Owhyee County,[1] are in the Salmon River Mountains, in the south central part of the State. Some mineral deposits exist in the Tertiary Volcanic strata of the Wood River region, Blaine County, and a few other localities, but they are almost wholly undeveloped.

The four districts in the Salmon River Mountains containing such deposits are the Yankee Fork, Thunder Mountain, Parker Mountain, and Gravel Range (Singiser) districts. The Musgrove district is reported to have deposits that are essentially similar but occur in older rocks. All these districts, except the Musgrove, were visited by the writer in the summers of 1925 and 1926. The present paper summarizes the data obtained in these visits and also the published information on the districts. The writer hopes to follow it with a more detailed report after additional field work has been done.

The data now available justifies the belief that the deposits in these districts constitute valuable future reserves of the precious metals. Development work so far has been shallow, and only the most accessible and richest parts of the lodes have been mined. In some districts certainly and in others probably large masses of low-grade, more or less refractory ore remain untouched Metallurgical difficulties have been among the principal reasons for the failure to work some of the lower-grade ores profitably. The lack of success in developing some of the known lodes has discouraged search for others. This lack of exploration coupled with the fact that outcrops of such lodes are likely to be very inconspicuous, leads to the suggestion that other lodes with shoots of high-grade ore, as yet unsuspected, may be present in the 1,000 square miles of outcrops of Tertiary lava in the Salmon River Mountains and in the extensive exposures of similar rock in the surrounding region. Thus lodes of this type constitute a large potential reserve of the precious metals subject to the development of local transportation and of the metallurgy of such ore.

In addition to the gold and silver ore some lead, zinc, and copper ore is known, and in the past lead and copper ore has been shipped from deposits in Tertiary strata. Antimony deposits exist but have not yet been exploited. Tin

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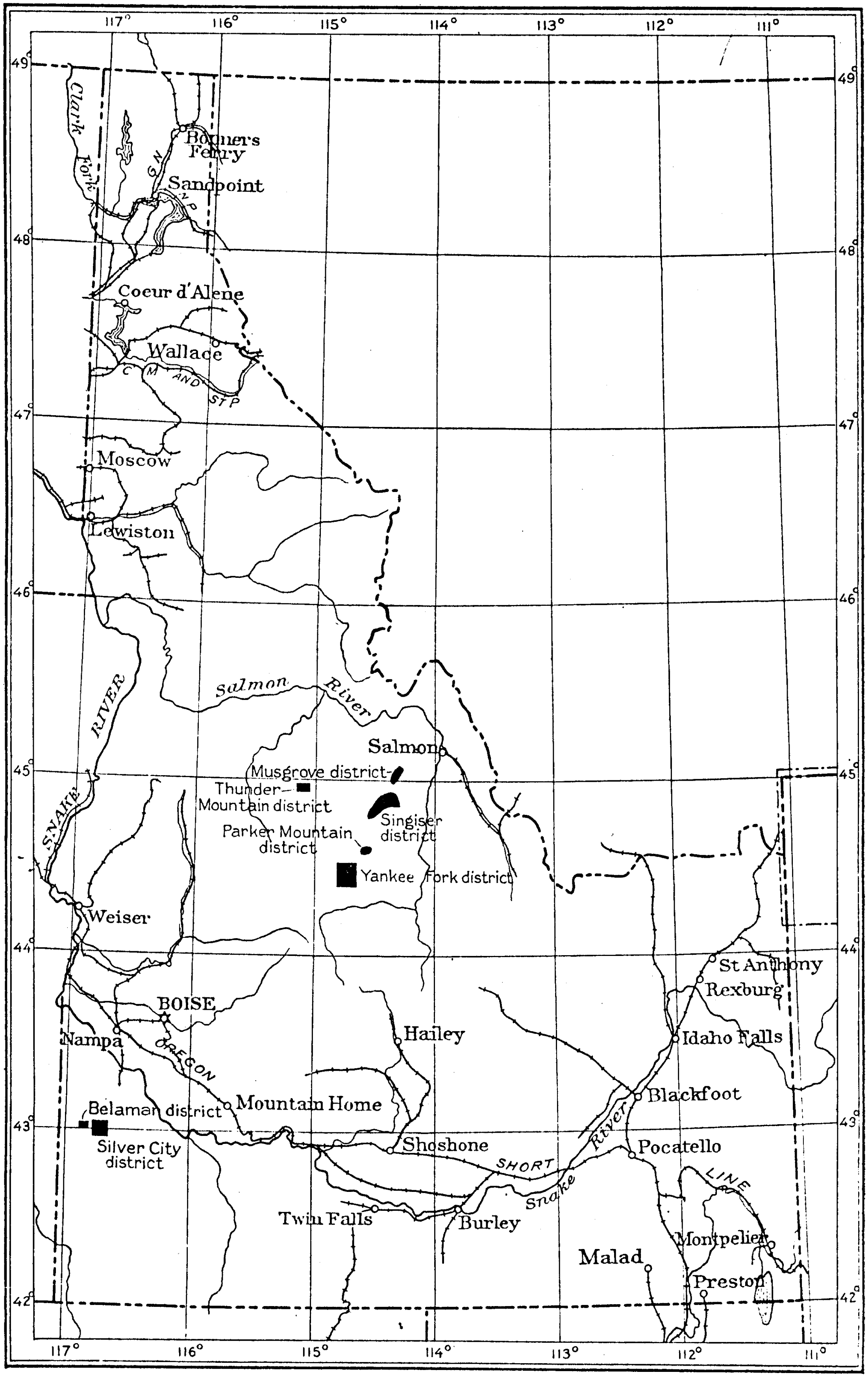
[1] Piper, A. M., and Laney, F. B., Geology and Metalliferous Resources of the Region about Silver City, Idaho: Idaho Bur. Mines and Geology Bull. 11, 1926.



SKETCH MAP SHOWING THE LOCATION AND APPROXIMATE EXTENT OF THE DISTRICTS DESCRIBED -1- A is present in placers derived from the Tertiary volcanic rocks but has not been found in place. An attempt to develop a deposit of opals, apparently in gravel, met with failure but opals occur in place in several localities, and it may eventually be found possible to mine them successfully. Lignite is interbedded with the Tertiary tuff in several localities but is of doubtful value.

LOCATION OF THE DISTRICTS

The location and approximate extent of the districts here described are shown on the accompanying map. The largest of them, the Yankee Fork district is in northwestern Custer County, on the Yankee Fork of Salmon River. Most of it is in unsurveyed Tps. 12 and 13 N., R. 15 E. The next largest, the Thunder Mountain district, is on Monumental Creek in eastern Valley County. Nearly all of it is in unsurveyed T. 19 N., R. 11 E. The Gravel Range and Parker Mountain districts are both small. They are in southwestern Lemhi County, the former mostly in unsurveyed T. 18 N., Rs. 17 and 18 E., the latter in unsurveyed T. 15 N., R. 16 E. The Musgrove district, also small, is north of the Gravel Range district in Lemhi County, largely in unsurveyed T. 20 N., R. 18 E. As here used, the term "Musgrove District" includes that part of the Blackbird district in which the ore is similar to that of the other districts described in this paper.

MEANS OF ACCESS

None of the districts described are near a railroad, but all except Thunder Mountain and Parker Mountain can be reached by automobile. Thunder Mountain is connected with Cascade by a road which is still passable for a wagon. The road into the Parker Mountain district was used mostly in winter, when the mines were in operation, and part of it is now impassable for wheeled vehicles. In all the districts there are some mines and prospects that cannot be reached by vehicles at present.

