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Geology and Mineral Deposits of Idaho: A Summary

Paul B. Bronken

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GEOLGY AND MINERAL
DEPOSITS OF IDAHO: A SUMMARY

by
Paul B. Bronken

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A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
Butte, Montana
May 17, 1947
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Montana School of Mines
Butte, Montana
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GEOLOGY AND MINERAL DEPOSITS
OF IDAHO: A SUMMARY
By Paul Bronken

INTRODUCTION

The great diversity on mineral wealth in Idaho establishes it as one of the principle mining states in the union. Mining first began in the state with the discovery of placer gold in the Pierce City district in 1861, and since that date has become one of the leading industries of the state. At present, Idaho has nearly 200 recognized mining districts of which the greater part of them have been individually described in various technical reports. However, to the knowledge of the writer, there is no one treatise that includes a description of the general geology and the mineral deposits of the entire state. It is therefore the intent of the writer to make this report a general summary of the geology and mineral deposits of this state from the existing data obtainable in technical publications.

The purpose of the report is two-fold; first, to better acquaint the writer with the geological aspects of Idaho, and secondly, to give the reader a general geological picture of the state.

Since the source of material for this report was obtained almost entirely from technical reports, most of which
were limited to the description of small regions and individual mining districts, the big problem was the compilation and correlation of the specific localized data into overall generalities that would cover the whole state. This report is not complete in any one phase, but nevertheless, effort was made to emphasize the paramount features of Idaho's geology, and its many mineral deposits.

Acknowledgements

Throughout the preparation of this report the friendly advice and material assistance given by Dr. Eugene S. Perry, Head of The Department of Geology, Montana School of Mines, proved invaluable in making this task easier and more enjoyable. For this assistance I express my sincere gratitude. I also wish to acknowledge the help received from Mrs. Loretta B. Peck, Librarian, who aided in a search for reports, and also who made a special effort to obtain publications related to the subject that were not a part of the school's library.
Mining first began in Idaho with the discovery of placer gold at Pierce City in 1860. The territory of Idaho at that time was quickly populated with prospectors who found gold in practically every stream bed from the Snake River Plains north to the Canadian line. In 1866, only 6 years after the discovery of gold, the territory had reached its highest gold production of 375,000 fine ounces per year. (See Plate 2).

The rich placer deposits were soon depleted so far as possible by the crude and primitive methods of extraction. As a result of the overflow of prospectors from the Murray gold rush in 1885, the Coeur d'Alene lead-silver and zinc district was discovered that year; and it has since been developed into one of the richest mining centers of lead, silver and zinc ever discovered. The Coeur d'Alene region at present time produces 87% of Idaho's silver, 92% of the lead, 93% of the zinc, and 76% of the copper, with a total annual value of around $38,590,000 as compared to $43,000,000, the state's total annual mineral production.

The various other metal mines in south-central Idaho were discovered in much the same way as were the mines of the Coeur d'Alene region. The exact dates of their discovery are not all known, but broadly and generally, most of the important ore deposits were discovered and developed before
the turn of the century. Production from the mines in the general region of south-central Idaho has not been large as compared to that of the Coeur d'Alene region, but nevertheless, sufficiently large enough to be of major importance during the early part of the 1900's. (See Plate 9).

Since 1933 Idaho has remained the largest producer of silver in the United States. Its peak production of silver was in 1937 with 19,500,000 ounces, of which 75% came from 10 mines, all except one were in the Coeur d'Alene region. The Sunshine mine in the Coeur d'Alene was the largest producer.

In 1945 Idaho attained first place among the zinc producing states for the first time by producing 166,426,000 pounds of zinc, which was a 9% decrease compared with the peak year of 1944.

Lead production was the greatest in the state during World War I. Although the production has declined in years since, it still remains second only to Missouri in lead output.

During the late 1930's several antimony and tungsten deposits were developed in Valley county, which during the recent war years produced 85% of the antimony and 52% of the tungsten obtained from domestic sources. Mercury, of considerable quantity, was also produced during the emergency from mines in both Valley and Washington counties. (See Plate 12).
Perhaps the greatest potential mineral resource in Idaho is the immense phosphate rock deposits in Bear Lake, Caribou, Bannock, Bingham, and Bonneville counties. Conservative estimates by members of the U. S. Geological Survey, accredit Idaho with over 85% of the total phosphate resources of the United States, amounting to 268,299 acres out of a total of 396,612 acres. At present the production of phosphate rock in Idaho is not very large, but with the advent of hydrometallurgical methods of processing the crude phosphate rock into fertilizers, the production of Idaho's phosphate will soon come to be of major importance. (Ref. 52, 60, 61, 62).
TOPOGRAPHY

Idaho may be divided topographically into the following physiographic provinces: the Lake Region in the north; the Plateau Region; the Central Mountain Region; the Snake River Plains; the Eastern Mountain Region; and the Southwest Mountain Region.

The Lake Region extends from Coeur d'Alene Lake and the Spokane River to the international boundary line. This region was formed by a combination of block faulting, followed by glaciation. The lakes which now exist are shrunken remnants of a large lake which extended from near Spokane to the Arrow Lakes in British Columbia, and to Missoula, Montana. The now remaining lakes of considerable size are Coeur d'Alene Lake and Lake Pend Oreille.

The Plateau Region is the eastern extension of the great lava plains of the Columbia River. This region comprises the country around Moscow and Lewistown, Idaho, which is known as the Palouse Hills. In the northern part of this region, the land surface is characterized by low, rolling hills of about the same elevation. The southeast portion of the Plateau Region has been deeply dissected by the Snake and Salmon Rivers, and divided by these streams into separate plateaus, ranging from about 2200 to 4500 feet in elevation.

The Central Mountain Region occupies more than half
the state. It extends from Canada to the Snake River Plains, and across the state from east to west in the central part. This vast labyrinth of deep canyons and high mountains has been formed by the elevation of what was formerly a plain or plateau, followed by tremendous erosion of the country by swift mountain streams which resulted from this elevation. The deepest canyons are those of the Salmon and Snake Rivers. The Salmon River, "The River of No Return", divides the state completely from east to west, and its canyon has in places a depth upwards of one mile. The Snake River Canyon in the Seven Devils Region is equally as deep. Its impassibility in this area forms a natural boundary line between Idaho and the states of Oregon and Washington.

The highest mountains are in the south-central part of the state at the headwaters of the Salmon River. The highest surveyed mountain is Mt. Hyndaman with an elevation of 12,078 feet, but the highest reported mountains are White Cloud Peaks in the Sawtooth Range which are stated to be 13,500 feet in elevation. Also included in the Central Mountain Region is the Bitterroot Range, which forms the continental divide, and the boundary between Idaho and Montana.

The Snake River Plains have an area of 20,000 square miles, and extend from the Oregon line to the foot of the Teton Mountains in northwestern Wyoming. This region was
formerly the site of a lake, known geologically as Lake Payette, which was filled not only with sandy sediments brought in by the streams, but also by lava flows. The Snake River has cut its channel through these beds, and in so doing has given rise to several important waterfalls, where rocks of different hardness have been encountered. The elevation of the Snake River Plains ranges from about 2,000 feet in the west to upwards of 4,500 feet in the eastern section. The Snake River Plains are the most populated areas in the state, because fertile soils support the majority of Idaho's agriculture.

The Southeast Mountain Region is quite different from the mountain mass of central Idaho. The mountains in this region are typical ranges, similar to the ranges of the Great Basin Region in Nevada and Utah. They were formed primarily by folding and faulting of the sedimentary rocks of which they are composed, rather than by erosion. The valleys between the ranges are relatively flat and suitable for farming, since they have not been deepened by swift moving streams.

In the southwest corner of the state are the Owyhee Mountains that rise sharply from the floor of the Snake River Plain to an elevation of about 8,000 feet. These mountains are the result of Tertiary block faulting, which according to A. L. Anderson (6) was a northern continuation
of the Great Basin faulting in Nevada. However, the Owyhee Mountains are not typical of the Basin and Range system to the south, in that the blocks are closer together and more irregular, which gives them a more rugged topography. (Ref. 1, 6, 11, 18, 27, 31, 33, 44, 47).

Climate

The varied topography and vast extent of Idaho give it a number of distinct climatic zones. The entire state comes under the modifying influence of the equable climate of the North Pacific Ocean, and is protected by its great north-eastern mountain barrier from the severe cold waves that sweep the plains east of the continental divide.

