The Geology and Mineral Resources Sections in *Mineral and Water Resources of Idaho*

Compiled by
U.S. Geological Survey *in cooperation with*
Idaho Bureau of Mines and Geology,
Idaho Department of Highways, *and*
Idaho Department of Reclamation

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Idaho Bureau of Mines and Geology
Department of Lands
Moscow, Idaho 83843

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MINERAL AND WATER RESOURCES
OF IDAHO

REPORT
PREPARED BY THE
UNITED STATES GEOLOGICAL SURVEY
IN COLLABORATION WITH
IDAHO BUREAU OF MINES AND GEOLOGY
AND THE
IDAHO DEPARTMENT OF RECLAMATION
AT THE REQUEST OF
SENATOR FRANK CHURCH
OF IDAHO
OF THE
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS
UNITED STATES SENATE

Printed for the use of the Committee on Interior and Insular Affairs

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WASHINGTON : 1964
MEMORANDUM FROM THE CHAIRMAN

To Members of the Senate Committee on Interior and Insular Affairs:

I am transmitting for your information a report entitled "Mineral and Water Resources of Idaho," prepared by the U.S. Geological Survey at the request of our colleague, Senator Frank Church.

This detailed survey will be particularly helpful to government and business leaders in Idaho. It will also be valuable to the Congress and members of this committee as we consider legislation regarding mineral and water development.

Henry M. Jackson, Chairman.
FOREWORD

This report was prepared at my request by the U.S. Geological Survey in cooperation with the Idaho Bureau of Mines and Geology. Its purpose is to make all significant data on Idaho's important mineral and water resources available to interested citizens, to professional personnel in mining and water development, and to government, civic, and industrial leaders. I think that purpose has been well met.

I wish to thank all of those both in Idaho and the Geological Survey who have contributed to the making of this report.

FRANK CHURCH.
MINERAL AND WATER RESOURCES
OF IDAHO

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PREPARED AT THE REQUEST OF
SENATOR FRANK CHURCH OF IDAHO
OF THE
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS
UNITED STATESSenate
HON. FRANK CHURCH,
U.S. Senate,
Washington, D.C.

DEAR SENATOR CHURCH: We are pleased to transmit a summary report on the mineral and water resources of Idaho, which has been prepared by the Geological Survey in collaboration with the Idaho Bureau of Mines and Geology. This report has been prepared in response to your request of May 24, 1963.

Mineral commodities known to occur in Idaho are described in the report, together with information on their manner of occurrence, distribution, and relative importance to the present and to the future mineral industry of the State. Surface and ground water supplies are described by major drainage areas, with information on chemical quality of the water, on water usage, and on waterpower. Also included is a section on recreation. The narrative discussions are supplemented by maps and other illustrations.

It is hoped that data in the report will supply you with the information you desire.

Sincerely,

ARTHUR A. BAKER,
Acting Director.
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INTRODUCTION AND SUMMARY

(By A. E. Weissenborn, U.S. Geological Survey, Spokane, Wash.)

This report describes the mineral and water resources of Idaho, their occurrence in the State, their uses in industry, and their relative importance to the economy of Idaho. In an introductory section, the mineral industry and its place in the State’s economy are briefly discussed. A description of the geology of the State and its influence on the water and mineral resources of the State is also included in this section.

The mineral industry, with a total production of over $256 million and a production in 1962 of $82.6 million, forms an important segment of Idaho’s economy. The State’s contributions to the national economy have likewise been large. At least 40 different mineral commodities have been produced in the State. Idaho leads the Nation in the production of silver and antimony. In most years, it is first or second among the States in the production of lead and zinc and accounts for a large proportion of the domestic production of cadmium. It has, in time of urgent national need, accounted for as much as 40 percent of the domestic production of tungsten. Its nonmetallic mineral industry has grown greatly in the last few years; in 1962 it produced 1.9 million long tons of phosphate rock, most of which was manufactured into fertilizer to increase the productivity of western farms.

Idaho is generously supplied with water, but there is great variation from area to area. Extremes of annual precipitation range from 60 inches to 8 inches or less, the driest part of the State being the Snake River Plain. Generally speaking, the supply of water exceeds the need in the northern counties, but in the southern part of the State, there are areas of serious shortage. North of the Snake River Plain, most of the streams are perennial, but some streams south of the plain are intermittent. Nearly all the streams draining Idaho flow to the Pacific Ocean through the Columbia River. Because of the seasonal distribution of the flow of many of its streams, reservoir storage is required to maintain adequate supplies of water for irrigation during the growing season.

Ground water is one of the most important renewable resources in Idaho. About 2.6 million acre-feet was withdrawn in 1960 as the sole or principal supply for irrigation of more than 800,000 acres of land, principally in the Snake River Basin. Large amounts are also used for municipal, domestic, industrial, and livestock uses. The Snake River Plain, east of Bliss, and the gravel beneath Rathdrum Prairie, east of Spokane, Wash., are two of the Nation’s most productive aquifers. Discharge from the Snake River Plain aquifer near Bliss is 6,000 cubic feet per second; discharge from the Rathdrum Prairie aquifer is about 1,500 cubic feet per second.
More than 3 million acres are irrigated in Idaho, more than 2½ million acres of which are in the Snake River Basin. There remains about 8.8 million acres of unirrigated but otherwise arable lands in the Snake River Basin, much of which could be supplied with water, but technical and legal problems will have to be solved first.

Most of the surface water is suitable for most uses with a minimum of treatment, but contamination from irrigation discharge and industrial and municipal wastes are having a detrimental effect on both surface and ground water.

There are 37 developed waterpower projects having a total installed generating capacity of 1,476 megawatts in Idaho. The State's gross theoretical power capability at developed and undeveloped power sites is 11,149 megawatts. The waterpower potential of the Pend Oreille and Bear Rivers in Idaho is almost fully developed, but the Snake River has the greatest total development. The Salmon River has the greatest waterpower potential of any stream in Idaho but has no power site developments.

The report has been compiled chiefly by the staffs of the U.S. Geological Survey and the Idaho Bureau of Mines and Geology, but members of the University of Idaho, the Idaho Department of Highways, and the Idaho Department of Reclamation have also contributed. It is based essentially on published information on the geology and resources of Idaho but has been supplemented by material in the files of the U.S. Geological Survey, and the Idaho Bureau of Mines and Geology, and the personal observations of the 37 contributors to the report.

The intention has been to present an objective appraisal of the resources of the State based on the information that is available now. All commodities that occur in significant quantities in Idaho are discussed, even though they are not now being utilized or are considered to have only slight potential for development. It is realized that new discoveries and developments, and changes in economic condition may significantly alter some of the conclusions that have been reached. Treatment of each commodity is necessarily brief, but comprehensive bibliographies are attached to each major segment of the report for the convenience of those who wish to inquire further into Idaho's mineral and water resources. Throughout the text, specific references are made to these sources of information.

Mr. A. E. Weisenborn assembled the various sections of the report and coordinated the efforts of the individual authors. Dr. K. K. Reid, acting director, Idaho Bureau of Mines and Geology, and Dr. E. F. Cook, formerly director of the Idaho Bureau of Mines and Geology, were most helpful in arranging for participation of the various authors from State agencies.

In acknowledging the efforts of those who have participated in preparation of this report special reference is made to A. L. Anderson and C. F. Ross. A. L. Anderson, formerly professor of geology at the University of Idaho, and for many years a professor at Cornell University, submitted his manuscript sections of this report only a short while before his untimely death. Working in the field during
his summer vacations on behalf of the Idaho Bureau of Mines and Geology, he mapped the geology of an extremely large part of the State. C. P. Ross, now retired after a long and distinguished career with the U.S. Geological Survey, also has mapped and studied the geology of large sections of Idaho. His contributions to our knowledge of the geology of the State have been enormous. These two men have contributed immeasurably to the advancement of knowledge of the geology and mineral resources of the State.
THE MINERAL INDUSTRY IN IDAHO

(By A. E. Weisenborn, U.S. Geological Survey, Spokane, Wash.)

Idaho's mines and quarries have produced more than $2.6 billion of new wealth. Most of this has come from the Coeur d'Alene region, one of the great mining districts of the world, but almost all parts of Idaho have contributed to the more than 40 mineral products whose value makes up this total. With this record, the mineral industry can justly claim an important role in the development of the Gem State from a nearly trackless wilderness little more than 100 years ago to a modern community in which more than 700,000 people live.

The first white men known to have set foot in what is now the State of Idaho were members of the Lewis and Clark Expedition who, in the fall of 1805, crossed the Bitterroot Mountains over the Lolo Trail and descended the Clearwater River. They were followed, and perhaps preceded, by the mountain men and the fur traders. After these, came the missionaries and the westward-bound immigrants in search of new lands. By 1843, hordes of immigrants were beginning to follow the Oregon Trail across the Snake River Plain on their way to the Oregon country, but with few exceptions they merely passed through Idaho. To the mountain man, the trapper, and the immigrant must go the credit of first opening the Idaho country, but it remained for the miner to establish the first permanent settlements, except for a few Mormon farming communities in the southern part of the State (Bolino, 1960). Development of the mineral industry provided the impetus for the establishment of railroads and other means of communication, and provided markets for local agricultural and forest products.

It is not certain when and where metals were first discovered in Idaho. The presence of placer gold in the Boise Basin is reputed to have been known to a Hudson Bay Co. trapper as early as 1844 (Wells, 1964). Ross (1890) reports the discovery of gold on the Pend Oreille River in 1856 by a member of the Stevens Expedition, but Indian hostility prevented exploration. Ricard (1882) also notes that in 1858 members of the Mullan Expedition that surveyed the military road across the Bitterroot Mountains found vein outcrops and some gold, probably in or near what is now the Coeur d'Alene region. These and other less well documented reports indicate that gold and other metals were known in Idaho for some years before mining began, but exploitation of these discoveries was delayed largely because of the hostility of the Indians to miners entering their lands. However, in February 1860, E. D. Pierce discovered placer gold on the North Fork of the Clearwater. In August he returned with a prospecting party to Orofino Creek, and the following winter the town of Pierce was established. The Orofino mining district was organized in January 1861, and Idaho's mineral industry was born (Wells, 1961, p. 3). By July 1861, 5,000 were were in the area, and prospecting had extended to the South Fork of the Clearwater, where Elk City was founded
(Ricard, 1932, p. 312). In spite of continued Indian hostility, prospecting spread south, and additional discoveries were made in 1861 and 1862 on other tributaries of the Snake, the richest of which were at Florence and Warren. Idaho's major gold rush began in the fall of 1862, when placer discoveries were made at several places in Boise Basin. By 1863, 25,000 miners were in southern Idaho, and mining was being done at Centerville, Pioneerville, Idaho City, Placerville, and other localities. Idaho City alone had a population of over 6,000 and was larger than Portland, Ore. Prospectors swarmed through the hills, and other discoveries soon followed. Placer gold was found in 1863 in numerous places south of the Middle Fork of the Boise River. Prospecting uncovered gold-bearing lodes at Placerville, Idaho City, Ophir, Bonaparte, Rocky Bar, and other localities. Discoveries were made in the following year south of the Snake River in Owyhee County (Wells, 1944). By 1864, practically all of the placer areas and many of the gold lode deposits now known in the State had been found. However, the rich placers were exceedingly short lived. The boom days of Pierce and neighboring camps were over after 1864, but in this brief period $20 million worth of gold was produced (Ross, 1930, p. 3). By 1872, the gold rush days in central and south-central Idaho were finished, and mining declined drastically. Placer mining continued for many years at numerous places—and had a marked revival in the depression days of the 1930's—but the bonanza ground was removed in the early years of mining, and since 1911 most of the placer gold has been recovered by dredges.

Miners searching for placers soon found outcropping veins. Early attempts to mine these veins and treat the ore in crude arrastas and stamp mills mostly failed. Mills built in the Silver City area of Owyhee County in 1864 to treat the silver-gold ores were more successful and marked the real beginning of lode mining in Idaho. Later, with improved techniques of mining and milling, gold veins in Boise Basin and elsewhere were worked successfully, but lode gold production, although it lasted much longer, never reached the commanding position once held by placer mining (Ross, 1930, p. 6).

Such were the golden beginnings of Idaho's mineral industry. Dramatic, exciting, though not as lucrative as the gold rush days of California or Montana, these events had an effect on the subsequent history of Idaho far out of proportion to the amount of the gold produced. They brought people and money into the area—Ross (1936a) states that the initial placer activity in Idaho yielded over $30 million—and they provided markets for the farmer who followed the miner. Rudimentary roads replaced the Indian trails; the territory was explored and prospected. Thus, the way was cleared for the permanent settlement of the country and the development of lode mines—first of gold and silver, then later of the more prosaic base metals that now play such an important role in Idaho's economy.

Although some lead had been mined previously as a byproduct of silver mining, base-metal mining did not come into prominence until the development of lead mines in the Wood River area about 1885, and the discovery of the Bunker Hill mine in the Coeur d'Alene area in 1885 (Ross, 1930; Umpleby and others, 1930; Ricard, 1932). Exploitation of these areas marked the beginning of Idaho's mineral industry as we now know it. Growth was spectacularly rapid and, with few
exceptions, the value of mineral production climbed to a peak in 1916 coincident with World War I—a peak which as shown in figure 1 has never been exceeded.

Other periods of high production coincide with the boom of the late 1920's, the defense requirements of World War II and the Korean episode, and assembly of Government stockpiles of strategic minerals during the 1950's. Interspersed with these, were periods of reduced production marked by decreased prices and lessened demand, especially following each war and during the depression of the 1930's. Termination of the stockpile program led to a sharp decline that reached a low point in 1960. Since then, mineral production has again risen with the possibility that a new high will be reached. Note that in figure 1 the value of the minerals produced is expressed in constant dollars, with the 1937-39 dollar taken at 100. This gives a somewhat different curve than if values had been expressed in dollars without correcting for changes in the value of the dollar, but more nearly compares actual amounts of materials produced.

Idaho produces at least 40 different mineral products. These products are important to the local economy, and many of them are essential materials in the national economy. In 1962, Idaho led the Nation in the production of silver and lead and was second in the production of zinc. For most years, it has ranked first or second among the States in the production of these metals. It has accounted for almost the entire domestic output of antimony—formerly from the Yellow Pine mine, now mostly as a byproduct from the silver ores of the Coeur d'Alene district—and accounts for a large proportion of the domestic production of cadmium, also from Coeur d'Alene ores. Idaho also has been a leading producer of tungsten. In the critical war period 1942-44, it accounted for 40 percent of the domestic tungsten production, and from 1948 to 1957 it ranked fifth and sixth among the tungsten-producing States. From 1961 to 1968, it was the chief domestic source of cobalt, and from 1956 to 1959 the placer of Bear Valley in central Idaho supplied almost the entire domestic production of niobium and tantalum.

Idaho is outranked only by Florida and Tennessee in the production of phosphate rock, and by New York in the production of garnet. At times it has been an important producer of mica.

The relative value of many mineral commodities or groups of commodities that have been produced from 1861-1962 is shown in figure 2. Idaho's mineral economy depends heavily on three metals—lead, silver, and zinc—and other mineral commodities except, perhaps, gold, have played a relatively minor role. Of the three major metals, lead and silver have been by far the most important. No zinc was recovered until about 1965, and for many years it was of relatively minor importance, but since 1943 it has at times been equally as important as lead. This is the result of two factors—increasing consumption of zinc and the increasing zinc content of Coeur d'Alene ores relative to lead, in deeper parts of the deposits.

The sources of most of Idaho's metals and the dominance of the Coeur d'Alene district in Idaho's metal production are shown graphically by figure 3. In this chart, the areas of the circles are proportional to the unadjusted dollar value of the production from 28 metalliferous districts in the State. The chart shows only the value of
Data from U.S. Bureau of Mines Minerals Yearbooks; U.S. Geological Survey Mineral Resources Volumes; Hubbard (1955), Ross (1930), and other sources.

**Figure 1.**—100 years of mineral production from Idaho, 1862–1962.
Figure 2—Idaho's mineral production by commodities, 1901-1902.
Circle areas proportional to dollar value.

the production of gold, silver, lead, zinc, and copper since 1906. If production before that date had been considered—impracticable because of the lack of reliable records—some of the older districts would show more favorably. Cobalt, mercury, antimony, and tungsten have contributed significantly to Idaho's mineral production, but production figures by districts are not available for these metals. If this production could have been included, such districts as Blackbird, Blue Wing, and Yellow Pine would have looked more impressive. In any case, the ratio between the Coeur d'Alene district and the rest of the State would not have been changed appreciably.

According to figure 2, the nonmetallic minerals have accounted for barely 10 percent of Idaho's total mineral production. This, however, underestimates the present importance of the State's nonmetallic minerals. Previous to about 1926, the value of Idaho's nonmetallic mineral production was almost inconsequential. The growth of the nonmetals industry began about 1938 and has been spectacularly rapid since about 1953. In 1958, the value of nonmetallic minerals amounted to a little over $1 million, or only 2.2 percent of the value of all mineral production. In 1958, only 15 years later, this had risen to 7.7 percent of the value of all mineral production, and the value was more than five times what it had been in 1938. In another 15 years, nonmetallic production had doubled and amounted to 17.7 percent of all minerals produced. In 1962, this figure had increased again to nearly 2½ times what it had been in 1958 and amounted to 36.7 percent of the value of all minerals produced. Figure 1 shows this increase graphically. Construction materials (sand and gravel and stone) and phosphate rock dominate the nonmetallic minerals industry (fig 2). The rapid expansion in the use of these commodities can be attributed to the increased utilization of fertilizers on western farms and to the greatly increased amount of highway and other construction within the State.

In 1962, the value of all minerals produced in Idaho amounted to $82.6 million, compared to cash receipts of $450.2 million from farm marketings (Fulkerson and others, 1963). Although overshadowed by agriculture, the mineral industry is nevertheless of great importance to Idaho's economy. In 1962, 3,206 men, with an annual payroll of $18.8 million, were employed in the State's mines and quarries; an additional 2,910 with an annual payroll of $17.7 million, were employed in smelters and plants directly concerned with processing mineral raw materials. Considering the relatively small population, the mineral industry obviously is a very important element in Idaho's economy.

The number of mines operating in Idaho and employment in the State's mineral industries are shown graphically in figure 4. The most striking feature of figure 4 is the tremendous increase in the number of placer mines during the 1930's and the sharp decline following that period. The sharp peak is partly the effect of the rise in the price of gold that occurred in the early 1930's, which made placer mining attractive. It also reflects the effect of the depression of the 1930's when many men, unable to find employment, attempted to eke out a living by operating small placer mines. The sharp decline is the effect of Order L-208, which prevented gold mines from obtaining needed supplies during World War II. Following the war, there was a brief revival of placer mining, but in the face of rising costs and a fixed
Figure 4.—Metal mines operating in Idaho 1920-62 and employment in the mineral industries in Idaho 1947-62.
price for gold nearly all the placer mines have closed. The production of placer gold is now insignificant.

Lode mining shows a somewhat different picture (fig. 4). From 1920 to 1940, the number of lode mines increased gradually. This was followed by a decline during World War II, as many small mines, especially gold mines, shut down because of manpower shortage or the inability to obtain needed supplies. Following the war, the number of mines in operation increased to another peak in 1947, but has been steadily declining ever since. This decline correlates closely with the sharp decline in the production curve for metals shown in figure 1 and brings out the effect of the slump in metal prices after the Korean conflict and the termination of the stockpiling program. The lower chart of figure 4 shows employment in Idaho's metal mines. Like metal production, it has undergone a significant decrease. In 1947, 5,439 were employed in Idaho's metal mines; in 1962, the labor force had decreased to 2,996. The low point was reached in 1969, when only 2,292 were employed in metal mines, but this figure is affected by a prolonged strike in the Coeur d'Alene district. With the current increased demand and more favorable prices for lead, zinc, and silver, it appears that a downward trend of employment may be halted and perhaps reversed.

The decrease in the labor force in metal mines has been partly offset by a significant increase in employment in processing plants (fig. 4). This is largely a result of an increase in employment in plants having to do with the preparation of phosphate fertilizers and in those that make stone, clay, and glass products (Fulkerson and others, 1963, p. 342). In spite of the great increase in the production of nonmetallic minerals, there has been no corresponding increase in employment at nonmetallic mines since 1947, probably because of increased mechanization of the mines.

The Coeur d'Alene district, Idaho, is one of the great mining districts of the world. It has produced more silver than any other district in the United States; it is one of the country's leading producers of both lead and zinc; and it is one of the very few districts in the world whose production is in excess of $2 billion. It far outshadows all other districts in Idaho, and all other districts in the Pacific Northwest, except Butte, Mont. It has been in continuous production for over 80 years; its metals have contributed significantly to the industrial might of our Nation in time of peace and have helped assure its security in time of danger. Its importance to the economy of Idaho and the Pacific Northwest can scarcely be exaggerated.

The very importance of this single district to the mineral industry of the State is in itself a cause for some concern. In the past few years, the district has faced many serious problems brought on by low metal prices and rising costs. Some ore bodies have been mined out. Most of the mines are deep and are becoming deeper. The district must meet severe competition from domestic and foreign mines. The search for ore to replace that which has been extracted is difficult and expensive. Not all of it has been successful, but discoveries in recent years at the Galena and Lucky Friday mines have been particularly encouraging. Vigorous, well-planned exploration now in progress at a number of places in the district offers promise of new discoveries and continued life for many years to come. With rising prices and
increased demand for all three of the major metals the district produces, the situation has improved greatly.

Although it may be far in the future, eventually even such a mighty giant as the Coeur d'Alene district must wither and die. There is no district now known in Idaho that can take its place. However, given the need and the proper incentive, it is reasonable to expect that by vigorous exploration, and the use of the tools of geology, geochemistry, and geophysics now available—and perhaps others yet to be developed—other ore deposits or districts will be brought into production that will enable Idaho to maintain a strong position as a metal producer.

Idaho's nonmetallic mineral industry has grown mightily since World War II. Further growth seems assured. Idaho's population has increased slowly but steadily. With increased population and increasing industrialization, there should be greater need for many of the nonmetallic mineral products which Idaho now provides. These same factors should make feasible the development of deposits of other nonmetallic minerals which are not now being utilized but which are found in Idaho—some in considerable abundance. New developments in mineral technology will promote the use of new materials or utilize familiar materials in new ways. As an example, a recent announcement by the Anaconda Co. of the development of a method for economically extracting alumina from high-alumina clays could foreshadow the eventual large-scale utilization of Idaho's large resources of this material.
GEOLOGY


INTRODUCTION

Idaho, with an area of about 84,000 square miles, includes parts of three distinct physiographic provinces. These are the Northern Rocky Mountain province, the Columbia Intermontane province, and two small segments of the Basin and Range province. Each province differs markedly in topography, climate, and natural resources. Their distinctive character is a direct reflection of difference in the stratigraphy, structure, and chemical and physical composition of the underlying rocks, all of which profoundly affect human activity. Figure 5, slightly modified from a map previously published (Ross and Forrester, 1958, fig. 1), shows these provinces, as well as some of their subdivisions.

The State consists of a complex array of mountain ranges, intermontane valleys, and plains. The descriptions below are grouped mainly in accord with the three geomorphic provinces cited above, and are abstracted in large part from three recent summary papers (Ross and Forrester, 1958; Ross, 1962a, b).

TOPOGRAPHY

Idaho is one of the most scenic of the Western States. It is largely mountainous. The only major expanses of relatively gentle topography are the Snake River Plain and valleys along its southern border. Even these areas are dotted by hills, isolated and in groups, and gashed by steep-walled canyons.

The Northern Rocky Mountain province within northern and central Idaho consists of a rather ill-defined unsystematic assemblage of mountains that border the Snake River on the east and continue south to the Snake River Plain. The principal components which merge one into another are: Selkirk, Bitterroot, Clearwater, Salmon River, and Sawtooth Mountains (fig. 5). Some of the most scenic alpine topography in the United States can be found in the Sawtooth Mountains in the vicinity of Ketchum and Stanley.

Mountain ranges north of the Snake River Plain include the Beaverhead, Lemhi, and Lost River Ranges, and the Pioneer Mountains. Southeast of the Snake River Plain are such ranges as the Bannock, Port Neuf, and Bear River. Broad, elongate basins lie between these ranges, as is common in the main Basin and Range province to the south, of which this southern area is a part.

Altitudes above sea level range from 710 feet at the juncture of the Snake and Clearwater Rivers at Lewiston to 12,555 feet at Mount Borah in the Lost River Range, the highest point in the State. Mountain peaks in the narrow northern "Panhandle" of Idaho are mostly at altitudes of 7,000 feet or less. The Snake River Plain near the
Figure 5.—Physiographic provinces and subdivisions in Idaho.
Figure 6.—Generalized geologic map of Idaho.
Oregon border is little more than 2,000 feet above the sea, but in its northeastern part its altitude exceeds 5,000 feet. Except for a few areas along its southeastern border, Idaho is in the drainage basin of the Columbia River, and most of it is drained by the Snake, Salmon, and Clearwater Rivers. In Hells Canyon below Homestead, the Snake River runs through a gorge 7,000 to 8,000 feet deep, the deepest on the North American Continent.

STRATIGRAPHY

Layered rocks of many geologic ages are exposed in Idaho and they record sequential changes in the geologic history of the State. The distribution and character of these rocks are reflected in the topography of the State. Along with the igneous and metamorphic rocks, they exert strong controlling effects on the nature and locations of the State's mineral resources. Distribution of the rock units—sedimentary, igneous, and metamorphic—which underlie the State is shown in figure 6, a greatly generalized geologic map of Idaho. This map is based on a previously published geologic map of Idaho by Ross and Forrester (1947) but embodies numerous changes based on later work, in part unpublished. On the map the different kinds of rocks are broadly differentiated by type and by geologic age. It is customary to give individual rock units specific names, and the stratigraphic nomenclature commonly used in various parts of Idaho is given in figure 7. Reference to this chart will be helpful in reading this section.

PRECAMBRIAN ROCKS

The oldest rocks in Idaho are Precambrian in age. Most of these belong to the Belt Series, but highly metamorphosed sedimentary rocks of uncertain but possibly older age occur at a few places in Idaho. Some gneisses in the Clearwater region underlie rocks of the Belt Series and may thus be pre-Belt (Anderson, 1930). Comparable rocks are found near Coeur d'Alene (Calkins and MacDonald, 1909, p. 33-35). These and other highly metamorphosed rocks that crop out in Kootenai County east of Mount Spokane and in the vicinity of Sandpoint may also be of pre-Belt age.

Other highly metamorphosed gneisses in northern Fremont County are continuous with known pre-Belt rocks in southwestern Montana, and their age is not in doubt. Similar-appearing rocks occur in northern Lemhi County, near and north of Shoup. Strongly recrystallized sedimentary rocks, including schist, quartzite, and marble occur in central Idaho; for example, in the Sawtooth Range (Reid, 1963) and the Pioneer Mountains. These rocks bear no marked similarity to any of the above rocks; further, they bear little resemblance to Belt rocks. Their age is much in doubt, and their age assignment is highly tentative. Somewhat comparable rocks are found also in the Albion Range.