The Salmon River Mountains are not penetrated by any railroads, but four branch lines terminate close to their borders. These are the Gilmore & Pittsburgh Railroad to Salmon, and three branches of the Oregon Short Line which terminate at Mackay, Ketchum, and McCall. Mackay is the most accessible railroad point to all the districts here described except Thunder Mountain, which is reached from Cascade, on the McCall branch. Salmon would be the natural outlet for the districts in Lemhi County were it not for the fact that the best roads from them run south through Challis to Mackay. The completion of a projected road north to join that which extends down Salmon River to Shoup and improvement of the road from Salmon through Leesburg will change the situation in this respect.

The distance by road from Bonanza, in the Yankee Fork district, to Mackay is about 110 miles and to Ketchum about 80 miles. The distance from the Parker Mountain district to Mackay is about 80 miles, of which nearly 15 miles can not at present be traveled by a wheeled vehicle. The distance from the Gravel Range district to Mackay is about 100 miles and to Salmon about 55 miles. The Musgrove district is about 35 miles from Salmon and 120 miles from Mackay. The Thunder Mountain district is about 80 miles from Cascade, of which about 53 miles can be traveled by automobile. Good roads could be built into all these districts without excessive difficulty should development in them warrant it. Roads built and maintained by several governmental agencies will soon reach within a few miles of all except possibly Thunder Mountain.

H I S T O R Y A N D P R O D U C T I O N

In the following pages the salient features of the history of the districts in the Salmon River Mountains that contain ore deposits in Tertiary volcanic rocks are briefly summarized. The available data are incomplete but are adequate to give a good general idea of the situation. The principal published information is in the early Mint reports, the annual volume of Mineral Resources, and Umpleby's reports on Custer and Lemhi counties.[1] This has been supplemented by local inquiry and observation.

YANKEE FORK DISTRICT

The Yankee Fork and Gravel Range districts were discovered in the seventies of the last century, but only the former was worked to any extent at that time. In this district, as in so many others in south-central Idaho, the boom days were in the late seventies and the eighties, before most of the deposits in the other districts here described were discovered.

The total production of the Yankee Fork district is probably somewhat over $12,000,000 of which less than $500,000 appears to have been produced since 1900. In the early eighties the average annual production is supposed to have been as much as $1,000,000. More than 70 properties have been operated in the district, but two-thirds of the total production appears to have come from the General Custer mine, and about half of the remainder from the Charles Dickens, Lucky Boy, McFadden, Golden Sunbeam, and Montana, especially the first two.

Probably only about a quarter of the precious-metal bullion produced has been in gold. The remainder was in silver. Umpleby estimates that in the ore from the three largest producers there was about 85 ounces of silver to 1 ounce of gold. Some of the ore from the Golden Sunbeam, Montana, and a few other mines contained as much or more gold than silver. Compartively little base ore has been mined, but the Mint report for 1885 noted the production of 1,481,000 pounds of lead, valued at $483,185, and there has certainly been some lead production in other years. Some of those familiar with the district believe that considerable amounts of lead and copper ore remain in the mines.

The ore sent to the railroad by pack train in the early days was valued at $500 to $3,000 to the ton but presumably had been hand sorted. The smelters at Bayhorse and Clayton, both started in 1880, furnished a near by market for some of the ore. From the early eighties until it shut down in 1905 the General Custer mill treated most of the ore of the district. At first the ore fed to this mill contained $150 to $300 a ton in silver and gold, but in the later days of operation the average grade fell to $30 a ton and less. Some of the ore mined more recently is of even lower grade. The ore of the largest ore body of the Golden Sunbeam, discovered in 1906, is reported to have contained only $2 to $4 a ton. This mine was shut down in 1911, and thereafter activity in the district decreased, although some production has been obtained in most years up to the present time. When the district was visited in 1925, less than a dozen miners remained where once there were several thousand. In 1926, however, there was a revival of interest, and a number of the oldtimers returned to try once more to find new ore in the old mines.

Placer mining started in the district in 1870 but was never very successful. It led to the discovery of lode mines in 1875 and succeeding years, and since then compartively little attention has been paid to placers until recent-

[1] Umpleby, J. B., Some Ore Deposits in Northwestern Custer County, Idaho: U.S. Geol. Survey Bull. 539, 1913; Geology and Ore Deposits of Lemhi County, Idaho. U. S. Geol. Survey Bull. 528, 1913.

ly. In the summer of 1926, as reported, tests were made along Yankee Fork and Jordan Creek in order to determine the feasibility of dredging the gravel.

THUNDER MOUNTAIN DISTRICT

The Thunder Mountain gold district had a brief but eventful period of activity. It was discovered in 1895, was actively worked from 1902 to 1906 and has been almost completely abandoned ever since. Although its production is not large it is one of the most widely known districts in south central Idaho because of the well-advertised but short-lived boom there in 1902. The odium it then acquired is not altogether deserved, as the district has possibilities for the future.

Mineral was discovered in the district by the Caswell brothers & Huntley in 1895. They are reported to have made $6000 to $7000 during each of several subsequent summers by sluicing the soft surface material at the site of the Dewey mine. Their claims were purchased in 1901 by the Thunder Mountain Gold & Silver Mining & Milling Co., which named the property the Dewey mine and started work at once. A 10-stamp mill was packed in and erected the same year. As a result of widely circulated exaggerated accounts of the richness of the new gold district there was a rush to it in 1902. Bell[1] estimates that between 2000 and 3000 people visited the district in the spring of that year. Claims were staked in an area of about 20 square miles surrounding the original discovery, but underground work of any consequence has been done at only about half a dozen places in the district, and nearly all the production has come from the Dewey mine. Even there systematic production ceased in 1907. The landslide which started at the Dewey mine in May, 1909, and flooded the town of Roosevelt put an end to the enthusiasm of most of those remaining in the district. Since then there has been only desultory activity except for test runs in a 10-stamp mill at the Sunnyside mine during recent summers.

The Dewey produced about $350,000 and the Sunnyside about $5,000 in the period between 1900 and 1908.[2] The Caswell Brothers & Huntley may have obtained $40,000 or more from the Dewey outcrops. The total production of the district recorded in Mineral Resources, since 1908, is $18,542, and the amounts not definitely recorded are small. Most of this production came from surface work at the Dewey. A little was obtained by placer mining elsewhere. It is estimated that more than 60 per cent of the total bullion produced in the district was gold and the rest silver. The average ore contains $10 or less to the ton, although small amounts of high-grade ore have been found near the surface. Almost no base metals are known in the ore of this district.

GRAVEL RANGE (SINGISER) DISTRICT

The Gravel Range district, sometimes called the Singiser district, was discovered in the early seventies. At that time an arrastre was operated near the present Monument mine by Mexicans, and a little placer mining was done near the present Rabbitfoot but substantial progress was not made until 1895, when the principal campaign of development at the Monument mine started. The chief production at this mine appears to have been made in 1907 and

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1 Bell, R. N., Facts about Thunder Mountain; Eng. and Min. Jour. vol. 74 pp. 273-275, Aug. 30, 1902.

2 Umpleby, J. B. and Livingston, D. C. A Reconnaissance in South-Central Idaho: Idaho Bur Mines and Geol. Bull 3, p. 6, 1920.

1908. Work at the property ceased in 1912. Active development at the Rabbitfoot mine started in 1905 and continued until about 1914. There are several other prospects in the district, but the two mentioned are the only ones where any considerable development work has been done and the only ones at which mills have been erected. Except for some assessment work and a little placer mining in the gulch below the Rabbitfoot mine there has been no mining activity in the district for many years.