The mean annual temperature ranges from about 36°F., in the coldest region centering in Custer County, to 55°F. along the middle reaches of the Snake River. In the lower valley of the Snake River and its tributaries, the weather is mild enough for even the more tender fruits. Precipitation varies even more than temperature, but in general, it is greatest in the mountainous regions and least in the open plains. The driest regions are along the great southwest bend of the Snake River, in the Lost River country. The most humid region of the state is in the Panhandle area in the northern part, where the prevailing northwest winds precipitate their loads at the foot of the Rocky Mountains. (Ref. 63).
HISTORICAL GEOLOGY OF IDAHO

Most of northern and central Idaho as far south as Lincoln county was covered in late Algonkian time (uppermost Proterozoic) by a shallow Belt sea in which clastic sediments were deposited, and they accumulated to great thickness. The Belt sediments, in large part argillaceous with some calcareous beds, were early converted into quartzites and argillites. They were cut by diabase dikes probably also of Algonkian age. With local exceptions these rocks are only moderately folded, although they were regionally metamorphosed, in part by igneous agencies. In many places they are cut by shear zones and faults, some of which have large displacements, such as the Osborn Fault in northern Idaho and north-western Montana. Most of central Idaho has long been a positive area. The northern part of the state, which contains the most valuable mineral deposits of today, has no record of marine invasion since early Paleozoic time.

Throughout Paleozoic time much of the eastern half of Idaho was intermittently covered by deeper seas in which material, now converted to quartzites, argillites and marbles totaling tens of thousands of feet in thickness, was laid down. The Paleozoic seas appear not to have extended westward and northward into the positive area now occupied by the Idaho Batholith. The Paleozoic sediments
that are present on the western side of the batholith were deposited in seas that came up from the southwest. The end of the Paleozoic era was marked by the deposition of the Phosphoria formation (Permian) in southeastern Idaho, and by volcanic activity in western and southwestern Idaho.

By far the greater part of Idaho contains no Mesozoic sedimentary rocks, and most of it appears to have been dry land continuously since Permian times; although, in the most southeastern part of the state over 25,000 feet of strata, in part marine, and in part continental were deposited during the Mesozoic Era. The seas of the Rocky Mountain geosyncline advanced and retreated from time to time in this area, thus giving rise to series of marine strata interbedded with the continental deposits that were laid down during the periods of emergence. The marine sediments of the Mesozoic in this area range from relatively pure limestones to sandy and calcareous shales, whereas the continental deposits are red sandstones depicting aridity. At the close of the Mesozoic in Idaho, came the great Laramide revolution, during which the great thickness of Mesozoic strata were deformed and raised into mountainous structure. The interval between the Cretaceous and the Tertiary in southeastern Idaho was occupied by erosion of the uplifted Mesozoic strata.

The only other area of Mesozoic deposition is along
the middle portion of the western border of the state. Here, as exposed in the canyon of the Snake River, are marine and volcanic strata believed to be of Triassic or Jurassic age.

The most important happening during Mesozoic time was the great granitic intrusion of central Idaho, known as the Idaho Batholith. The exact date of this intrusion has not been positively limited to one period. There is definite evidence that places it before Middle Tertiary and not before Jurassic time. Most authors suggest that it started in the Jurassic and continued on through to the end of Cretaceous time. The profound orogenic disturbances accompanied by this great igneous intrusion gave rise to the large mountain mass that now occupies the central part of the state, and constitutes a great part of the northern Rocky Mountains.

In central Idaho deformation was more intense during intrusion of the batholith than at any other time, although there is comparatively obscure evidence of several earlier diastrophic disturbances of much less magnitude. Farther east, however, intense deformation occurred near the close of the Cretaceous, in which overthrusting persisted into Montana until Eocene time.

Cenozoic times in Idaho was largely an era of erosion that was interrupted from time to time by diastrophic changes,
and by deposition of terrestrial sediments and lava flows. South-central Idaho, during Cenozoic times, was an area of great volcanic activity, in that volcanism continued interrupedly from Miocene on through to Pleistocene times. Interbedded with these volcanic flows are the lacustrine deposits of the Snake River Plains, which were deposited in what was known, geologically, as Lake Payette.

Glaciation in north and central Idaho during Pleistocene time marked the last of any geological changes within the state. Recent erosion has accomplished little change in the topographical features developed in Quaternary times. (Ref. 1, 13, 17, 18, 27, 31, 36, 44, 45).

SOME STRUCTURAL FEATURES IN IDAHO

Snake River Downwarp

Underneath the late volcanic flows that cover the larger part of the Snake River Plains are great thicknesses of Tertiary lake beds interbedded with earlier lava flows. This area was a basin of deposition since early Tertiary times, in which several thousand feet of terrestrial sediments and extrusive lavas were laid down. The area continued to sink as more sediments were deposited until a great structural depression resulted. The depression, which has been called the Snake River Downwarp, extends in broad crescent shape across southern Idaho from Yellowstone
Evidence of the downwarp are the tilted or dipping lake beds and lava flows on both sides of the axis of the downwarp toward the axis. The formations which take part in the downwarp are in the order of their age: the lower series of the Columbia River basalt of Miocene age, the terrestrial Payette formation of Middle and Upper Miocene age, the upper series of the Columbia River basalt of Upper Miocene age, the Owyhee rhyolite of Upper Miocene and Pliocene age, the terrestrial Idaho formation of Pliocene and Pleistocene age, the terrestrial Upper Mesa formation of Pleistocene age, the Snake River basalt of Pleistocene age, and the terrestrial Lower Mesa formation of Pleistocene age.

Deep well logs near Ontario, Oregon, which is on the western end of the downwarp, record passing through the Idaho formation of Pliocene age at 2,300 feet below sea level. It is, therefore, reasonable to infer that the present position of these formations, far below the sea level, is due to subsidence caused by downwarping. (Ref. 24).

Recent Block Faulting In Idaho

Late block faulting is relatively widespread in Idaho, and extends well into the north-central part of the state. It is easily recognized in the mountainous areas and in adjacent plateaus on the west where simple tilted block mountains have been produced. Many of the faults are great
in length, and are flanked on their east sides by steep straight and continuous scarps. It has been recognized along the east side of the central mountainous area where long, well-defined ranges, separated by broad alluvial basins like those in the Great Basin of Utah and Nevada, have been formed. These eastern ranges, unlike those along the western border of the state, have straight, well-defined valley fronts, and faceted spurs on their west sides, and are tilted to the east. It is interesting to note, that along the western border of the state the fault scarps face mainly to the east, whereas along the east side of the state, they face west. A. L. Anderson (6), states that the significance of this arrangement is not yet understood unless it was due to collapse of a central area.

Much of the block faulting in Idaho is characterized by its youthfulness. Tilted blocks in most localities have been little modified by erosive agencies, in that the fault scarps are exceptionally well preserved.

The young faulting in Idaho is apparently a continuation of the Great Basin faulting and represents the progressive dying out of that type of deformation to the north. According to Anderson's interpretation (6), the late epoch of block faulting probably began rather late in Pliocene time, and probably accompanied the widespread crustal unrest at the close of the Tertiary period. Again he states that
movement probably continued into the Pleistocene, but the faulting had been completed, or largely completed, before glaciation, inasmuch as some of the scarps have been somewhat glaciated, and the basins outlining the depressed blocks are partially filled with glacial deposits. (Ref. 6).

Osburn Fault

The Osburn fault, long recognized as an earth fracture of major importance, is one of the most pronounced tectonic fractures in northern Idaho. It crosses the state in a west-northwesterly direction, passing through Shoshone county in the vicinity of Wallace. It extends from Spokane, Washington, to perhaps Deer Lodge, Montana, a distance of about 300 miles. The apparent vertical displacement caused by the Osburn fault is widely different in various places along the strike, ranging from less than 1,000 feet to more than 10,000 feet. It has a horizontal displacement from 10 to 15 miles, which makes it very difficult to correlate the opposite sides of the fault. The main fault plane dips between 60 to 70 degrees south, and its complex fracture is distributed through a zone from 100 to 200 feet wide.

Its movement, according to Umpleby (57), was contemporaneous with the mineral deposition in the Coeur d'Alene region during the close of the Mesozoic, or more specifically, in late Cretaceous or early Eocene time. Detailed studies indicate that the mineralization accompanied
granitic intrusion related to the Idaho Batholith, on the one hand, and to faulting on the other; and Umpleby suggests that the great movement along the Osburn fault involved gliding on the molten subsurface zone of the igneous intrusive.

Economically, the Osburn fault is of great importance in that the most productive mines in the Coeur d'Alene region lie in and near the fault zone. (Ref. 57).

Bannock Overthrust

In southeastern Idaho a series of thrust faults were noted by members of the U. S. Geological Survey as early as 1908. Several of these thrust zones were once thought to be individual faults, but in reality, they are parts of one great overthrust, to which the name Bannock is given, from Bannock county, Idaho, where the fault is best developed.