Precambrian rocks correlated with the Belt Series probably once covered all of central and northern Idaho and are still abundantly exposed, especially north of the North Fork of the Clearwater River. The series constitutes a thick unit composed mainly of argillaceous and quartzitic rocks with subordinate amounts of calcareous rocks. In Boundary County, some conglomerate and volcanic strata are
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**Figure 7:** Stratigraphic names commonly used in various parts of Idaho. Compiled by R. R. Reid and A. E. Weissenhorn from many published sources and some unpublished material.
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**Figure 1:** Stratigraphic names commonly used in various parts of Idaho (continued).
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**Figure 7:** Stratigraphic names commonly used in various parts of Idaho (continued).
included. Stromatolites (algae fossils), locally abundant in the Belt Series in Montana, are present also in Idaho. Probably the entire series was laid down in shallow marine water, but since deposition it has been subjected to widespread low-grade regional metamorphism. The aggregate thickness of Belt rocks in Idaho exceeds 20,000 feet in places, and in Montana the maximum thickness is thought to be over 40,000 feet.

The rocks of the Belt Series in most areas are recrystallized in varying degree but retain the appearance of sedimentary rocks. Locally, mostly near bodies of granitic rocks, they are so intensely metamorphosed that stratigraphic units are difficult or even impossible to recognize.

The stratigraphy of the Belt Series in the Coeur d'Alene region of northern Idaho was established by Calkins (Ransome and Calkins, 1908, p. 22-44) as the Prichard, Burke, Revett, St. Regis, Wallace, and Striped Peak formations. This succession is still accepted as the standard for that part of the State. These rocks are argillitic and quartzitic in the lower part of the section, and grade upward into fmiy argillites and quartzites. Many of the argillites might more properly be called slates.

In Boundary County, Kirkham and Ellis (1926) have used Canadian names to identify the rocks of the Belt Series. Their practice is not generally accepted, but their terminology is given in figure 7. These units cannot be correlated precisely with the Coeur d'Alene units. For long-range correlations, the broader terms pre-Ravalli, and Ravalli, Piegan, and Missoula groups are used (Ross, 1965b). In Boundary County and in Bonner County to the south, the Belt rocks are intruded by sheet-like bodies of gabbro and diorite commonly known as the Purcell sills. In the extreme northwestern part of Boundary County, Precambrian volcanic rocks rest on the Belt Series.

Most of the formations of the Belt Series in the Coeur d'Alene region are thought to have their counterparts in Clearwater County to the south (Hietanen, 1956; 1962; 1963 a, b, c) although intense metasomorphism hampers recognition of stratigraphic units.

Still farther south, rocks regarded as correlatives of the Belt Series are known, mainly near the Middle Fork of the Salmon River and in the Lemhi and Lost River Ranges. Most of these are included in the Yellowjacket formation and in the Hoodoo, Lemhi, and Swauger quartzites. Thick quartzites crop out in the region about Salmon (Anderson, A. L., 1907; 1961) but they cannot be correlated with formations in northern Idaho. Probably only part of the stratigraphic range known farther north is represented by these formations. There is a stratigraphic break in central Idaho between the Belt Series and the overlying Paleozoic beds, but the angular discordance is slight.

Precambrian rocks in Bannock County are far from exposures of rocks regarded positively as belonging to the Belt Series and they differ from rocks in that series. They include volcanic rocks and probably tillite (ancient cemented debris deposited by a glacier). They resemble the Belt Series in that they underlie Cambrian strata and are separated from these younger rocks by a nearly concordant contact and, in a broad way, may be correlated generally with the Belt Series.
Only a few age determinations of Belt rocks from Idaho have been published. On the basis of radioactivity measurements of pitchblende from the Sunshine mine, Coeur d’Alene district, Eckelmann and Kulp (1957, p. 1129-1130) concluded that the uranium mineralization occurred about 1,190 million years ago. The rocks that enclose the uranium minerals must therefore be still older (Wallace and others, 1960, p. 25).

**PALEOZOIC ROCKS**

Stratified rocks of Paleozoic age are abundant in southeastern Idaho and in parts of central and eastern Idaho east of the southern part of the Idaho batholith. The aggregate preserved thickness of Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian stratified marine rocks is well in excess of 50,000 feet; however, it is unlikely that Paleozoic rocks of that thickness were deposited at any one place or over broad areas. Rather, deep basins in which these sediments were deposited probably existed at different places and times during the Paleozoic.

The only thick and diverse strata assigned a Cambrian age are in and near Bannock and Bear Lake Counties, where a thick succession of quartzite and limestone is found. Thinner sandstones, limestones, and shales are known to the north, along the Montana line. In Custer County, phyllite and dolomite of possible Cambrian age are known. Quartzite, shale, and limestone of Cambrian age at Lake Pend Oreille in Bonner County lie in a downfaulted block surrounded by Belt rocks.

Ordovician quartzites, shales, and limestones are best known in eastern and southeastern Idaho, but extend into central Idaho east of the Idaho batholith. Silurian and Devonian strata have much the same distribution.

Mississippian, Pennsylvanian, and Permian strata, including sandstones, shales, and limestones much like those of neighboring Wyoming, Montana, and Utah, are found in eastern and southeastern Idaho. Among these are the White Knob Limestone and Copper Basin Formation, two assemblages of limestone and conglomerate more than 10,000 feet thick that range in age from Mississippian to Permian. In eastern and southeastern Idaho, the Phosphoria Formation of Permian age contains important phosphate deposits. A thick unit of volcanic rocks of Permian age is exposed in central Idaho near the Middle Fork of the Salmon River. Comparable volcanic rocks are also found in the Seven Devils region of western Idaho. In their upper part, the Seven Devils Volcanics are of Permian and Triassic age.

**MESOZOIC ROCKS**

Marine sandstones, shales, and limestones of Triassic age are exposed in southeastern Idaho in Bear Lake County, the Sublette Range, and in small areas near the Montana boundary. In western Idaho, in addition to volcanic rocks in the Seven Devils Volcanics, sedimentary strata thought to be of Triassic age extend intermittently from areas in Washington County to near Grangeville in Idaho County. Argillaceous rocks, in part schistose, predominate but limestone, sandstone, and conglomerate are also present.
Jurassic strata have a distribution in Idaho similar to that of the Triassic rocks just described. Most of the formations of Jurassic age are separated from each other by unconformities, whereas most of the Triassic units are mutually conformable. Hamilton (1963a) describes a unit along the Salmon River near Riggins consisting of slate, with some intercalated limestone, that probably is only a few hundred feet thick. Possibly Jurassic strata exist elsewhere in western Idaho.

A thick series of fresh-water and marine sedimentary rocks of Cretaceous age, largely sandstones and shales, cover large sections of southeast Idaho. One of these stratigraphic units, the Frontier Formation of Upper Cretaceous age, contains the most productive coal beds in the State.

**CENOZOIC ROCKS**

Cenozoic strata of Idaho are partly nonmarine sedimentary rocks and partly volcanic rocks ranging in composition from basalt to rhyolite.

Of the sedimentary rocks, the most widespread are those of the Idaho and Snake River Groups, which are found abundantly on the Snake River Plain. The Idaho Group of Pliocene and Pleistocene ages (Malde and Powers, 1962; Malde and others, 1963) includes seven formations which contain sediments, ash, and some basalt. The Snake River Group (Pleistocene and Recent) as now recognized, consists mainly of the younger part of the old Snake River Basalt, but includes some sedimentary rock. Sediments of the Idaho and Snake River Groups contain important deposits of diatomite and silica sands.

South of the Snake River Plain, beds of conglomerate and limestone with a maximum thickness of 1,500 feet have been correlated with the Paleocene and Eocene Washoe Formation of Utah. Beds of predominantly reddish conglomerate on the southern flank of the Centennial Mountains have been correlated with the Beaverhead Formation in Montana also of Cretaceous, Paleocene and Eocene age (Lowell and Klepper, 1953). Loosely consolidated clastic volcanic rocks of Pliocene age which mostly occupy intermontane valleys south of the Snake River Plain are grouped together on figure 6 as the Salt Lake Formation.

Poorly consolidated sand, silt, and gravel of lacustrine and fluvial origin are widespread in intermontane valleys in the southeastern part of the State. There are also wide areas of unconsolidated alluvium, glacial deposits, lake sediments, and windblown deposits of late Pleistocene to Recent age. These are all grouped together on figure 6 as "alluvial, glacial, and lake deposits."

Four major units of volcanic rocks are recognized in the State. These are the Challis Volcanics, the Columbia River Basalt, the Idaho Volcanics, and basalts of the Snake River Group.

The Challis Volcanics of Tertiary age are widespread in central Idaho. They consist dominantly of andesitic flows and interbedded pyroclastic rocks.① Conglomerate is common near the base. Locally a lower tuffaceous member fills depressions in the uneven surface upon which the Challis Volcanics were laid. The maximum thickness of the Challis Volcanics is about 5,000 feet.

① Pyroclastic rocks—a general term for indurated deposits of volcanic ejecta, including volcanic agglomerate, breccias, tuffs, and tuffs.
A large part of western Idaho from the Owyhee Mountains north nearly to Coeur d'Alene Lake is covered by flows of the Columbia River Basalt of Miocene and Pliocene(1) age. These flows consist of basalt and calcic andesite with some agglomerate and tuff. In places they are as much as 3,000 feet thick. Intercalated with them and in places underlying them are fresh water sedimentary rocks which form the Latah and Payette Formations. The Columbia River Basalt is an important source of construction stone, pumice, and pumiceite. Deposits of various types of clay, including high-alumina clay, are found in the Latah and Payette Formations, as are deposits of silica sand. Diatomite is mined from some beds in the Payette Formation.

The Idaho Volcanics and other silicic rocks are widely distributed along and near the border of the Snake River Plain. As shown on figure 6, they include rhyolitic rocks of early Pliocene age that intertongue with the Columbia River Basalt (Malde and Powers, 1962, p. 1200), early Pliocene ash flows, and—near the northern and northwestern border of the Snake River Plain—siliceous volcanic rocks which contain some interbedded sediments of Pliocene age.

Basalt of the Snake River Group covers large sections of the Snake River Plain, particularly the eastern two-thirds, and occupies the floors of some of the valleys to the south. Most of the flows are of Recent age and can be distinguished from the older basalts by their fresh appearance. They are exposed in spectacular fashion at the Craters of the Moon National Monument and at many other places on the Snake River Plain.

**INTRUSIVE ROCKS**

**EARLY INTRUSIVE ROCKS**

Sills and other intrusive bodies, mostly gabbro and diorite, intrude the Belt Series in northern Idaho but they are not quantitatively important. They are thought to have been emplaced near the end of the Precambrian Era.

Syenitic rocks in Idaho County north of Big Creek are provisionally regarded (Leonard, 1923) as of Paleozoic age, but may be older.

**INTRUSIVE ROCKS OF MESOZOIC AGE**

The Idaho batholith

The Idaho batholith, a striking geologic feature of the State, is one of the world's largest bodies of granitic rock. It is exposed from southern Elmore County northward through central Idaho and into Montana—an area nearly 250 miles long and 80 to 100 miles wide. It consists of a main body of granitic rocks and a complex and varied but incomplete border zone. Most of the intruded rocks in north-central Idaho belong to the Belt Series, but Paleozoic strata have been intruded on the southeast. On the west side, Triassic and possibly Jurassic rocks have been invaded. Lead-alpha analyses indicate an average age of the batholithic rocks somewhat in excess of 100 million years, which accords fairly well with the hypothesis of Late Cretaceous age arrived at by geologic means. Much of the batholith is overlapped
unconformably by Tertiary volcanic rocks, some of which may be as old as Eocene.

The main mass of the batholith is granodiorite and quartz monzo-
nite, but other rock types are included. Much of the batholith appears to have been intruded as a unit or as a number of large, related, and possibly gradational units.

Within the border zone of the Idaho batholith, the sedimentary rocks have been metamorphosed to gneisses and schists, within which are bodies of igneous rocks including quartz diorite, tonalite, and other rocks thought to be of metasomatic origin but with textures that resemble those of rocks of magmatic origin (Hamilton, 1966a; Hiestanen, 1956, 1962). Aplite and pegmatite are abundant in some of the gneisses.

Outlying intrusives

Smaller batholiths and stocks are exposed on all sides of the Idaho batholith and at varying distances from it. These include the Kaniksu batholith (which extends from south of Pend Oreille Lake northward into British Columbia), the Owyhee batholith in Owyhee County, granitic masses in Cassia County, and numerous other small plutons (fig. 6). These have sufficient resemblance to the Idaho batholith so that in the past they have been assumed to be related to it, but many of them cannot be closely dated on the basis of field relations. Two age determinations from the Gem stock near Wallace indicate that this body is about the same age as the Idaho batholith (Jaffe and others, 1938, p. 159–160), but Lowdon (1961, p. 102) has shown that parts of the extension of the Kaniksu batholith into British Columbia may be of Tertiary age. An increasing number of outlying intrusive bodies in Idaho are likewise suspected of being Tertiary in age, and thus not directly related to the Idaho batholith. Granitic rocks that cut the Seven Devils Volcanics in western Idaho, however, are somewhat metamorphosed and may be older than the batholith.

TERTIARY INTRUSIVE ROCKS

Granitic rocks of Tertiary age crop out at several places in central Idaho. They are extensively developed along the Middle Fork of the Salmon River and in the Sawtooth Mountains (Reid, 1963). These, with associated dikes, form a wide northeast-trending belt that extends from Boise County into Idaho County. Small stocks of Tertiary age are scattered through Custer, Blaine, and Butte Counties east of the Idaho batholith, and Tertiary dikes are plentiful throughout central Idaho. The granitic rocks generally range in composition from granite to diorite. They are regarded as 60 million years old or younger and are believed to be related to the Challis Volcanics, but some may be older (Anderson, 1952). Small masses of potassium-rich rocks in Bonneville County are regarded by Anderson and Kirkham (1931) as of Tertiary age.

GEOLOGIC HISTORY

The geologic history of Idaho is complex. The area now occupied by the Idaho batholith, as well as most of the area to the north, is
thought to have been a landmass or a "structurally positive" block since the end of the Precambrian. It stood above the Paleozoic seas while sediments were being deposited in basins to the east and southeast (Ross, 1962b). Sediments were also being deposited on the west, but to a lesser extent. Although there was no major crustal deformation during the Paleozoic Era, these basins of deposition were raised above sea level many times, resulting in numerous breaks in the stratigraphic record.

The Mesozoic Era was marked by powerful crustal deformation and by large-scale igneous activity. The structurally positive area of central Idaho was sharply uplifted early in the era and the structurally weak Paleozoic sediments were flexed into long folds. The main part of the Idaho batholith was emplaced during the Cretaceous Period. The sedimentary rocks were refolded and, along the southeastern border, were intricately contorted in broad conformity with the shape of the batholithic mass. On the east side of the batholith the sediments have been thrust to the northeast along low-dipping thrust faults. Similar faults along which the rocks have been thrust to the northwest have recently been recognized by Hamilton (1960), and, like those to the east, may be related to the emplacement of the batholith. Genetic relations between emplacement of the batholith and deformation of the stratified rocks seem clear, but whether the intrusion of the granitic rocks was the cause of the deformation or whether the deformation created an area of "low pressure" into which the granite rocks made their way is open to argument. Certainly in some localities the evidence seems compelling that the granitic rocks were injected forcibly.

Further folding and the development of faults, many with northeast trend, accompanied and followed the eruption of the Challis Volcanics and the intrusion of related igneous rocks in the early part of the Tertiary. Faulting and mild warping continued during Miocene time and affected the Columbia River Basalt (Hamilton, 1963b).

Two main periods of deformation, a gentle warping in the Jurassic and a more intense one in the Cretaceous, mark the two major periods of folding in central and southeastern Idaho. The folds trend northwest and are broken by numerous faults, mostly reverse faults. In early studies a long and folded thrust fault called the Bannock overthrust was postulated (Mansfield, 1927, p. 150-152), but this has recently been reinterpreted as an imbricate thrust zone composed of several separate faults (Armstrong and Cressman, 1963).

In the northern part of Idaho, the rocks of the Belt Series almost everywhere have been folded into a series of broad folds that commonly trend west of north, but they have been intensely deformed in the vicinity of some of the major faults. The outstanding structural feature is a complex system of northwesterly trending faults that occupy a zone extending from the St. Joe River northward to the north end of Pend Oreille Lake (fig. 6). This is but a small segment of a major structural break known as the "Lewis and Clark line" that extends from Idaho for many miles eastward into Montana (Wallace and others, 1960, p. 25; Billingsly and Locke, 1939, p. 36). Displacement is large along the major faults that make up the Lewis and Clark line. One segment of the "line" is represented by the Osburn Fault, which passes through
the Coeur d’Alene district. The rocks on the north side of this fault are believed to have moved about 12 miles eastward relative to the south side (Wallace and others, 1960), dividing the district into two distinct parts. Eastward displacement of the north side of the Hope Fault, the northernmost member of the “line,” has been estimated to be as much as 8 miles (Harrison and Jobin, 1963). It is probable that these and other faults of the system are old structural breaks along which movement has occurred at several different times.

The most striking young structural feature in the State is the Snake River Plain—a great, curving depression now filled mostly by volcanic rocks. This depression was formerly thought of as almost entirely the result of a downwarp (Kirkham, 1927, p. 34–36; Kirkham, 1931), but recent mapping by Malde and others (1963) has demonstrated the presence of many normal faults in the western part of the plain, showing that the rocks have been fractured and not merely downwarped. These faults do not, however, eliminate downwarping as a contributory factor, especially in the eastern part of the plain.

ECONOMIC GEOLOGY

Each of the major periods of deformation outlined above has had deposits of metallic minerals related to it, but assignment of specific deposits to the appropriate periods presents difficulties. Some metallic mineralization probably took place in Precambrian time (Anderson, 1951, pp. 593–594) but deposits regarded as Precambrian have not proved to be of much economic significance. Numerous determinations of the age of the lead in the deposits of the Coeur d’Alene district, the most important in the State, give results indicating a Precambrian age (Cannon and others, 1962; Kerr and Kulp, 1952; Kerr and Robinson, 1953). However, most geologists familiar with the Coeur d’Alene district believe that the economically important ore deposits were emplaced late in Cretaceous time.

It has long been customary to regard most of the metallic mineral deposits in Idaho, including nearly all the productive lead-silver deposits, as being related to the Idaho batholith. This deduction is supported by the spatial association of some deposits with the batholith or with subsidiary intrusions related to it, by abundant evidence that the deposits are of mesothermal type and formed at considerable depth, and by mineralogical similarities that indicate a similarity of source material (Ross, 1931, 1933). The possibility has been pointed out (Anderson, 1951), however, that many deposits commonly regarded as related to the Idaho batholith may date from an early Tertiary epoch of mineralization associated with intrusions later than the Idaho batholith.

Many gold-silver deposits are found in the Challis Volcanics and other volcanic rocks of Tertiary age, and other gold-silver deposits are clearly associated with Tertiary intrusives. They obviously must have been emplaced after the intrusion of the Idaho batholith. Some precious metal deposits, including some that have produced richly in the past, may be associated with a still younger period of Tertiary
mineralization. Mercury deposits in the State are also believed to be of middle to late Tertiary age or later.

Deposits of nonmetallic minerals are many and varied. They include fluor spar and barite in veins and replacement; clays derived from the weathering of granitic rocks; bedded deposits such as diatomite, volcanic ash, and silica sand found in the volcanic and interbedded sedimentary rocks on the Snake River Plain; phosphate deposits found in phosphorite beds of Permian age in southeastern Idaho; as well as numerous minerals such as garnet, monazite, and thorium minerals derived from the weathering of metamorphic or igneous rocks. The occurrences, economic importance, and geologic association of these and many other commodities are described in the various commodity chapters of this report.

Water resources in the State are strongly influenced by the topography and by the geology and structure of the underlying rocks. The heaviest precipitation, much of which falls as snow at higher elevation, is in the mountainous parts of the State; the least is on the Snake River Plain. Numerous aquifers are sources of ground water in many parts of the State. The sequence of lava flows beneath the Snake River Plain is one of the world's most productive aquifers. Spectacular amounts of water are discharged through these flows into the Snake River at Thousand Springs and at other large springs in the Snake River Canyon. Surface- and ground-water resources of the State are discussed in considerable detail in the section on water resources.

A mineral deposit, whether it is metalliferous or nonmetallic, is merely an unusual concentration of some mineral or minerals that are present in many rocks. It is the result of a combination of geologic processes that have caused this concentration at some particular place. As such, it is an integral part of the stratigraphy, structure, and geologic history of the area in which it occurs. The more thoroughly the geology is known, the more effectively the mineral potential of the area can be assessed and exploration of its mineral resources be done. Knowledge of the geology is also essential for the proper development of the water resources of a region, particularly the ground-water resources.

For accurate recording of geologic and other data and for a multitude of planning purposes topographic maps are a necessity. Figure 8 shows the areas of Idaho that have been mapped topographically on a scale of about 1 inch to the mile or larger and for which maps are available from the Geological Survey. Although topographic maps are available for the more populated areas, a large part of the State—including many of the important mineralized regions—has not been adequately mapped. Figure 9 is a similar map showing the status of geologic mapping in the State through the efforts of various agencies. Only about half the State has been mapped geologically on scales larger than 1:250,000; of this, only a small portion has been mapped geologically on a scale of 1 inch to the mile or larger. The remainder has been mapped only in reconnaissance or not at all. Obviously much topographic and geologic mapping remains to be done before the State of Idaho can be considered to have adequate coverage.
Figure 8.—Published topographic mapping in Idaho, November 1963.
EXPLANATION

Published geologic map at scales 1:63,360 or larger

Published geologic map at scales 1:63,360 to 1:250,000

Mapping that shows only part of the geologic formations or contains blank areas is omitted.

Figure 9.—Published geologic mapping in Idaho, January 1964.
MINERAL AND WATER RESOURCES OF IDAHO

SELECTED REFERENCES

—1951, Metamorphic epochs in Idaho: Econ. Geology, v. 46, no. 6, p. 592-607.


MINERAL RESOURCES

ANTIMONY


Domestic mine production of antimony metal has come chiefly from Idaho, which has furnished the entire U.S. output during many of the past 10 years. The total antimony production in Idaho from the beginning to 1960 has an estimated value of $17,200,000. The United States is the largest consumer of antimony metal and its products in the world. Much of the antimony is imported; from China in the past and, since about 1935, from Mexico and Bolivia. (See Table 1 for a comparison of Idaho and U.S. mine production of antimony.)

Table 1.—Mine production of antimony in Idaho and the United States, 1932 to 1962, in short tons of contained metal.

<table>
<thead>
<tr>
<th>Year</th>
<th>Idaho United States</th>
<th>Year</th>
<th>Idaho United States</th>
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<tbody>
<tr>
<td>1932</td>
<td>484 433</td>
<td>1940</td>
<td>1,438 1,438</td>
</tr>
<tr>
<td>1933</td>
<td>697 657</td>
<td>1941</td>
<td>5,036 3,471</td>
</tr>
<tr>
<td>1934</td>
<td>694 649</td>
<td>1942</td>
<td>1,060 2,150</td>
</tr>
<tr>
<td>1935</td>
<td>740 599</td>
<td>1943</td>
<td>1,150 2,150</td>
</tr>
<tr>
<td>1936</td>
<td>739 733</td>
<td>1944</td>
<td>704 766</td>
</tr>
<tr>
<td>1937</td>
<td>734 1,285</td>
<td>1945</td>
<td>704 766</td>
</tr>
<tr>
<td>1938</td>
<td>800 550</td>
<td>1946</td>
<td>602 631</td>
</tr>
<tr>
<td>1939</td>
<td>796 500</td>
<td>1947</td>
<td>549 590</td>
</tr>
<tr>
<td>1940</td>
<td>2,622 424</td>
<td>1948</td>
<td>624 749</td>
</tr>
<tr>
<td>1941</td>
<td>552 521</td>
<td>1949</td>
<td>777 750</td>
</tr>
<tr>
<td>1942</td>
<td>715 2,944</td>
<td>1950</td>
<td>810 671</td>
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<tr>
<td>1943</td>
<td>3,591 2,559</td>
<td>1951</td>
<td>810 671</td>
</tr>
<tr>
<td>1944</td>
<td>14,080 4,733</td>
<td>1952</td>
<td>869 689</td>
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<tr>
<td>1945</td>
<td>1,472 1,600</td>
<td>1953</td>
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<tr>
<td>1947</td>
<td>3,482 3,482</td>
<td>1955</td>
<td>3,482 3,482</td>
</tr>
<tr>
<td>1948</td>
<td>4,000 6,000</td>
<td>Total</td>
<td>44,205 50,309</td>
</tr>
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</table>


2 Prior to 1942, antimony production in Idaho and the United States was negligible on a yearly basis except possibly for the years 1941 to 1943, when the World War II demand for antimony spurred a production of several thousand tons for that period.

Antimony is used in alloys and compounds with other metals and non-metals. It imparts hardness and color, expands on solidifying, is fire resistant, and is resistant to corrosion by acids. Because of its diverse properties, it is used in the manufacture of ammunition, batteries (in the form of antimonial lead), type metal, bearing metal, cable coverings, collapsible tubes, foil and solder, and in the paint, fabric, ceramic, rubber, plastics, and electronics industries. Antimony compounds are also used in medicines (Callaway, 1960).

Commercial deposits of stibnite and tetrahedrite, the principal sources of antimony, are not abundant in the United States (White, 1951), but in Idaho antimony is recovered as a minor byproduct from
complex ores which are commonly mined for lead, silver, zinc, and copper. Tetrahedrite, mined for its silver and copper content, is the principal mineral of the complex ores, and antimony is recovered as a byproduct from it. Deposits in Idaho in which tetrahedrite is a common ore mineral include those in the “Silver Belt” of the Coeur d’Alene district, the Wood River region, and the Clark Fork district. Stibnite, an antimony sulfide is found in hydrothermal veins and in some replacement deposits in Idaho, including deposits in the Yellow Pine district, and the Pine Creek area of the Coeur d’Alene district. Native antimony has been found in veins associated with silver and arsenic ores, but its occurrence is rare.