Practically the entire production of the district has been in gold and silver, and nearly or quite all of it came from the Monument and Rabbitfoot mines and from placers below the Rabbitfoot. Umpleby[1] states that it is probably safe to assume that the total production is less than $100,000. So far as can be judged from available data, this is a very liberal figure. The average ore produced at the Monument assayed about $11 to the ton, and that at the Rabbitfoot was probably of even lower grade. Some high-grade ore has been found at the Monument. The ore at this mine contains some lead and copper but, so far as known, not in commercial quantity. Umpleby estimates that the precious metals in the ore of this mine are in the ratio of 1 part of gold to 18 of silver. Antimony ore is exposed in prospect pits near Meyers Cove, formerly Three Forks, but none has been shipped. Opals and tin have been found in the district, and small quantities of opals appear to have been marketed about 1902.

PARKER MOUNTAIN DISTRICT

The Parker Mountain district is the most recently discovered and least developed of the districts here described. It was discovered in 1904, and as recorded in Mineral Resources, it reported production in 1905, 1906, 1907, 1908, 1912, 1913, and 1915. The production came from the Parker Mountain and Williams properties, principally the former. Some milling machinery was installed on the Parker Mountain property in 1908, and more later. Little has been done in the district for over 10 years.

Definite data as to the total production are not available, but it probably does not amount to much over $10,000. The ore ranges in value from $10 to $20 to the ton, but the average is probably nearer the lower figure. There is more silver than gold in the ore, but the ratio is much lower than in the ore of the Monument mine, in the Gravel Range district.

MUSGROVE DISTRICT

The Musgrove district has not been visited by the writer, and few data regarding it available. Comments in the annual volumes of Mineral Resources indicate that gold and silver ore was cyanided in 1913, 1914, 1915, and 1921 in the mill of the Musgrove Mining. Umpleby[2] says that deposits in the Blackbird district, apparently including those in the Musgrove district, were discovered in 1893. He also says that the average ore of the Musgrove group assays about $20 in gold and silver to the ton.

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1 Umpleby, J. B., Geology and Ore Deposits of Lemhi County, Idaho. U. S. Geol. Survey Bull. 528 ;.173, 1913.

2 Umpleby, J. B., op. cit. pp. 160, 165.

GENERAL GEOLOGY

The geologic data here presented in condensed form are based largely on mapping in the Castro quadrangle, which lies between meridian 114° 30' and 115° west longitude and parallels 44° 30' and 45° north latitude, supplemented by trips to the districts here described and other localities in south central Idaho. Published data on the geology of the region have also been freely drawn on. The field work referred to has resulted in the accumulation of many new data, which necessitate some modification of current conceptions as to the geology of the region. The new facts and conclusions are presented here only in outline, their detailed discussion being reserved for later papers.

SUMMARY

The stratified rocks of the Salmon River Mountains include metamorphosed sedimentary beds, largely of Algonkian age; somewhat altered lava and pyroclastic rocks, which may be as old as Permian; and younger lava and tuff, which though largely Miocene may range from Oligocene to Pliocene. Some of the unconsolidated gravel on high terraces may perhaps be of Pliocene age. Glacial detritus and later alluvium are present in some of the stream valleys. Granitic rocks both older than and intrusive into the Miocene (?) lava occupy large areas. There are dikes, most of which are related to the later granitic intrusions. These dikes appear to have caused notable contact metamorphism in the rocks which they cut.

The region has been subjected to at least two major orogenic disturbances. One of these was in pre-Cambrian time, the other presumably of late Mesozoic time. During the Tertiary and Quaternary periods there has been a series of uplifts, and the rocks have been broken by numerous normal faults.

Among the more important new data brought to light during the present investigation are the existence of volcanic strata older than those commonly recognized as Tertiary, the presence of large masses of granitic rock of Tertiary age, and the contact metamorphism related to dikes of Tertiary age. Modification of present conceptions regarding the physiography of the region is also suggested by the data obtained.

STRATIFIED ROCKS

Old Sedimentary Rocks

Distribution: Metamorphosed sedimentary rocks crop out in a number of localities in the Salmon River Mountains. The largest areas are in northwestern Lemhi County near Leesburg, in Custer County between Challis and Bonanza, and in Valley County near Leesburg. There are other areas northwest of Warren near Yellow Pine, and at intervals along the Middle Fork of Salmon River and some of its tributaries, especially Camas and Loon creeks. Small blocks in the granitic rocks are exposed in numerous places.

Character and Age: The sedimentary strata are in greater part more or less impure quartzite, grading into slate and schist. Calcareous beds, largely dolomitic, are present in several localities but make up a small part of the total. The original thickness must have been much more than 10,000 feet, but in most localities only fragments of the complete section remain. No fossils have yet been found in these beds. There seems little doubt that most of them are to be correlated with the Belt series farther north and east and hence are of Algonkian age. Some Paleozoic beds may be present, especially in northwestern Custer County.

Casto Volcanics

Name and Age: In the Casto quadrangle and northwestward and eastward beyond its limits there are extensive exposures of volcanic strata of intermediate composition which are clearly older than those of Miocene (?) age. These beds, which differ from any hitherto reported from south central Idaho, are here named the Casto volcanics, from the quadrangle which contains the greater part of the known exposures. An extended discussion of the formation will be given in the final report on the Casto quadrangle, and only the salient features regarding it are mentioned here. A tentative correlation with similar beds of Permian age in western Idaho is considered the most probable, but conclusive evidence is lacking.

Distribution: The known areas in which such rock is exposed aggregate about 200 square miles, nearly all in the Casto quadrangle. Similar exposures extend along the west side of the Middle Fork of Salmon River for some miles north of the region thus far mapped. From the incomplete data available it appears improbable that any considerable amounts of volcanic beds older than the Miocene (?) strata exist elsewhere in central Idaho east of 115° 45' west longitude. In western Idaho there are great thicknesses of old volcanic beds. Most of these are in southwestern Nez Perce and western Adams and Washington counties and are of Permian age.[1] It is supposed that the Casto volcanics may be the stratigraphic equivalents of these beds, but the evidence is by no means conclusive. Volcanism appears to have extended into Triassic time[2] in at least the southern part of the region where the Permian volcanic strata are exposed.

Character: In the region here described the Casto volcanics comprise lava flows largely brecciated, and tuffs. At the base in several localities there is a conglomerate with tuffaceous matrix in which most of the pebbles are derived from the old sedimentary rocks mentioned above. Most of the lava ranges in composition from rather sodic andesite to dacite but there are some beds of more calcic and some of more silicic composition. All the strata show evidence of alteration. The thickness is not accurately known but probably exceeds 3,000 feet. There are no mines and few prospects in these rocks.

Tertiary Volcanic Rocks

Distribution: Areas aggregating more than 1,000 square miles of the Salmon River Mountains are underlain by lava and associated clastic beds such as are generally assigned to the Tertiary. Probably the whole range was at one time covered by the lava. Indeed the distribution of present exposures suggests that nearly all of Idaho from the Snake River Plain to about 45° 10' north latitude and large parts of it beyond these limits was once covered by such rocks. The largest area of Tertiary volcanic rock in the Salmon River Moun-

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1 Laney, F. B., personal communications.

2 Livingston, D. C., A Geologic Reconnaissance of the Mineral and Cuddy Mountain mining Districts, Washington and Adams Counties, Idaho; Idaho Bur. Mines and Geology, Pamphlet 13, pp 5,6, 19?5.

tains extends from the vicinity of Iron and Moyer creeks southwestward to the vicinity of Basin Creek, west of Bonanza. Forney is near its northern limit; Meyers Cove near its northwestern boundary; and Challis near its southeastern boundary. Another large area extends from the region north of Edwardsburg southeastward nearly to the Middle Fork of Salmon River. There are detached smaller areas between these two large ones.

General Character and Age: The stratigraphic succession is variable and, except in a few localities, has not been worked out in detail. In a very general way the strata between Challis and the Middle Fork may be divided into three groups which grade into one another and change in character more or less from place to place.