The trace of the Bannock fault extends approximately 270 miles from the region north of John Grays Lake, in southern Bingham county, Idaho, to the vicinity of Woodruff, Utah. The general trend of the fault trace is slightly west of north, and the direction of movement was from the west. The structure of the underlying block, as shown in the mountainous portions of the region, comprises a series of folds, for the most part close and overturned toward the east.

On the west side of Bear Lake, in the southeast corner
of the state, where Cambrain and Ordovician quartzites overlie the Woodside and Thaynes formations of Triassic age, the minimum throw has been estimated by Richards and Mansfield (40) to be at least 12,000 feet. Farther to the north in the Georgetown Canyon region, the missing formations indicate a minimum vertical component of movement in that locality of about 8,500 feet, and the minimum horizontal component has been suggested by the same authors to be not less than 12 miles, as interpreted from the lateral measurements of allochthons of the overthrust sheet. The age of the fault has been suggested by these writers to be in the time interval from late Cretaceous to early Eocene. (Ref. 40).

Old Erosion Surface in Idaho

A plateau surface has long been recognized in central Idaho, and over much of the state has been described as a feature of erosion. Plateau remnants, several square miles in extent, and reaching a maximum elevation of about 10,000 feet, are common throughout the mountainous region. Profound erosion has deeply dissected the plateau surface, and some canyons, such as the Salmon River Canyon, reach a depth of 5,000 feet.

Umpleby (55) places the old erosion surface as of Eocene age, and suggests that the great granitic batholith of late Cretaceous or early Eocene age initiated or accompanied the
initiation of the cycle of erosion which resulted in the old erosion surface.

Over much of Idaho no satisfactory datum plane has been recognized between the Algonkian and the Pleistocene. In the southeastern part of the state, formations of Paleozoic age are present, and along the western side are great sheets of Miocene basalt. Other datum planes might have been recognized, but they are all well removed from the plateau area; thus, where a datum plane is most needed, the Eocene erosion surface is best preserved. The value of the surface lies in time determination, that is, in dating the ore deposits of the mountainous region. The earlier deposits associated with the Idaho Batholith are cut by the Eocene surface, but the later deposits are enclosed in or associated with the eruptive rocks which fill the valleys developed after its elevation. Therefore, reasoning from the datum plane, the deposits may be rather definitely placed in one or the other of two distinct periods of mineralization. (Ref. 28, 45, 55).

STRATIGRAPHY

General Stratigraphy of Idaho

In no one place in Idaho is the complete sedimentary record to be observed, and one must travel to widely separated areas to see the strata of the different periods. The most complete section lies in the southeast corner of the
state where 46,000 feet of sediments constitute the stratigraphic sequence from early Paleozoic time to late Mesozoic time. Even in this area there is nowhere a complete stratigraphic sequence present, although, the sequence has been determined by combining data from different parts of the district, and from other areas. Extensive and widespread lava flows of the tertiary period conceal many of the older rocks in this section of Idaho, thus making it still more difficult to find good complete sections.

Sedimentary rocks later than pre-Cambrian in age are absent in northern Idaho, although Tertiary lavas on the western side of the region and unconsolidated Tertiary and Quaternary deposits in the valleys and low lands are present. The rocks of the Belt series predominate in this northern area, as can be seen from the geological map of Idaho. (Plate 4). The Belt rocks are also present in central Idaho where erosion following mountain uplift hasn't entirely removed them.

Sedimentary rocks of Paleozoic age crop out irregularly in the southeast part of the state, and less extensively north of the Snake River Plains in the east-central part of the state. There are also a few outcrops of Carboniferous strata in the west-central part of the state near the Oregon-Idaho boundry line. Although the Paleozoic beds were originally deposited horizontally or nearly so, they have
been warped, folded, and faulted so that now they stand in attitudes ranging from horizontal to vertical. The truncation of the formations by erosion has exposed them where they may be seen at many places, except where younger lava flows have completely covered them.

Mesozoic sedimentary rocks have the smallest surface extent of the exposed sediments in Idaho, even though where they crop out in the extreme southeastern part of the state, they have an aggregate thickness of over 25,000 feet. Similar to the Paleozoic beds in this region, the Mesozoic beds have been warped, folded, and faulted into the mountain ranges of the region. The sequence of the Mesozoic rocks in southeast Idaho is fairly easy to determine, because the beds are well exposed, and easily correlated with the Mesozoic strata of neighboring regions. A small area along the Snake River in the Seven Devils region is the only other area of exposure of Mesozoic rocks within the state of Idaho.

Lava flows of Tertiary age are exposed over a larger area than any other group of rocks or sediments of any one era. They are most widespread in the south-central part of the state, but the lavas of the Columbia River lava flow cover large areas on the western side of the state from the Palouse country in the north to the Snake River Plains in the south. In the Snake River Plains area, flows of Tertiary lava are interbedded with lake bed deposits of the same age,
the lake deposits being of greater thickness, but of less areal extent.

The Tertiary lake beds cover large areas in the western part of the Plains region, and they are extensive to the north and south of the Plains region in the eastern part of the state. The outcrop of slightly dipping lake beds along the flanks of the Snake River Downwarp indicate that the terristrial sediments of Tertiary age at one time covered most of southern Idaho. Recent block faulting in southern Idaho also has exposed the lake beds under the younger lava flows. The series of Tertiary lake beds and lava flows in the Snake River Plains region has been slightly warped into a large syncline, constituting the Snake River downwarp. In the southeastern and southwestern parts of the state the Tertiary sediments also have been warped, and they are more faulted than in south-central Idaho, due to the late Tertiary block faulting.

The greater part of Idaho has a mountainous terrain that has been the source of the unconsolidated sediments of Quaternary age which are found in practically all the valley floors within the mountainous regions. In the southern part of the state, where the climate has been somewhat semi-arid since Quaternary times, much of the recent sediments are wind-blown deposits that had their source to the flat lying plains to the north. (Ref. 16,17,18,23,24,36,39,41, 49,51,58).
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**Legend:**
- **Permian:** Phosphoria Formation, Wells Formation, Brazer Limestone, Madison Limestone, Upper Devonian, Three Forks Limestone, Middle Devonian, Jefferson Limestone, Upper Ordovician, Fish Haven Dolomite, Lower Ordovician, Garden City Quartzite, Garden City Limestone, Upper Cambrian, St. Charles Limestone, Jounan Limestone, Bloomington Formation, Blacksmith Limestone, Ute Limestone, Lower Cambrian, Brigham quartzite.
- **Pennsylvanian:** Casto Volcanics, Wood River Formation.
- **Upper Mississippian:** Brazer Limestone, Milligen Formation.
- **Mississippian:** Grand Veil Dolomite, Jefferson Dolomite, Laketown Dolomite.
- **Upper Devonian:** Trail Creek Formation, Saturday Mt. Formation, Kinnikinikin Formation.
- **Middle Ordovician:** Lower Ordovician, Ramshorn Slate, Bayhorse Dolomite.
- **Lower Ordovician:** Swan Peak Quartzite, Garden City Limestone.
- **Algonkian (Belt):** MONTANA SCHOOL OF MINES LIBRARY BUTTE.
- **Striped Peak Shale:** Wallace Shale, St Regis Shale, Revett quartzite, Burke Shale, Prichard Argillite.
Pre-Cambrian Rocks: (36, 39)

The Belt rocks of north and north-central Idaho are the only pre-Cambrian rocks of any importance within the state. In northern Idaho, where they have an aggregate thickness of about 17,000 feet, they are the only consolidated sedimentary rocks. In the Coeur d'Alene region, Ransome and Calkins (39) have subdivided the Belt series into six formations based upon lithologic characteristics since all the rocks of the Belt series are devoid of fossils.

The Prichard slate, the lowest formation, is a very thick accumulation of sediments, composed in the greater part of argillite, regularly banded in light to dark shades of blue gray. The formation also contains some gray indurated sandstones, which occur at various horizons, but which are especially abundant near the top. It has a thickness of over 8,000 feet, and at no place affords exposures of an underlying Archean complex.

The Burke formation is so named because of its extensive areal development and good exposures in the vicinity of the town of Burke. It is composed of siliceous rocks, prevailingly fine grained, thin bedded, and of a light greenish-gray tint. The lithologic character ranges, however, from that of fairly pure, nearly white quartzite to that of dark-gray siliceous shale. Again the quartzite is more abundant.
in the upper part, and the shale in the lower part of the formation, and the formation exhibits a transition into the quartzitic and argillaceous formations that lie above and below it. Its thickness has been determined to be about 2,000 feet.