Antimony deposits were discovered in Idaho during early gold and silver rushes in the State. Stibnite deposits on Swanholm Creek, Elmore County, were probably the first to be discovered between 1870 and 1880, but little attention was given to them. In 1885, two antimony claims on Pine Creek in the Coeur d’Alene district were located and were worked sporadically from that time until 1918, producing stibnite ore. Although the Yellow Pine antimony deposits were discovered around 1900, antimony production did not begin in this district until 1932 (Ross, 1963). The Yellow Pine district was the major producer of antimony from stibnite ores in the United States until 1992, when economic conditions forced the cessation of antimony operations. Since 1992, almost all antimony produced in Idaho has been as a byproduct from silver-copper-lead ores treated by the Sunshine Mining Co. plant near Kellogg, Shoshone County. Recovery of antimony from ores of the Sunshine mine and adjoining properties in the Coeur d’Alene district began at this plant during World War II.

The Bunker Hill Co. at Kellogg has produced antimonial lead as a byproduct of smelting operations for close to half a century. Bunker Hill receives ores from the Coeur d’Alene district (boulangerite, a lead-antimony sulfide, occurs at the Bunker Hill mine and several other mines) and many other unspecified mine sources, so its production is not listed with the antimony production of the State. The location of the mines or mining districts having antimony production as potential resources are shown on figure 10.

In the Yellow Pine district (fig. 10, No. 1), near Stibnite, Valley County, the two major mines are the Yellow Pine and the Meadow Creek. The Bradley Mining Co. (successor to the old Yellow Pine Co.) commenced producing antimony ore from the Meadow Creek mine in 1932 and subsequently produced 3,900 tons of antimony up to 1938 when the company shifted its principal production to the Yellow Pine mine nearby. In 1949, the Bradley Mining Co. began operation of a new smelter to treat antimony and gold concentrates. When the recovery of antimony ceased in 1952, this plant continued intermittent operation receiving shipments from the Sunshine Mining Co. In 1962, the Antimony Gold Ore Co. again started antimony mining in the Yellow Pine district.

Major north-trending faults cut the granitic rocks of the Idaho batholith in the Yellow Pine district, and the important complex base metal deposits are localized along northeast-trending branches of these faults. The stibnite ore occurs in veins and high-grade stockworks and is associated with pyrite, arsenopyrite, quartz, and vein feldspar; as disseminations in monzonitic rocks; and as a cementing
EXPLANATION
Production plus resources, short tons contained antimony

- Greater than 10,000
- 100 to 1,000
- 1,000 to 10,000
- Less than 100

The Bunker Hill Company smelter

Antimony Deposits
1. Yellow Pine district
2. Antimony Ridge mine
3. Sunshine mine and adjoining properties
4. Coeur d'Alene antimony mine
5. Star antimony mine
6. Pearson prospect and Hannibal claims
7. Stanley mine
8. Clark Fork district
9. Weber mine
10. Bermuda mine
11. Wood River region
12. Meyers Cove deposit
13. Nugent antimony mine

Figure 10.—Antimony in Idaho.
material in brecciated zones. The oxidation products of antimony sulfides are evident near the surface of the deposit. Other metals associated with the antimony ore are gold, tungsten, copper, and silver; considerable amounts of gold and tungsten have been produced.

At Yellow Pine, antimony and tungsten have been the chief metals produced. Reserves in 1950 were estimated to be 14,500 tons of metallic antimony which could be mined if the price of antimony were 40 cents per pound, and an additional 20,000 tons of antimony which could be mined if the price were higher. This district contains the largest known stibnite resources in the United States and has the greatest potential resources of antimony ores in any district in the State. This district has been described by Bradley and others (1943), Cole and Bailey (1948), Cooper (1931), Schrader and Ross (1926), and White (1949).

Quartz-stibnite veins in granitic rocks occur at the United Mercury Mines Co.'s Antimony Ridge mine (No. 2), 10 miles west of the Yellow Pine mine; a small amount of silver is associated with the ore. The mine produced 400 tons of antimony from 1940 to 1942 and was the second largest antimony producer in Idaho in 1941. Reserves are considered small.

In 1961, a new showing of stibnite was reported in the Profile Summit area north of Yellow Pine. In the summer of 1963, the Oberbillig mill at Yellow Pine treated a small tonnage of stibnite ore from an unidentified prospect near Stibnite (Leonard, B. F., written communication, February 1964).

Antimony-bearing minerals are prevalent throughout the Coeur d'Alene district, Shoshone County. The geology and ore deposits of the district have been described by Ransome and Callins (1908), Jones (1920), Umpleby and Jones (1925, pp. 121-123), Shonon and McConnell (1939), and Fryklund (in press). (See also the silver-lead-zinc chapter of this report for a more complete description of this district.) Three types of antimony-bearing ores occur: (1) silver ore in which tetrahedrite is the principal mineral but from which copper and antimony are recovered (Colton, 1961); (2) lead-zinc ores that contain minor amounts of antimony chiefly in tetrahedrite; and (3) quartz-stibnite veins that contain a little gold, silver, and, rarely, zinc (Fryklund, 1961).

The more important antimony occurrences are south of the Osburn fault in an area known as the "Silver Belt." In this "Belt," freibergite, the silver-bearing variety of tetrahedrite predominates. The Sunshine mine and nearby associated properties (No. 3) are the most important producers. This mine has been in production since 1904, but has been most profitable since the late 1920's. Between 1904 and 1959, the Sunshine mine produced 6,145,467 tons of crude ore, which contained approximately 20,751 tons of antimony. A plant to treat antimony-bearing ores was built during World War II, was shut down in 1944, and reactivated in 1955. Some shipments of Sunshine's stockpile of antimony cathode metal were made to the Bradley Mining Co.'s antimony smelter at Stibnite in the mid-1930's. These shipments were discontinued in 1957 when Sunshine began operation of its own facilities for further refining cathode antimony to remove arsenic. Other silver mines in this area that have supplied minor
amounts of antimony concentrates to the Sunshine plant include the Galena (Vulcan) in 1938 and the Silver Summit in 1961. Production from the Sunshine refinery has been at a yearly rate of about 1/4 million pounds of antimony. Reserves are considered adequate for continuous operations for an indefinite period.

The Coeur d'Alene Antimony mine (No. 4) about three-fourths of a mile west of the Pinehurst store on the west side of Pine Creek, is in the Pine Creek area of the Coeur d'Alene district (Thomson, 1919). This mine was active from 1893 to 1896, from 1915 to 1918, and again in the early 1950's. Total production to 1918 was about 250 tons of antimony. Quartz-stibnite veins occur here in a fault or shear zone in Precambrian slate. The Coeur d'Alene Antimony mine produced 44 tons of ore assaying 16 percent antimony in 1940—probably from mine dumps. Antimony ore also has been produced at the Star mine (No. 5), which is on the East Fork of Pine Creek. The property was discovered in 1914 and some ore was shipped from it in 1916, but it has not been productive since then. The deposit consists of quartz-stibnite veins in slates of Precambrian age. Some pyrite and minor sphalerite are associated with the stibnite. North-west of the Star mine are the Pearson prospect, and the nearby Hannibal claims (No. 6). A shipment of 20 tons of antimony ore was made from the Pearson prospect in 1916, but no shipments have been made from the Hannibal claims. At these properties, stibnite occurs in veins in a shear zone in slate and altered dike rock.

In the eastern part of the Coeur d'Alene district, the Stanley mine (No. 7), 1 mile north of Burke, produced some antimony before World War II from a gold-bearing quartz-stibnite vein in quartzite and argillaceous shale. Lenses of stibnite occur along a vein at the Benton property which adjoins the Stanley mine. The Houghland mine, 8 miles from Burke, produced stibnite ore from flat-lying quartz veins up to 1917.

Lead-zine deposits in the Clark Fork district (No. 8), Bonner County, were discovered shortly after 1888, and the first shipments of ore were made in 1913 (Lorain, 1946). Galena, tetrahedrite, and sphalerite occur here in steeply dipping veins in faulted Precambrian rocks of the Belt Series, but antimony has not been recovered from the ores of this district (Anderson, 1939a). Elsewhere in Bonner County, stibnite occurs in massive form in the silver ore from the Weber (Webber) mine (No. 9), south of Lake Pend Oreille and at an antimony prospect near Smith's ranch, 4 miles south of the town of Lakeside (Calkins and MacDonald, 1909, p. 92-107).

The Hermada mine (No. 10) in the Swanholm district, Elmore County, was a major antimony producer between 1947 and 1952. Native antimony and stibnite occur in lenticular pods in granite. At the nearby Black Warrior mine, a number of small quartz veins containing minor amounts of stibnite were explored by bulldozing during the 1950's. No antimony is known to have been produced from this property (Popoff, 1953).

Antimony occurs in the complex lead-zinc-silver ores of the Independence, Triumph, North Star, and many other mines in the Wood River region (No. 11) of Blaine County. Tetrahedrite and boulangierite are common in small amounts throughout the region in granitic and sedimentary rocks (Umpleby and others, 1930, p. 81-126, 174-
A few quartz-stibnite veins of negligible value occur here also. Stibnite occurs in veins in quartz monzonite at the Ironside (Ironclad) claims in the Vienna mining district. There has been no antimony production recorded from the mines in Blaine County.

The lead-iron-antimony sulfide, jamesonite, is the principal ore mineral at the Livingston mine in Custer County. Several other mines near Livingston also contain jamesonite. A small amount of antimony has been produced from quartz-stibnite veins at the Golden Age silver mine near Idaho City, Boise County.

The Meyers Cove deposits (No. 12) in Lemhi County have been worked chiefly for fluor spar. The fluor spar occurs in lodes along minor complex zones of fracturing in silicified tuff. One of these lodes is reported to contain some stibnite (Anderson, 1949a).

The Nugent antimony mine (No. 13), 4 miles northeast of Silver City, Owyhee County, is developed on a quartz-stibnite vein in granodiorite; the average grade of the vein is reported as 10 percent antimony (Piper and Lacey, 1926, p. 80; White, 1951, p. 11). Production from this mine totals about 100 tons of antimony, and reserves may contain as much as 200 tons. Stibnite also occurs in a large gold-silver-bearing quartz vein in the Mammoth district.

Some antimony has been produced from quartz-stibnite veins in Deadwood Gulch near Warren, Idaho County (Shannon, 1928). Minor amounts of antimony are found in the ores from the Bigger Lead, Gold Crest No. 1, and Kimberly Lode mines in Idaho County (Kaiser and others, 1964, p. 49-54). In Clearwater County, a small amount of stibnite in quartz has been noted in float above a vein on the Driessel property.

**BARITE**

(By D. A. Brobet, U.S. Geological Survey, Denver, Colo.)

Barite (BaSO₄) is a relatively soft, generally white to gray, heavy crystalline mineral that has a specific gravity of 4.5. It occurs in vein, replacement, and residual deposits either alone or more commonly in association with quartz, chert, jasper, fluorite, celestite, and various carbonate and metallic sulfide minerals (Brobet, 1968, p. 82).

The United States has been the world's leading consumer and producer of barite since World War II. Domestic production annually is 1.5 to 2 million tons. Domestic production of about 0.75 to 1 million tons annually must be supplemented by imports.

About 90 percent of the barite is ground to minus 325 mesh for use as mud in drilling deep oil wells. The heavy weight of the mud assists in the drilling process and in controlling high oil and gas pressures at depth. The other 10 percent is used both as barite and in the preparation of barium compounds for a great variety of products and industrial processes. Among these are paint pigments (lithopone), filler in paper, textiles, rubber goods, asbestos products and linoleum, heavy aggregate for concrete paving material, electronic equipment, ceramics, and glass manufacture. The quality standards of the crude barite vary for different uses (Brobet, 1969, pp. 62-63). The December 1968 market price for crude mud grade
barite (generally specified minimum of 4.20 specific gravity) ranged from $12 to $16 per ton.

Barite was mined in Idaho intermittently between 1922 and 1959, but only a small amount as compared to the total production in the United States. In 1959, Idaho's production amounted to about 23,000 tons (Cook, 1961, p. 64).

The Sun Valley mine SE ¼ sec. 26, T. 3 N., R. 16 E. (Bonnie and Barium Sulfate claims) near Hailey, Blaine County, has yielded most of the barite mined in Idaho (fig. 11, No. 1). The J. R. Simplot Co. of Pocatello, Idaho, has operated the mine since 1897. The barite occurs in lenticular masses in the Wood River Formation of Pennsylvanian and Permian age. The barite bodies follow the regional structural trend which strikes about N. 60° W. and dips 50° SW. This trend is locally distorted by faults, one of which apparently forms the northeast boundary of the deposit (Brobst, 1958, p. 97). The exposed area of the deposit is about 2,000 by 200 feet. The best grade of ore is 84 to 88 percent barite (Kihlgard, 1950, p. 60), but this is mixed with leaner ore, necessitating selective mining. This grade of ore is sufficiently good to yield a product of 4.0 to 4.1 specific gravity that is suitable for use in drilling mud without further concentration. Some of the ore is iron stained and it generally has a higher specific gravity than the unstained ore. Silification has occurred near the faults and fractures; the grade of ore improves away from the silicified zone.

Barite occurs with fluorite in a zone of mineralization across Fluorspar Ridge in the Meyers Cove district, Lemhi County (fig. 11, No. 2). The ore deposits are associated with the Casto (Permian!) and Challis (Eocene (?)) Oligocene and Miocene (?) volcanic rocks, and with intrusive igneous rocks of Miocene age. The barite is distributed periiodically in the veins. Much of the fluorite mined contains 2 to 3 percent barite. Some ore shoots contain as much as 10 percent barite and some deposits contain even more (Anderson, 1954a, p. 18). It is likely that any barite shipped from this district would be a coproduct from the mining of fluorite.

Some barite was mined in 1959 from lenses in the Copper Basin Formation of Mississippian and Pennsylvanian age in the Muldoon district, Blaine County (fig. 11, No. 3). Some barite occurrences of doubtful value are reported in Custer County (Hubbard, 1953, p. 7).

The barite resources of Idaho are influenced by two main factors, the quantity available and the economic factors which govern whether or not a given deposit can be worked profitably. Of the known deposits, only the barite lenses at the Sun Valley mine can be worked for barite under present conditions; elsewhere, abundant barite gangue associated with some fluorite or base and precious metal veins conceivably could be produced as a byproduct. A major change in economic conditions would be required to change this picture significantly. Barite is a low-priced commodity, and the high cost of transportation from Idaho to the major national markets discourages active prospecting. A geographic shift in industrial demand for barite, or the discovery of large new deposits consisting predominantly of high-grade barite could alter significantly the economic position of this commodity.
EXPLANATION

\[\text{Barite mine or prospect}
1. Sun Valley mine
2. Mayera Core district
3. Muldoon district
\]

Figure 11.—Barite mines and prospects in Idaho.
BERYLLIUM


Beryllium is a rather uncommon light metal that has a wide variety of uses, both as pure or alloyed metal and in chemical compounds. More than half of the beryllium used is alloyed with copper to make a strong, hard, fatigue-resistant alloy that is much used in springs and other devices that must be free of the magnetic properties of steel or steel's tendency to rust or to spark during impact or abrasion. Beryllium oxide is used as a refractory because it has a high melting point, high electrical resistance at high and low temperatures, and high thermal conductivity and resistance to thermal shock. Recent developments include the use of the metal and its oxide as moderators and neutron reflectors in nuclear reactors and as a neutron source in neutron generators. The metal is used in inertial guidance mechanisms of missiles because of its rigidity, but its brittleness has hindered large-scale use as a structural material in missiles and manned aircraft. Beryllium-rich alloys with aluminum were reported in 1963 to have potentially large-scale use in aircraft. Alloys with aluminum, nickel, and magnesium are now used on a small scale. Beryllium minerals and compounds are used in special ceramic materials. Speculative uses include the incorporation of the metal in solid missile fuels and explosives.

The total amount of beryllium used in the United States is not large, as compared with that of many other metals. The consumption of ore increased from 1,013 tons in 1946 to an all-time high of only 9,692 tons in 1960. The industrial importance of the metal is, however, far more significant than these amounts might suggest, as is indicated by the ninefold increase in consumption over the 15-year interval.

Adequate and increasing supplies of ore have been obtained by importing the mineral beryl, which contains 10 to 14 percent BeO. This ore mineral is obtained from pegmatites in South Africa, Brazil, Argentina, India, and elsewhere. Only about 6 percent of our supply is from domestic sources. The low productivity of our pegmatites has caused attention to shift to deposits of other types. The successful exploration for these deposits may well make the United States self-sufficient in beryllium within the next decade.

Idaho is not well endowed with pegmatitic deposits of beryl (fig. 12). They are known in only a few areas, which have yielded, at most, a ton of beryl and show little evidence that they can ever be much more productive. Even though the nonpegmatitic deposits, found in four areas, have also been unproductive, they may eventually become important. The discovery of additional and perhaps better nonpegmatitic deposits may be expected in central and east-central Idaho. Regions containing Challis Volcanics, especially near volcanic vents, as well as those containing intrusive rocks of Tertiary age, might be particularly promising for discoveries, although the deposits themselves are more likely to be in older sedimentary rocks associated with the igneous rocks than in the igneous rocks themselves.

Beryl-bearing pegmatite, commonly associated with the Kaniksu batholith, is found in a rather widespread area near Priest Lake,
Figure 12.—Beryllium in Idaho.
Bonner County. Most of the localities are west of the lake in the Wabaningo (Lakeview) Mountain area (fig. 12, No. 1) and along the roads to Gold Peak and Hughes Meadow. One locality is east of Priest Lake and on the west side of Sundance Mountain (No. 2). Beryl is in quartz-microcline-muscovite pegmatite that forms dikes in granodiorite or, uncommonly, in gneiss. In the Wabaningo Mountain area locally beryl is found in the granodiorite.

Beryl has been found in muscovite-rich pegmatite in a small area near Avon (No. 3), eastern Latah County (Stoll, 1950, pp. 36-54). Other accessory minerals in the pegmatite are graphite, black tourmaline, microcline, biotite, garnet, and small amounts of uranium minerals. The beryl crystals range from less than one-tenth inch to 18 inches in length. A few crystals were found in the wall rock of the pegmatite. About 100 pounds of beryl were estimated to have been sold by 1946 (Reed, 1948, p. 9-19) mostly obtained as a byproduct of mica mining.

Bluish to bluish-green beryl has been found in the Sawtooth Range in central Idaho (No. 6), particularly in the area near Glenn Peak and Mount Everly (Reid, 1963, p. 23-26). The beryllium-bearing deposits are chiefly in a pink, rather sodic and vuggy quartz monzonite, but also include pegmatitic occurrences, all of which intrude the Idaho batholith. Beryl forms single grains and clusters of radiating crystals along joints and is in veins accompanied by quartz, garnet, and albite. Unjointed quartz monzonite contains scattered spherical aggregates of beryl, and of albite or quartz. Beryl also is in orthoclase-quartz veins or pegmatites, most of which are flatly and compact; a few are steep and vuggy. The beryl in the Sawtooth Range is accompanied by fluorite, which is reported to be in all the rocks.

The beryl in the Sawtooth Range is blue like the beryl found embedded in granitic rocks in several other similar districts. Some is clear gem-quality aquamarine. Only beryl in cavities in steeply dipping orthoclase-quartz veins has been altered.

Reportedly, beryl has been found in the Cathedral Rocks area, Lemhi County (No. 7), an area of Tertiary intrusive rocks, in an occurrence that may be similar to that of the Sawtooth Mountains, which is 90 miles to the south.

Crystals of blue beryl have been found in cavities in a granite rock in the Boise Basin (No. 4), Boise County. Though clear and of gem quality, many are badly broken. A sample containing several percent BeO has been obtained from the molybdenum-bearing veins along the Roaring River, Elmore County, about 30 miles southwest of the Sawtooth Range beryllium area.

CLAYS


Interest was focused on the clay deposits of Idaho during World War II when the U.S. Geological Survey and the U.S. Bureau of Mines investigated high kaolin clays as a possible source of aluminum under the strategic minerals program. From 1945 to 1947, production
of all kinds of clay products tripled, but it has remained fairly steady since. Renewed interest in the Idaho clays as a possible source of aluminum was stimulated by the construction of an aluminum plant at Columbia Falls, Mont., in 1935 by the Anaconda Aluminum Co. and by more recent experimental work by the Anaconda Co. at Anaconda, Mont., on the production of alumina from Idaho clays. Alumina (Al₂O₃) is the material from which aluminum is made. Several other companies have investigated other possible uses for the clays, and as a result the future production of clays looks promising.

Clays are natural materials composed of very fine particles (clay minerals) that are principally hydrous aluminum silicates, but may contain small amounts of iron, magnesium, potassium, sodium, calcium, and other less important ions. The following clay minerals are found in the clay deposits of Idaho: kaolinite, halloysite, montmorillonite, and probably illite. A clay deposit consists of one or more of the clay minerals and may contain nonclay minerals in varying quantities; the most common of these minerals are quartz, feldspar, mica, and minerals containing iron and titanium. Variations in mineral and chemical composition, particle size and shape, impurities, and other characteristics of the clay deposits result in a wide range of physical properties that determine the economic usefulness of the clays. Physical properties of the clays include plasticity, color, refactoriness, specific gravity, porosity, deformation with drying and firing, green and fired strength, viscosity and gel strength. The purity of the clay enhances the economic value of most clay deposits, but for some uses, particularly in making common brick and tile, certain nonclay minerals are desired for color and to control shrinkage.

Clays have been classified in numerous ways according to their use in industry and the arts, their varied modes of occurrence, differences in physical properties, chemical composition, and other factors. Perhaps the best known use of clays is in the manufacture of fired ceramic products which consume about two-thirds of all industrial clay. Included in this category are the structural clay products such as building brick, drain tile, sewer pipe, terra cotta, and similar items. Their manufacture requires large tonnages of clay and in many instances the clays that contain gritty impurities or pigmentary materials are as well or better suited than the more pure kaolins. Some lightweight aggregates for concrete are made by firing clays that will expand on sintering. Refractories are manufactured from clays having a high fusion point (cone 19 or above). The material most commonly used in refractories is known as fireclay. Whiteware and porcelain are ceramic products usually made by blending relatively pure kaolin clays (china clays) with feldspar and flint. It is essential that clays used in making whiteware be free from materials that burn to an off-white color. Pottery and stoneware are made from a variety of clays but the better products require clays that are semirefractory and fire to a dense product. The manufacture of portland cement consumes the largest tonnage of clay but much of this material is more nearly a shale than a clay.

There are a number of nonceramic uses for clay. One of the most important of these is as a filler and coater in the manufacture of paper. Specifications for coater clay are more rigid than for filler clay but in both cases a relatively pure kaolin clay is demanded. It
must have a high degree of whiteness and brightness, a closely controlled particle size and be free from abrasive particles. Coater clays must also remain fluid when pulped in water at a relatively high percent of solids. In addition, coater clays must adhere satisfactorily to the paper surface and they must be compatible with printing inks. Other applications in which clay may be used as a filler or extender include rubber products, fertilizers, pesticides, insecticides, adhesives, linoleum, textile sizing, etc.

Certain clays, either in their natural state or after acid activation, possess bleaching properties. Such clays are used in decolorizing animal, vegetable, or petroleum oils and fats, and are usually non-swelling bentonites that consist of montmorillonite. Other bentonites expand when immersed in water to several times their normal volume and form a gel. This type of bentonite is used principally as a stabilizer in compounding the heavy muds required for oil-well drilling and for sealing earth-lined canals and reservoirs.

The composition, mineral structure, methods of identification and testing of the various clays for different uses have been summarized by Murray (1960), Klimefelter and Hamlin (1957), and by Grim (1953 and 1962).

In 1961 Idaho produced 27,000 short tons of clay valued at $20,000, according to Fullkerson and others (1962, p. 324). These figures, however, do not include fireclay, kaolin, or bentonite, because production figures were withheld to protect individual companies. Based on the work of D'Amico (1962, pp. 11-37), Idaho in 1961 ranked 43d in both quantity and value of clay produced, but if the production figures for fireclay, kaolin, and bentonite had been included, it would have ranked higher. Overall production for 1962 remained substantially the same as for 1961. There was a sharp drop in the amount of miscellaneous clay for making heavy clay products which was offset by an increase in the output of paper filler (kaolin) and fireclays. Preliminary production figures for 1962 indicated a total of 35,000 tons valued at $70,000 (Fullkerson and others, 1963, p. 339). These figures do include fireclay, bentonite, and kaolin. The clay produced in the State includes common clay for making brick tile, kaolin for making refractory products, and a small amount of bentonite used as a watertight seal. Production of kaolin as a paper filler began in 1961.

Refractory clay

Clays suitable for intermediate- to high-heat duty refractories are used to produce firebrick and fireclay mortar in Latisha County (Sinning and Kelly, 1949, table 11; Hesterman and others, 1960, p. 20-24) (fig. 18, No. 1). Prior to 1956 the refractory clay mined at the Benson pit was processed by the Troy Firebrick Co. at Troy. The clay from this deposit is a residual clay derived from granodiorite (Hesterman, 1960, p. 290). In 1956, A. P. Green Fire Brick Co. of Mexico, Mo., purchased the property. This company opened a new pit at Helmer, in transported clay of the Latisha Formation. The clay is a mixture of kaolinite and halloysite and requires calcining before it can be made into a brick and fired in the kiln.

Filler clay

In 1955, J. R. Simplot Co. began investigating the Bovill area, Latisha County (No. 2), for a clay that could be used as a possible
Figure 13.—Clay in Idaho.
source of raw material for ceramic (whiteware) and as a filler for paper. By 1961 a beneficiation plant was constructed and shipments of paper-filler-grade clay were made; in addition, glass sand was produced as a byproduct. At first the clay was obtained from a pit west of Bovill that contained transported clay of the Latah Formation; since then residual clay derived from granodiorite was found to be more satisfactory for paper filler. Shipments from this plant are going to paper mills in Washington, Oregon, and northern Idaho. Kelly and others (1965) have published some data on the physical and chemical properties of the halloysitic clay near Bovill, and have compared them with other similar clay deposits in the Northwest.

*High-alumina clay*

During World War II, the U.S. Geological Survey and the U.S. Bureau of Mines investigated the high-alumina clay deposits of Latah, Kootenai, and Idaho Counties. The results of this work, including drill-hole logs and assay data, have been published by the Geological Survey (Hosterman and others, 1960). In 1952 the Anaconda Co. made a preliminary study of the clays in Latah County for a potential source of alumina, which might be of future importance to the aluminum plant at Columbia Falls, Mont. (Stephens, 1966, p. 405). They were successful in producing alumina at a pilot plant in Anaconda, Mont., and according to recent press releases (Mining World, July 1963), alumina from this pilot plant has been used in selected pots at the aluminum refinery at Columbia Falls. The initial tests have been successful and it is believed that the process will make clays economically competitive with bauxite as a source of aluminum. Production on a commercial scale could open a large market for the high-alumina clays of Latah County, although these clays would have to meet competition from higher grade eastern clays.

According to Hubbard (1956, table 1), Latah County contains 186.9 million tons of measured and indicated high-kaolin clay reserves and 277.1 million tons of inferred clay resources—a total of about 464 million tons in an area of about 20 square miles. He also states that approximately 300 square miles in Latah County are geologically favorable for clay deposits. If the clay deposits outside of Latah County are included, the area of favorable high-alumina clay deposits extends from Kootenai County to Idaho County (Sohn, 1952).