The lower group consists dominantly of varicolored flows whose average composition approaches that of quartz latite. Bright tints of lavender and green are common in these rocks. The thickness is in most places more than 1,000 feet.

The middle group consists mainly of cream-colored tuff with generally subordinate amounts of nearly white rhyolitic lava. In some places nearly black obsidian, in part markedly spherulitic, is prominent in these light-colored beds, especially in the lower part of the series. Here and there other dark-colored strata occur in them. In places this group attains a thickness of more than 1000 feet, but in some localities it is almost completely absent. This group contains all the known opal deposits, and it and its apparent equivalents farther west contain most of the ore deposits here described.

The upper group consists mainly of reddish and brownish flows containing much glassy material. Most of the flows appear to have the composition of rhyolite and quartz latite, although more calcic beds also exist. Near Meyers Cove 1,600 feet of such lava with minor amounts of interbedded tuff has been measured. The total thickness of the group is probably greater than this.

The upper members of this upper group appear to be interbedded with the so-called "lake beds" in the vicinity of Challis. The reconnaissance examination disclosed little essential difference in character between these "lake beds" and the tuff of the middle group referred to above, although they are evidently not stratigraphic equivalents. It has become customary to use the term "lake beds" for light-colored, generally fine-grained clastic strata occurring in mountain valleys in Idaho, Montana, and neighboring regions, but some of the beds so denominated are not of lacustrine origin. There is abundant silicified wood in "lake beds" along Salmon River about 12 miles above Challis. Lignitic layers have been found in such beds in several places, notably near Salmon, but none of them have much commercial value.

The grouping suggested above probably holds in a broad way for all the Tertiary volcanic rocks in the Salmon River Mountains, although there is considerable variation. The available evidence, though inconclusive, strongly suggests that these rocks are of Miocene age. The possibility that the lowest strata may be Oligocene can not be excluded but it is improbable that any are as old as Eocene.

A younger group of rhyolitic lava, unconformable on lava of supposed Miocene age, is reported by Umpleby[1] to exist north of Lemhi River but has

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[1] Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, pp. 48, 120, 1913.

not been recognized in the Salmon River Mountains. Umpleby suggests that these younger strata may be Pliocene.

Local Variations: In the Yankee Fork district only the two lower groups appear to be represented and the rocks on the whole are somewhat more calcic than the average elsewhere. The upper group appears a few miles east of the district and is exposed at least as far east as Challis.

In the Thunder Mountain district most of the rocks, both flows and tuffs are light colored, are of rhyolitic composition, and contain considerable glass. They probably belong to the middle group described above, although the succession differs from that in the Casto quadrangle. Tuffaceous conglomerate is abundant and is exposed at several places, and there are also a number of outcrops of basalt, which, however, nowhere much exceeds 200 feet in thickness. The total thickness of the strata in the district exceeds 1,000 feet. In the vicinity of Rainbow Peak, a short distance farther west, 2500 to 3000 feet of bright-colored porphyritic lava with some tuff is exposed. These beds probably include strata equivalent to the lower group and to the rocks of the Thunder Mountain district.

In the mines of the Parker Mountain and Gravel Range districts the principal rock is rhyolite having a groundmass of partly devitrified glass. It belongs to the middle group. Cream-colored tuff is exposed on Silver Creek and elsewhere in the Gravel Range district and is common in the Parker Mountain district.

Quaternary Detritus

Both glacial deposits and alluvium are present in the region. The glacial debris was laid down by Pleistocene glaciers of the alpine type and is confined to the upper portions of stream valleys in the mountains. Except in Prairie Basin in southwestern Lemhi County, the amount of such deposits remaining is small, and nearly all have been reworked by water.

Most of the alluvium is of postglacial origin, although it is conceivable that some of that on the higher river terraces is preglacial and perhaps even as old as Pliocene. Alluvium is present in nearly all the stream valleys but is abundant only in a few of the wider ones, such as that of Yankee Fork near Bonanza and Round Valley on Salmon River.

INTRUSIVE ROCKS

Cretaceous (?) Granitic Rocks

More than half of the Salmon River Mountains is underlain by granitic rock, which has in recent years been generally considered to belong to the Idaho batholith and its satellites. Part of it, as will be shown below, is distinctly younger than the rest, and further subdivision will doubtless be made as detailed work progresses. However, it appears probable that the conception that most of the granitic rock in Idaho was formed during one period of intrusion will be found to be correct.

With the exception of the younger rock referred to above, the granitic rocks wherever seen have petrographic similarities more striking than their differences. Most of them are gray medium grained rocks, having the composition either of granodiorite or of quartz monzonite, although varieties exist both more calcic and more silicic.

The age of these granitic rocks has not been definitely fixed and probably can not be closely determined from available data in the Salmon River Mountains. They are certainly older than the Miocene (?) volcanic rocks. For several reasons, to be discussed in other papers, the writer is inclined to believe that they are at least as old as Cretaceous.

Miocene (?) Granite

Distribution and Age: Along the Middle Fork of Salmon River from a point above Marble Creek to a point below Bernard Creek occurs a pink granite that is strikingly different in appearance from that just described. Its extent beyond the limits mentioned is not known. It appears to grade into similar but grayer granite on and north of Camas Creek. Darker, gneissic igneous rock, more or less admixed with metamorphosed sedimentary rock, is associated in places with both the pink and the gray granite. Study of the relations of these rocks has not been completed, but it appears that pink granite crops out over fully 200 square miles and the associated gray granite covers several score square miles in addition.

The pink granite cuts the lower flows of the Miocene (?) lava and hence is younger than these flows and distinctly younger than the Idaho batholith. Like the lava, it may for the present be tentatively assigned to the Miocene.

Relations to Ore Deposits: It is probable that the solutions that produced the ore deposits here described originated in magma related to that which consolidated as the pink granite above referred to. The grouping of the deposits within a few miles of the borders of this granite mass as now exposed lends support to this theory. Granitic rock of apparently similar age is known elsewhere in Idaho only in the Hailey[1] and Sawtooth[2] quadrangles. This meager distribution may in part account for the relative scarcity of ore deposits of this kind in Idaho.

Dikes

Character and Age: The region contains numerous dikes and other small intrusive masses, which appear to range in age from Algonkian to Miocene and perhaps Pliocene. Most of them are related to the Miocene (?) granite.

Small masses of metamorphosed igneous rock, largely gabbro, were noted in the Algonkian sedimentary rocks west of Yellowjacket. As these igneous rocks are as highly metamorphosed as the sedimentary rocks that they cut, it is believed they are likewise Algonkian. There are also dikes genetically associated with the granitic rock of the Idaho batholith and its outliers and presumably with the Casto volcanics.

Much the most abundant and prominent dike rocks in the region are the porphyritic rocks believed to be related to the pink Miocene (?) granite. The genetic relation between the dikes and the granite is clear for the pinker dikes but not so certain for some of the grayer varieties. All these porphyritic rocks are of silicic composition, and most of them approximate the composition of granite porphyry and granophyre.

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[1] Umpleby, J. B., Westgate, L. C. and Ross, C. P. Geology and Ore Deposits of the Wood River Region (Hailey Quadrangle). U. S. Geo. Survey Bull. (In preparation)

[2] Behre, C. H., personal communication founded on field work in Sawtooth Quadrangle.

Contact Metamorphism: W. H. Newhouse, the writer's assistant in the summer of 1925, has studied the contact metamorphism in the southern part of the Casto quadrangle. He finds that calcareous sedimentary rocks which have been cut by these dikes show metamorphism, as a result of which spinel, olivine, phlogopite, diopside, muscovite, apatite, zircon, titanite, rutile, orthoclase, plagioclase, hornblende, actinolite, tourmaline, epidote, and lollingite have formed. The amount of material added to the limestone is, according to Newhouse, too great to have been derived from the small dikes alone, and hence it is probable that the dikes merely acted as conduits for emanations from some deep-seated source, presumably the same as that of the pink granite.