The Revett formation is composed mainly of hard white thick-bedded quartzite, although it contains some softer arenaceous beds. In general the middle part of the formation is the most purely siliceous, and the lowermost and uppermost parts are softer and thinner bedded. The Revett formation has a thickness of 1,200 feet, and of all the formations in the district, it is the most resistant to erosion, and it constitutes the summits of many of the elevated peaks within the area.

The stratigraphic unit next above the Revett quartzite is the St. Regis formation. It resembles the Burke in general composition, and in texture of its rocks, which are indurated shales and sandstones. Sun cracks, ripple marks, and other features give evidence of deposition in shallow water. In contrast to the light-colored Burke rocks, the St. Regis beds are dark-green to purple, the latter color being especially characteristic. It has a thickness of 1,000 feet.

The Wallace formation consists chiefly of thin-bedded rocks which contain a considerable amount of the carbonates
of calcium, magnesium and iron. This feature of its composition is highly characteristic, and distinguishes it from all other formation in the district. The lower part is composed chiefly of green slate containing more or less calcareous material; the middle part is composed of thin alternating beds of impure limestone, bluish and greenish-gray argillites, and a light-colored indurated calcareous sandstone or quartzite; and the upper part is composed chiefly of more or less calcareous argillite with some thin laminae of limestone. The formation was named from the town of Wallace where 4,000 feet of the formation affords several good exposures.

The uppermost formation of the Belt series in the Coeur d'Alene region is the Striped Peak. The formation, whose top has been removed by erosion, is quite similar to the St. Regis, and further description of its lithologic character is unnecessary.

Cambrain Rocks: (36, 51, 58)

In southeastern Idaho the oldest rocks are of Cambrain age and consist of quartzites, limestones, shales and some sandstones, with an aggregate thickness of about 7,000 feet. The Cambrain system contains seven formations that will be briefly described in ascending order.

The Brigham quartzite, of Lower Cambrain age, consists of massive more or less vitreous quartzite or quartzitic
sandstone, generally of purplish or reddish tinge, together with conglomeratic layers and some beds of hard, sandy micaceous shale. Its thickness ranges from 1,000 to 1,600 feet.

The Langston limestone is exposed above the Brigham quartzite in a few localities in southeastern Idaho. It is a massive, bluish-gray limestone with many round concretions, and the limestone weathers to a buff color. It ranges in thickness from 250 to 600 feet.

The Ute limestone, composed of blue to bluish-gray thin-bedded fine-grained limestones and shales, lies above the Langston, and is easily differentiated from the latter by a shale member comprising the lower 30 feet of the formation. The total thickness is 760 feet.

The Blacksmith limestone, which lies stratigraphically above the Ute limestone, is similar to the upper beds of the Ute, but the bedding is more massive, and the boundary between the two formations is generally marked by low cliffs. Its thickness is 750 feet.

The Bloomington formation lies conformably above the Blacksmith limestone. Its lower member consists of a olive-green shale, above which lie a series of bluish-gray, thin-bedded limestones. Its thickness is 1,200 feet.

The Nounan limestone is a massive-bedded, whitish or light-gray, somewhat coarsely crystalline colomitic limestone. The upper part of the formation is composed of
massive beds of limestone, portions of which contain streaks of impure chert. Its thickness is 1,050 feet.

The St. Charles limestone consists of bluish-gray to gray arenaceous limestones, which pass at the base into thin-bedded gray to brown sandstones. Its thickness ranges from 950 to 1,200 feet.

The Cambrian rocks in south-central Idaho are grouped into two formations, the Garden Creek phylite, the lowermost formation, and the Bayhorse dolomite of Upper Cambrian age. The Garden Creek phylite is composed exclusively of a dark-gray or nearly black phylite with abundant silvery sericite. The base is not exposed but it is believed to be several hundred feet thick. The greater part of the Bayhorse dolomite is composed of thick-bedded dolomite that tends to form prominent cliffs. The dolomite is light-gray and weathers readily to a rusty buff color. It has an average thickness of 1,000 feet.

Ordovician Rocks: (36, 51, 58)

The Ordovician system in southeastern Idaho is represented by a series of gray limestones, quartzites, black cherty to gray magnesium limestones and dolomites, which have been divided into three formations which in ascending order are the Garden City limestone, the Swan Peak quartzite, and the Fish Haven dolomite. The system is well exposed in this area, and has an aggregate thickness of about 2,200 feet.
The rocks of the Garden City limestone form a succession or thick and thin-bedded gray limestones about 1,250 feet thick. A characteristic feature is the presence throughout the formation of a conglomerate or breccia that consists of elongated fragments of limestone.

The Swan Peak quartzite is composed of about 500 feet of white quartzite, whose weathered surfaces are characterized by a peculiar vertically jointed or stem-like structure.

The Fish Haven dolomite is a fine-textured, medium-bedded, dark-gray to blue-black, cherty dolomite, about 500 feet thick.

In the Bayhorse district in south-central Idaho, there have been named three formations belonging to the Ordovician period. The Ramshorn slate is the lowermost of the three, and consists of thin-bedded argillaceous rocks with well developed slaty cleavage. Its color ranges from a dark-green to purple, and it has a variable thickness, ranging from 2,000 to 4,000 feet thick.

The next formation above the Ramshorn slate is the Kinnikinic quartzite, a nearly pure quartzite with small amounts of shaly beds. The prevailing color of the fresh quartzite is white or nearly white, but some exposures have a distinctive lavender color.

The Saturday Mountain formation is composed dominently of a shaly dolomite, much of which contains enough carbon-
aceous matter to be black on the fresh surface. Its thickness differs due to close folding, the average is about 3,000 feet. The Saturday Mountain and the Kinnikinic formations correspond to the Phi Kappa formation in the neighboring Wood River region.

Silurian Rocks: (36, 51)

In southeastern Idaho the Silurian system is represented by only two occurrences of small areas of Laketown dolomite. It includes light-colored calcareous and sandy beds that lie apparently conformable above the Fish Haven dolomite. Its thickness is from 0 to 1,000 feet.

The lower of the two Silurian formations in south-central Idaho is the Trail Creek formation. It is a brownish-gray calcareous argillite whose top or bottom isn't exposed well enough to determine its thickness, but it is believed to be several hundred feet thick.

The Laketown dolomite in the Bayhorse district consists of moderately thick-bedded, bluish-gray dolomitic limestone, much of which weathers rusty. None of the exposures include the total thickness of the formation. In two localities it has been calculated to be from 2,500 to 3,000 feet in thickness.

Devonian Rocks: (36, 51)

Devonian rocks are found in several small areas in southeastern Idaho. They are divided into the Jefferson
limestone or dolomite of Middle Devonian age, and the Three Forks limestone of Upper Devonian age. The two formations are different lithologically; the Jefferson limestone as exposed is a dark, nearly black magnesium limestone, and the Three Forks above consists of thin beds of impure reddish limestone. The combined thickness of the two does not much exceed 1,000 feet, the Jefferson dolomite being about 900 feet in thickness.

The Jefferson dolomite of south-central Idaho is very similar in all respects to the Jefferson limestone of Montana which is the type area. The Jefferson is distinguished in southern Idaho by its color which is dark bluish gray, and by the abundance of the fossil coral Favosites. It has a thickness of 1,150 feet.

The Grand View dolomite, of Upper Devonian age and equivalent to the Three Forks, is a fine-grained dolomitic limestone lighter in color than the Jefferson below, and it has a thickness of 1,100 feet in this locality.

Mississippian Rocks: (36, 51)

In southeastern Idaho the Mississippian series includes two formations, the Madison limestone below and the Brazer limestone above. Both formations are characterized by rather pure gray limestones, but there are lithologic as well as faunal differences. Both formations are greatly affected by structural movements, and are exposed only as a
result of deformation and erosion. The Madison consists of 1,000 feet or less of thin-bedded, dark bluish-gray limestones. The Brazer formation, which rests with apparent conformity on the Madison limestone, is massive light-to dark-gray limestone, much resembling the Madison; and it has an average thickness of 1,100 feet.

In south-central Idaho the Milligen formation corresponds to the Madison in the southeastern part of the state. The greater part of the Milligen formation is a black carbonaceous argillite with some beds calcareous and others sandy. Its total thickness is 3,000 feet or more.

The Brazer limestone in the Bayhorse district is composed of a magnesian limestone. Most of the beds are moderately dark gray, but some are nearly white, and others are almost black. The Brazer in this locality is over 2,000 feet thick.