*Bentonite*

Bentonite is composed of the clay mineral montmorillonite. In Idaho it is used chiefly for sealing irrigation canals, reservoirs, and potato cellars, and a small quantity is used in rotary-drilling muds. Bentonite is mined at Oreana and Grandview, Owyhee County (No. 5). Bentonite also occurs 4 miles southeast of Salmon, Lemhi County, where it is mined from thin beds in the Kirtley Formation of Anderson (1929). The gray to pale-buff beds appear sedimentary in origin and probably represent debris from the tuffaceous material of the Challis Volcanics (Anderson, 1926, p. 99).

*Common clay*

Common clay includes those used to make heavy-clay products such as building brick and tile. Because the cost involved in shipping heavy-clay products is high, only local clay deposits can be used
economically. In many instances, such deposits may be of any material that can adhere to itself and that can be dried and fired without distortion. These clays are mixtures of kaolinite and illite and are usually low-grade, very high in impurities, and color is not particularly important. Only four companies throughout the State were producing heavy-clay products in 1961. They were Jensen Brick Co. at Payette, Payette County (No. 3), which is no longer in business; Pullman Brick Co. at Boise, Ada County (No. 4); Burley Brick & Sand Co. with clay pits at Burley, Cassia County, and Heyburn, Minidoka County (No. 6); and Idaho Falls Brick & Tile Co. at Idaho Falls, Bonneville County (No. 7).

The Jensen Brick Co. formerly mined silty clay beds of the Idaho Group in western Payette County, but the clay supply became exhausted in the vicinity of the plant. There are, however, additional clayey beds of the Payette Formation and Idaho Group in the hills east of Payette and in the southwest part of Payette County that could continue to supply a reasonable quantity of raw material for a brick industry (Savage, 1961a, p. 40).

The Pullman Brick Co., southeast of Boise, obtains clay from a pit near Barber. Most of the clay in this area is clayey silt or silty clay occurring in the Payette and Idaho units or in Recent fluviatile deposits. According to Savage (1958, p. 63), good firebrick has been produced from this area in the past. Future development, however, will depend upon local markets.

The Burley Brick & Sand Co., Inc., mines silty clay from two pits—one east of Burley in Cassia County and the other at Heyburn in Minidoka County. Both clay pits are in the alluvial flood-plain deposits near the banks of the Snake River. Over a period of many years, considerable clay was mined from the Burley pit (Anderson, 1931, p. 160), but the Heyburn pit has been in operation only since 1957.

The Idaho Falls Brick & Tile Co., the only plant operating in eastern Idaho, produces about 4 million bricks on a 4-month-year basis. The plant obtains raw material from pits at Ammon and Bone, Bonneville County, which contain alluvial clay of the Snake River flood plain. Some clay is also shipped from a pit near Roberts, Jefferson County, to the Idaho Falls brick plant. This pit contains clay that is interbedded with the Snake River basalt flows (Savage, 1961b, p. 62).

Pottery and miscellaneous clay
A small but growing industry has been established at Clark Fork utilizing clay from a deposit southwest of Cabinet in Bonner County. The clay bed, 15–20 feet thick, underlies several square miles of the river valley. It contains kaolinite and montmorillonite with some quartz and muscovite and is interlayered with silty clay, silt, and sand. A variety of pottery vases and pitchers are being produced as a part-time occupation by several townpeople at Clark Fork. The clay throws well on a potter’s wheel, has a red-brown burning color and produces a mature ceramic body when fired to cone 04 (Savage, written communication).

Silty clays from near Hagerman in Twin Falls County have been utilized by the Snake River Pottery Co. for a number of years in the manufacture of various ceramic items, sold mainly through local outlets and specialty stores. No doubt pottery or similar items have been
produced by hobbyists or semicommercial operations using clays from other localities throughout the State. Because the locations from which such materials have been obtained are not precisely known and because in many instances the material is at the best silt clay, the deposits are not shown on figure 13.

**ECONOMIC CONSIDERATIONS AND RESOURCE POTENTIAL**

Two important economic factors control the clay products made in Idaho, and therefore affect the type of clay mined. One group of clay products supplies local markets only, and the other group of clays competes for distant markets. The clay used to supply the local market is made into heavy, low-cost brick and tile, and therefore it must be cheap to mine, close to the brick plant, and close to the consumer. This economic control results in the concentration of brick and tile plants and clay pits around the metropolitan areas (fig. 13). The second group of clay products capable of competing for distant markets includes refractories and paper-filler clay currently being produced in Latah County. Possibly the high-alumina clays might be included in the not too distant future. The value of these clays is dependent upon a specific property or on a certain quality of the finished product, and transportation costs to distant markets is less significant. Bentonite generally falls into the second group because of its special properties, but in Idaho it is only used locally due to large amounts of impurities.

The supply of raw clay for clay products now produced in Idaho is more than adequate for the needs of the immediate future. Resources of common clay are virtually inexhaustible, although depletion of local pits and changing of consumer requirements will result in periodic adjustments in the raw materials used for heavy-clay products. Present sources of clay used for intermediate- and high-heat-duty refractories and paper-filler clay will undoubtedly continue to meet demands for some time. In addition, there are a considerable number of other deposits of clay present in Idaho that are suitable for these uses, but they are less favorably located with respect to present plants and transportation. Bentonite resources for local uses are probably adequate for many years and deposits are undoubtedly known at several localities other than where it is now mined. Thorough prospecting and testing would probably reveal large resources and possibly better quality than is now mined and used.

Idaho is one of the few States that contains large resources of undeveloped high-kaolin clay deposits that may serve either as a future source of aluminum or in other uses requiring white kaolin clay. A few of the potential uses include ceramic whiteware, paper-coating clay in addition to paper-filler clay, and an expansion of the present refractory clay-products industry. Beneficiation of the clay would produce such byproducts as glass sand and titanium. In Latah County, where investigations of the clay deposits have been concentrated, there are about 464 million tons of clay resources containing more than 20 percent available alumina and less than 5 percent available iron. Additional high-kaolin clay deposits occur north of Latah County to Kootenai County and south to Idaho County, a total area approximately 150 miles long and 60 miles wide (fig. 13).
COAL


Coal represents plant material that accumulated in swamps and marshes, and which has been progressively transformed into several types of coals that may be ranked according to their carbon content. Lignite is the lowest rank, followed in increasingly higher ranks by subbituminous, bituminous, and anthracite. Transformation of coal is affected by several factors including age, weight of original overburden, and deformation. The older coals or the more deformed coals generally are of higher rank. The higher rank coals also have higher heat content and lower amounts of volatile matter and moisture.

In the United States coal is used primarily for heat energy, about 50 percent of it for generating electricity. Lignite, however, lends itself to gasification and carbonization and a great variety of products other than heat energy are derived from it. Hydrogen and carbon monoxide are produced from lignite and are used to make ammonia and other chemicals. Aromatic chemicals and tars produced by carbonization can be used to make plastics, synthetic fibers, road surfacing materials, and a host of other products. Lignite also is a source of activated carbon used for decolorizing and filtering.

Idaho has not been a significant producer of coal and only a few areas in the State contain coal beds of size and quality adequate to have encouraged mining. Carbonaceous material, including some coal, however, is widespread in part of southeastern Idaho (Andrews and others, 1947, p. 6-8). Lignite also has been mined at some localities in central and southern Idaho. Most of the better coal in Idaho is in sedimentary rocks of Cretaceous age. Lignite and other lower ranked coal also occur in rocks of Miocene and/or Pliocene age. The known coal and lignite deposits are discussed in the following paragraphs, and the localities are shown on accompanying figure 14. Representative analytical data on samples of these coals are presented in table 2.

Horseshoe Creek district.—The Horseshoe Creek district (fig. 14, No. 1) in western Teton County is the principal coal producer in Idaho. This district, often referred to as part of the St. Anthony or Teton Basin coalfield, is about 5 miles long and 2 miles wide. Most of the coal has been mined from the NW¼ sec. 6, T. 4 N., R. 44 E., and from several mines and prospects along a belt of outcropping coal beds that extend to the northwest. The field has been mined sporadically since 1882.

The coal beds are in the Frontier formation of Cretaceous age and they crop out in two parallel belts about a mile and a half apart. Beds in each belt dip steeply to the southwest, are offset by many tear faults, and are contained in a structural block between two major thrust faults. At the northwest end the belts are overlain by volcanic rocks of Tertiary age and at the southeast end by older overthrust rocks. The number of coal beds in the western or principal belt is unknown, but Kilggaard (1951a, p. 28) describes 9 beds of bituminous coal that are 14 inches or more in thickness. Two of these beds, the Brown Bear and the Progressive, separated stratigraphically about 90 feet, have produced most of the coal. Where mined, the
EXPLANATION

Coal fields

1. Horseshoe Creek district
2. Pine Creek area
3. Willow Creek-Caribou district
4. Continental Divide area
5. Goose Creek field
6. Reynolds Creek area
7. Sukers Creek area
8. Horseshoe Bend field
9. Salmon area
10. Orofino area

Figure 14.—Coal and lignite deposits of Idaho.

30-722 D - 64 - 5
<table>
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<tr>
<th>Sample No.</th>
<th>Location</th>
<th>Condition of sample</th>
<th>Analyses in percent</th>
<th>Ultimate</th>
<th>Heat value, Btu/ib*</th>
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<tr>
<td></td>
<td></td>
<td>A, as received; B, moisture free</td>
<td>Moisture</td>
<td>Volatile matter</td>
<td>Fixed carbon</td>
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<td>A69225</td>
<td>Horseshoe Creek district, Teton County</td>
<td>Idaho mine, SW 4 sec. 30, T. 5 N., R. 44 E., from coal seam bed, sample taken 600 feet from portal</td>
<td>A</td>
<td>9.7</td>
<td>45.6</td>
</tr>
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<td></td>
<td></td>
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<td>58.6</td>
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<tr>
<td>15119</td>
<td>Brown Bear mine, SW 1/4 se. 24, T. 5 N., R. 44 E., from north entry, 600 feet from portal (Woodruff, p. 366)</td>
<td>A</td>
<td>11.5</td>
<td>57.5</td>
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<td>15115</td>
<td>Horseshoe mine, Brown Bear bed, NW 1/4 se. 5, T. 5 N., R. 44 E., sample taken 200 feet from portal (Woodruff, p. 366)</td>
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<td>7.7</td>
<td>59.7</td>
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### GOOSE CREEK FIELD, CASHI COUNTY

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### CONTINENTAL OXIDE AREA, CLAY COUNTY

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### HORSHEO PEND FIELD, SUMME COUNTY

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### WALLOW CREEK-CAPITOL DISTRICT, CONNELLY COUNTY

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1. All samples analyzed by U.S. Bureau of Mines except those marked by asterisk, which were analyzed by Idaho Bureau of Mines and Geology.
2. British thermal units.
Brown Bear bed has averaged about 5 feet in thickness and the Progressive bed 9.5 feet, although the latter bed contains an interbedded parting of sandy clay that ranges from a few inches to more than 1 foot in thickness. The coal is of excellent quality. It ranges from subbituminous to bituminous in rank and is low in ash content (table 2). Output of coal, however, has been hindered by mining problems resulting from the steep dips and faulted condition of the beds. There also has been a problem of contamination by wall rocks that have sloughed into the broken coal as it was mined.

Pine Creek area.—The Pine Creek area, south of the Horseshoe Creek district, is part of the Teton Basin field. There are several prospects on Pine Creek Pass, near the road from Teton Basin to Swan Valley (No. 2). A prospect in the SW¼NW¼ sec. 24, T. 3 N., R. 44 E., contains 2 feet of crushed coal with much clay (Mansfield, 1929, p. 124). Moisture and ash content of the coal is high, and heating values are low (7,276 B.t.u.). About a mile to the east, old prospects explore what is considered the same coalbed. There are several coaly lenses ranging from 2 to 8 inches in thickness.

Southeast of Pine Creek a group of coal prospects are reported by Mansfield (1929, p. 130) along Rainy Creek, about 100 yards southwest of the trail from Pine Creek to Fogg Hill. These explore carbonaceous shale and have been nonproductive.

Coal prospects also have been reported northwest of Pine Creek, in the area between Pine Creek and the Horseshoe Creek Basin. Some of these have been examined by the writer and found to be carbonaceous shale of the Phosphoria formation and not coal. There could, however, be coal outcrop in the area, although the highly folded and faulted nature of the rocks would make any coal mining difficult.

Coalbeds in the Pine Creek area were believed by Schultz (1918, p. 66) to be in the Bear River formation.

Willow Creek-Caribou district.—South of the Teton Basin field there are several coal prospects in the Willow Creek-Caribou district (No. 3). Most have been known since the turn of the century but none have any recorded production. The coaly material is in carbonaceous shales of the Bear River or the Wayan formations. Moisture and ash content of the coal is high and the heat value low.

The Cloward prospect is in the SE1/4 sec. 6, T. 1 N., R. 40 E. The deposit consists of a series of carbonaceous shale beds in which there is some coaly material. The deposit has been explored by a 100-foot entry.

The Miller mine, also known as the Brinno mine, is in the NE1/4 SE1/4 sec. 34, T. 2 N., R. 40 E. This mine was worked first in 1900 and subsequently developed by a 40-foot shaft and a short entry (Schultz, 1918, p. 66). The entry explores a steeply dipping carbonaceous and gyspiferous shelf member of the Wayan formation in which are two coaly layers, each a few inches thick.

The Croley mine is in the SE1/4 SW1/4 sec. 27, T. 1 S., R. 41 E. Two tunnels that were caved when visited by Mansfield (1921, p. 133), explored a coalbed said to be as much as 18 inches thick. The coal was reported to burn, but it crumbled and would not form lumps. Another prospect in sec. 24, T. 1 S., R. 40 E. is believed to have explored the same coaly bed.
The Fall Creek coal prospect in the NE¼ sec. 4, T. 1, S., R. 42 E., consists of an abandoned inclined shaft sunk in 1922 to a depth of about 30 feet on a 4-foot bed of coal or shale. The bed is about 75 feet below the top of the Bear River formation, and Vine (1939, p. 269) notes that it consists of sheared coaly shale in which are thin lenses of coal, clay, and limestone. He points out that carbonaceous material in the shale makes it appear like coal but that a sample of the material indicates that the ash content is too high for commercial use as a fuel (table 2). He also notes that the top foot of the bed averages 0.04 percent uranium and the basal 3 feet 0.01 percent uranium.

Continental Divide area.—Coal of the Frontier formation crops out at the headwaters of Cottonwood Creek, in northern Fremont County, near the Montana line (No. 4). On the Idaho side of the line, the Frontier formation is covered on all sides by volcanic rocks of Tertiary age, which limit the outcrop. The coal and the host rocks are very similar to those of the Horseshoe Creek Basin. Several beds a few inches thick occur in the area and the outcrop of the principal one may be followed for more than a quarter of a mile. A prospect was located on this bed in 1912, in the SW¼ SE¼ sec. 11, T. 14 N., R. 38 E. An entry was driven down the moderately dipping bed for about 110 feet. This entry shows the coalbed to average 2 feet 8 inches in thickness, to be fresh and hard, and to rank from subbituminous to bituminous (Mansfield, 1929, p. 150).

Goose Creek field.—The Goose Creek field (No. 5) is in southern Cassia County, and extends into Box Elder County, Utah, and into Elko County, Nev. It is about 260 square miles in area and is part of a larger basin. Tertiary rocks cover most of the basin and include the Payette (1) formation of Miocene or Pliocene (1) age, and the overlying Salt Lake formation of Pliocene age (Mapel and Hail, 1939, p. 217). These formations are tilted to the east at an average dip of about 3°. Locally, they have been slightly folded and faulted. Carbonaceous shales and beds of lignite occur in both the Payette (1) and Salt Lake formations. There are two principal stratigraphic intervals in which lignite occurs. The lower one—the Worthington bed—is in the Payette (1) formation, and the upper one—the Barrett bed—is in the Salt Lake formation.

According to Bowen (1913b, p. 258) lignite was mined from a 4-foot thickness of the Worthington bed in the SE¼ sec. 23, T. 16 S., R. 29 E., and sold at Oakley, but it was not good fuel because of the high moisture and high ash content. Mapel and Hail (1939, p. 242) describe the Worthington bed as carbonaceous shale, locally lignite, 2 to 5 feet thick, and about 500 feet below the top of the formation. They describe the Grant zone of lignite in the NW¼ sec. 2, T. 13 S., R. 29 E., as a bed previously considered by Bowen (1913, p. 259) to be the Worthington bed. According to Mapel and Hail, the Grant zone crops out along the valley of Trapper Creek and is only 125 feet below the top of the Payette (1) formation. The zone consists of six thin lenticular beds of carbonaceous shale and lignite interbedded with shale, sandstone, and volcanic ash in a stratigraphic interval about 60 feet thick.

Mapel and Hail also describe four carbonaceous shale zones in a 650-foot-thick stratigraphic interval in the lower part of the Salt Lake formation. Of these four zones, the Barrett bed or zone, about
800 feet below the top of the formation and 30 feet below a prominent bed of welded tuff, is the thickest and most persistent. This zone crops out over a wide area but is thickest along the Coal Banks Creek-Beaverdam Creek area, where it consists of 10 beds of carbonaceous shale and lignite that range in thickness from 1 foot to 10 feet and which are in a 50- to 80-foot stratigraphic interval. The zone has been explored by mine workings in the NW\(\frac{1}{4}\) sec. 5, T. 15 S., R. 21 E., and near the head of Coal Banks Creek in sec. 34, T. 15 S., R. 21 E. Analyses of lignite from the zone are given in table 2.

The Barrett zone is uraniumiferous and averages more than 0.005 percent uranium, where exposed in the district. The most uraniumiferous locality is in sec. 26, T. 16 S., R. 21 E., where the uppermost 1 foot of an 8-foot unit contains 0.12 percent uranium (Mapel and Hall, 1939, p. 248). The lower interval of the zone also is believed to contain considerable amounts of oil shale, although no analyses of these shales are known. Analyses of lignite from the Barrett zone are given in table 2.

Owyhee County.—A lignite, sandstone, and shale sequence about 70 feet thick, part of the Fayette formation, crops out 1 mile west of Reynolds Creek, sec. 11, T. 2 S., R. 4 W. (No. 6) (Duncan, 1933, p. 14). In the carbonaceous shales, there is one bed of lignite about 2 feet thick. A bed of lignite also occurs on a tributary of Sucker Creek, 1.3 miles south of U.S. Highway 95 and 1 mile east of the Idaho-Oregon State boundary (No. 7).

Horsehoe Bend field.—Thin beds of lignite and subbituminous coal occur in the Fayette formation of Miocene and Pliocene (?) age along the east side of theayette River near Horsehoe Bend in western Boise County (No. 8). The coalbeds have been prospected at a number of localities in an area about 15 miles long and 1 to 5 miles wide. A limited amount of coal has been mined for local use at the Henry or Robb prospect in the NW\(\frac{1}{4}\) sec. 3, T. 6 N., R. 2 E. Bowen (1913a, p. 249) described the bed worked in 1911 at the Henry prospect as an irregular thickness of subbituminous coal, locally as much as 20 inches thick. A sample from this bed is described in table 2. The most extensive section of coal beds is along Brainard Creek, NE\(\frac{1}{4}\) sec. 1, T. 7 N., R. 2 E., where five beds ranging from 12 to 22 inches in thickness crop out in a vertical distance of about 160 feet. Elsewhere in the field, the coalbeds generally range from 4 to 11 inches in thickness.

In 1938, lignite was mined from a 4-foot bed at the Gaston mine west of the Horsehoe Bend area in sec. 34, T. 7 N., R. 1 E. Mining was by open-cut methods, but only a small amount of coal is believed to have been produced.

Lemhi County area.—Lignite has been known in the Salmon region since early pioneer days and often has been mined and burned for local use. Lignite beds crop out near the mouth of Pollard Canyon, immediately south of Pollard Creek, about 2 miles west of Salmon (No. 9). The lignite is in lake basin sediments of middle Tertiary age. The lignite beds have been mined from several adits that are close to the boundary between secs. 2 and 11, T. 21 N., R. 21 E. Where exposed underground, the main lignite bed is 3.5 to 5 feet thick but contains some partings. At the outcrop, the upper 0.3 of a foot of the lignite assays 0.0034 percent uranium.
Thin beds of lignite in Tertiary rocks also crop out below the mouth of Wimpy Creek, across the Lemhi River from Baker. The beds are less than 2 feet thick. Some lignite has been mined for local use but it is undesirable because of its high ash content and because it burns with a smoky flame.

**Orofino area. —** Coal of the Orofino area (No. 10) is of inferior quality and ranges in rank from lignite to subbituminous. It occurs as thin beds in the La Taha Formation of Miocene age, interbedded in Columbia River basalts. Lupton (1916, p. 104) describes the principal prospect, as on the south side of Orofino Creek, NE1/4 sec. 12, T. 36 N., R. 3 E. (No. 10). Three closely spaced flat-lying coalbeds, none of which are more than 12 inches thick, were explored by mine workings at this location. Another coal prospect along Orofino Creek is in sec. 6, T. 36 N., R. 4 E. Elsewhere in the district, coal crops out in NW1/4 sec. 2, T. 36 N., R. 2 E.; SW1/4 sec. 1, T. 36 N., R. 1 E.; sec. 14, T. 35 N., R. 3 E., and at several places along Little Canyon, 10 to 12 miles south of Orofino.

**PRODUCTION**

Coal production in Idaho cannot be tabulated accurately. The Horseshoe Creek district in Teton County has been the principal producer, but during the early days of mining, coal was hauled in wagons from a number of small prospects and records were not kept. Mansfield (1920, p. 143) quotes Hillman, who estimated that from 1903 to 1917 the district produced about 24,000 tons of coal. During the periods 1927-29 and 1931-32, more than 33,000 tons were mined and at least 14,000 were mined during later years. Kilsgaard (1951a, p. 32) estimates that total output from the district would be in the order of 100,000 tons.

Small amounts of lignite have been mined from the Goose Creek district and from scattered prospects in the Horseshoe Bend field but all has been consumed locally and there are no production records.

**RESOURCES**

Although lignite and coal deposits are widely scattered throughout parts of Idaho, only the Horseshoe Creek district and the Goose Creek field contain appreciable tonnages.

Kilsgaard (1951a, p. 33) estimated 3.5 million tons of coal in the Brown Bear and Progressive beds of the eastern belt of coalbeds of the Horseshoe Creek district. This coal was calculated to be within 600 feet of the surface. By extending the projection of coalbeds to a depth of 1,200 feet below the surface, and by including coal of the Boise bed, he calculated an additional 3.5 million tons. To this amount could be added a comparable tonnage of coal in other beds of the western and eastern belts, but this additional estimate is necessarily more indefinite because of limited outcrops and the faulted condition of the beds. The Frontier formation coalbeds have been considered to extend east of the Horseshoe Creek district, and to underlie the foothills west of the Teton Basin as well as the basin itself. This is quite probable; however, the coal in these areas is so deeply buried that it probably will not be mined within the foresee-
able future. For example, the Phillips Petroleum Co. drilled a well in sec. 28, T. 4 N., R. 44 E., about 1 mile east of the eastern belt, and the hole passed out of the Frontier formation at a fault contact at a depth of 4,640 feet. Presumably, the hole encountered coal but at depths too great to be profitably mined. Any coal farther to the east, under the Teton Basin, would be expected to be even deeper. There are hundreds of millions of tons of carbonaceous shale and lignite in the Goose Creek district, but these have no value as commercial fuel at the present time. Large tonnages could be mined by open-pit methods, however, and it is conceivable that the area may be mined someday for gasous and coal tar products, if not for fuel. Coal and lignite deposits elsewhere in Idaho either are too low in rank, too deeply buried, or too irregular to warrant inclusion in any resource estimate.

COBALT AND NICKEL
(By J. S. Vhay, U.S. Geological Survey, Spokane, Wash.)

Cobalt is important to an industrial economy, even though the amounts used are small compared with some other metals; about 10 million pounds per year have been consumed recently. The four largest uses are in high-temperature cutting, and wear-resistant alloys (27 percent), for magnets (25 percent), in high-speed tool steels, etc. (10 percent), and in salts and driers (10 percent). Other uses, in which cobalt is generally not replaceable, are in hard-facing alloys, cemented carbides, and as ground-coat frit.

Idaho is one of the few cobalt-producing areas of the United States. Cobalt was recognized in the Blackbird district in Lemhi County before 1909. A small amount of ore was produced in 1915, but the potential of the district was not recognized until the 1940’s when, under the stimulus of World War II, an intensive search was made for cobalt deposits. From 1951 until June 1959, the Blackbird district produced nearly 14 million pounds of cobalt and was also an important copper and gold producer. The mine, which was operated by Howe Sound Mining Co., was closed after the termination of a Government contract to purchase cobalt. There has been no production of cobalt since 1959, but leasers are now mining ore for the copper content.

The ore occurs in a series of northwest or north-striking northerly plunging lenses in tightly folded metamorphosed sedimentary rocks a few miles east of the Idaho batholith (Vhay, 1948; Anderson, 1947d) (fig. 13). The metamorphosed sediments are believed to correlate with the Yellowjacket formation of Belt age. The metallic minerals are cobaltite, safflorite, chalcopyrite, pyrite, and native bismuth. The proportion of bismuth is unusually high for this type of deposit and may have economic value. Gangue minerals are quartz, biotite, chlorite, ankerite, tourmaline, and several rarer minerals.

Although the Blackbird district is one of the world’s leading cobalt districts from the viewpoint of resources, metallurgical difficulties have deterred its exploitation. The process of separating the cobalt from the copper is expensive. Without a premium price, the district was unable to meet competition from foreign ores. The future of

* Average uses 1961–63.
EXPLANATION

Cobalt Deposits

- Producing mine
- Cobalt occurrence

1. Blackbird district
2. Coeur d'Alene district
3. Montgomery prospect
4. Franklin prospect
5. East Fork prospect

Bunker Hill zinc refinery

Figure 15.—Cobalt in Idaho.
the district depends on improvements in metallurgical technology or on higher prices for cobalt or copper—or a combination of both. Cobalt is produced as a byproduct in the Coeur d'Alene district. Because cobalt (and manganese) are detrimental to the production of electrolytic zinc, the electrolytic zinc plant at Kellogg has been removing cobalt and stockpiling the cobalt-rich material. According to the U.S. Bureau of Mines Minerals Yearbook, the total reported stockpiled from 1933 to 1962 amounts to 2,935 tons containing about 176,500 pounds of cobalt, but as far as is known none has been sold. Gersdorffite (NiCoFe)AsS has been identified in the Polaris mine (Willard, 1941) and in the Silver Summit mine (Fryklund and Hutchinson, 1954), both in the "Silver Belt"; and cobalt bloom (probably bieberite) has been noticed in other mines in the Coeur d'Alene district.