GEOLOGIC HISTORY

The scantiness of fossils in this region makes it impossible to fix dates with accuracy, but the major events in the geologic history of the region are known and their approximate chronologic order can be given.

For a long time in the Algonkian period the region was submerged under a sea in which a great thickness of sediments accumulated. These sediments were consolidated, folded, intruded by small igneous masses, and metamorphosed apparently before the dawn of the Paleozoic era. All the subsequent geologic events have left their effects on these ancient rocks, until now they are highly metamorphosed and much disturbed.

Paleozoic seas washed the southeastern part of central Idaho and may have extended far enough to cover part of the site of the Salmon River Mountains, but most of this region appears to have been dry land and exposed to erosion from the end of Algonkian time to the first outbreak of volcanism, which occurred not earlier than the Permian epoch and may have been much more recent. During this early volcanism thousands of feet of flows and pyroclastic deposits accumulated. No beds of unquestionably marine origin have been found in them, but if the hypothesis that they are related to the Permian volcanic rocks farther west is tenable a sea existed both west and east of this region, if it did not actually cover the region during this period of volcanism. The same thing may have been true if the volcanism took place during Triassic time.

The intrusion of the Idaho batholith probably occurred in the later part of the Mesozoic era. At about this time, probably during and following the intrusive activity, there were extensive orogenic movements. These occasioned uplift, broad-scale folding, and in places overturning and overthrusting, with associated normal faulting. In this general region the average strike of the major structural features then produced is northwest. Most of the ore deposits in Idaho are generally believed to have been formed at this time and to be genetically related to the batholithic intrusion.

In Tertiary time presumably in the Miocene, after a period of quiesence and erosion, volcanism broke out on a grand scale. Thousands of feet of lava was piled upon the surface, and granite and associated dikes were forced upward until they penetrated the lower part of the Miocene (?) effusive rocks. This is the period in which the ore deposits that are the subject of this paper are believed to have been formed.

The diastrophism associated with the Miocene (?) igneous activity was less violent than that associated with the intrusion of the Idaho batholith. It included uplift, and the Miocene (?) lava was thrown into gentle folds and broken by numerous normal faults. The faults are the most characteristic and striking features resulting from the earth movements of this time. The major faults strike northeast, almost at right angles to the strike of the major features resulting from the earlier diastrophism. Minor faults with various strikes also exist. The volcanism in the general region probably persisted into the Pliocene epoch and the associated earth movements likewise continued into that epoch and even later. Most of the activity of both types, however, appears to have terminated in the Miocene. During late Tertiary time erosion apparently continued uninterrupted until the region was reduced to rather low relief.

The physiographic history from the Pliocene epoch to the present time has been an eventful one, of which many details remain to be elucidated. There appear to have been oscillation of the earth's crust and resulting interference with the normal development of the drainage. Some movement probably has taken place along fault planes up to recent time. The glaciation in the higher country during the Pleistocene epoch has had its effect on the topography. The streams have recently been rejuvenated and are now actively eroding.

M I N E R A L   D E P O S I T S

The essential features of the mineral deposits in the Tertiary volcanic strata in the Salmon River Mountains and of the placer deposits derived from them are summarized below. Available details regarding development in individual mines will be given in the more complete report to be published later by the U. S. Geological Survey.

These deposits include lodes that are valuable principally for their precious-metal content but that in places contain lead and copper ore, antimony lodes, opal deposits in lava, and placers containing gold, silver, tin and opals. All the deposits here described are in or closely related to lava and tuff believed to be of Miocene age. In addition to these deposits there are in the pre-Tertiary rocks of central Idaho numerous ore deposits which may be of similar age. These include such deposits as those in and near Boise Basin[1] containing lead and other metals, and the antimony, gold and quicksilver lodes in the Yellow Pine district and Valley County[2]. The evidence for the Miocene age of these deposits is far from conclusive. They differ in many respects from those described in the present paper and, if of similar age, were probably formed at greater depths.

GOLD AND SILVER LODES

General Features

The gold and silver deposits in place in Tertiary volcanic rocks in the Salmon River Mountains are of two general classes, which grade into each other. These are (1) fissure fillings, in most of which the principal gangue is ribbon banded very fine grained quartz and the characteristic metallic mineral is a selenide, and (2) zones of widespread alteration in beds of lava and tuff in which the original feldspar of the rock is more or less completely converted to a clay mineral chemically similar to halloysite. For convenience the

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[1]Balard, S. M. Geology and gold resources of Boise Basin, Boise County, Idaho. Idaho Bur Mines and Geology Bull 9. 1924.
Ross, C. P., A disseminated lead prospect in northern Boise County, Idaho: Idaho Bur Mines and Geology Pamphlet 20, 1926
[2]Schrader, F. C., and Ross, C. P., Antimony and quicksilver deposits in the Yellow Pine district, Idaho; U. S. Geol Survey Bull 780 pp 137-167, 1926.

deposits of the first class may be referred to as vein deposits and those of the second class as replacement deposits, although both fissure filling and replacement have occurred in all the deposits here discussed. The deposits of both classes rarely contain enough metallic minerals to be perceived without careful examination. The presence of precious metals in most of the ore can be determined only by testing, and the quantity present can not be satisfactorily determined except by fire assay.

The proportion of gold and silver varies markedly in the different deposits. In most of them silver much exceeds gold in amount. The proportion of gold is greater in most of the deposits of the second class than in those of the first, but the average value of the ore is lower. Most of the ore now in sight has a value of less than $15 a ton, and the ore in the replacement deposits may not have an average value as great as half this figure. Much ore far richer than this has been mined in the past in the Yankee Fork district, and pockets of rich ore, probably all of supergene origin, have been found in the other districts. There has been some production of lead and copper ore, probably from lodes of the first class, in the Yankee Fork district. More ore of this kind presumably remains in the lodes, but the history of mining in lodes in Tertiary volcanic rocks elsewhere in the United States does not encourage the idea that large and valuable base-metal ore bodies will be found in such rocks in the districts here described.

Vein Deposits

The deposits in which fissure filling is characteristic include most of the veins in the Yankee Fork district, probably all in the Parker Mountain district, the vein in the Monument mine and probably others in the Gravel Range district, and the veins in the Musgrove district. The veins of this class follow zones of fracture and shearing. Most of them strike northeast and dip west, but there are numerous exceptions to this rule. The ore has mainly formed by deposition along fractures. Replacement of the wall rocks has occurred in all these veins but, except in zones of brecciation, appears rarely to have produced ore of commercial grade. Some of the veins are continuous for hundreds and perhaps thousands of feet along the strike. The maximum width reported is 18 feet, but most individual veins are much narrower. The average width of the more continuous veins in the Yankee Fork district is about 4 feet. In most of the workings, however, instead of individual veins of this character, there are numerous small gash veins separated by more or less altered rock.

None of the veins have been followed to depths as great as 1000 feet, and in most of the mines development has been carried only a few hundred feet below the surface. The only mines deeper than 300 feet are in the Yankee Fork district. The only mines deeper than 300 feet are in the Yankee Fork district. The accessible parts of all mines visited during the present investigation are at even shallower depths.