Pennsylvanian rocks: (36, 51)

The Pennsylvanian rocks in southeastern Idaho all belong to the Wells formation. Like the Mississippian formations, the Wells is brought to the surface by deformation and erosion. The Wells formation has three variable but fairly distinct parts; a lower sandy and cherty limestone series, a middle sandy series, and an upper siliceous limestone. The total thickness of the formation ranges from 2,000 to 2,400 feet.
The Wood River formation of the Bayhorse district in south-central Idaho is by far the thickest formation in that area, this thickness amounting to 8,000 feet or more. In this district it consists mainly of impure quartzites, both argillaceous and calcareous, but in some places limestone beds are present.

Permain Rocks: (36, 37, 51)

The Permain rocks in southeastern Idaho constitute a single formation, the Phosphoria, which although not of great thickness, maintains a high degree of uniformity in character over a wide area. The formation contains two distinct lithologic units. The upper unit consists of massive limestones and cherts, called the Rex Chert member. The lower unit comprises the phosphatic shales with which are included beds of limestone and natural rock phosphate. The Rex Chert member has a thickness of about 500 feet, whereas the phosphatic shale member is only between 150 to 200 feet thick.

North of the Bayhorse district are few minor outcrops of volcanic rocks which are believed to be of Permain age. Little or no mineralization has been found in or near these volcanic rocks, so that little importance is attached to their occurrence.

Triassic Rocks: (36)

Triassic rocks occur only in southeastern Idaho where
they are well developed along the eastern border of the state. Three subdivisions totaling 5,350 feet in maximum thickness are distinguished; in ascending order they are the Woodside shale, Thaynes group and the Timothy sandstone, all of the Lower Triassic series. In addition three other formations of uncertain age, the Higham grit, Deadman limestone, and the Wood shale, whose combined thickness is 550 feet, are considered provisionally Triassic.

The Woodside shale in this region is composed largely of fine-grained, dark-red shales, with subordinate occurrences of buff, brown, and greenish-gray shales. The lithology of the Thaynes is similar to that of the Woodside in many respects. In general, the lithologic differences is that the shales of the Thaynes are greener in color, and the Thaynes has more prominent limestone beds.

The Timothy sandstone is a sugary, yellowish to grayish sandstone. In some localities the Timothy sandstone consists of cross-bedded and coarse-textured sandstones with conglomeratic layers in which the fragments are small pieces of limestone like that of the Thaynes.

Jurassic Rocks: (36)

The Jurassic system is equally well represented in south-eastern Idaho. It includes four formations, named in ascending order, the Nugget sandstone, the Twin Creek limestone, the Preuss sandstone, and the Stump sandstone. The three
sandstone units are characteristically fine-grained, and color ranges from red to light-greens. Combined thickness is 3,200 feet. The Twin Creek limestone is characteristically a massive brown sandy limestone together with thin and cross-bedded limestones.

Cretaceous Rocks: (36)

Above the marine Jurassic formations lies a series called the Gannet group, composed of conglomerates, fresh water limestones, and sandstones containing a fresh water fauna. These rocks have been correlated with the Kootanai formation of Montana. Unconformably upon the Gannet group lies another series of sandstones, shales, carbonaceous shales, limestones and conglomerates that have an apparent thickness of 11,800 feet. This series has been included in the Wayan formation, and according to Mansfield (36), are placed in the lower Cretaceous.

Upper Cretaceous rocks are not reported to be present.

Tertiary Rocks: (17, 23, 24, 36, 39, 51)

The beds assigned to the Eocene series in southeastern Idaho consist of conglomerates, soft sandstones, and fresh water limestones, and they are referred to as the Wasatch formation. The exposed thickness of the Wasatch does not exceed 1,500 feet in this area, but the beds have been greatly eroded and may have been much thicker.

Unconformably upon the Wasatch deposits in some areas,
and upon pre-Tertiary sediments in areas where Lower Tertiary sediments are not present, lies a group of light-colored grayish or yellowish conglomerates with associated marly, gritty, or sandy beds of similar tints that produce white or light-colored soils. The beds are tentatively regarded as of Pliocene age by Mansfield (36), and are included in the Salt Lake formation.

In northern Idaho, Tertiary deposits are the only other sedimentary rocks that are younger than the pre-Cambrian rocks of the Belt series. They consist of deposits of gravel, sand and silt laid down upon the eroded surfaces of the older rocks by streams and glaciers.

By far the greatest accumulation of Tertiary sediments is in the Snake River Plains area, where several thousand feet of lacustrine deposits are interbedded with the extensive lava flows of this period. The beds of the lowermost Payette formation consist chiefly of well-consolidated ash, carbonaceous or coaly shale, and sandstone. The total thickness of these sediments ranges from 800 to 1,000 feet.

The Idaho formation of Pliocene and Pleistocene age consists mainly of light-colored lacustrine shales with a few sandy beds at the lower part of the formation. Most of the formation is well stratified, but on the whole, the formation is poorly consolidated.

Quaternary Rocks: (17, 24, 36, 39, 51)
Quaternary deposits in most of Idaho, excepting the Snake River Plains area, consist mainly of partly and completely unconsolidated clastic deposits resulting from glacier action and recent erosion. In the Snake River Plains where the climate has been semi-arid since Tertiary times, the deposits of Quaternary age are mostly wind-blown deposits of sand, silt and volcanic ash.

IGNEOUS ROCKS OF IDAHO

Granitic Rocks

Since the earliest reconnaissance work in Idaho, the great mass of granitic rock in the central part of the state has stood out as one of the most conspicuous features of its geology. The greater part of the intrusive granitic rock within the state belong essentially to one geologic unit, which has come to be called the Idaho Batholith. The geological map of Idaho, Plate 4, shows the extent of this large intrusive mass.

The Idaho Batholith is composed mainly of quartz monzonite, although some rocks, mainly marginal, are granodiorite, and minor amounts of other granite rocks occur. It is now exposed over 16,000 square miles, extending from the vicinity of Boise northward through the center of Idaho into Montana. In the northernmost part of the state, is another exposure of intrusive igneous rocks which have been genetically related to the main igneous mass in the central
part of the state.

Most of the southern, western and eastern borders of the Idaho Batholith are rimmed with Tertiary rocks, mainly Miocene volcanics. Near the southeastern end, the batholith intrudes a thick series of Paleozoic strata ranging in age up to the Pennsylvanian. Farther north on the eastern border of the batholith, the bordering formations are mostly Algonkian quartzites and slates of the Belt series and Tertiary volcanic rocks which were deposited against it. To the northeast the batholith extends into part of Montana, where it is bordered mainly by Belt rocks. The northern part of the batholith, in Idaho, is intrusive into the Belt rocks.

It appears from available data that the Idaho Batholith and the majority of the neighboring stocks have steep sides, but expand downward. So far as present data shows, there is no evidence that the batholith has a floor or is restricted at depth. Roof pendants, which are widely distributed over the exposed part of the batholith, indicate that the original surface of the batholith was but little above the tops of the present mountains of granitic rock.

Lindgren in 1898 recognized the intrusive igneous character of the batholith, and suggested that the mineral veins in it were of Cretaceous or early Tertiary age. In
a later report (27) he considered the batholith to be probably post-Triassic in age. Umpleby (55), mainly as a result of his interpretation of the physiographic history of the region, considers the batholith to be of late Cretaceous or early Eocene age.

The principle uncertainty as to the age of the Idaho Batholith lies in deciding the length of time which elapsed between its intrusion and the deposition of the Tertiary volcanic rocks on its eroded surfaces. To summarize, the Idaho Batholith is probably younger than Triassic, and probably as old as Lower Cretaceous, and certainly as old as Upper Cretaceous. According to C. P. Ross (42), a batholith of such a magnitude is generally related to major orogenic disturbances, and thus he regards this batholith as one of the products of widespread diastrophism which occurred in the Cordilleran region near the end of Jurassic time.

Granitic rocks younger than the Idaho Batholith are known along the Middle Fork of Salmon River, and in and near the Wood River region in south-central Idaho. The main body of these younger rocks, consisting dominately of pink granite, has been judged by C. P. Ross (42) to be of Miocene in age.

The only other rocks of approximately granitic texture in Idaho which have been proved to be of Tertiary age are those in the northwestern part of the Wood River region,
Blaine county. In this locality the rocks consist of a complex of irregular stocks and large dikes ranging in composition from granite porphyry to diorite porphyry. Numerous related dikes, smaller and finer-grained, are also present. (Ref. 5, 9, 13, 25, 42, 47, 51, 56, 58).

Volcanic Rocks

Tertiary volcanic rocks make up the second large group of igneous rocks in Idaho. They are widely distributed throughout the greater part of southern Idaho and along the western flank of the Idaho Batholith as far north as the city of Coeur d'Alene.