Other occurrences of cobalt are known in Idaho, but none appear to have any economic significance. They are listed below:

Segregations of sulfides in basic intrusions in Boundary County (and probably in Bonner County also) are reported to carry nickel and copper; it can be inferred that a little cobalt is present (Killsgaard, 1951b).

Wagner observed the cobalt mineral gersdorffite in prospects on the south slope of the St. Joe Mountains (Shoshone County). He reports (1949), "Gersdorffite ** occurs in microscopic quantities in most of the deposits." Under a discussion of the future outlook of the district, he points out that it "is none too promising," as the country rock of the area is the relatively unfavorable Wallace Formation.

On the East Fork claims on Indian Creek (Indian Creek district, Lemhi County), cobalt rocks are present in a few small discontinuous veins.

Nickel is essential in an industrialized economy, mostly as an alloying element in steels. No nickel has been marketed from ores produced in Idaho, although the cobalt metal produced from the ore of the Blackbird district does contain a small amount of nickel as an impurity. A rough calculation shows that about 470,000 pounds of nickel has come from this district while cobalt was being produced.

All the other deposits mentioned under cobalt also contain a little nickel, usually more nickel than cobalt, but all probably of little economic value.

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**COPPER**

(By J. S. Thay, U.S. Geological Survey, Spokane, Wash.)

Copper is vital to an industrial economy because of its excellent conductivity, malleability, corrosion resistance, and tensile strength. Although in 1962 Idaho produced only slightly over 0.3 percent of the total production of copper in the United States, the value of the copper produced is important in the State's economy. Of the total value of the State's mineral production in 1961 (Cook, 1962), the value of the copper was 9.8 percent, ranking sixth in importance. In 1968, the year of maximum copper production, the value of the copper was about $5,180,000.
Production of copper in Idaho is summarized by districts in table 3. Three categories are shown: districts that have produced over 50 million pounds of copper, those that have produced 1 million to 50 million pounds, and those that have produced between 50,000 and 1 million pounds. About 15 other districts have produced smaller amounts of copper but are not listed. Recorded copper production started about 1894 and is shown in figure 18. The locations of the districts listed in table 3 are shown in figure 17. The index number of the districts in the figure correspond to those in the table.

About 65 percent of the copper produced in the State is a byproduct of the mining of other metals—principally lead, zinc, and silver—but also of cobalt, gold, and tungsten.

Mines in the Coeur d'Alene district (table 3, Nos. 3, 4, 5, and 17) have produced about 56 percent of the total copper in the State. About three-quarters of the copper production from the Coeur d'Alene area was obtained as a byproduct from the mining of lead, silver, and zinc ores, but one mine in the Hunter district, the Snowstorm (No. 4), operating from 1904 to about 1915, produced mainly copper. The other two copper-producing districts in the State that are in the over-20-million-pound category of table 3 are the Alder Creek district (No. 1), Custer County, and the Blackbird district (No. 2), Lemhi County. The Alder Creek district is essentially a copper producer, but the Blackbird district was operated principally for the cobalt content of its ore. It also produced considerable gold and some nickel.

Of the districts having 1-million- to 30-million-pound production, as shown on table 3, the Seven Devils district (No. 6), Adams County; the Loon Creek district (No. 11), Custer County; the Eureka district (No. 13), the group of districts east of Salmon (No. 14), and the McDevitt district (No. 15), all in Lemhi County; and the St. Joe district (No. 18) in Shoshone County produced principally copper, although in several of these districts a considerable amount of gold was also produced. Except for the Blue Wing district (No. 12), which was in operation principally for the tungsten content of its ore, the rest of the districts operated principally for the lead and silver content of their ores and to a lesser extent for the gold.

Similarly, in the third category of table 3 (districts that have produced 50,000 to 1 million pounds), the proportion is about 74 percent byproduct copper versus 26 percent copper production with minor gold. The districts operating principally for copper are: Copper Basin (No. 23), Custer County; Ramsey Ridge (No. 26), Idaho County; Hoodoo (No. 27), Latah County; Birch Creek, and Nicholia (No. 28), Lemhi and Clark Counties. Districts operated mainly for gold (Nos. 19, 30, and 31) produced relatively little copper—possibly a total of 400,000 pounds. The rest of the districts in this category operated mostly because of the lead-silver content of their ores.

The geologically inferred reserves of the Coeur d'Alene district, of the Blackbird district, and of the Alder Creek district will contribute copper to the economy for a long time. Many of the other lead-zinc-silver producing districts (mainly in Blaine, Bonner, Custer, and Lemhi Counties) will continue to produce some byproduct copper indefinitely.

A number of disseminated copper deposits, such as the Red Ledge deposit in the Seven Devils district and the IXL deposit in the Cuddy
<table>
<thead>
<tr>
<th>Index No. or Fig.</th>
<th>County and district(s)</th>
<th>Production in pounds</th>
<th>Geological Features</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coeur d'Alene region: Salmon, Patter, and Place</td>
<td>87,000,000 (1900-60)</td>
<td>Contact deposit with chalcopyrite in staurolite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Lemhi: Blackbird</td>
<td>60,000,000</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Shoshone:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Butte Deposit:</td>
<td>32,746,000 (1915-25)</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Butte Deposit:</td>
<td>35,000,000 (1920-40)</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Adams: Seven Devils</td>
<td>10,000,000</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Hickey</td>
<td>1,000,000 (1920-40)</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Warm Springs</td>
<td>5,000,000 (1915-25)</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Banner: Pond and Clark Fort.</td>
<td>1,000,000 (1915-25)</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
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</tr>
<tr>
<td>10</td>
<td>Coeur d'Alene region: Salmon, Patter, and Place</td>
<td>3,000,000 (1915-25)</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Lead Creek</td>
<td>1,070,000</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Erma</td>
<td>5,000,000</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Eureka</td>
<td>6,000,000 (1915-25)</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
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<tr>
<td>14</td>
<td>Elycovo</td>
<td>1,000,000 (1915-25)</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
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<tr>
<td>15</td>
<td>McDevitt</td>
<td>5,000,000 (1915-25)</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Texas and Spring Hill</td>
<td>1,100,000 (1915-25)</td>
<td>Replacement deposit with chalcopyrite in quartz veins in the Bunsen schist</td>
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<tr>
<td>District</td>
<td>Production (tons)</td>
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<td>--------------------------------</td>
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<tr>
<td>17 Rhode Island</td>
<td>2,000,000 (1843-45)</td>
<td>Replacement deposits with silver, lead, zinc, and gold in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
<td></td>
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</tr>
<tr>
<td>18 St. Joe</td>
<td>1,700,000 (1848-49)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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</tr>
<tr>
<td>19 Boise Basin and nearby gold-</td>
<td>80,000 (1878-81)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<td>producing districts</td>
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<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<tr>
<td>20 Boundary</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<tr>
<td>21 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<tr>
<td>22 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<tr>
<td>23 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<td>24 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<td>25 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<td>26 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<td>27 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<td>28 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<td>29 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<td>30 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<tr>
<td>31 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<tr>
<td>32 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<tr>
<td>33 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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<tr>
<td>34 Boise</td>
<td>80,000 (1878-80)</td>
<td>Replacement deposits of mixed sulfides in shear zones of fault rocks. Hydromagnesite copper. Replacement deposits of mixed sulfides in shear zones of fault rocks. Chalcopyrite and pyrite in fault rocks cut by quartz veins.</td>
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</tbody>
</table>

**Note:** Production figures for periods shown in parentheses. Where no dates shown, figure is estimated total production.

Figure 16.—Estimated copper production in Idaho, 1884 to 1962.
Figure 17.—Copper in Idaho (numbers refer to mining districts listed in table 3).
Mountain area, are still undeveloped and their potential is as yet unknown. Should these, or other similar deposits, come into production, Idaho’s rank as a copper producer could rise considerably.

DIATOMITE

(By W. W. Staley, University of Idaho, Moscow, Idaho)

Diatomite is formed by the accumulation of the highly siliceous remains of diatoms, a group of minute organisms that live in most kinds of fresh or salt water bodies. The cellular structure of these remains coupled with the small size of the individual hydrous silica shells provides a very lightweight porous and absorbant material. Diatomite has many uses that may be broadly grouped as filters, insulators, and nonabsorbent fillers, and a host of minor uses such as abrasives and absorbent fillers.

Approximately half a million tons of diatomite are used annually in the United States, and the United States is the leading world producer. The diatomite production has grown more than sixfold in volume in the past 30 years, while average prices per ton have increased from $14.81 in 1933 to $50.08 in 1962.

Diatomite deposits are seldom free of other sediments and organic debris, so nearly all diatomite mined requires treatment after mining to prepare it for industrial use, principally removal of grit, and calcining to remove moisture and organic substances. Deposits are usually mined by quarry or open-pit methods. California has been the leading producer of diatomite since 1910. Other producing States in 1962 include Nevada, Washington, Arizona, Maryland, and Oregon in that order. Despite the presence of a number of diatomite deposits, Idaho has produced only nominal amounts of diatomite—an estimated 880 tons valued at about $13,000 in the period 1927 to 1944 (Idaho Bureau of Mines and Geol. Bull., 18, 1961, p. 69) is the only recorded production. A processing plant at Grandview was destroyed by fire in 1946, and since then there has been only occasional production to supply local demand for insulation. For example, the roof of the Owyhee County courthouse at Murphy was insulated with bulk diatomaceous earth from a deposit on Sinker Creek. Small quantities have been used also as a filter medium by Idaho sugar beet refineries.

A low apparent density of powdered diatomite is a good indication of its value for use as a filter medium, filler, and insulation. Idaho diatomaceous materials in powder form range from 0.12 to 0.39 apparent density (water=1). This is equivalent to 7.5 to 24.3 pounds per cubic foot, respectively. The apparent densities for solid diatomite materials are 0.41 (25.6 pounds per cubic foot) and 0.79 (49.3 pounds per cubic foot) (Powers, 1947, p. 6).

Maximum usefulness of diatomite is based on the amount and kind of contaminating impurities, sizes, and shapes of the diatoms, type of diatom, the extent of breakage of the silica skeleton, and clean and unfilled frustules. This information is determined by microscopic examination.
Eardley-Wilmot (1928, p. 15) suggests these criteria for classifying according to use.

**Insulation.**—Any type of diatom is suitable, but material should be clean and free from very much impurity, especially for high temperature.

**Filter medium.**—Best filter media contain a variety of sizes and shapes with long-type diatoms predominating. Impurities should be minor and noncontaminating to the filtered substance.

**Polishing media.**—Types of diatoms should be small and free from grit.

**Filler.**—Type of diatom is unimportant but they must be unfilled.

**Concrete admixture.**—Any type of diatom may be used when diatomite is used as pozzolan material.

Generally speaking, diatomite has about the same mode of occurrence throughout the world. It is derived from a living organism—the diatom—which belongs to the Class Diatomacea of the Kingdom Protista. This organism extracts silica from its aqueous surroundings and forms a siliceous shell or frustule composed of two valves. Over 10,000 species and varieties of diatoms have been recorded, from 0.010 to 0.500 millimeter in size and with a wide variation in shape. Diatoms may occur in fresh or salt water. They occur in great abundance in the cold salt water of the polar regions. Upon dying, the diatoms fall to the bottom of the sea, lake, or pond and decompose. The almost indestructible siliceous frustules accumulate to form deposits of diatomite. Under favorable conditions, deposits may be very pure with little accompanying clay, sand, silt, chemical precipitates, organic material, or other impurities. If conditions for maintaining a basin are favorable, and an adequate supply of silica and nutrients are available, thick deposits will result. The maximum growth of diatoms occurred in the upper part of the Tertiary Period (Miocene and Pliocene Epochs). The large amount of volcanic ash deposited during the middle and late Tertiary was available as a source of silica. Many hot springs high in silica also flowed during this period.

As described by Powers (1947, p. 3), southern Idaho had conditions favorable for the development of deposits of diatomite. Downwarping of the region and extrusion of lava interrupted the drainage pattern and numerous ponds, lakes, and swamps developed. In each of these, locally supplied sediments, volcanic ash, and diatom remains were deposited. Most of the diatomite is in the Idaho Group (Pliocene and Pleistocene), where it is associated with loosely consolidated beds of clay, sand, and volcanic ash, or in Miocene sediments associated with the Columbia River Basalt.

**Description of deposits**

Locations of Idaho deposits as described by Powers (1947) are shown on figure 18. Many of the locations consist of several exposures or pits several hundred feet or less from each other. Samples from exposures in certain areas showed variations in diatoms and physical properties. Table 4 is a compilation of the principal average characteristics. Data shown in the table are suggestive of the material to be expected of the general locality. Samples of different exposures present at these localities showed minor differences in diatoms and physical characteristics.
EXPLANATION

Area underlain by sedimentary rocks of Idaho and Snake River Groups of Pliocene and Pleistocene Ages

Area underlain by Columbia River Basalt and associated sediments of Miocene Age

Diatomite deposit

Numbers refer to localities described in text.

Figure 18.—Diatomite deposits in Idaho (numbers refer to localities listed in table 4 and described in text).
<table>
<thead>
<tr>
<th>Locality (shown on fig. 18), county, town, range, and section</th>
<th>Color</th>
<th>Dry weight points per cubic foot</th>
<th>Absorption, in percent</th>
<th>Potential applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ada, T. 3 N., R. 3 E., sec. 5 or 7.</td>
<td>White</td>
<td>20.0</td>
<td>Poor</td>
<td>Filter</td>
</tr>
<tr>
<td>3. Ada, T. 14 S., R. 2 W., sec. 16.</td>
<td>White</td>
<td>21.8</td>
<td>Poor</td>
<td>Filter</td>
</tr>
<tr>
<td>4. Blaine, T. 3 N., R. 1 E., sec. 20.</td>
<td>White to cream.</td>
<td>25.8</td>
<td>Poor</td>
<td>Filter</td>
</tr>
<tr>
<td>5. Camas, T. 3 N., R. 14 E., sec. 33.</td>
<td>White</td>
<td>36.9-38.9</td>
<td>Poor</td>
<td>Filter</td>
</tr>
<tr>
<td>7. Elmore, T. 10 S., R. 10 E., sec. 20.</td>
<td>Cream.</td>
<td>36.6</td>
<td>Poor</td>
<td>Filter</td>
</tr>
<tr>
<td>8. Elmore, T. 12 S., R. 11 E., sec. 20.</td>
<td>Cream.</td>
<td>36.6</td>
<td>Poor</td>
<td>Filter</td>
</tr>
<tr>
<td>9. Gooding</td>
<td>Gray-white</td>
<td>36.3-38.1</td>
<td>Poor</td>
<td>Filter</td>
</tr>
<tr>
<td>11. Owyhee, T. 5 S., R. 2 W., sect. 3, 4, 11.</td>
<td>Cream.</td>
<td>36.6</td>
<td>Poor</td>
<td>Filter</td>
</tr>
<tr>
<td>12. Owyhee, T. 11 S., R. 2 W., sect. 36, 36, 36, T. 12 S., R. 2 W.</td>
<td>Gray-white</td>
<td>27.5-30.0</td>
<td>Poor</td>
<td>Filter</td>
</tr>
<tr>
<td>13. Twin Falls, T. 8 N., R. 6 E., sect. 20.</td>
<td>Gray-white</td>
<td>43.7-45.0</td>
<td>Poor</td>
<td>Filter</td>
</tr>
<tr>
<td>16. Washington, T. 12 N., R. 4 W., west half of township.</td>
<td>Tan-cream white</td>
<td>41.3-43.1</td>
<td>Poor</td>
<td>Filter</td>
</tr>
</tbody>
</table>

1. Considerable impurity, noncommercial.
2. Impure, noncommercial.

Source: Data compiled from Powers (1947).
For a more precise description of locations or materials, Powers (1947) should be consulted.

Ada County.—No. 1: Deposit is approximately 3.5 miles east of Boise in sec. 7, T. 3 N., R. 3 E. The diatomite occurs in a fault-bounded, wedge-shaped mass up to 300 feet in length, with estimated reserves of about 7,000 tons dry weight.

No. 2: This deposit is approximately 9 miles north of Boise in sec. 20, T. 5 N., R. 2 E. A diatomite bed 4 to 5 feet thick is exposed intermittently for as much as 200 yards. The overburden is thick but some material has been removed for insulation. Lack of development work prevents estimating the tonnage.

Adams County.—No. 3: This deposit is approximately 3 miles from Indian Valley in sec. 5, T. 14 N., R. 1 W. The diatomite bed ranges from 12 to 15 feet in thickness and can be traced for 250 feet. There was insufficient development to estimate reserves.

Boise County.—No. 4: A diatomite deposit near the intersection of Adams, Gem, and Boise Counties, in sec. 1, T. 5 N., R. 1 E. is exposed in a road cut along old Highway 15. The diatomite is about 8 feet thick and is covered with 18 feet of overburden. Reserves were not estimated.

Camas County.—No. 5: Diatomite crops out approximately 3.3 miles north of Fairfield near an unimproved road in sec. 33 or 34, T. 2 N., R. 14 E., about a mile inside the Sawtooth National Forest. Two outcrops about 250 yards apart expose numerous layers of diatomite interspersed with volcanic ash, sand, and clay. Capping the deposit is 10 to 15 feet of basalt. No estimate of the tonnage was possible.

Elmore County.—No. 6: A 5-foot-thick bed of diatomite is exposed in a vertical bluff along a dry gulch (Alkali Creek) in sec. 15, T. 5 S., R. 9 E., north of U.S. Highway 30. The bed is overlain by 20 feet of sandy clay and 15 feet of basalt.

No. 7: This deposit is 4.5 miles east of King Hill on Bellmare Creek in sec. 34, T. 4 S., R. 11 E. Two feet of diatomite is found under 10 to 25 feet of basalt and clay. Eight carloads were reported as shipped to the Armstrong Cork Co. in 1936 (Powers, 1947, p. 13). Reserves were estimated at 48,000 tons dry weight.

No. 8: Pasadena Basin, 4 miles south of King Hill, is rimmed by loosely consolidated sediments including two beds of diatomite. The exposure roughly parallels the Snake River from sec. 15 to secs. 5, 6, and 8, T. 6 S., R. 11 E., to sec. 36, T. 3 S., R. 10 E. One stratigraphic section showed 10 feet of impure diatomite at the bottom, another 36-foot thickness of diatomite above this, with a final capping of 36 feet of sand, clay, and gravel.

Gem County.—No. 9: A 5-foot bed of diatomite crops out at a locality 3¼ miles southeast of March. The material is too impure for commercial use.

Owyhee County.—No. 10: Diatomite occurs in parts of secs. 14, 15, 19, and 20, T. 1 S., R. 3 W., on the east side of Reynolds Creek, about 2 miles southwest of Wilson. There are numerous pits and exposures of diatomite beds up to 5 feet thick, and a reserve of 20,000 tons dry weight was estimated.

No. 11: Diatomite crops out between Bates and Pickett Creeks near the junction of secs. 2, 3, 10, and 11, T. 5 S., R. 1 W. Between the two

* Numbers correspond to numbers on figure 18 and table 4.
creeks a wedge-shaped area several hundred feet on each side is underlain by a diatomite bed 13 feet thick. Outside this area the diatomite probably continues beneath the overburden. This block contains an estimated 80,000 dry tons of diatomite. Several tons have been used for insulating houses near Nampa.

No. 12: This, the largest occurrence of diatomite in Idaho, is located about 56 miles southwest of Grandview in secs. 34, 35, and 36, T. 11 S., R. 2 W., and secs. 2 and 3, T. 12 S., R. 2 W.

The diatomite occurs in a lenticular basin cut in andesitic lava, and is overlain by 10 to 20 feet of basalt. The deposit is 1,000 feet north-south by 2,000 feet east-west with a maximum thickness of 150 feet in the center, and contains an estimated 4,200,000 tons of material.

A few tons have been extracted and used for cement admixture, polish, insulation, and filter media for dry-cleaning fluids. A small calcining plant located in Grandview was destroyed by fire.

Twin Falls County—No. 13: Diatomite occurs in sec. 29, T. 8 S., R. 14 E., approximately 11 miles northwest of Buhl. Several layers, the maximum being 8 feet thick, are interbedded with sand and clay. There is a 30-foot clay overburden topping the 8-foot diatomite bed.

Washington County—No. 14: Outcrops of diatomite can be traced about 2 miles along a ridge located in secs. 10 and 11, T. 13 N., R. 5 W. The probable continuation of this exposure is found about 3 miles to the northwest in sec. 31, T. 13 N., R. 5 W., and sec. 4, T. 12 N., R. 5 W. A minimum thickness of 15 feet has been exposed in a small quarry. Maximum thickness of overburden is approximately 40 feet, but a large amount of diatomite is available under 2 to 10 feet of loose soil and clay. The reserves here are estimated to be 250,000 tons dry weight.

No. 15: Diatomite is exposed by a canal and road cut in sec. 31, T. 11 N., R. 4 W., about 6 miles east of Weiser. A thickness of 15 feet is exposed in the canal cut. This bed is probably a continuation of No. 14 to the southeast.

No. 16: East of Mann Creek in T. 12 N., R. 4 W., the Idaho Formation has several exposures of diatomite beds, and some are near U.S. Highway 93. There are several beds, ranging from 6 feet to 18 feet in thickness. The overburden is too thick to permit mining of more than a limited tonnage.

RESOURCES

The diatomite deposits have not been tested or developed in enough places to provide the basis for a resource estimate. Powers (1947) estimated 4,615,000 tons in six deposits described above, but considerably greater quantities might be developed by additional exploration.

FLUORSPAR


Fluorspar, which is a mineral aggregate or mass containing enough fluorite (CaF₂) to be of commercial interest, is essential in the chemical, aluminum, steel, and ceramic industries. It is presently the only important source of fluorine, an element indispensable to our present way of life.
Fluorite is softer than quartz and harder than calcite, the two common minerals with which it may be confused, and is heavier than either one. It displays a vitreous luster and a wide array of colors, ordinarily in shades of green or purple; the colors may range from white and water clear to yellow, green, blue, rose, purple, red, bluish and purplish black, and brown. Fluorite commonly crystallizes as cubes or octahedrons but may occur in massive form; crusts; globular aggregates showing radial fibrous textures; or banded cryptocrystalline forms resembling chalcedony, with which it may be closely associated. It has perfect octahedral cleavage, and this property along with its crystal forms, color, heaviness, and hardness may be sufficient to differentiate it from other minerals.

The fluorine chemical industry continues to grow as a greater volume and variety of products are made. Hydrofluoric acid, made by treating fluor spar with sulfuric acid, is the basis for most of these chemicals. Hydrofluoric acid is the starting point for inorganic fluorides used extensively in insecticides, preservatives, dielectrics, and production of uranium; and for organic fluorides, which are fluorinated hydrocarbons or fluorocarbons that serve as refrigerants, aerosol propellants, resins, elastomers, plastics, drugs, and many other widely used products. The acid is also used as a catalyst in the manufacture of alkylate, an ingredient in high-octane aviation and automobile fuels.

In the aluminum industry, the fluor spar converted to hydrofluoric acid is used to make aluminum fluoride and synthetic cryolite, which serves as the electrolyte in the reduction of aluminum to aluminum metal. For this purpose, about 140 pounds of the highest grade fluor spar converted to synthetic cryolite and aluminum fluoride is required for each ton of aluminum metal produced.

Fluor spar is invaluable to the steel industry as a flux in basic open-hearth, basic-oxygen, and electric furnaces. It reduces the viscosity of the slag and facilitates the removal of phosphorus and sulfur from the steel. From 3 to 16.5 pounds of fluor spar is used for each ton of steel produced (Kuster, 1963, p. 567).

In the ceramic industry, fluor spar is vital in the production of enamels for coating steel and cast iron that are used in stoves, refrigerators, bathtubs, cooking ware, sinks, and cabinets. The fluor spar makes up to 15 percent of the weight of the enamel batches. It is also essential to the manufacture of opal container glass, as it promotes the formation of centers of crystallization. This use requires 50 to 500 pounds of fluor spar per 1,000 pounds of sand.

Fluor spar is marketed under three grades—acid, ceramic, and metallurgical. Acid-grade fluor spar, used for making hydrofluoric acid, is the highest grade and must contain not less than 97 percent CaF₂, with specific limitations on quartz, calcite, and sulfur content. Specifications for ceramic-grade fluor spar are not quite so high and depend in part on qualifications set forth by the buyer; in general, acceptable material contains at least 95 to 95 percent CaF₂, not over 2.5 percent silica, less than 0.12 percent ferric oxide, and limited calcite. Metallurgical-grade fluor spar must contain more than 60 percent effective calcium fluoride, and generally not over 0.5 percent sulfur or 0.5 percent lead. Effective calcium fluoride is that percentage of calcium fluoride remaining after subtraction of 2.5 percent calcium fluoride
for each percent of silica. In 1962, about 653,000 tons of fluor spar
was consumed in the United States—approximately 57 percent as acid
grade, 7 percent as metallurgical grade, and 6 percent as ceramic grade
(Kuster, 1963).

The United States is the world’s leading consumer of fluor spar
and, for a long time, was the leading producer. Since 1982, imports
have exceeded production and, in 1962, amounted to nearly 600,000
tons—approximately three times the domestic production (Kuster,

Since 1960, Mexico has been the world’s leading producer of fluor spar.

Despite a considerable potential, Idaho has made but a small con-
tribution to the fluor spar production of the United States. Although
the presence of fluor spar deposits within the State was long known,
the economic potential of the deposits was not recognized until 1941.

The total production of fluor spar in Idaho was made from 1901 to
1953, when 12,797 tons was produced, mainly for the U.S. Govern-
ment stockpile. Depressed prices and inability to meet foreign com-
petition have since discouraged attempts to mine fluor spar in almost
all districts of the Western United States.

Fluorite is sparingly present in some of Idaho’s metalliferous
deposits. Major concentrations, however, are restricted to fissure
and breccia veins and lodes in which fluorite—along with much
lesser amounts of barite, calcite, and quartz or chalcedony—is the
chief mineral. Fluor spar is found at numerous locations within a
northeast-trending belt extending through south-central Idaho (fig.
19), where the fault zones, mineral deposits, dike zones, and larger
intrusive bodies of Tertiary age are mainly oriented northeast (Ross,
1931, pp. 183–194; Ross and Forrester, 1947). The major fluor spar
districts and most of the minor deposits are within 35 miles of an ex-
posed fluorspar mass of Tertiary age (fig. 19) which cuts the Tertiary
Challis Volcanics along the Middle Fork of the Salmon River. The
known fluor spar deposits occur in rocks that are older than Miocene,
mainly flows and pyroclastics of the Challis Volcanics (early Ter-
tiary, probably mostly Oligocene according to Ross, 1961, p. 179),
Casto Volcanics of Permian (?) age, Bayhorse Dolomite of Cam-
brian (?) age, and granitic rocks of the Idaho batholith (Cretaceous).
The deposits are products of early Tertiary epithermal mineralization.