The predominant gangue in the veins is cryptocrystalline quartz, with which in places are small amounts of opal, adularia, calcite, and albite. The hypogene metallic minerals include selenides, pyrite, galena, chalcopyrite, enargite, tetrahedrite, and probably others. Some of the free gold is presumably hypogene. In most of the ore almost no metallic minerals are visible except bands of black, extremely fine particles. This black material contains selenium and evidently carries much of the gold and silver in the ore. It is so fine grained and so thoroughly mixed with the quartz that the minerals composing it have not been determined. Similar material in the closely allied deposits of the Silver City region[1] has been identified as naumannite, the silver selenide. In the deposits here described, as in those of Republic, Washington[2] a gold selenide is probably also present. The vein matter is in general conspicuously and finely banded. Most individual bands are only a fraction of an inch thick. Some of the quartz bands are colored pink. The contacts with the wall rocks are fairly sharp. In places there are angular inclusions of the wall rock in the vein quartz. Drusy cavities exist in places but do not appear to be common.

Hydrothermal alteration is widespread in the Yankee Fork district and is strongly developed in the vicinity of all the vein deposits. This alteration appears to be everywhere essentially similar to that in the replacement deposits. Some of the altered rock contains sufficient gold and silver to constitute ore, especially where it is thoroughly sheared or brecciated. This material constitutes a gradation between the vein deposits and the replacement deposits. The alteration consisted in partial replacement by quartz and a clay mineral. The altered wall rocks in the Yankee Fork district have not been examined microscopically, but as seen in the field they resemble those of the other districts.

Replacement Deposits

The replacement deposits are best developed in the Thunder Mountain district, where all the known lodes are of this type, but they are also represented in the Rabbitfoot and probably the Silver Creek properties in the Gravel Range district. The lode in the Golden Sunbeam mine and the chimney-like shoot in the Montana mine, both in the Yankee Fork district, appear from available descriptions to resemble this class more nearly than the vein deposits characteristic of this district. The following description is based mainly on examination of the Thunder Mountain district, where the deposits are not only larger but much better exposed at the present time than any others of the class seen. The Golden Sunbeam and Montana ore bodies, referred to above, have not been visited by the writer, and it is understood that large parts of the underground workings in each mine are now inaccessible.

The ore bodies of this class, so far as observed, are in rhyolitic tuff or lava, which contains much glass and negligible quantities of ferromagnesian material. The ore in most of them is in roughly lenticular bodies approximately parallel to the bedding of the enclosing rock. As the volcanic beds have not in general been greatly folded, the plane of greatest extension in such ore bodies is inclined less than 25° from the horizontal. They do not in general have walls or other well defined limits except that some, at least, terminate upward against a comparatively impervious stratum. In other directions they fade out gradually. The distinction between what is ore and what is merely somewhat altered country rock is primarily a matter of assay value. It appears that in some of the deposits there are zones of fracturing along which alteration is more intense and may continue to greater depths than elsewhere. Also in most of them there are scattered quartz stringers.

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1 Piper, A. M. and Laney, F. B. Geology and metaliferous resources of the region about Silver City, Idaho: Idaho Bur. Mines and Geology. Bull 11, pp. 76-77, 1926.

2 Bancroft, Howland, and Lindgren, Waldemar. The ore deposits of northeastern Washington: U. S. Geol. Survey Bull. 550 pp. 148-151, 1914.

These two facts serve to ally these deposits with those of the vein class just as the character of the wall-rock alteration in the vein deposits allies them to the replacement deposits. Fundamentally the two classes are probably closely related in origin.

The dimensions of the ore bodies of the replacement class are large. One stope in the Dewey mine is 10 square sets high, 46 square sets long, and of unknown but considerable width. This stope represents only a fraction of the total ore body. The blanket-like ore body in the Sunnyside mine is more than 20 feet thick and has been developed for a length of about 700 feet down the dip and a maximum width of more than 300 feet. The average dip is less than 20°, and the lower end of the developed ore is less than 150 feet below the surface. Comparably large ore bodies appear to be present in a number of other mines, in the Thunder Mountain and other districts, but the grade of most of the ore is below $10 a ton, and metallurgical difficulties are encountered in treating it.

Replacement in these deposits has not been confined to individual beds. At the Sunnyside mine, although ore containing more than about $3 a ton appears to be confined to a zone little more than 20 feet thick, the rock for 200 feet or so below is altered and contains some gold. The upper limit of mineralization in this mine is a dark-colored, clayey rock, apparently a mud flow, which evidently proved impervious to the solutions that percolated through and mineralized the rholitic tuff. Broadly similar conditions appear to exist in several of the other deposits, but none of the others are so well exposed at the present time.

Most of the ore in the replacement deposits in the Thunder Mountain and Gravel Range districts looks merely like slightly weathered volcanic rock, containing in places sparsely disseminated cubes of pyrite and veinlets, some of which contain a white clay mineral with tiny quartz crystals scattered through some of it and others consist of fine-grained quartz. Even under the microscope no metallic minerals other than the rather rare pyrite were detected in the specimens of typical ore collected. The rock, however, is irregularly silicified, and the feldspathic material in it, both crystalline and glassy, has been largely replaced by a clay substance apparently identical with that in the veinlets mentioned above. This clay mineral, or possibly mixture of two minerals, appears to have a composition similar to that of halloysite, but unlike halloysite it is distinctly crystalline and has high indices of refraction. It is to be further studies by Clarence S. Ross, of the U. S. Geological Survey, and others.

The gold in the ore that has been mined is largely in the metallic state. Some of it has resulted from supergene alteration, but much of it is probably the product of the original mineralization. The low recoveries by amalgamation that have been reported doubtless resulted in part from the fact that much of the metallic gold is finely divided. It is possible that some of the gold, instead of being free, is in the form of a selenide or some other mineral not susceptible of recovery by simple amalgamation. It is reported that in the Dewey mine in the Thunder Mountain district, losses in milling increased with depth, while the grade of the ore decreased. The higher grade of the ore near the surface in both the replacement and the vein deposits is clearly in part to be attributed to the effects of supergene enrichment. The increased difficulty in milling the deeper ore may result from increase in the proportion of the gold contained in selenides or sulphides. Umpleby and Livingston[1] state that some of the gold in the Dewey mine was associated with pyrite. Nodules of pyrite containing leaf gold in the center were found, and in general the pyrite assayed $40 to $80 a ton in gold. A large part of the gold, at least in the richer ore, in the Thunder Mountain district is in seams in the altered rock rather than evenly disseminated through the rock. It is probable that this is also ture of the replacement deposits in the other districts.

Supergene Processes

It is probable that much of the rich ore mined in the early days in all the districts and still occasionally discovered in small quantities was the product of supergene enrichment. Some of this ore is reported to have assayed as much as $7,000 a ton in gold and silver. This rich ore was found close to the surface and appears to be absent even at the shallow depths to which most of the mines have penetrated. Even in the early days such ore was rarely found in large amount. It yielded its metal readily to simple amalgamation, whereas increasing difficulty in treatment and decreasing recoveries as depth was attained appeared to be the general rule. The rich ore of the early days was rusty and contained manganese oxide. The gold contained in it appears on the average to have been much coarser than that in the present ore. All these facts point to a supergene origin for this ore. On the other hand, in the greater part of the deposits unoxidized pyrite is exposed at the surface, the ore has a tenor of less than $20 to the ton and shows almost no oxidation, and the recovery by amalgamation is low. So general are these conditions in the ore bodies as now exposed that it seems clear that in most places supergene processes played a minor part and that ore bodies formed or enriched by such agencies are scanty in distribution and quantity.

The only place where ore believed to be of supergene origin was observed during the present investigation is at the Dewey Mine in the Thunder Mountain district. Here rather coarse flakes of free gold occur along crevices in rhyolitic tuff. There is considerable iron and manganese oxide in and near the crevices. The broken and altered rock in the crevices is rarely as much as an inch wide. At one place several such stringers terminate upward against a lignitic layer about a foot thick. There is no evidence of slumping or of removal of any considerable quantity of material. It is thought that the seams were mineralized to some extent by the hypogene solutions and that the gold was redistributed and redeposited by supergene solutions. This resulted in the local enrichment which now makes it possible for lessees with little equipment to obtain sufficient metal from these tiny seams to satisfy them. The gold contains so much silver that it is rarely worth as much as $14 an ounce.