The oldest volcanics are the lower series of the Columbia River basalt flows of Miocene age, which covered practically all of western and south-central Idaho, with the exception of the mountainous areas in the central and southeastern part of the state. The upper series of the Columbia River basalt, of Upper Miocene age, was equally widespread. In the Snake River Plains area, the upper series is separated from the lower by the lacustrine Payette formation of Middle and Upper Miocene age. The basalt in both series differs in character from place to place, but generally, the upper series is less porphyritic than the lower series. The rocks of both series may be classified as dark medium-grained and vesicular, and porphyritic with
lath-like grains of labradorite, augite and olivene in a dark glass matrix. In south-central Idaho, the Miocene volcanics have been called the Challis Volcanics, which is a local name given to the lava flows related to the Columbia River basalts.

The Owyhee rhyolite of Upper Miocene and Pliocene age, which overlies the basalts, is part of a very extensive volcanic sheet that is involved in the Snake River Downwarp throughout Idaho; and it extends in scattered erosional remnants over areas in the region bordering the downwarp in Utah, Nevada, Montana and Wyoming. The flows in the eastern part of the plains area corresponding to the Owyhee rhyolite, belong to the widespread westward extending sheets of the Yellowstone Park region. A great part of the lava in the eastern plains has a similar origin. South of the plains area are several old, and relatively small acidic lava and tuffaceous cones that suggest the mode of origin of some of the rhyolitic flows. The thickness of the Owyhee rhyolite ranges from a few feet in some localities to 2,000 feet or more in other localities, the average thickness being from 700 to 1,000 feet. The lithologic characteristics differ in different localities. It generally has a pale lavender to mauve color, and contains considerably more feldspars than quartz.

The Snake River basalts make up the last large lava
series in southeastern Idaho. According to Russell (53),
the Snake River Basalt covers in the neighborhood of 2,000
square miles, and it is credited by him as being the second
largest lava field in North America. At all places this
basalt is less weathered and usually more fine-grained than
the Columbia River basalt. It is a heavy, dark-gray to black
rock which contains varying amounts of olivene, magnetite
and labradorite. The immediate origin of the basalt is indi-
cated by cones and vents that are found in several localities
over the Snake River Plains, time of eruption has been
placed in the Pleistocene period. The extent of the Snake
River Basalt can be seen on the Geologic Map of Idaho,
Plate 4, on which it is colored-in as light orange.

Lavas believed to be of modern time are present in
the north-central plains area. The most recent are those
occurring in the "Craters of the Moon National Monument"
which Stearns (54) intimates were poured out not much more
than 250 to 1,000 years ago. (Ref. 11, 17, 23, 24, 47, 53,
54, 56, 58).

ECONOMIC GEOLOGY

The ore deposits of Idaho, with a few exceptions, may
be grouped into two major classes corresponding in time to
the two major intrusive periods. The earlier of these,
which is related to the Idaho Batholith, includes gold-
bearing veins formed within the batholith and in its out-
liers, together with the products of igneous metamorphism in parts of the invaded rocks. The later deposits are lodes in shear zones at greater distances from the source. The earlier class includes the "mother lodes" of most of the placer deposits on which mining in the state was first started. It also includes the lead-silver and zinc lodes for which the state is now noted, as well as various other deposits of minor importance.

The second class is related to the Tertiary intrusive, and these deposits noted mainly for their gold and silver content. More specifically, all the ore deposits in Idaho of Tertiary age are related either to the Miocene granites and associated dike rocks, or to the Challis volcanics (Miocene) and strata correlatable with them. In most places both the intrusive and effusive rocks are exposed in the vicinity of the lodes.

Pre-Cambrain deposits are not present in Idaho, except possibly in some of the less important districts in the northern part of the state, where mineralization seems to have accompanied the intrusion of diabase sills in the Belt series. Here as elsewhere, two kinds of deposits may be recognized: those which were formed shortly after the intrusion of the great Idaho batholith, probably in late Cretaceous time; and those of late Tertiary age, which developed after the outburst of the Tertiary lavas.
A few unimportant deposits of copper and lead ores of uncertain age occur in the Paleozoic limestones of the ranges in the extreme southeast corner of the state.

The upper parts of the late Cretaceous ore deposits have to a considerable extent been removed by erosion, and the parts now exposed contain ores formed at considerable depths, or at least in the lower parts of the original veins. They are mainly fissure veins, but in places, as in southern Lemhi County and in the Wood River district, these merge into replacement deposits of galena and other sulphides in limestone.

During Quaternary time erosion, both by normal stream action and glacial action, in at least two stages, was active throughout the state. This, coupled with the erosion referred to above, has removed the upper portions of both the Cretaceous and Tertiary ore deposits so generally that oxidized ore bodies are exceptional; and with few exceptions, supergene enrichment is negligible. This has also resulted in the accumulation of large placer deposits.

To best describe the geology of the mineral deposits in Idaho, the following section will include the economic geology of the more important ore deposits of both Cretaceous and Tertiary age. (Ref. 3, 13, 48, 49).

Typical Ore Deposits of Mesozoic Age
Coeur d'Alene Region: (3, 39, 49, 52)
The deposits of the Coeur d'Alene region in northern Idaho, which have yielded in large percentage of the lead production in the United States, are the only important galena-siderite veins of mesothermal origin in the United States. The ores occur along shear zones in fine-grained sericitic quartzite of the Belt series, in a region containing a number of small intrusive stocks of monzonite which are genetically related to the Idaho Batholith. The mineralized fractures are minor breaks of small throw in rocks which are folded and strongly faulted. The ore deposits are composite replacement veins or lodes, ranging in width up to 40 feet, the average being about 9 feet. The veins trend northwesterly with nearly a vertical dip, and the more persistent veins have been followed for several thousand feet along the strike.

The metallic minerals are galena and sphalerite, with some pyrite, and in some mines a little tetrahedrite, although the general absence of tetrahedrite is the chief distinction between the lead ores of the Coeur d'Alene region and the Wood River district.

The galena is low in silver, but so much of it is produced that a large output of silver results. Siderite is the chief gangue mineral. Quartz is also present, and barite, calcite and dolomite are rare. An increase in the proportion of sphalerite, pyrite, and pyrrhotite is reported.
at depth in most of the mines. The ore deposits show gradations to certain contact deposits produced by igneous intrusions from the same cooling magma. The date of their formation is therefore narrowly limited to the period between the intrusion of the monzonite and the final cessation of igneous activity. As stated before, the monzonite intrusion is believed to have taken place in the Cretaceous along with the Idaho Batholith.

The zinc deposits of the Coeur d'Alene region are characterized as pyrometasomatic deposits occurring in Algonkian sedimentary beds which have been metamorphosed to biotite schists and fine-grained quartzites. Both types of rocks contain variable amounts of garnet, pyroxene, biotite and muscovite. In some places the ore bodies cut through apophyses of monzonite, which are off shoots from the stock related to the Idaho Batholith. Sphalerite is the chief mineral, but galena, magnetite, pyrite and quartz generally occur.

Seven Devils District: (26, 49, 52)

This district contains the first contact metamorphic deposits recognized to occur in America as was pointed out by Lindgren (26) in 1900. Lindgren regards the deposits as of pneumatolytic origin formed during the solidification of an intrusive diorite magma. The ore deposits occur mainly in blocks of limestone engulfed in quartz diorite
or granodiorite, supposedly an outlier of the Idaho Batholith. The ore consists of bornite and chalcopyrite in a gangue composed chiefly of garnet, epidote and pyroxene. Zoisite, actinolite and tremolite are fairly common.

Wood River District: (29, 49, 52, 58)

The Wood River District in south-central Idaho includes four mining districts of importance (Plate 8, Nos. 20, 21, 22 & 26). This district has been described as having the typical tetrahedrite-galena-siderite veins of mesothermal origin for the state of Idaho. The veins, most of which are narrow, occur chiefly in a calcareous shale of Carboniferous age, bordering both sides of an elongated intrusive granitic stock. The stock is an outlier of the Idaho Batholith, and in this area is composed mainly of quartz monzonite and quartz diorite. Few veins lie within the granitic mass. The primary ores become leaner at depth because of pinching of the veins, and because of an increase in the proportions of sphalerite, pyrite and quartz.

Mackay District: (49, 52, 56)

The mining districts around Mackay, Idaho, are notable because the ore bodies all occur in garnetized blocks of limestone that are engulfed in a granite porphyry. The granite porphyry forms a stock 10 square miles in area which is regarded as an outlier of the Idaho Batholith. No ore occurs in the limestone along the contact of the
stock, but the ore is wholly restricted to blocks of limestone well within the porphyry, and it extends to depths as great as 700 feet beyond the contact surface. The ore consists of andraditic garnet and interstitial chalcopyrite with minor amounts of pyroxene, pyrite, pyrrhotite and fluorite. Two stages of metamorphism are recognized within the limestone ore bodies; marmorization, probably contemporaneous with intrusion, followed by metasomatism after an interval long enough to allow the border of the stock to solidify to a shell at least 700 feet thick.