The four most important fluor spar localities are near Meyers Cove,
western Lemhi County; in the Bayhorse district near Challis, Custer
County; near Big Squaw Creek along the Salmon River, Idaho
County; and in the Stanley area, Custer County.

The discovery in 1941 of the Meyers Cove deposits (fig. 19, No. 1)
marks the beginning of the Idaho fluor spar industry (Anderson,
1948a). Within a year of their discovery, most of the deposits were
acquired by Chumac Mines Co. In 1949, the property was taken over
by Fluorspar Mines, Inc., and a flotation mill operated from 1951 until
the mill was destroyed by fire in April 1963. During this period of
operation, 37,482 short tons of fluorite-bearing material was treated
from which 10,979 short tons of acid-grade, 998 short tons of ceramic-
grade, and 100 short tons of metallurgical-grade fluor spar was re-
covered (Anderson, 1954a, p. 10). After the loss of the mill, the
property was returned to Chumac Mines Co. and has been inactive since
then.
Figure 19.—Fluorspar in Idaho.
The Meyers Cove deposits are restricted to a belt 3 miles long and 2 miles wide in which Casto and Challis Volcanics have been complexly fissured and otherwise fractured, intruded by small bodies of Tertiary rhyolite porphyry and granophyre, and then mineralized with fluorite and variable amounts of barite, chalcedony, and calcite as fillings of fissures and fillings and replacements of breccia zones (Anderson, 1954a; Cox, 1954). These bodies, ranging from small seams a few inches thick to lenticular masses as much as 20 feet thick and several hundred feet long, contain 40 to 85 percent CaF₂ averaging about 50 percent CaF₂.

The fluor spar deposits near Challis (No. 2) are in the northern part of the Bayhorse district, mostly on Keystone Mountain, in Daughtery Gulch to the north, and in several of the silver-lead mines near the old town of Bayhorse (Anderson, 1954b, p. 2). Although fluorite had been recognized previously in the Bayhorse district (Umpheley, 1913b, p. 74–75; Ross, 1937, p. 102, 143), commercial deposits were not found until about 1947. Most of the discoveries were explored by bulldozer and underground exploration. Mining in the Daughtery Gulch area yielded 175 tons of metallurgical-grade fluor spar containing 88 percent CaF₂ and 243 tons of milling-grade material containing 85 percent CaF₂ (Anderson, 1954b, p. 6). Mining ceased in late 1953 and has not been resumed.

The fluor spar deposits near Challis are along the crest, flanks, and faulted offsets of the Bayhorse anticline and occur as fissure and breccia fillings in the Bayhorse Dolomite (Anderson, 1954b). Minerals other than fluorite are quartz, calcite, and in some deposits scattered sulfides of base metals incorporated from older, genetically unrelated mineralization. Much of the fluorite occurs as small colorless crystals, which in breccia zones were deposited on boxwork quartz. The veins are mostly small, a few inches to several feet thick and several hundred feet long, but one, a fissure-breccia vein, is as much as 18 feet thick and more than 900 feet long. The breccia deposits range up to 30 feet wide and several hundred feet long. In most of the deposits the fluor spar content ranges from 30 to 50 percent CaF₂.

In the northeastern canyon wall of the Salmon River near Big Squaw Creek (No. 3), fluor spar is localized along the hanging wall of a wide quartz vein in a biotite gneiss pendant within the Idaho batholith. Several fluor spar bodies as much as 14 feet thick, 600 feet long, and containing about 70 percent CaF₂ are exposed. These deposits are about 34 miles west of Shoup and 25 miles by river below the end of the road. There has been no production, but substantial resources of fluor spar are inferred.

At the locality east of Stanley (No. 4), shear zones in the Idaho batholith, Challis Volcanics, and rhyolite dikes contain fluor spar (Choate, 1962, pp. 76–88). The Giant Spar vein, held by the Aluminium Co. of America, is as much as 15 feet thick, and samples were reported to contain about 70 percent CaF₂.

Minor deposits of fluor spar (fig. 12), mainly representing a single vein or several small veins, include those in the Edwardsburg district (No. 5) (Burchard, 1933, p. 14: Shenon and Ross, 1936, pp. 96–108); Pungo Creek area (No. 6): Parker Mountain district (No. 7) (Burchard, 1935, p. 14); Blue Wing district (No. 8) (Anderson, 1945, pp. 195–203; Callaghan and Lemmon, 1941, pp. 8–13); Yankee Fork
district (No. 9) (Choate, 1962, pp. 89-90); and Alta district (No. 10) (Umpleby and others, 1930, p. 206). Occurrences of fluorite in deposits of other minerals have been reported in the Siler prospect (No. 11) (Anderson, 1959, pp. 87-88); Alder Creek district (No. 12) (Umpleby, 1917, pp. 53, 100-101); Sawtooth Mountains (No. 13) (Reid, 1965, p. 36); Roaring River district (No. 14) (Schrader, 1924, p. 92); and Silver City-DeLamar district (No. 15) (Lindgren, 1933, p. 165; Shannon, 1928, p. 176).

Idaho has an excellent potential for the production of fluor spar. Nearly a million tons of indicated and inferred fluor spar containing about 45 percent CaF₂ is estimated for partly explored deposits in the four major districts discussed above. Deposits in these and other districts contain a large tonnage of lower grade material, but the lack of sufficient quantitative data precludes estimating the size and grade of these potential resources. Underground workings, diamond drilling (Anderson, 1954a, p. 19, 22-25), and geologic factors indicate that the Meyers Cove area may become an important source of fluor spar. In the Challis area the surface exposures show exceptional promise and suggest that the Bayhorse district may contain the most important concentration of fluor spar in Idaho. The State has not yet been adequately prospected, and more discoveries are to be expected when favorable economic conditions in the domestic fluor spar industry lend encouragement to further search and exploration.

Aside from the fluor spar deposits, a vast potential source of fluorine is the carbonate-fluorapatite in the phosphate rock of the Phosphoria formation of Permian age in southeastern Idaho. (See chapter on Phosphate.) The phosphate rock contains about 3 percent fluorine, or approximately 1 percent F for each 10 percent P₂O₅ (Altschuler and others, 1958, p. 54). Were all the fluorine recovered from phosphate rock being mined in Idaho, the fluorine production would amount to more than 50,000 tons annually. With a reserve of several billion tons of phosphate rock in Idaho, the potential supply of fluorine from phosphate rock is more than 300 times that in the resources that were estimated for the four major fluor spar districts of Idaho. Efficient low-cost methods of producing fluorine compounds other than fluorosilicic acid and silicofluorides must be employed by the numerous processing plants before fluorine from phosphate rock can be recovered in marketable form on a large scale.

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GARNET

(By M. D. Dasch, U.S. Geological Survey, Washington, D.C.)

Garnet is a collective term for a group of six minerals that have similar chemical and physical properties, including crystal form. These orthosilicate minerals have the same basic chemical structure in which different elements, such as calcium, magnesium, iron, etc., substitute for one another to form a series. Garnet is hard, moderately heavy, and commonly is dark red or reddish brown. It is an accessory mineral in many metamorphic rocks, particularly gneisses and schists, and also occurs in contact metamorphic rocks, such as recrystallized limestone, and in some igneous rocks. In Idaho, significant quantities of garnet
occur in metamorphic rocks of the Precambrian Belt Series, and in granitic rocks of the Idaho batholith.

Heavy minerals that are resistant to chemical and physical breakdown commonly may be weathered from bedrock and concentrated by moving water into placer deposits. In many beach and river sands relatively heavy, hard, and chemically resistant garnet minerals have accumulated with other detrital minerals, such as ilmenite, magnetite, and monazite. Many of these heavy minerals are dark colored; they give a blackish hue to the placer deposits which are commonly referred to as "blacksands."

Transparent, flawless garnet of attractive color may be cut into gems (see discussion of "Gemstones"). Garnet, however, is more important as an industrial material. Almandite, an iron-aluminum garnet, is the common garnet of gneissic and schists, and the most widely used variety in industry. With a hardness of 7.5 to 8, a sharp fracture, and toughness, it is an excellent abrasive.

About 45 percent of the garnet produced in the United States is consumed in the manufacture of abrasive-coated papers and cloths that are used for finishing wood, leather, and other materials. Thirty-five percent is used in the glass and optical industries, and 20 percent is used for sandblasting and for miscellaneous purposes (Vogel, 1960, p. 12). Garnet producers face active competition from producers of both natural and artificial abrasives. Garnet is more desirable than low-cost quartz, for the garnet fracture gives a preferable finish to certain materials; furthermore, individual garnet grains deliver heavier blows during sandblasting than quartz grains of equal size. Garnet lacks free silica and, therefore, cannot cause silicosis, a lung disease caused by the inhalation of silica dust. However, for some uses, as in many metalworking applications, garnet cannot compete with the higher cost synthetic abrasives, silicon carbide and aluminum oxide, for it is too friable and soft. During World War II, Idaho garnet was used for sandblasting in the aluminum, aircraft, and shipbuilding industries in California and the Pacific Northwest. Most garnet mined in the State today is sold to west coast aircraft industries for use in sandblasting, but some is shipped to the Midwest and to Japan.

As early as 1886, significant quantities of almandite were reported from placer gravels near Lewiston, Nez Perce County, Idaho. Abrasive garnet was first recovered in Idaho in 1940; at that time a small screening and classifying plant was built in southeastern Benewah County by Garnet Mines, Inc., of Spokane. Production statistics have been reported annually since 1940, and Idaho has ranked second in U.S. production since 1943 (U.S. Bureau of Mines Minerals Yearbook, annual volumes, 1940-82).

Most garnet has been recovered from Benewah County placers in the Emerald Creek area near Fernwood; some production has come from adjacent deposits in Shoshone County. A minor amount has been reported as a byproduct of monazite production in the Warren district, Idaho County. In Valley County, garnet has been recovered in processing stockpiled ilmenite concentrates which were dredged in the Cascade area, and also as a byproduct of niobium-tantalum placer operations in Bear Valley. In 1962, the latest year for which production information is available, garnet from placers in Benewah and Valley Counties was marketed for abrasive purposes. According to
a news release January 11, 1964, in the Moscow, Idaho, Idahoanian, the Garnet Abrasive Co. in Benewah County produced 3,790 short tons of garnet in 1963, with a net value of $225,000.

Annual production figures are not otherwise available for Idaho garnet production. It has been estimated, however, that from 1940 through 1960, 48,292 short tons of garnet, valued at $8,113,605, was mined in the State (Idaho Bureau of Mines and Geology Bulletin 18, 1961, p. 69). Most Idaho garnet has been produced as a primary mine product, with only minor quantities recovered as a byproduct.

The available published information on the Idaho garnet industry is contained mainly in reports on black sand placer investigations which have been conducted for heavy minerals such as monazite. Monazite, a phosphate of rare earth elements, has been in demand owing to its thorium content. In the early 1950's, the U.S. Geological Survey and U.S. Bureau of Mines personnel studied a number of placers in central Idaho, and the latter drilled many test holes, primarily to analyze black sands for possible monazite resources. Where detailed analyses were made, garnet content has been reported.

Placers which currently are being dredged for garnet, and placers which may be worked for garnet in the future are described briefly in the following paragraphs. Many of these placers are discussed in a comprehensive review of central Idaho black sand deposits by Savage (1961a); nevertheless, many other placers containing significant quantities of garnet undoubtedly exist, but have not been reported in the published literature. Locations of the following placers and placer areas are shown on figure 20.

**Benewah County**

*Emerald Creek placers (fig. 20, No. 1).*—Garnet is disseminated in micaeous schist of the Precambrian Belt Series, which is estimated to be 4,000 feet thick in the Emerald Creek area. Almandite has weathered from the schist and has been concentrated in extensive alluvial deposits that contain up to 30 percent of the mineral. Three to eight feet of overburden must be stripped from the placer before the garnet-bearing deposit can be mined. The garnet, which has a maximum grain size of three-sixteenths of an inch, is processed at a plant in the nearby town of Fernwood. It is dried, crushed, and screened; the crushed garnet is a better abrasive owing to its sharper cutting edges (Crandall, 1950; Chandler, 1960).

The placers are mined for garnet only. Garnet Mines, Inc., of Spokane developed the deposit and built a small screening and classifying plant in 1940. Several companies have worked this productive placer since that time, but the Idaho Garnet Abrasive Co. has been the principal producer. In 1961, Emerald Creek Garnet Milling Co. was a minor producer, but in 1962 their plant was badly damaged by fire. In 1964, Sunshine Mining Co. of Kellogg, Idaho, purchased the Idaho Garnet Abrasive Co.

**Boise County**

*Boise Basin monazite placers (No. 16).*—Boise Basin, a small area in the southwestern part of the Idaho batholith is one of the famous early gold placer mining districts of the West. Heavy minerals in the black sands of the basin were derived from granitic rocks of the area. Most of the black sands are composed primarily of ilmenite and
Figure 20.—Garnet placers in Idaho.
magnetite, but quantity of black sand and percentage of contained garnet vary widely in different parts of the Basin. According to Kline (Savage, 1961a, p. 43), in the Basin as a whole, black sand averages 6.04 pounds in each cubic yard of gravel and contains about 14.6 percent garnet. In the Elk-Morse Creek area, the black sand averages only 2.71 pounds per cubic yard of gravel, but garnet comprises 54 percent of the total black sand.

Clearwater and Idaho Counties

Clearwater area (No. 3).—Little is known about the extent of black sand placers in the Clearwater area. Garnet is locally abundant in rocks of the Idaho batholith and in the Prichard Formation and Orofino Series of Anderson (1930) of the Precambrian Belt Series. Both anhedral and euhedral garnet are plentiful in the Clearwater placers, particularly adjacent to areas underlain by metamorphosed rocks of the Belt Series. Ilmenite, magnetite, and garnet appear to be the most common placer minerals in the area.

Burgdorf-Scott area (No. e).—Heavy minerals in placers of this area are derived from the Idaho batholith and from metamorphosed Precambrian rocks. Garnet is abundant and varies from 0.05 to 6 pounds a cubic yard of gravel. It is very common in deposits adjacent to Warren, in Warren Meadows, and in the Ruby Creek area. A black sand concentrate from the Thorpe placer, Seccesh Creek, reportedly averaged 40 percent garnet.

In 1939, the Idaho Titanium & Mining Co. recovered a small amount of garnet from monazite concentrates which were dredged by the K. & D. Mining Co. at Ruby Meadows in the Warren district. About 100 tons of refined garnet sand was marketed for $6,500.

placer area (No. 4).—Precambrian gneiss and schist in the area contain garnet. Placer gravels have an average of 1.2 pounds of garnet a cubic yard, and concentrates of black sand average 10 percent garnet.

Shoshone County

Spokane Sand & Sales Co. operation, Fernwood area (No. 8).—Garnet has been dredged from alluvial deposits in the Fernwood area near the Benewah County line. The Spokane Garnet Sand & Sales Co. reported an unspecified amount of production in 1958 and 1959; the garnet was marketed out of State as an abrasive.

Valley County

Bear Valley radioactive mineral placers (No. 14).—The Bear Valley placers are located in the central part of the Idaho batholith. Erratically distributed lenses of black sand contain abundant ilmenite, magnetite, and garnet that have been derived from rocks of the batholith. In the upper Bear Valley area and in the central Bear Valley area, garnet averages 7.84 and 9.89 pounds a cubic yard of gravel respectively.

The placers have a high content of niobium, tantalum, and uranium minerals. In 1955, the Porter Bros. Corp. began dredging operations for recovery of thorium-bearing monazite and of columbite, euxenite, and other minerals containing niobium and tantalum. Ilmenite, magnetite, zircon, and garnet were stockpiled as byproducts of the operation (Dayton, 1958; Mining World, 1958). Byproduct garnet sand
was marketed from 1959 through 1963, the latest year for which production information is available.

**Deadwood area (No. 13).**—Heavy minerals in the Deadwood placer have been derived primarily from rocks of the Idaho batholith; ilmenite, magnetite, and zircon are most abundant in the area. Sands along the shore of the Deadwood Reservoir yield considerable garnet. Samples taken in the Deadwood River Valley north of the reservoir indicate that the garnet content averages 0.45 pound a cubic yard of gravel.

**Cascade area.**—The Cascade area encompasses a number of placers on the western edge of the Idaho batholith. Seven of them contain significant quantities of garnet and are listed below:

- **Beaver Creek monazite placer (No. 8).**—Irregularly distributed ilmenite, magnetite, monazite, and smaller quantities of zircon and garnet are present in black sands derived from granitic rocks of the Idaho batholith.
- **Big Creek monazite placer (No. 11).**—Black sands with high values of ilmenite, monazite, garnet, and zircon have been derived from granitic rocks. In 1950, the Baumhoff-Marshall Co. began dredging operations for monazite in the Big Creek placer area south of Cascade; ilmenite, zircon, and garnet also were recovered from concentrated black sands.
- **Corral Creek monazite placer (No. 12).**—Black sands containing high ilmenite and monazite values were derived from granitic rocks of the batholith. The lateral extent of heavy mineral lenses is variable and the garnet content is relatively low.
- **Gold Fork placer (No. 6).**—This exceptionally large deposit contains abundant ilmenite, garnet, magnetite, and sphene, in order of descending amounts.
- **Horsethief Basin monazite placer (No. 9).**—Ilmenite, monazite, and minor garnet have been derived from local granitic rocks, and concentrated in this black sand placer.
- **Peersol Creek monazite placer (No. 10).**—Abundant ilmenite and monazite, and less plentiful magnetite, garnet, and zircon have been derived from local bedrock sources and concentrated in lenticular beds of coarse sand and fine gravel. The black sand lenses vary from 3 to 30 feet in thickness and are irregularly distributed.
- **Scott Valley monazite placer (No. 7).**—Black sands containing ilmenite, garnet, magnetite, monazite, and zircon have been derived from granitic rocks of the region.

The Cascade area as a whole averages about 3.5 pounds of garnet a cubic yard of gravel. Garnet content of the individual placers has been recorded by Savage (1961a) and is tabulated below:

<table>
<thead>
<tr>
<th>Placer</th>
<th>Average content black sand in pounds per cubic yard of gravel</th>
<th>Average content garnet in pounds per cubic yard of gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaver Creek</td>
<td>15.10</td>
<td>0.07</td>
</tr>
<tr>
<td>Big Creek</td>
<td>15.40</td>
<td>1.57</td>
</tr>
<tr>
<td>Corral Creek</td>
<td>4.90</td>
<td>0.98</td>
</tr>
<tr>
<td>Gold Fork</td>
<td>25.32</td>
<td>2.65</td>
</tr>
<tr>
<td>Horsethief Basin</td>
<td>7.92</td>
<td>2.28</td>
</tr>
<tr>
<td>Horsethief Creek</td>
<td>14.41</td>
<td>4.48</td>
</tr>
<tr>
<td>Scott Valley</td>
<td>18.54</td>
<td>1.99</td>
</tr>
</tbody>
</table>
In recent years, garnet has been recovered in the Cascade area as a byproduct of monazite operations; recovery from the Big Creek placer has been specifically mentioned in the literature. In 1957 the Boise plant of the Baumhoff-Marshall Co. began recovery of garnet and other heavy minerals from stockpiled ilmenite concentrates that were dredged in the Cascade area between 1951 and 1955. The Baumhoff-Marshall Co. was succeeded by the J. R. Simplot Co. in 1959; garnet recovery from previously dredged sands of Valley County was reported through 1962.

Garnet is plentiful in Idaho; according to Hubbard (1955, p. 29), "Idaho's reserves of garnet for abrasive purposes are virtually inexhaustible." At present, the commodity is mostly produced from placers that are dredged for garnet only. The domestic market is adequately supplied by established garnet producers; consequently there has been little incentive for recovering garnet as a byproduct from placers dredged for other minerals. The market for Idaho garnet is principally in the western United States, although some garnet has been shipped to the Midwest and Japan as previously stated.

Reserve figures for Idaho black sand placer minerals have not been published. The lack of resource data may be explained by one or more factors: the lower limits of the placers have not been penetrated in the majority of test borings, and the volumes of practically all of the placers are unknown; erratically distributed lenses containing black sands vary substantially in thickness, lateral extent, and in percentage of contained heavy minerals; and many black sand placers, such as the Boise Basin placer, were originally dredged for gold and the natural distribution of the sediments has been disrupted.

An exception to the lack of reserve figures is an estimate of black sand reserves at the head of Bear Valley quoted by Savage (1961a, p. 84). At a mining rate of 5.5 million cubic yards of gravel a year, it is estimated that black sands could be produced for 30 years in this area. If the estimated average garnet content of 7.84 pounds a cubic yard of gravel is correct, 588 million pounds of garnet could be recovered during that span of time.

In addition to the large quantities of garnet in the Emerald Creek area, Benewah County, garnet is very plentiful in the Warren, Cascade, and Bear Valley placers. Savage (1961a, p. 149) estimated that the gravel of eight central Idaho placers (excluding the Emerald Creek area) averaged about 1.9 pounds of garnet a cubic yard. Garnet recovered as a byproduct from some of these placers depends upon demand, and upon successful recovery of other economic placer minerals.

At the Barton mine in New York State, garnet is recovered, not from a placer deposit, but directly from almandite-rich metamorphic rock. In some areas of Idaho, similar garnet-rich rocks are exposed; they have served, at least in part, as the source for nearby placer black sands. These metamorphic rocks, however, have not been processed for garnet. Several areas in western Clearwater County near the western edge of the Idaho batholith contain highly garnetiferous metamorphic rock of the Precambrian Belt series. If the quality of garnet is adequate for industrial use, perhaps these and other garnet-rich rocks in the State could be profitably exploited. Investigations may indicate that Idaho has minable garnet resources in deposits other than black sand placers.
GEMS AND GEM MATERIALS

Gems and gem materials are naturally occurring substances that are prized because of their beauty, durability, and rarity. Many materials have been used as gems. A few of the gems are recovered from lode deposits, but because of their durability and weight, gems and gem materials are more often obtained from placer deposits.

The value of a gem or gem material depends on rarity and beauty. Sapphires, rubies, and emeralds are valued at several hundred to several thousand dollars per carat, whereas, some varieties of silica minerals are a few dollars a pound. Many gem materials find a market in industry. Diamond and corundum because of their hardness are used in dies, bearings, and abrasives. Garnet and quartz are widely used as abrasives. Optical quartz is used in the electronic industry, optical calcite is used in the manufacture of optical equipment, and both with fluorite are used as piezoelectric strain gages.

The growth of the hobby of collecting gems and gem material has focused the attention of a great number of collectors on the more common varieties of gem material. The precious gems are emerald, sapphire, diamond, and ruby. The semiprecious gem materials are all others that meet the requirements of beauty, rarity, and durability. The semiprecious gem material has caught the eye of the amateur collector or "rock hound." Today, the largest dollar value is in the semiprecious material bought by the "rock hound."

Idaho has several deposits of gem stones (fig. 21), none of which is in continuous production. Diamonds have been reported from the gravels near Cascade, Idaho, but the quality and size are unsuitable for economic consideration. Corundum crystals, including a few gem-quality sapphires and rubies have been found in placers near New Meadows, Adams County, and in the Clearwater drainage. Sapphires and rubies also have been reported from poorly identified localities in Idaho County.

Rock crystal and amethyst, varieties of quartz, have been found in Custer County. "Rock hounds" have stripped most of the easily accessible deposits because the price of light-colored amethyst in the rough is $20 to $30 per pound. No significant commercial deposits have been found.

Jasper and chalcedony and agate, the variegated variety of chalcedony, are found in many localities in the State. The most famous jasper is the "Bruneau Jasper" found near the town of Bruneau, Owyhee County. Jasperized petrified wood is very much in demand by the collector.

The Clearwater River Valley is one of the few collecting localities in the world for gem quality sillimanite, also known as fibrolite. Rounded pebbles of fibrolite have been found in the gravels of the Clearwater River from Lewiston, Idaho, to almost 100 miles upstream, an especially prolific stretch lying between Lewiston and Myrtle (Sinkanks, 1969, p. 589). "Rock hounds" congregate in the area during the late summer to collect while the water is low. All collections are made from the gravels along the riverbed. No commercial production is known.

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In the past, fire opal has been an important gem material in Idaho, but in the last few years spotty finds have been the only opal reported. Several localities along the Clearwater River have been reported and two localities in southeast Idaho have produced some stones. No significant production has been made in the last few years.

Garnet is mined in Benewah County and sold as an abrasive. In the past the placer work in Bear Valley, Boise County, Idaho, produced garnet as a byproduct, but the operation has been closed down for 2 years.

On Emerald Creek, Benewah County, gem-quality garnet is found. "Rock hounds" prize the garnet, and considerable business is conducted by local collectors. Star garnet also is obtained from Emerald Creek. It is highly prized by collectors and can be bought in most Idaho "rock hound" shops.

In the search for beryl, many small deposits of aquamarine—the gem variety of beryl—were reported. Some of the material is of gem quality. In general, the aquamarine is fractured and does not lend itself to polishing. No commercial deposits of gem material have been reported.

A few specimens of topaz have been found in the Dismal Swamp placer in Elmore County.

Zircon is abundant in the gravels of many of the streams that drain the granitic rocks of the Idaho batholith, but the crystals are all small. As far as is known, no specimen-quality material has been found.

Aside from garnet for the abrasive industry, commercial production of gem material in Idaho has been extremely limited. However, the value of Idaho gem material collected by "rock hounds" and amateur collectors has been considerable. No accurate figure is available, but it may be as much as $35,000 annually. The amount of money expended in the State for purchase of gas, food, and lodgings by mineral collectors and "rock hounds" may exceed this by several times. Some gem materials other than those mentioned have been found but are not abundant. More detailed information on occurrences of all types of gem material in Idaho can be found in Sinkankas (1959) and Schiegl (1957). Also, various guidebooks and atlases, published for the benefit of mineral collectors and "rock hounds," are available at most "rock shops."

GOLD

(By M. H. Bergendahl, U.S. Geological Survey, Denver, Colo.)

Since man first began to organize himself into society and conduct business, gold has been prized as a medium of exchange and a basis for monetary systems. Because of its beauty, durability, and malleability, gold has been widely used in jewelry manufacture, plating, foil, binding, lettering, and interior decoration. Small quantities of gold are used in dentistry and the glassmaking industry. Gold is an efficient reflector of infrared radiation, hence it is being used more and more in scientific apparatus and the aerospace industry.

PRODUCTION AND OUTLOOK

In 1962 world gold production reached an alltime high of 50 million ounces due largely to increased output of the Republic of South Africa.
and the U.S.S.R. In contrast, the United States produced only 1.5 million ounces in 1962, the lowest peacetime gold production since 1884 (Ryan and Tucker, 1963, p. 599). A combination of high mining costs, a fixed selling price of $50 per ounce, and decrease in grade are the salient factors responsible for the current unhealthy plight of the gold mining industry.