In ore containing notable amounts of hypogené sulphides, such as some of that from the Yankee Fork district, enrichment by oxidation and removal of much of the sulphide material, leaving the precious metals behind, probably played an important part in raising the grade of the material near the surface. Most of the ore, however, contains so small a proportion of material that would yield readily to solution by percolating ground water that in most of the deposits this process must have been of small importance. On the other hand, nearly all the hypogene metallic minerals that occur in relatively small amounts in most of the deposits are rich in gold and silver and probably constitute an adequate source for the precious metals in the pockets of high-grade

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[1] Umpleby, J. B., and Livingston, C. D., A reconnaissance in south-central Idaho: Idaho Bur Mines and Geology Bull 3, p. 6, 1920

ore. If conditions were such that these minerals were soluble in the existing ground water local enrichment by subsequent redeposition from such solutions could readily have been effected. The redeposition may have been occasioned by reduction resulting from contact with lignitic layers in the rocks, or in some other way. It is thought that many of the small bodies of high-grade ore referred to above may have had such an origin.

ANTIMONY DEPOSITS

Only one deposit of antimony ore appears to be known in the Tertiary strata of the Salmon River Mountains, and this is developed only by two shallow prospect pits. It is on the west side of Camas Creek about a mile by trail from Meyers Cove, Custer County. It may be considered to be in the Gravel Range district, although west of and different from all the other ore deposits in that district.

The country rock is silicic tuff. The tuff was first brecciated, and then partly silicified, and the fractures were filled with chalcedony. The chalcedony and silicified tuff were in turn partly replaced by barite and stibnite. Deposition of barite continued after that of stibnite ceased. Coarse aggregates of barite have partly replaced radiating masses of stibnite needles, and crusts composed of small barite crystals envelop the individual needles composing some of the large clusters of stibnite. Also some of the fracture planes in the tuff are lined with coarse druses of barite in which needles of stibnite are enclosed in crusts of barite crystals. The fractures near the end of the mineralization cavities were lined with drusy aggregates of quartz crystals. Development is insufficient to give an adequate idea of the size of the deposit, but it is evidently considered of small promise for no work appears to have been done at the prospect for years.

There are a number of antimony deposits elsewhere in Idaho[1] and the writer has suggested[2] that some of them may be of Tertiary origin. None of the antimony deposits in Idaho, except the one here described, are in Tertiary volcanic rock. This fact and the curious relations between the stibnite and barite in the ore make this prospect of scientific interest.

PLACER DEPOSITS

Gold, tin, and opals have been found in gravel in the parts of the region covered by Tertiary volcanic rocks. The gold, with its associated silver, and the opals are undoubtedly derived from deposits in these rocks. The tin probably had a similar origin, but tin minerals have not yet been found in place anywhere in the region. Gold is the only product of placer mining in the region which has proved at all profitable. Although opals have been found in placer gravel in this region the deposits most likely to prove of value are in the bedrock.

Gold Placer Mines

The gravel in the gulches and debris on the slopes near the precious metal lodes here discussed generally yields metallic gold on careful panning.

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1 Schrader, F. C., and Ross, C. P., Antimony and Quicksilver Deposits in the Yellow Pine District, Idaho: U. S. Geol. Survey Bull. 780 pp. 144-156, 1926

2 Idem, pp. 157-159.

Most of the gold is fine and contains enough silver to bring its value down to $11 to $14 an ounce. None of the deposits of placer gravel so far tested have proved to be rich, and the total production from them has been small. The cheapness of placer methods and the small amount of equipment required have led to their successful use in working the decomposed material in the outcrops of some of the lodes, notably at the Dewey mine, in the Thunder Mountain district.

Yankee Fork District: The most extensive mining of placer gravel derived from the Tertiary strata has been on Jordan Creek and Yankee Fork, in the Yankee Fork district, and on Silver Creek below the Rabbitfoot mine, in the Gravel Range district. The production at both localities has been small, partly because of the difficulty experienced in recovering the fine gold. If the tests made in the summer of 1926 lead to the installation of a dredge on Yankee Fork the placer deposits of this district may increase in importance.

The gravel in the Yankee Fork district was not examined in detail during the present investigation. Just above Bonanza the valley of Yankee Fork widens out, in notable contrast to the V-shaped canyon farther upstream; the old town of Bonanza is built on a broad, terraced flat underlain by coarse gravel which is well over 100 feet thick, perhaps several hundred feet. Extensive deposits border the stream from this point to Salmon River. Most of the placer mining in the past appears to have been done in the smaller but presumably richer gravel deposits above Bonanza, especially along Jordan Creek, a tributary that enters Yankee Fork half a mile above the town. The gravel is composed largely of silicic lava, and much of it ranges in diameter from a few inches up to a couple of feet or even more.

Gravel Range District: Silver Creek in the vicinity of the placer workings is a small stream flowing in a comparatively large, open valley among rolling hills. The gravel is as coarse as that along Yankee Fork and is so abundant that the present stream seems inadequate to account for it. Much the greater part of the gravel is composed of lava and tuff such as form the neighboring hills, but there are scattered boulders of quartzite and various granitic rocks. Some of these may have been brought down by the stream from its headwaters, which may extend into an area of pre-Tertiary rocks. It is thought, however, that much of the gravel is outwash from Pleistocene glaciers which has been rearranged by Silver Creek and the other streams in the vicinity. Under this hypothesis the boulders of older rocks may have come from outcrops beyond the present divides. If the gravel is of glacial origin it has been extensively reworked in comparatively recent time. This is shown by the presence in it of a skeleton, apparently that of an Indian woman, and of numerous beaver teeth. Mr. Lee Ramey, in charge at the Rabbitfoot mine says that he found the skeleton in a placer ditch 20 feet below the surface and that some of the beaver teeth were also buried in the gravel at considerable depths. Part of the skeleton is hard and heavy, as if partly petrified, but most of it is soft and whitened by weathering. The beaver teeth look comparatively fresh and are little discolored.

Heavy sand obtained by Mr. Ramey from sluices along Silver Creek at the lower Rabbitfoot camp has been examined by E. V. Shannon, of the National Museum, W. T. Schaller, of the U. S. Geological Survey, and the writer. Most of the sample consists of subrounded fragments of lava, vein quartz, and chalcedony, but the heavy minerals present include augite, magnetite, ilmenite, hematite, feldspar, zircon, pyrite, limonitic pseudomorphs after pyrite, and small amounts of wood tin, cassiterite crystals, garnet, olivine, and native copper. The gold originally present in it has been removed.

Whatever the origin of the gravel there seems little doubt that much of the gold in it was derived from the vicinity of the Rabbitfoot lode mine, nearly 4 miles up Silver Creek from the Rabbitfoot lower camp, where the placer workings are situated. The soil and debris derived from the ryolitic lava over a considerable area surrounding the lode mine are reported to contain small quantities of fine gold. The minerals in the heavy sand referred to above are all such as might be derived from the lava, and the vein quartz and chalcedony in the sand have textures characteristic of such material in the lodes in the Tertiary lava of this region.

Tin Placers

The presence of tin minerals in the heavy sand from the Rabbitfoot placer has been mentioned above. The only place in the region where an attempt to recover such minerals from placer gravel appears to have been made is at the junction of Panther, Musgrove, and Moyer creeks, in southwestern Lemhi County. It is near the downstream end of Prairie Basin, an open, hilly area underlain by gravel that is presumably of glacial origin. The gravel is derived mainly from the Tertiary volcanic rocks. The locality has been briefly described by Umpleby[1] and by Livingston[2]. Livingston failed to find cassiterite but notes that several hundred cubic yards of gravel had been washed there several years before his visit. It is not clear whether this work was done in search of tin or gold, but apparently neither was found in large amount. It appears improbable, although by no means impossible, that tin in commercial quantity will be found either in placer gravel or in lode deposits in this region.