Loon Creek District: (49, 52, 56)

Chalcopyrite-quartz veins of mesothermal or replacement in origin occur in several districts in Idaho. Among these, the Lost Packer vein in the Loon Creek district is typical of those in other districts. The ore occurs in a steeply dipping fissure in a mica schist. The mineralization, consisting of chalcopyrite with pyrite and some pyrrhotite in a blue quartz, is localized in three shoots, each about 200 feet long and averaging 2 to 3 feet wide. Replacement rarely extends outside the fissured zone. Similar deposits are found in the St. Joe district, in the Big Creek district of south-central Idaho, the Clark Fork district, the Oxford district, the Lolo district and in Boundary county.

Elk City District: (13, 38, 49, 52)

This district, underlain by rocks related to the Idaho
Batholith, is typical of Mesozoic gold and silver deposits, both lode and placer. The quartz monzonite of the batholith is capped by small roof pendants of quartzite, and the valley around Elk City is floored by Tertiary sediments. Most of the lodes are made up of quartz lenses, the maximum thickness ranging up to 20 feet, and the length being 300 feet or more. The lodes are grouped in a radiating system in Mesozoic rocks. Sulfides commonly make up less than 5 per cent of the ore and include pyrite, tetrahedrite, sphalerite, chalcopyrite, galena, with some native gold and minor amounts of other metallic minerals. With local exceptions, oxidation is shallow. Gold is widely distributed as placer in small amounts in the Tertiary sediments, and results in the so-called high level deposits of the area. These have been left as the gold content was too low for profitable working under primitive methods of operation. Richer deposits, now largely worked out, were formed by reconcentration of the old sediments in two stages along modern streams. Recently there has been a revival of placer mining in several regions similar to the Elk City district due to modern means of concentration by large gold dredges.

**Typical Ore Deposits of Tertiary Age**

**Silver City District:** (49, 52)

The Silver City region in Owyhee county is the best known, and by far the most productive of the areas in Idaho.
containing Tertiary lodes. The region contains a stock of granodirite, petrographically similar to, and presumably of about the same age, as the Idaho Batholith. Small blocks of schistose sedimentary rocks remain locally on the margin of the stock. The ore shoots are found in veins that follow minor faults in Tertiary volcanic rocks, chiefly rhyolite. The principle hypogene metallic minerals of the region include argentite, electrum, jamesonite, ruby silver, and related minerals together with naumannite, owyheeite, stibnite, tetrahedrite, arsenopyrite, galena, pyrite, marcasite and other minerals in minor amounts. The gangue minerals include barite, calcite and quartz, which is by far the most abundant gangue mineral. The very rich ore that has been mined near the surface resulted from supergene enrichment, but the larger part of the ore that has been mined was of hypogene origin. The veins tend to be exceptionally persistent along both strike and dip. Some are several thousand feet long and the Oro Fino-Golden Chariot vein is still strong at a depth of 2,500 feet below the outcrop.

Alder Creek District: (2, 32, 49, 52, 56)

This district and the Lava Creek district in western Butte county are the two other remaining districts of noteworthy importance of Tertiary mineralization.

The Alder Creek district is underlain largely by dolomitic limestone of the Brazer and other Paleozoic sedimentary
formations. Granite and related porphyries of probable Miocene age cut both the Paleozoic and Tertiary strata. The ore deposits lie along the border of the main intrusive mass, the ore being in part in the limestone, and in part in the igneous rock. In most deposits of the district, the principal hypogene mineral is chalcopyrite, although much of the ore that has been mined had been more or less thoroughly oxidized. Some lead veins are reported to be present in outlying parts of the district, but little is known about them.

The Lava Creek district in Butte county contains Carboniferous sedimentary rocks overlain by the Challis volcanics (Miocene), both intruded by granite and related dikes of Miocene age. The ore deposits are mainly in the Challis volcanics. Some are valuable for silver, others for lead and zinc, and a few for antimony, copper, or tungsten. The lodes are fissure veins and breccia zones, and formed mainly by replacement but in part by fissure filling.

NON-METALLICS IN IDAHO

Coal: (52)

Three kinds of coal are known in Idaho. One of these is the graphitic anthracite in Carboniferous strata near Ketchum, Blaine county, which at the present time has no value as fuel. A second type is in Cretaceous rocks in Bonneville, Clark and Teton counties, and it is generally
MINING DISTRICTS IN THE STATE OF IDAHO

1. Pend Oreille
2. Coeur d'Alene
3. Pierce City
4. Elk City
5. Ten Mile
6. Gibbonsville
7. Florence
8. Mackinaw
9. Warren
10. Seven Devils

11. Bayhorse
12. Yankee Fork
13. Loon Creek
14. Nichoia
15. Texas
16. Banner
17. Quartzburg
18. Dome
19. Alder Creek
20. Vienna and Sawtooth
21. Warm Spring
22. Little Smokey
23. Yuba
24. Bear Creek
25. Featherville
26. Mineral Hill
27. Neal
28. Silver City
29. Mineral Hill
30. Stibnite
31. Yellowpine
32. Mackay