Idaho, which ranks ninth among the States in total gold production, exemplifies the national trend in that its gold output for 1962 was only 5,845 ounces, as contrasted with the 149,816 ounces produced in 1941. Total gold production of Idaho from 1863 to 1962 is 8,300,738 ounces. Figure 22 shows the annual gold production from 1880 to 1962 and the major factors affecting fluctuations in the industry.

Placers were the main source of gold in Idaho before 1900, but large-scale dredging operations had exhausted many of them by 1920. Throughout most of the 1920's, gold mining declined, due mostly to increased interest and activity throughout the State in silver-lead-zinc deposits, especially in the Coeur d'Alene district. The increase in the price of gold from $20.67 to $35 per ounce in 1933 resulted in an immediate rejuvenation and expansion of both gold lodes and placers, culminating in a high output of 149,816 ounces in 1941. World War II and the consequent imposition of WPB Order L-208 forced closure of most of the gold mines, and the postwar economy, with its sharply increased costs, was not favorable for a return to the booming period of the late 1930's. A large part of Idaho's gold during the 1946-51 period came from large-scale mining of antimony-gold ores in the Yellow Pine district. When Yellow Pine closed in 1952, gold production dropped to less than 20,000 ounces per year. From 1954 to 1959 the bulk of Idaho's gold came as a byproduct of copper-cobalt ores of the Coles mine in the Blackbird district. When this mine closed in 1960, gold production of the State dropped to its present low level of less than 6,000 ounces per year.

What of the future? Assuming a continuation of the current cost-price imbalance, there is little likelihood of revitalization of the State's gold mining industry. The large base metal deposits in Idaho yield very little byproduct gold; the known placers do not offer promise for a sustained resurgence, considering that they have been worked on a large scale for so many years. Moreover, exploration for new gold lodes and development of known ones are discouraged by the unfavorable economic climate. Should these conditions change, a revival of interest in gold mining in Idaho is likely.

MINERALOGY AND GENERAL GEOLOGIC FEATURES OF GOLD DEPOSITS

Gold occurs most commonly in the elemental form, as tiny grains in quartz and in metallic sulfides. Gold often forms an alloy with silver, and where almost equal amounts of each metal are present, the compound is known as electrum. Gold is also found in telluride minerals, the most common of which are calaverite, sylvanite, krennerite, and petzite. In rare occurrences, gold forms natural compounds with mercury, bismuth, and chlorine.

The lode gold deposits of Idaho are spatially related to the Idaho batholith, a large complex mass of granitic intrusive rocks that ranges in age from Jurassic through Cretaceous and underlies much of the
central and northern parts of the State (fig. 23). Some gold lodges are related to the batholithic rocks, but the better known deposits are much younger and accompany Tertiary dikes and other small intrusive bodies that occupy shears and zones of weakness in the batholithic rocks.

**Types of Gold Deposits**

Gold deposits in Idaho may be generally classified as fissure veins, replacement deposits, and placers. In the past, most of the gold in Idaho has been mined from placers, but the latter deposits have been more thoroughly worked; veins and replacement deposits seem to hold more promise for future production. The major districts are described briefly in Table 5.

**Fissure Veins.**—In this category are included all open-space fillings such as breccia deposits, fissure veins, and mineralized shear zones. These deposits are formed by deposition of ore minerals from ascending hydrothermal solutions in preexisting open spaces, such as fractures, faults, and joints. Deposition in the fissures was effected by lowering of temperature, changes in Eh and pH, and lowering of pressure as the solutions made their way to the surface. Common ore minerals of such deposits are pyrite, chalcopyrite, galena, sphalerite, arsenopyrite, pyrrhotite, stibnite, cinnabar, realgar, orpiment, tetrahedrite, enargite, scheelite, silver sulfarsenides, and sulfantimonides. Gold occurs in fine grains chiefly in pyrite and quartz. In some deposits small amounts of galenobismuthite, bismuthinite, tetradyrmite, molybdenite, and gold tellurides are found locally. The predominant gangue minerals of fissure vein deposits are quartz, chalcedony, calcite, barite, and siderite.

Examples of fissure vein deposits that have yielded substantial amounts of gold are in the Silver City district, which includes the DeLamar, Florida-War Eagle Mountain, and Flint camps, in Owyhee County. Graphite and biotite schists of undermined age are the oldest rocks in the district, though they are present in only a few outcrops. Intruding these rocks is a stock of granodiorite, possibly related to the Idaho batholith. The granodiorite is cut by aplite, dacite, and diorite porphyry dikes, which may or may not be genetically related to the stock (Ross, 1941, p. 81). Miocene basaltic lavas were poured onto an erosion surface etched into the granodiorite, and younger rhyolite flows covered the basalt (Piper and Laney, 1926, p. 20-38). The veins cut rhyolite, the granitic stock, and basalt; follow no consistent trend, and are clearly post-Miocene in age (Lindgren, 1900, p. 163-183). Some faulting occurred after ore deposition (Piper and Laney, 1926, p. 38-50).

The veins of the district are fracture fillings and may be classified into four types (Piper and Laney, 1926, p. 63): (1) veins characterized by white or milky quartz as in the Flint area, (2) veins composed of lamellar quartz, typical of the DeLamar area, (3) silicified shear zones such as the Poorman, and (4) quartz-cemented breccias, of which the Orofino-Golden Chariot vein is an example. All types are remarkably persistent, traceable for thousands of feet along strike, and extend as much as 2,500 feet below the surface (Ross, 1941, p. 81).

The ore minerals are argentite, electrum, jamesonite, ruby silver, naumannite, owyheite (lead-silver sulfantimonide), stibnite, and
Figure 23.—Gold-producing districts of Idaho and areas underlain by Mesozoic and Tertiary granitic rocks (numbers refer to mining districts listed in table 5).
<table>
<thead>
<tr>
<th>Index No. on</th>
<th>District</th>
<th>Manner of occurrence</th>
<th>Amount (in ounces) and kind of gold production</th>
<th>Remarks</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Bingham County: Snake River placer.</td>
<td>Gold-bearing gravels along Snake River.</td>
<td>26,200 placer</td>
<td></td>
<td>Anderson and Wagner, 1946, pp. 4-10; Ulgilby, Wetegate, and Ross, 1933, p. 84; Ross, 1941, p. 12.</td>
</tr>
<tr>
<td>3</td>
<td>Cusco</td>
<td>Gold-bearing veins in granodiorite and quartz monzonite of the Idaho batholith; gold and silver-bearing veins in faulted Alkaliplagioclase sedimentary rocks.</td>
<td>102,000 lode</td>
<td>Most activity occurred before 1910.</td>
<td>Ulgilby, Wetegate, and Ross, 1933, p. 84; Ross, 1941, p. 12.</td>
</tr>
<tr>
<td>4</td>
<td>Warm Spring</td>
<td></td>
<td>76,000 lode</td>
<td>Gold a byproduct of silver-lead ores.</td>
<td>Ulgilby, Wetegate, and Ross, 1933, p. 84; Ross, 1941, p. 12.</td>
</tr>
<tr>
<td>5</td>
<td>Boise County: Boise Bath</td>
<td>Placer in younger of 2 alluvial deposits: fine-grained altered Tertiary age in granodiorite of Fortuna or Crescenta age.</td>
<td>Roughly 2,200,000, mostly from placer.</td>
<td>Mostly productive gold district in Idaho.</td>
<td>Ulgilby, Wetegate, and Ross, 1933, p. 84; Ross, 1941, p. 12.</td>
</tr>
<tr>
<td>6</td>
<td>Placerville</td>
<td>Gold-bearing gravels associated with nepheline dikes in quartz monzonite of Fortuna or Crescenta age.</td>
<td>25,000 lode</td>
<td></td>
<td>Ulgilby, Wetegate, and Ross, 1933, p. 84; Ross, 1941, p. 12.</td>
</tr>
<tr>
<td>7</td>
<td>Quartz City</td>
<td>Placer in younger of 2 alluvial deposits: fine-grained altered Tertiary age in granodiorite of Fortuna or Crescenta age.</td>
<td>About 490,000 lode</td>
<td></td>
<td>Ulgilby, Wetegate, and Ross, 1933, p. 84; Ross, 1941, p. 12.</td>
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<tr>
<td>8</td>
<td>Butte County: Mount Pigma.</td>
<td>Deposits in replacement bodies in Pennsylvanian sedimentary rocks near granitic rocks of the Idaho batholith.</td>
<td>16,000 to 60,000, mostly from placers.</td>
<td>Maximum of 16,000 lode.</td>
<td>Ulgilby, Wetegate, and Ross, 1933, p. 84; Ross, 1941, p. 12.</td>
</tr>
<tr>
<td>9</td>
<td>Cusco County: Big and Little Stock-Roseta.</td>
<td>Deposits in replacement bodies in Pennsylvanian sedimentary rocks near granitic rocks of the Idaho batholith.</td>
<td>20,000 placer</td>
<td>Gold at Placerville placer.</td>
<td></td>
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<tr>
<td>10</td>
<td>Cusco, Minidoka, and Jerome Counties: Snake River placer.</td>
<td>Gold-bearing gravels at various localities along Snake River.</td>
<td>20,000 placer</td>
<td></td>
<td>Ulgilby, Wetegate, and Ross, 1933, p. 84; Ross, 1941, p. 12.</td>
</tr>
<tr>
<td>11</td>
<td>Clearwater County: Fier.</td>
<td>Gold placer in stream channels and in high terrain gravel. Deposits in replacement bodies in Pennsylvanian sedimentary rocks near granitic rocks of the Idaho batholith.</td>
<td>About 86,000, mostly placer.</td>
<td>Earliest gold discovery of compression in Idaho, most productive period was in 1860's.</td>
<td>P. 16, 30, 31, 32, 33, 34.</td>
</tr>
<tr>
<td>12</td>
<td>Custer County: Alder Creek</td>
<td>Contact metamorphic bodies along a limestone-granite contact. Copper sulfides and sulfides-containing gold are the ore minerals.</td>
<td>25,000 lode</td>
<td></td>
<td>Barton, Wells, and Obergili, 1938, p. 4-7; Ross, 1941, p. 27; Thomas and Ulgilby, 1924, p. 114; Lindgren, 1934, p. 105; Savage, 1948, p. 141-146.</td>
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<td>13</td>
<td>Loon Creek</td>
<td></td>
<td>About 26,000 placer, 14,000 lode</td>
<td>Most placer production was in 1870's.</td>
<td>Ross, 1941, p. 12.</td>
</tr>
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</table>
14 Yankee Fork: Shallow silver-gold veins in Tertiary volcano
type rocks, placer in gravels along Yankee Fork of Salmon River.

15 Elmore County: Gold and silver-bearing sulde veins in frac-
tured granite of the Idaho batholiths of Jur-
assic or Cretaceous age.

16 Feather River: Placers along South Fork of Boise River.

17 Nez: Gold-bearing quartz-sulfide veins associated
with felsic porphyry dike.

18 Pine Grove: Oxidized sulde veins in granite of the Idaho bath-
olith.

19 Rocky Bar: Veins were along Four Creek: Gold-bearing
sulde veins in granite of the Idaho bath-
olith.

20 Gem County: Westview (Pearl): Mineralized fissures in a zone of dikes that cut
quartz dikeite and granodiorite of Late Tertiary age.

21 Idaho County: Buffalo Hump: Gold-bearing fissure veins in meta-
diabase dyke that was
t ursted by quartz monzonite of the Idaho
batholith.

22 Elk City: Placers in high-grade aureoles of Tertiary age;
loose in quartz lenses in granite of the Idaho batholith.

23 Duda: Quartz-pyrite veins containing gold in quartz
monzonite or granodiorite of the Idaho
batholith.

24 French Creek: Rich placers in stream gravels e to 10 feet thick.

25 Grange: Gold and pyrite disseminated in shear zone in
siltstone of Cretaceous of the Snake Range and
granodiorite and dacite.

26 Simpson-Camp Howard-Sligo: Placers in beach and stream gravels.

27 Tonkolli: Placers in gravels of Newton Creek: quartz-
sulfide veins in gulch of the Snake Range and
quartz monzonite of the Idaho batholith.

28 Warren-McMillan: Placers in conglomerates and Bannack
alumite, beach, and high-grade sandstone and Recent stream deposits. Gold-
-bearing quartz-sulfide veins in quartz mon-
zonite of the Idaho batholith.

29 Latah County: Hoodoo: Placers along Pahsue River and Hooedoo Creek.

232,000 lode, 14,000 placer.

Value of production about equally divided between
silver and gold.

250,000 lode, 8,000 placer.

About $305,000 lode, 75,000 placer.

About $25,000 lode, 5,000 placer.

About 18,000 lode, 3,000 placer.

About 10,000 lode, 5,000 placer.

About 8,000 lode, 1,000 placer.

About 7,000 lode, 1,000 placer.

About 5,000 lode, 8,000 placer.

About 3,000 lode, 500 placer.

About 300 lode, 50 placer.

About 200 lode, 10 placer.

About 100 lode, 5 placer.

About 50 lode, 5 placer.

About 10 lode, 5 placer.

About 5 lode, 5 placer.

About 1 lode, 1 placer.

About 1 lode, 1 placer.
<table>
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<tr>
<th>Index No. on Fig. 29</th>
<th>District</th>
<th>Manner of occurrence</th>
<th>Amount (in ounces) and kind of gold production</th>
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<td>30</td>
<td>Lewiston County, Blackbird</td>
<td>Mineralized veins and replacement bodies in altered granite, north Idaho</td>
<td>16,000 lode</td>
<td>Gold in byproduct of copper mining. Little gold production in Idaho</td>
<td>Unglueck, 1921, p. 160; Vaux, 1898</td>
</tr>
<tr>
<td>31</td>
<td>Carmen Creek, Edna, Fiddletown, Idaho</td>
<td>Gold in byproduct of copper mining. Little gold production in Idaho</td>
<td>26,000 placer</td>
<td>Lodes are present, but have not been productive.</td>
<td>Unglueck, 1921, pp. 123-127; Ross, 1941, p. 99</td>
</tr>
<tr>
<td>32</td>
<td>Ohlinville, Idaho</td>
<td>Narrow faulted quartz-sulfide veins in slate of the Belt series</td>
<td>About 100,000 placer and lode</td>
<td></td>
<td>Unglueck, 1921, pp. 128-135; Ross, 1941, p. 10; Bingham, 1897, pp. 7-9; Unglueck, 1921, pp. 128-160; Ross, 1941, p. 73</td>
</tr>
<tr>
<td>33</td>
<td>Mackinaw</td>
<td>Gold-bearing quartz-sulfide veins in slate of the Belt series and granite stock of the Idaho batholith</td>
<td>271,000 placer, some lode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Mineral Hill and Indian Creek, Idaho</td>
<td>Gold-bearing quartz-sulfide veins in slate of the Belt series and granite stock of the Idaho batholith; placer production along Bunker Creek</td>
<td>87,000, mostly lode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Kirlin Creek, Idaho</td>
<td>Gold-bearing quartz-sulfide veins in slate of the Belt series and granite stock of the Idaho batholith</td>
<td>37,000, mostly placer</td>
<td>Large-scale hydraulic operations in 1969 yielded unrecorded amount of gold.</td>
<td>Lounsbury and Metzger, 1939, pp. 79-81; Unglueck, 1921, pp. 159, 161; Ross, 1941, p. 74</td>
</tr>
<tr>
<td>36</td>
<td>Texa, Idaho</td>
<td>Valuable containing lead-silver-gold in Paleozoic carbonaceous rocks.</td>
<td>21,700 lode</td>
<td>Byproduct gold from lead mines near Pittsburgh.</td>
<td>Unglueck, 1921, pp. 128-138; Anderson, 1948, pp. 63-64</td>
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<td>37</td>
<td>Yellow Jacket</td>
<td>Vein filling and replacement deposits in the Jurassic to the Cambrian</td>
<td>23,000 lode</td>
<td>District decline with closure of Yellow Jacket mine in 1997.</td>
<td>Unglueck, 1921, pp. 92-94.</td>
</tr>
<tr>
<td>38</td>
<td>Owyhee County, Silver City</td>
<td>Vein filling and replacement deposits in the Jurassic to the Cambrian</td>
<td>18,000 placer</td>
<td>District decline with closure of Yellow Jacket mine in 1997.</td>
<td>Unglueck, 1921, pp. 130-138; Anderson, 1948, pp. 63-64</td>
</tr>
<tr>
<td>39</td>
<td>Power County, Snake River placer</td>
<td>Vein filling and replacement deposits in the Jurassic to the Cambrian</td>
<td>630,000 placer and lode</td>
<td></td>
<td>Unglueck, 1921, pp. 130-138; Anderson, 1948, pp. 63-64</td>
</tr>
<tr>
<td>40</td>
<td>Butte County, Coeur d’Alene</td>
<td>Vein filling and replacement deposits in the Jurassic to the Cambrian</td>
<td>17,000 lode</td>
<td>Considerable silver also produced.</td>
<td>Unglueck, 1921, pp. 130-138; Anderson, 1948, pp. 63-64</td>
</tr>
<tr>
<td>41</td>
<td>Valley County</td>
<td>Gold-bearing quartz veins and stockwork</td>
<td>30,000 lode</td>
<td>Considerable silver also produced in large quantities.</td>
<td>Unglueck, 1921, pp. 130-138; Anderson, 1948, pp. 63-64.</td>
</tr>
<tr>
<td>42</td>
<td>Yellow Pine</td>
<td>Gold-bearing quartz veins and stockwork</td>
<td>100,000 lode</td>
<td></td>
<td>Unglueck, 1921, pp. 130-138; Anderson, 1948, pp. 63-64.</td>
</tr>
</tbody>
</table>

tetrahedrite. Arsenopyrite, galena, pyrite, and marcasite occur in minor amounts (Ross, 1941, p. 81). Included in the gangue are quartz, barite, calcite, chalcedony, and valencianite, a rare variety of orthoclase occurring as gangue in some deposits (Lindgren, 1900, p. 166-167). Practically all of the gold occurs in electrum, the natural alloy of gold and silver (Piper and Laney, 1926, p. 75). The Silver City district has produced roughly 1 million ounces of gold and an amount of silver about equal in value to that of the gold.

Replacement deposits.—Ore deposits formed by replacement can be considered under two major genetic types—massive sulfide bodies and contact metamorphic deposits. When mineralizing solutions travelling along fissures encounter certain carbonates, shales, or arkosic sandstones, the physicochemical environment will often be such that deposition and replacement of the constituent rock minerals by ore minerals will occur, resulting in large irregularly shaped tabular masses of galena, pyrite, sphalerite, chalcopyrite, pyrrhotite, magnetite, and tetrahedrite. The wall rock peripheral to the sulfides is usually converted to dolomite or jasperoid.

Contact metamorphic deposits are replacements caused by heat and mineralogic emanations in country rock adjacent to an intrusive mass. In addition to the sulfides listed above, oxides, notably magnetite, arsenides, and sulfosalts comprise the ore mineralogy. The gangue, commonly referred to as skarn, consists of a complex assemblage of lime-silicate minerals.

In general, replacement deposits in Idaho have not been a major source of gold. They have been mined chiefly for lead, silver, copper, and cobalt, and gold has been extracted as a byproduct.

Placers.—Gold placers are accumulations of gold in gravels, where the gold has been separated and concentrated by gravity through the action of wind or moving water.

Placers in Recent stream gravels have been highly productive in the Boise Basin, Yankee Fork, and French Creek-Florence districts (Savage, 1961b). Older placers in bench and terrace gravels occur in many areas at altitudes as much as 500 feet above the present drainage. Substantial quantities of gold have been mined from these perched deposits in the Pierce and Elk City districts (Savage, 1961a, and Reid, 1960). Both high-level gravels and Recent stream gravels have been worked on a large scale in the Warren-Marshall district.

Placers in the Mount Pisgah (Caribou Mountain) district of Bonneville County were actively worked in the 1870's. Much of the placer material may be of glaciofluvial origin. It is mixed with colluvium and slopewash. Caribou City was one of the richest glaciofluvial deposits, but Iowa and McCoy Creeks, downstream from Caribou City yielded reworked placer gold. Timeup, City, and Barnes Creeks were also placered (Savage, 1961b, pp. 80-86).

GYPSUM AND ANHYDRITE


Gypsum and anhydrite occur in considerable quantities in many parts of the United States. The resources of both minerals are great,
although many of the deposits are in areas too far from consuming centers to be worked profitably. Gypsum is the more useful of the two minerals; about 3.3 million tons was produced in the United States in 1962. No comparable figures are available for anhydrite production, but probably no more than 200,000 tons was produced in 1962.

Gypsum is hydrated calcium sulfate (CaSO₄·2H₂O); when pure it contains 25.3 percent lime (CaO), 46.6 percent sulfur trioxide (SO₃), and 20.9 percent water. Anhydrite is calcium sulfate and when pure contains 41.19 percent CaO and 55.81 percent SO₃.

Most gypsum mined in the United States is calcined and used for plaster, which is used primarily in the manufacturer of wallboard, lath, and other prefabricated gypsum products. Uncalcined or raw gypsum is used in portland cement as a setting retarder and as an agricultural mineral. Anhydrite is used in the United States as an agricultural mineral and to a lesser extent as a retarder for portland cement.

Gypsum is found in three widely scattered areas in Idaho: in Bear Lake, Lemhi, and Washington Counties. None of these deposits are large and the only ones that have been worked are in Washington County, where no more than 5,000 tons of gypsum has been produced. Because of their small size and impure nature, little gypsum is expected to be produced from these deposits except for use locally as an agricultural mineral.

Gypsum occurs 3½ miles east of Montpelier, Bear Lake County, in rocks of the Wells Formation of Pennsylvanian age (fig. 24, No. 1). The gypsum is in bedded deposits about 1,000 feet above U.S. Highway 50 in SW₁/₄ SW₁/₄ sec. 32, T. 13 S., R. 45 E., and in the adjoining part of sec. 5, T. 13 S., R. 45 E. (Mansfield, 1927, pp. 348-349). The gypsum ranges in thickness from 4 feet in section 32 to 20 feet in section 5. It is white, sugary, and in places pure. An analysis of the 4-foot-thick bed in section 32 shows it to contain about 88 percent gypsum, although the thicker bed in section 5 is much less pure. The amount of gypsum present is not known, but the deposit is difficultly accessible and too small to be used except locally for a soil conditioner.

Small gypsum deposits have been reported in Lemhi County in the center part of sec. 10, T. 14 N., R. 28 E. (fig. 24, No. 2) (E.T. Ruppel, written communication, 1961). These deposits are each less than 100 feet in length, and range from 5 to 15 feet in width. The gypsum appears to have been deposited by hot springs in a fault zone that cuts Mississippian (?) limestone. The gypsum is mixed with calcareous fault gouge and breccia and is too impure to be used commercially.

The most extensive and accessible gypsum deposits in the State are in Washington County. These include deposits along the Snake River about 30 miles north of Weiser, a deposit of unknown extent near Mineral, and a reported occurrence at Iron Mountain.

The Snake River deposits are in sec. 7, T. 13 N., R. 7 W. (fig. 24, No. 3) (McDvitt, 1952, p. 8). The gypsum is just above river level at the bottom of a steep canyon, and is in beds that range from 12 to 15 feet in thickness in a sequence of about 1,000 feet of yellowish gray and green shales of Triassic age. The gypsum is yellow to buff, thin-bedded and medium-crystalline. Included in the deposits are pellets of green siliceous limestone in lenses and beds as much as 2 feet thick.
EXPLANATION

Gypsum occurrence

Gypsum deposit from which some production has been reported

Numbers refer to localities mentioned in text.

Figure 24.—Gypsum in Idaho.
Crystals and isolated masses of anhydrite are found within the gypsum at a depth of 5 feet below the surface, and in places the entire gypsum mass becomes anhydrite within 20 feet of the surface. Analysis of 25 pounds of material from this deposit shows 83.7 percent gypsum, 4.8 percent anhydrite, 2.1 percent calcite, and 9.4 percent insoluble and other constituents (McDivitt, 1952, p. 9).

A deposit has been reported south of Mineral in secs. 4 and 8, T. 14 N., R. 6 W. (fig. 24, No. 4) by Livingston (1935, p. 2). The gypsum is reported to be in two or more beds in an outcrop of limestone 100 feet wide. Although these beds are faulted, they can be traced for about 2½ miles along the outcrop.

Additional gypsum has been reported by Mr. Kenneth Steck, of Weiser (oral communication, 1957) at Iron Mountain, east of Mineral, in sec. 14, T. 14 N., R. 6 W. (fig. 24, No. 5). Nothing else is known of this occurrence.

Gypsum of mineralogical interest only has been reported by Shannon (1926, p. 459-460). These include selenite crystals associated with massive bornite in the south Peacock mine in the Seven Devils district, Adams County; small crystals of gypsum found with native sulfur east of Soda Springs, Caribou County; very thin veinlets of satin spar (?) gypsum in the oxidized ore and the adjacent wall rock in the Adler Creek area, Custer County; selenite in clay, Elmore County, near Mountain Home; and gypsum associated with soluble sulfates and nitrates in small amounts in soils, southeast of Homedale, Owyhee County.

IRON

(By R. R. Asher, Idaho Bureau of Mines and Geology, Moscow, Idaho)

Iron and steel are the backbone of American industry. In 1961, 99 million tons of iron ore were consumed in the United States as compared to 6 million tons of copper, lead, zinc, and aluminum (Holiday and Lewis, 1965). Adequate reserves of iron ore are considered essential to the safety and economic well-being of the country.

Most of the iron ore consumed is used for the manufacture of steel, cast iron, wrought iron, and numerous alloys of iron with other metals. The steel industry is the largest consumer. Aside from iron and steel manufacture there are other uses of iron ore, and though these are quantitatively small, they are important locally. Iron ore is used in paint pigments, cement, basic refractories, fluxing agents in nonferrous metal smelting, and as constituents of catalytic agents. Lump magnetite has been used as heavy aggregate in special concretes, shielding material for atomic reactors, heating gas manufacture and purification, and as a heavy medium for ore concentration in sink-float plants and jig beds. During World War II, magnetite was used as ship ballast (Reno, 1960).

The iron ore minerals are hematite, Fe₂O₃, containing 70 percent iron; magnetite, Fe₃O₄, containing 72.4 percent iron; limonite, a hydrous iron oxide of variable composition, containing 50 to 63 percent iron; and siderite, FeCO₃, containing 48.2 percent iron. Hematite and magnetite are by far the most important commercially. Under certain conditions the sinter obtained from the roasting of pyrite and
pyrrhotite (iron sulfide minerals) for the production of sulfuric acid can be marketed as iron ore (Hunting, 1966, p. 183-194).