The source of the tin in the two localities mentioned is uncertain. As no cassiterite has been found in any of the lodes in the region, it is probable that where present in the bedrock it is very sparsely disseminated. Only after concentration by natural processes in the gravel and further concentration artificially in the heavy sand obtained from washing this gravel does it become sufficiently abundant to be recognized. As most of the gravel at the two localities is composed of Tertiary lava and tuff, and as the heavy sand containing the cassiterite, at least at Rabbitfoot, is such as might well be derived from such rocks, it seems probable that the cassiterite came from them rather than from the older rocks. Boulders of pre-Tertiary rocks exist in the placer gravel, however, and therefore it is not absolutely certain that the cassiterite did not come from lodes in such rocks. Cassiterite has been reported to occur in placer deposits in two other localities in Idaho.[3] One of these is the Silver City district, Owyhee County, where most of the bedrock is Tertiary lava. The cassiterite here is the variety known as wood tin, like most of that in Lemhi County. The other is the Coeur d'Alene district, Shoshone County, where most of the rock belongs to the Belt series. Most tin lodes in the world are in pre-Tertiary rocks, especially granite, but tin veins in Tertiary rhyolite are known in Mexico, New Mexico, and Nevada.

OPALS

The only place in the Salmon River Mountains where opals have been mined is on Panther Creek near the mouth of Opal Creek, in the eastern part of the

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1 Umpleby, J. B., op. cit., p. 74.

2 Livingston, D. C. Tungsten, cinnabar, manganese, molybdenum, and tin deposits of Idaho; Idaho Univ. School of Mines Bull 2, Vol 14, pp 43-45, 1919.

3 Shannon, E. V., The minerals of Idaho: U. S. Nat. Mus. Bull 131, p. 201, 1926.

Gravel Range district. Work was done here early in the present century but ceased so long ago that little trace of the old workings remains.

The bedrock here is Belt quartzite, but it is heavily mantled with gravel and soil. According to local report all the opals were obtained from the gravel The opals first found were in boulders exposed at the surface near the stream. Later a short tunnel was driven into the east bank of the stream in the hope of finding better opals. At least part of this tunnel was in coarse gravel, but it appears from published descriptions that part of it may have been in bedrock containing opals in place. Umpleby[1] says that the opals here occurred as "linings and fillings in the vesicles of darkgray glossy rhyolite." King[2] says that they are abundant in a dike of porphyry 150 feet wide which runs parallel to the creek for a mile and a half. He got his information from Mr. S. V. Le Sieur, who reported that he discovered the occurrence in May, 1902. Some opals of satisfactory quality were obtained but the quantity was not great. The principal difficulty encountered was that the opals were so brittle and were enclosed in rock so hard that it proved almost impossible to get them out without fracturing. A wheel for grinding off the matrix was installed, but results were unsatisfactory.

Opals of apparently good quality are reported by Mr. Lee Ramey to occur in lava in Black Mountain, about 4 miles southwest of the locality just described. No development has been attempted at this place.

In the course of mapping the Casto quadrangle, opals, some of which had considerable fire, were noted on a tributary of the South Fork of Camas Creek. This tributary enters the South Fork from the north nearly 3 miles above the confluence of the South Fork with Camas Creek. The opals are in fractures and vesicles in dark-purple and green glassy rhyolite and black obsidian below a prominent bed of cream-colored tuff near the head of the east branch of the tributary and nearly three-quarters of a mile from its confluence with the South Fork. At this place also there is no evidence of any work having been done. Most of the opaline material here is not of gem quality, but the locality is worth prospecting by anyone interested in opal mining.

Shannon[3] reports that fire opal has been found in Tertiary "lake beds" at Idaho City, Boise County; in basalt near Moscow, Latah County; and in basalt and rhyolite in several localities in Owyhee County, besides the locality on Panther Creek in Lemhi County described above. Common opal is found in the Tertiary strata in a number of places in the State.

SUGGESTIONS TO PROSPECTORS

The Tertiary volcanic rocks in the area within about 30 miles in an air line on each side of the Middle Fork of Salmon River above the mouth of Big Creek may well contain undiscovered deposits similar to those described in this paper. The light-colored silicic lava and tuff appear to be more likely to contain ore deposits than the darker strata, although this is not a universal rule. Wherever the rock looks more altered or rusty than similar rock near by or contains disseminated pyrite or veinlets of chalcedony it should be tested with

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[1] Umpleby, J. B. op. cit., p. 174.

[2] King, G. F., U. S. Geol. Survey Mineral Resources, 1902 p. 853

[3] Shannon, E. V., op. cit. pp. 182-186

the gold pan. Distinction should be made between the veinlets of semitransparent, more or less brightly colored opal that are common in these rocks and are of little economic significance and the veins of dense white or pinkish chalcedony, especially if they are strongly banded, which are likely to contain gold. Some of the lava has prominent flow banding and may at first glance be mistaken for banded chalcedony, but the differences between the two are readily apparent on careful examination.

Many of the known lodes in the region were discovered by careful panning of gravel and soil in areas where outcrops of ore in place had not been recognized. The lodes in general contain so small an amount of sulphides that oxidation can not produce prominent stains on the rocks, and the masses of easily recognizable limonite characteristic of the outcrops of many ore deposits of other types are not to be expected. Careful, methodical panning in areas considered possibly favorable is the best method for the discovery of new ore deposits in the Tertiary volcanic rocks of this region.

It may be worth while to point out that pyrite is widely disseminated in the lava along Warm Spring Creek in the Challis National Forest and that some of the lava close to the granite contact on the ridge between Warm Spring and Aparejo creeks in the Salmon National Forest is rusty and altered as though by mineralization. No tests were made in either locality during the present investigation. Probably by far the greater part of the rocks in both, if they contain precious metals at all, are of much too low grade to be profitably mined However, the indications of mineralization in both localities are sufficient to encourage search in them by anyone interested in ore deposits of the kind here considered.

Tin is known at present in this region only in the placer gravel. If it is concentrated anywhere in lodes in the bedrock, such lodes can best be found by tracing the cassiterite in the gravel to its source by means of systematic panning. Although well-formed crystals of cassiterite exist in the gravel near the Rabbitfoot mine, they are so rare as to be negligible in prospecting. The variety known as wood tin is more common and can be detected by panning. Wood tin has somewhat the colors and appearance of dry wood. The common botryoidal or reniform masses with a radiating fibrous texture internally more nearly resemble some forms of limonite and may be mistaken for that substance on casual examination. They can be distinguished from limonite by the greater hardness and weight (specific gravity).

Lava flows in which there is some dark-colored obsidian appear to be favorable for the occurrence of opals, although by no means all outcrops of obsidian contain opal, and some nonglassy lava does contain it. Obsidian is easily recognized from its resemblance to dark bottle glass. It is not common in the region. As it is hard but brittle, sharp, angular fragments of it may be found in talus or gravel at a greater distance from the outcrop than would be expected with most rocks. It should be remembered that although common opal is plentiful in the region only the far scarcer opal of gem quality is of value. This is distinguished by the iridescent sparkle, known as fire, which is seen inside the stone when exposed to the sunlight.

All the localities in the Salmon River Mountains where fire opals are known to occur are in the drainage basins of Panther and Camas creeks, as already noted. It is probable, however, that exposures in other parts of the region could be found. Most of the deposits are in rocks belonging to the middle group of Miocene (?) volcanic strata.