Areas Described

Boise
27 24 23

Idaho Falls
26 25 22 21

. Pocatello
<table>
<thead>
<tr>
<th>Mine or Mining District</th>
<th>Locality</th>
<th>Metals Produced</th>
<th>Total Production</th>
<th>Type of Deposits</th>
<th>Principal Minerals</th>
<th>Age of Deposits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Pend Oreille District</td>
<td>Bonner County</td>
<td>Ag, Au, Pb</td>
<td>$2,000,000</td>
<td>Fissure filling in Belt Sediments</td>
<td>Polybasite Galena</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>2) Coeur d'Alene Region (8 Districts)</td>
<td>Shoshone County</td>
<td>Pb, Zn, Ag, W &amp; Au</td>
<td>1 Billion (Plus)</td>
<td>Replacement in shear zone</td>
<td>Galena Sphalerite Tetrahedrite Scheelite Native Gold</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>3) Pierce City District</td>
<td>Clearwater County</td>
<td>Au</td>
<td>$10,000,000</td>
<td>Placer</td>
<td>Native Gold</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>4) Elk City District</td>
<td>Gem County</td>
<td>Au</td>
<td>$18,000,000</td>
<td>Placer</td>
<td>Native Gold</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>5) Ten Mile District</td>
<td>Gem County</td>
<td>Au</td>
<td>$2,000,000</td>
<td>Placer</td>
<td>Native Gold</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>6) Gibbonsville District</td>
<td>Lemhi County</td>
<td>Au</td>
<td>$2,000,000</td>
<td>Placer</td>
<td>Native Gold</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>7) Florence District</td>
<td>Gem County</td>
<td>Au</td>
<td>$22,000,000</td>
<td>Placer</td>
<td>Native Gold</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>8) Mackinaw District</td>
<td>Lemhi County</td>
<td>Au</td>
<td>$6,500,000</td>
<td>Placer</td>
<td>Native Gold</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>9) Warren District</td>
<td>Gem County</td>
<td>Au</td>
<td>$15,000,000</td>
<td>Placer</td>
<td>Native Gold</td>
<td>Mesozoic</td>
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<tr>
<td>10) Seven Devils District</td>
<td>Adams County</td>
<td>Cu, Ag, Au</td>
<td>$1,000,000</td>
<td>Contact Met.</td>
<td>Chalcopyrite Tetrahedrite</td>
<td>Mesozoic</td>
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See Plate 8 For Location of Mining Districts
<table>
<thead>
<tr>
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<th>Age of Deposits</th>
<th>Principal Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Barking Fork District</td>
<td>Custer County</td>
<td>Ag, Pb, Cu</td>
<td>Replacement in Limestone</td>
<td>Mesozoic</td>
<td>Galena, Tetrahedrite-Chalcopyrite</td>
</tr>
<tr>
<td>2) Yankee Fork District</td>
<td>Custer County</td>
<td>Ag, Pb, Cu</td>
<td>Replacement in Tertiary Volcanics</td>
<td>Tertiary</td>
<td>Native Gold Chalcopyrite-Selenides</td>
</tr>
<tr>
<td>3) Loon Creek District</td>
<td>Custer County</td>
<td>Pb, Ag</td>
<td>Replacement in Paleozoic Limestones</td>
<td>Mesozoic</td>
<td>Galena, Tetrahedrite-Chalcopyrite</td>
</tr>
<tr>
<td>4) Nicholla District</td>
<td>Lemhi County</td>
<td>Au, Pb, Ag</td>
<td>Replacement in Pre-Camb. Schist</td>
<td>Tertiary</td>
<td>Native Gold Chalcopyrite</td>
</tr>
<tr>
<td>5) Texas District</td>
<td>Lemhi County</td>
<td>Au, Pb, Ag</td>
<td>Veins in Granite</td>
<td>Tertiary</td>
<td>Galena, Tetrahedrite-Chalcopyrite</td>
</tr>
<tr>
<td>6) Banner District</td>
<td>Boise County</td>
<td>Au &amp; Ag</td>
<td>Replacement in Ord. Limestone</td>
<td>Tertiary</td>
<td>Pyrrhotite, Galena</td>
</tr>
<tr>
<td>7) Quartsburs District</td>
<td>Bois County</td>
<td>Au</td>
<td>Veins in Granite</td>
<td>Tertiary</td>
<td>Native Gold, Galena</td>
</tr>
<tr>
<td>8) Dome District</td>
<td>Butte County</td>
<td>Pb, Ag</td>
<td>Replacement in Banded Limestone</td>
<td>Tertiary</td>
<td>Chalcopyrite, Sphalerite</td>
</tr>
<tr>
<td>9) Alder Creek District</td>
<td>Custer County</td>
<td>Cu, Zn</td>
<td>Veins in Granite</td>
<td>Tertiary</td>
<td>Chalcopyrite, Sphalerite</td>
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<th>Age of Deposits</th>
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<tbody>
<tr>
<td>20) Vienna and Sawtooth Districts</td>
<td>Blaine County</td>
<td>Ag, Pb</td>
<td>$2,000,000</td>
<td>Fissure filling in Granite</td>
<td>Galena</td>
<td>Mesozoic</td>
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<tr>
<td>21) Warm Spring District</td>
<td>Blaine County</td>
<td>Ag, Au, Pb, &amp; Cu</td>
<td>$10,000,000</td>
<td>Replacement in Limestones and Dolomites</td>
<td>Tetrahedrite Polybasite Galena</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>22) Little Smokey District</td>
<td>Camas County</td>
<td>Au, Ag, Pb</td>
<td>$1,000,000</td>
<td>Replacement in shear zone</td>
<td>Tetrahedrite Galena</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>23) Yuba District</td>
<td>Elmore County</td>
<td>Au, Ag</td>
<td>$6,000,000</td>
<td>Fissure filling in granite</td>
<td>Stephanite Pyrargyrite</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>24) Bear Creek District</td>
<td>Elmore County</td>
<td>Au, Ag</td>
<td>$4,000,000</td>
<td>Placer, Veins in Granite</td>
<td>Native Gold</td>
<td>Mesozoic</td>
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<tr>
<td>25) Featherville District</td>
<td>Elmore County</td>
<td>Au</td>
<td>$1,225,000</td>
<td>Placer</td>
<td>Native Gold</td>
<td>Mesozoic</td>
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<tr>
<td>26) Mineral Hill District</td>
<td>Blaine County</td>
<td>Ag, Au, Pb, Cu, Zn, As, Hg</td>
<td>$20,000,000</td>
<td>Fissure filling in shear zone</td>
<td>Tetrahedrite Arsenopyrite Galena</td>
<td>Mesozoic</td>
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<tr>
<td>27) Neal District</td>
<td>Elmore County</td>
<td>Au</td>
<td>$1,225,000</td>
<td>Quartz lenses in Granite</td>
<td>Native Gold</td>
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<tr>
<td>28) Silver City Region (6 Districts)</td>
<td>Owyhee County</td>
<td>Au, Ag</td>
<td>$75,000,000</td>
<td>Vein Deposits</td>
<td>Argentite Electrum Jamsonite Ruby Silver</td>
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<tr>
<td>29) Mineral Hill District</td>
<td>Lemhi County</td>
<td>Au</td>
<td>$1,400,000</td>
<td>Placer</td>
<td>Native Gold</td>
<td>Mesozoic</td>
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</tr>
</thead>
<tbody>
<tr>
<td>30) Stibnite District</td>
<td>Valley County</td>
<td>Sb, W, Au</td>
<td>$2,000,000</td>
<td>Lenses &amp; Veins in Granite</td>
<td>Stibnite, Scheelite, Native Gold</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>31) Yellowpine District</td>
<td>Valley County</td>
<td>Hg</td>
<td>$1,500,000</td>
<td>Dissemination of Cinnabar in Limestone</td>
<td>Cinnabar</td>
<td></td>
</tr>
</tbody>
</table>

See Plate 8 For Location of Mining Districts
of sub-bituminous grade and mined only on a small scale. A third type is Tertiary rocks in Ada, Boise, Custer, Gem, Lemhi, Nez Perce and other counties. Small beds of lignitic coal have been mined to some extent for local use. The abundant coal fields in the immediate surrounding states, namely Utah and Wyoming, limit the mining of coal in Idaho, and in particular because Idaho's coal is of an inferior grade and the deposits are not well known.

Gas and Oil: (20, 21, 22, 52)

Interest has long been displayed in the possibility of finding oil and gas in southeastern Idaho. In recent years drilling has been undertaken in two localities in Bannock county, and one each in Bonneville, Caribou, and Teton counties. There is a thick sequence of Paleozoic and Mesozoic sedimentary rocks in this part of Idaho. The Paleozoic beds, although largely marine, according to C. P. Ross (52), do not appear favorable as sources of oil or gas because they are too thoroughly indurated and metamorphosed.

The Cretaceous strata in Idaho are similar in age to those in Wyoming that have yielded oil on a commercial scale. Certain of the Cretaceous strata and even some of the lower Mesozoic strata in Idaho appear lithologically suitable as reservoir rocks. There is evidence of both gas and oil in Teton county, although as yet none has been found in commercial quantity. Recently this Teton area has been the
location of field survey work carried on by interested oil companies.

Building Stone: (52)

Stratified rocks of Tertiary age have furnished most of the building stone so far quarried in Idaho. Tuff and feldspathic and tuffaceous sandstone are the most used. Rocks of this kind are found in many localities, and have been used locally. At present, none of these rocks are shipped far from the quarries, but with increase in population and improvement of transportation, it may eventually be profitable to expand the industry. Probably this type of rock has been used because of ease in quarrying and dressing.

Portland Cement: (52)

The only plant now manufacturing Portland cement is that near Inkom, Bannock county, which started in 1928, and which since has been intermittently productive. Sufficiently pure limestone and suitable argillaceous rocks for use in making cement are known to be present in several parts of southeastern Idaho, and they are ready to be utilized when transportation and market conditions are favorable.

Mica: (52)

Pegmatite dikes in several localities contain muscovite mica of sufficiently good quality to be of commercial
interest. The dikes are commonly small and rarely are abundant, so that in localities remote from transportation they are of no immediate value. In Latah county, districts within convenient hauling distance of the railroad have produced mica to a total value of about $100,000 up to 1925. Similar mica bearing dikes exist in Clearwater and other counties.

Pumice: (52)

At and near American Falls and in Cassia county, pumice deposits were developed on a small scale several years ago. Recently, several companies in south-central Idaho have used considerable quantities of pumice as a lightweight aggregate in the construction of building blocks. The material used as the aggregate is readily obtainable in several localities in the Snake River plain region which makes it as cheap as sand and gravel if used locally.

Phosphate: (36, 37, 49, 52)

By far the most abundant non-metallic material in Idaho occurs in the immense phosphate rock deposits in the southeastern part of the state. The phosphate reserves in Idaho are the largest in the western phosphate field. It was estimated by Mansfield (37) that in southeastern Idaho there are 5,000,000,000 long tons of high-grade phosphate rock which have been relatively unexploited.

The phosphate beds occur in the Phosphoria formation
of Permian age. The formation is a marine deposit formed under conditions which slowed down the accumulation of ordinary sediments, while at the same time they permitted accumulation on the sea bottom of phosphatic sediments derived from solutions or colloids of organic origin. From these solutions were formed the oolites, which like grains of sand, were eventually aggregated and cemented into the present phosphate beds.

The phosphate-bearing member is usually around 100 to 180 feet thick, and is characterized by an oolitic texture and dark-gray to brown or black in color. The high grade bed of the member is usually from 5 to 30 feet thick. It commonly contains 70 per cent or more of tricalcium phosphate. The phosphate rock is mined by the usual underground methods, through shafts, drifts and stopes. It is used chiefly in the manufacture of superphosphate for the fertilizer trade. At present the immense phosphate beds of southeastern Idaho are considered as the greatest potential mineral resources of the state, and it is believed that in the near future the production of phosphate will soon be of equal importance with the state's metal production.
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