Iron ores occur in various types of deposits including segregations of magnetite and titaniferous magnetite in igneous rocks; contact metamorphic deposits of magnetite and specular hematite; replacement deposits of hematite and magnetite; sedimentary deposits of hematite, limonite, and siderite; residual or lateritic deposits of hematite and limonite; oxidation or gossan deposits of limonite; and placer deposits of black sands containing magnetite (Hunting, 1966, p. 183-194).

Iron deposits range in age from Precambrian to Tertiary. The deposits are found in a variety of geologic environments and include those found in basins of sedimentation, those associated with eroded, deep-seated intrusives, and those located in areas of deep tropical weathering (Bateam, 1942, pp. 560-574). The largest production in the United States is derived from residual deposits in sedimentary and metamorphic iron formations of Precambrian age in the Lake Superior region of Minnesota, Michigan, and Wisconsin (Reno, 1960).

The quantity and quality of the ore is the principal economic factor in the evaluation of an iron deposit. Direct shipping ore generally contains 50 percent or more iron and until recently, in the past 15 to 20 years, only such high-grade deposits could be exploited. Increased demands for iron and steel and depletion of high-grade deposits in many parts of the world led to the development of improved methods of beneficiation and increased mining efficiency so that many marginal iron deposits, containing 20 to 45 percent iron, became economically significant. Many millions of tons of iron were added to the domestic reserves of the United States when the low-grade taconite beds of Minnesota, containing magnetite as the ore mineral, became economic through improved methods of beneficiation (Reno, 1960).

Specifications for iron ore classify the material on physical and chemical characteristics. Specifications are variable depending on the smelting process to be used. In general, minimums of silica, titanium, phosphorus, calcium, aluminum, and sulfur are specified. phosphorus is limited to 0.045 percent for ore to be used in the bessemer furnace. The low titanium content specified prohibits the use of all but a few titaniferous magnetite deposits (Reno, 1960).

In addition to the quantity and quality of the ore, factors such as the availability of fuel and flux, location of markets for the finished products, and transportation costs for raw materials and finished products are important considerations. These factors have determined the geographic distribution of the iron and steel industry in the United States. The areas of expansion of the industry in the Western United States have been determined by these factors as well. The availability of an export market to Japan has increased interest in the development of western iron deposits.

In consideration of an individual deposit, quality and quantity of the ore are the first consideration but mining method must also be considered. The emphasis on increased mining efficiency and the need for low-cost extraction methods make a deposit that can be mined by open pit methods more desirable than a deposit that must be mined by underground methods. The distance of the deposit from adequate transportation facilities, freight rates, and the location of the deposit in regard to markets for iron ore are also important economic factors.
In 1961 the U.S.S.R., the United States, and France were the leading producers of iron ore. World production of iron ore was 497 million tons. The U.S.S.R. produced 110 million tons; the United States, 71 million tons; and France, 65 million tons (Hollday and Lewis, 1961). Prior to 1958 the United States led the world in iron ore production. Of the total world production prior to World War II the United States produced 38 percent (Batenan, 1942, pp. 560-574).

The United States has led the world in steel production since about 1890. In 1961 the United States produced 29 million tons more steel than the U.S.S.R., which was second in world production (Hollday and Lewis, 1961).

There has been no significant production of iron ore in Idaho. In the late 1800's and early 1900's some iron ore was used as a flux in lead smelting, but no figures on the tonnage mined are available. Production of 33,000 tons of iron ore has been recorded from 1938 through 1962 from three mines, two in Washington County in the Iron Mountain and Cuddy Mountain districts, and one in Benewah County on McCleary Butte. The mines in Washington County have produced magnetite ore containing about 88 percent iron, which was beneficiated by wet and dry magnetic methods. In addition to the production mentioned above, there have been small shipments of magnetite sand produced in connection with rare earth dredging operations in Valley County. In 1961, Idaho, with a production of 12,000 tons, ranked among the lowest of the 21 producing States.

The iron ore mined in Idaho has been used in steel mills and cement plants in the Pacific Northwest. The magnetite sands recovered in dredging operations have been marketed for use as heavy aggregate in concrete (Fulkerson and others, 1961, p. 382).

Because of increasing interest in western iron deposits, the Idaho Bureau of Mines and Geology in cooperation with the U.S. Bureau of Mines undertook a project to evaluate the iron resources of Idaho. An unpublished manuscript prepared in 1961 by A. E. Soregaroli and D. W. Young of the Idaho Bureau of Mines and Geology staff describing the geology of the various deposits has been used in the tabulation and discussion of individual deposits that follow, but information concerning grade, tonnage, or probable mining method of the various deposits is not available.

Table 6 describes briefly the more important iron-bearing districts and deposits in the State. Hematite and magnetite are the most important ore minerals, although limonite derived from siderite is locally important in northern Idaho. Replacement veins and irregular bodies are the most widespread type of deposit but contact metamorphic deposits are important, sedimentary deposits are present, and possibly one deposit formed by magmatic segregation is represented.

The number preceding a deposit in the tabulation refers to the corresponding number in the deposit on figure 25.

According to D. C. Holt, U.S. Bureau of Mines, Spokane, Wash. (personal communication) there are an estimated 12 million tons of iron ore in Idaho containing 35 to 64 percent iron. This estimate is based on geologic evaluations and sampling of known iron ore deposits and includes a great deal of inferred ore. The estimated tonnage is distributed in four general areas: Lemhi, Custer, and Butte Counties, 8 million tons; Clearwater and Idaho Counties, 6 million tons; Wash-
<table>
<thead>
<tr>
<th>Deposit</th>
<th>Location</th>
<th>Ore</th>
<th>Type of deposit</th>
<th>Remarks</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mackay area, Chubb County</td>
<td>About 6 miles west-southwest of Mackay.</td>
<td>Magnesite with limonite, some associated copper.</td>
<td>Steeply dipping contact metamorphic deposits near contact of Tertiary metavolcanics andesite. Related to copper deposits of Mackay region.</td>
<td>Potential for development of substantial tonnage of high-grade ore. Several small, low-grade deposits may be found.</td>
<td>Wells and Full. 1960, pp. 126-130; Foreman, R. H., and Young; Unpublished, J. B., 1977. Sorensen and Young.</td>
</tr>
<tr>
<td>Deposit</td>
<td>Location</td>
<td>Ore</td>
<td>Type of deposit</td>
<td>Remarks</td>
<td>References</td>
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</tr>
<tr>
<td>7. Blaklead deposit</td>
<td>Clearwater County, about 15 miles north of Lewis-Clark</td>
<td>Magnetite, minor copper.</td>
<td>Contact-metamorphic; ore is located in a block of limestone completely</td>
<td>Occurrences small, scattered, and of</td>
<td>Anderson, 1938, p. 68;</td>
</tr>
<tr>
<td></td>
<td>County, about 15 miles north of Lewis-Clark</td>
<td></td>
<td>surrounded by intrusives rocks of the Idaho batholith. Mineralization</td>
<td>of doubtful economic value. Prospecting for similar geologic conditions</td>
<td>Stegman and Young, 1</td>
</tr>
<tr>
<td></td>
<td>County, about 15 miles north of Lewis-Clark</td>
<td></td>
<td>occurs along contacts of Granite or Plutonic at Blackfoot Mountain</td>
<td>might discover larger, more valuable deposits.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>County, about 15 miles north of Lewis-Clark</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Clearwater district</td>
<td>Clearwater and Idaho Counties.</td>
<td>Magnetite partially</td>
<td>Replacement veins in metamorphic</td>
<td>Occurrences appear to be discontinuous</td>
<td>Macklin, 1987; Stegman-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>altered to limonite,</td>
<td>limestones, quartzites, and schists; veins occur near intrusive contacts of granite</td>
<td>and Young, 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>associated with</td>
<td>or gneiss along border zones of Idaho batholith. Short veins of limited</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>fine-grained minerals</td>
<td>length, 10 feet wide and small ore bodies.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Limonite occurrences</td>
<td>Lemhi, Boise, and Ada Counties.</td>
<td>Hematite and limonite</td>
<td>Replacement and fracture filling in</td>
<td></td>
<td>Sorensen and Young, 1;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>derived from the</td>
<td>Belt Series argillites and quartzites; steeply dipping veins 1 to 15 feet wide;</td>
<td></td>
<td>Tullis, 1944, p. 182.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>alteration of siderite.</td>
<td>a few of the veins are of substantial length, up to 300 feet; most are exposed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>for short distances of 150 to 225 feet.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MINERAL AND WATER RESOURCES OF IDAHO
<table>
<thead>
<tr>
<th>Deposit</th>
<th>Location</th>
<th>Description</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daisy deposit</td>
<td>Eastern Latah County, 3/4 mile west of Eddy</td>
<td>Limonite in cemented serpentine sandstone</td>
<td>Bergaroli and Young&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rotating Creek deposit</td>
<td>About 7 miles northeast of Potlatch, northern Latah County on the west slope of Gold Hill</td>
<td>Magnetite, minor alteration to limonite</td>
<td>Do&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hermesite replacement deposit</td>
<td>Lechil Range, northern Burt County</td>
<td>Hematite with some associated magnetite and goethite oxide</td>
<td>Bergaroli and Young&lt;sup&gt;1&lt;/sup&gt;, Uniyal and others, 1965, p. 196</td>
</tr>
<tr>
<td>Weepe deposit</td>
<td>Southern Clearwater County, near Weepe, 18 miles west of Greer</td>
<td>Limonite or bog-iron ore</td>
<td>McDonald, 1906; Bergaroli and Young&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup> In preparation.
Iron Ore Areas and Deposits

1. Mackay
2. Summit Lemhi Range
3. McConn Creek
4. Lemhi County Area
5. Cuddy Mountain district
6. Iron Mountain district
7. Blacklead deposit
8. Clearwater district
9. Latah-Benewah-Shoshone County area
10. Deary deposit
11. Hoteling Creek
12. Lemhi Range
13. Weippe deposit

Numbers correspond to deposits listed in table 6.

Figure 25.—Iron ore areas and deposits in Idaho.
Limestone and Related Materials

(By C. N. Savage, Idaho Bureau of Mines and Geology, Moscow, Idaho)

Lime-bearing rock production in the United States annually exceeds 450 million short tons. This is more than any metallic mineral produced and is exceeded in volume only by coal, sand, and gravel, and by water. There are virtually no substitutes for lime products in chemical and industrial usage.

Products manufactured from calcium and magnesium limestones are far too numerous to list here; for lime alone, there are over 7,000 uses (Lamar and Willman, 1938). Specific limestone uses, however, fall under the general categories: (1) calcium and calcium compounds, (2) cement and lime, and (3) dimension, crushed, and broken stone.

The largest volume of lime rock is used as crushed and broken stone for road aggregate and railroad ballast; significant amounts are also used in the manufacture of cement and lime, in the smelting of metals, and in agriculture.

In 1962, over 460 million tons of limestone and dolomite were produced with a value of about $650 million (Cotter and Jensen, 1963). Cement and lime products valued at approximately $1.3 billion were manufactured from some 192 million tons of this limestone (U.S. Bureau of Mines, 1963).

Limestones, including dolomitic rock, are composed of variable amounts of calcium-, magnesium-, manganese-, and iron-carbonates. These materials, originating from chemical precipitation and biological reactions, are deposited as sediments chiefly in lakes, shallow seas, streams, or springs. When subjected to further natural changes, particularly pressure and temperature variations, lime-bearing rocks may become more crystalline.

For most purposes, and particularly where chemical composition is not important, moderately hard, massive limestone or magnesian limestone is desirable. For dimension stone, workability, color, texture, and hardness are the most important considerations. Attractive colors, banding (t travertine or cave deposits), or the presence of shell structures (coquina), and the quality of taking a high polish (marble) may result in premium building- or trim-stone. For use in chemical,
metallurgical, and most nonconstruction uses, the calcium content, calcium to magnesium ratio, and the absence of impurities are critical, as shown on table 7.

**Table 7.—Commercial limestone classification**

<table>
<thead>
<tr>
<th>Rock type</th>
<th>Principal minerals</th>
<th>Ultradolomite percent</th>
<th>Range of principal compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calcite CaCO₃</td>
<td>Dolomite Ca₄MgCO₃</td>
<td>Magnesium carbonate MgCO₃</td>
</tr>
<tr>
<td>Upper-limestone</td>
<td>95-100</td>
<td>0-10</td>
<td>2-3</td>
</tr>
<tr>
<td>High-calcium limestone</td>
<td>85-95</td>
<td>0-10</td>
<td>2-3</td>
</tr>
<tr>
<td>Limestone</td>
<td>65-75</td>
<td>0-10</td>
<td>2-3</td>
</tr>
<tr>
<td>Magnesium or dolomitic limestones</td>
<td>45-55</td>
<td>0-10</td>
<td>2-3</td>
</tr>
<tr>
<td>High-magnesian limestone or dolol</td>
<td>35-50</td>
<td>0-10</td>
<td>2-3</td>
</tr>
</tbody>
</table>

General specifications for various uses are listed below (percent): ¹

Cement:
- Upper limits: SiO₂, 17 percent; Al₂O₃, 5 percent; Fe₂O₃, 3 percent; MgO, 5 percent; K₂O + Na₂O, 1 percent; P₂O₅, 1 percent.
- Lower limits: CaCO₃, 72 percent; SiO₂ + Fe₂O₃, 20 percent.

Nordz.—May use blast furnace slag, or shale for source of SiO₂ and Al₂O₃ additives. CaSO₄ 2 to 3 percent added to clinker as retarder before grinding; source may be gypsum.

Flux, etc.:
- Bessemer—Upper limits: S, 0.5 percent; P₂O₅, 0.01 percent.
- Blast furnace charge—Upper limit: MgCO₃, 20 to 50 percent; Al₂O₃ + Fe₂O₃, 1 percent; SiO₂, 3 to 4 percent.
- Pitching and lining—Lower limits: MgCO₃, 35 percent.
- Open hearth—Upper limits: MgCO₃, 20 percent; SiO₂, 1 percent; S, 1 percent; P₂O₅, 1 percent.
- Glass: High-calcium, low calcium or magnesian limestone low in Fe₂O₃ and P₂O₅.
- Calcium carbide: Highest purity CaCO₃, 97 percent; upper limits SiO₂, 1.5 percent; Al₂O₃ and Fe₂O₃, 0.5 percent; MgO, 0.5 percent; P₂O₅, 0.01 percent.
- Nonhydraulic lenses: ¹
- Upper limits—High-calcium, MgCO₃, 6 percent; low magnesian, CaCO₃, 68 to 86 percent; high magnesian, CaCO₃, 74 to 72 percent.
- Lower limits—High-calcium, CaCO₃, 91 percent; low magnesian, MgCO₃, 5 to 29 percent; high magnesian, MgCO₃, 28 to 46 percent.
- Hydraulie limestones: Low—Carbonates, 91 to 97 percent; other, ³ 3 to 9 percent.
- Moderate—Carbonates, 84 to 91 percent; other, ³ 9 to 16 percent. High—Car- bonates, 77 to 84 percent; other, ³ 16 to 25 percent.

"Natural cement rock" is limestone that contains the proper proportions of clay, silica, and iron impurities so that upon burning in a kiln portland cement is produced. Cement may be produced also by adding these materials to limestone and several kinds of rocks, or commonly a shale rock of the right composition will serve as a single additive. Relatively high silica content is permissible for cement and some other products, but magnesium oxide content usually should be less than 5 percent for most limestone uses (table 7).

Dolomitic or magnesian limestones or high magnesium limestones (dolomites) may be used to manufacture magnesium metal, high-magnesian lime, magnesite compounds, or refractories. Both mag-

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¹ Information from several published sources, including Illinois State Geological Survey Report Inv. 49.
² Less than 3 other constituents.
³ Principally SiO₂ + Al₂O₃.
esian limestone and limestone, when ground to the proper size (40 percent below 60 mesh screen), are now being used extensively as natural soil conditioners in place of prepared lime.

The potential value of lime-bearing rock is determined by its chemical and physical characteristics and its accessibility and proximity to suitable markets. Any rock tentatively selected for commercial use must be carefully checked against the desired specifications for a raw material. The amount available is also an important factor. For example, a cement plant should have a limestone deposit that is large enough to last at least 20 years or more. Even a relatively small cement plant with an 889,000-barrel per year capacity will require about 48 million cubic feet of limestone to insure 20 years of operation. In addition, about 16 million cubic feet of shale for additive would be needed in proximity to the plant. A measure of the amount of limestone required in the lime industry can be obtained from the fact that approximately 1.8 tons of limestone (55 percent CaO) are required to produce about 1 ton of quicklime. Thus the availability of raw materials must be balanced against the desired production rate and life of the plant.

Deposits of commercial-grade limestone and magnesian limestone are abundant in (1) south, southeast, and east-central Idaho; (2) along the Snake River north of Weiser and south of Lewiston; (3) along portions of the Clearwater River and its tributaries; and (4) adjacent to Pend Oreille Lake in the Idaho Panhandle. Other widely distributed lime-bearing rocks are found in different parts of the State (fig. 28).

The ages of Idaho limestones and magnesian limestones range from some of the oldest to some of the youngest rock formations in the State. A few of the potentially commercial formations will be briefly reviewed. It must be remembered, however, that the physical and chemical characteristics of any limestone may vary considerably from place to place.

In north Idaho, some formations of the Precambrian Belt series have been called "limestones." Some facies may approach the composition of a natural cement rock; however, locally, the principal liny rock, the Wallace formation, carries insufficient calcium oxide to qualify as a limestone (table 7). Both the formation and the Striped Peak formation may occur locally as calcareous (liny) and magnesian (dolomitic) siltstones and argillites. Silica and alkalies in these rocks tend to be too high, in most instances, to permit their commercial use, although reportedly some of the rock has been used as fluxstone.

In south Idaho, certain facies of the Albion Range group of Precambrian age rank as high-calcium limestone. Several small quarries in the Albion Range are evidence of the past commercial use of this rock.

Most of the lower Paleozoic rocks (Cambrian through Devonian) in southeastern and east-central Idaho tend to be very siliceous, magnesian (dolomitic) limestones. High-calcium limestones are rare, but some facies may approximate the composition of common limestone locally.

Upper Paleozoic rocks, particularly the Madison Limestone of Mississippian age; the White Knob Limestone, of Mississippian to Per-
EXPLANATION

Limestone Deposits

Quaternary and Tertiary
•• Travertine, tufa, fine-grained limestone

Mesozoic
• General limestone deposits (principally Triassic)

Paleozoic
•• Undifferentiated (includes limestone and magnesian limestone)

○ Carboniferous (principally high-calcium limestone)

•• Cambrian and Precambrian(?limestone and magnesian limestone

Limestone Production
○ Active cement plant
■ Lime production
▲ Quarry; active or abandoned

Figure 26.—Limestone in Idaho.
mian age; and the lower part of the Wells Formation (Darwin, Amsden, White Knob), of Pennsylvanian and Permian age, are generally some of the most widespread and purest limestones in Idaho. Of these, the Brazer (White Knob) appears to constitute the most extensive reserve of high-calcium limestone. The Brazer, Madison, White Knob, and Wells, however, all have sandstone and shale horizons. Also, these formations are locally rich in chert (silica) nodules and layers making them unfit for commercial use.

In north Idaho, the Cambrian Lakeview Limestone, adjacent to Pend Oreille Lake, ranges from common limestone to high-magnesian limestone (dolomite) and marble. These rocks have been exploited in the past for both cement and lime products. The Lakeview Limestone is readily accessible, but its wide range of composition would require careful quality control during production of the rock. This formation might provide agricultural limestone for north Idaho.

Probably of equal importance as the Paleozoic formations is the Triassic limestone in western Idaho along the Snake River and in Nez Perce, Lewis, and Clearwater Counties. This rock ranges from limestone through high-calcium limestone, and includes supercalcium limestone facies. Because of its physical qualities (color and hardness) some of this Triassic rock may have possibilities for use in commercial building, particularly as chips for terrazzo.

In southeast Idaho, Triassic lime-bearing rock is essentially noncommercial in quality.

The Jurassic Twin Creek Limestone occurs widely distributed in southwest Idaho. It tends to be somewhat arenaceous and argillaceous (silt- and clay-rich), but analyses suggest that locally much of this formation would be suitable for natural cement rock.

Cretaceous formations in southeast Idaho—for example, the Peterson, Draney, and certain facies of the Wayan—are very limy. These are dense fresh-water sediments that are locally magnesian limestones.

The Salt Lake Formation of Tertiary age contains thin beds of fine-grained limestone in southeast Idaho. Locally low in magnesium oxide, some of this rock occurs along Medicine Lodge Creek in Clark County. Travertine (banded limestone), in the same general area and of the same age, approaches a high-calcium limestone.

Travertine composed of supercalcium limestone occurs in the Fall Creek area in Bonneville County. Similar deposits of moderately large extent occur at other localities in southeast Idaho; for example, in the region southeast of Bruneau near the Bruneau River.

In the past, at least 34 out of 44 Idaho counties have produced some commercial products from limestone or magnesium limestone. Available statistics on past production, however, are inadequate because production is limited to a few enterprises and production figures are considered confidential.

Lime-bearing rock from this State has been used principally for agricultural stone, flux, cement rock, and lime (including the paper and sugar industries). Small quantities probably have been used in construction—for dimension stone and broken stone—but there appears to be no record of this use. More recently, the principal consumption of limestone in Idaho has been in the cement industry.

Two cement plants have operated within the State. One at Orofino in Clearwater County was closed, reportedly because of litigation.
The other, the plant of the Idaho Portland Cement Co., with a reported capacity of 949,000 barrels of cement per year, is in operation at Inkom in Bannock County. The Inkom plant operates at about 85 percent of capacity and utilizes approximately 178,000 short tons of limestone, from which it produces approximately 788,000 barrels of cement per year. This is a small plant by comparison to a plant in Alabama, which has a capacity of about 55 million barrels of cement per year.

Lime is used in the sugar industry, and much of it is produced by the sugar refiners for their own use. This production of "captive" lime has only recently been included in the U.S. Bureau of Mines Minerals Yearbook. Although locally available, much of the raw limestone used for this purpose has been shipped in from adjacent States. In 1961, 66,750 short tons of lime were produced, requiring approximately 64,000 short tons of limestone. In 1962, production increased over 44 percent to 67,560 tons of lime, requiring about 122,000 tons of limestone.

In the past, the papermill at Lewiston has used about 8,500 short tons of Idaho limestone per year; however, this figure has probably been reduced because of technological changes involving reprocessing of sludge and recycling of lime.

Although large quantities of reasonably accessible lime-bearing rock are present in Idaho, the outlook for increased consumption is poor because of the absence of large local markets. Thus, no major expansion is expected unless new limestone-consuming industries should appear in the region. Any future widespread use of Idaho limestone must be accompanied by better quality controls by potential producers in order to meet a variety of possible specifications.

There is no evidence to suggest that additional cement plants are needed in the region. Therefore, the use of limestone in Idaho should increase only at a moderate rate. However, gradually increasing demand for cement commodities may increase production at the existing Idaho plant.

According to a study made in 1962 by Williams and Roby (private report), additional markets for limestone exist in the Pacific Northwest. Some of these markets could be supplied economically by north Idaho rock. The available markets and current prices cited per short ton of stone, for the different uses, were cited as follows: sugar production, $2.75; papermaking, $3.71; smelter flux, $1.40; agricultural stone, $3.30; and ornamental stone; $15. Currently the Nez Perce Indian Tribe is trying to get quarries in Lewis County into production.

Research by the University of Idaho Department of Agriculture may indicate an increased need for agricultural limestone in north Idaho.

MANGANESE


Manganese is indispensable in the production of steel and is thus essential to our Nation’s economy. The chief value of manganese is as a desulfurizer; and more than 13 pounds are consumed in the pro-
duction of each ton of steel. Some is also used as an alloying metal in high-strength steels. More than 95 percent of the manganese consumed in the United States is for metallurgical purposes; the remainder is used, generally as oxide ore or concentrate, as the depolarizer in dry-cell batteries, in the manufacture of manganese chemicals, as a drying agent in paints and varnishes, as a pigment or to neutralize the effects of iron in glassmaking and ceramics, and in the leaching of uranium ores.

Manganese occurs in a variety of minerals in the earth's crust, but insofar as ore deposits are concerned only two types are important: (1) the numerous manganese oxide minerals, and (2) the manganese carbonate, rhodochrosite. Some manganese deposits are sedimentary in origin; others are in veins or replacement deposits that formed from hydrothermal solutions or less commonly, from hot spring waters. Later action by ground water has modified many deposits of both types by converting rhodochrosite and manganese silicates to manganese oxide minerals, changing original oxide minerals to different oxide minerals, and enriching or concentrating manganese.

Most of the manganese resources of the United States are in low-grade sedimentary deposits which are not economical to mine at the present time. Domestic reserves of high-grade manganese ore are limited, and the United States therefore relies heavily on imported manganese ores to supply its annual needs of about 2 million tons. The largest domestic production of high-grade ores and concentrates (+53 percent manganese) in recent years occurred in the 1950's under the stimulus of Government purchasing at premium prices for stockpiling. Annual domestic production in 1956, 1957, and 1958 exceeded 300,000 tons, but after Government purchasing ceased, domestic production declined sharply and in 1962 amounted to only 24,758 tons, most of which came from Montana.

Idaho is not a large manganese-producing State. According to Idaho Bureau of Mines and Geology Bulletin 18 (p. 68), the State has yielded a total of approximately only 12,000 tons of manganese ore, which is less than 1 percent of our annual consumption since the first recorded production in 1926. No manganese has been produced in Idaho since the Government stopped buying ore for stockpiling in the late 1950's. Most of Idaho's manganese ore has come from two areas—one near Cleveland in Franklin County (formerly part of Bannock County) (fig. 27, No. 1) and the other at Lava Hot Springs in Bannock County (No. 2).

Manganese was first found in the Cleveland area in 1922 (Hewett, 1923). There, beds as thick as 4 feet and irregular zones of soft, earthy manganese oxides with or without hard high-grade manganese oxide nodules occur in unconsolidated clay, sand, and marl several hundred feet above the floor of the valley of the Bear River (Hewett, 1928; Hewett and others, 1928, p. 204). The sediments accumulated in lakes that filled the valley in early Pleistocene time. Some manganese oxides also occur on the uneven surface of the older rocks at the base of the unconsolidated sediments. Ore from the deposits contained 30 to 49 percent manganese. The presence nearby of manganese-bearing travertine cones suggested to Hewett and Fleischer (1960, p. 37) that the manganese in these deposits was derived from hot spring waters. Vincent and Holmes (1929) have
EXPLANATION

 Deposits related to hot springs
 Manganiferous base or precious metal deposits
 Manganiferous quartz veins

1. Cleveland area
2. Lava Hot Springs
3. Burrit Creek area
4. Lava Creek district

FIGURE 27.—Manganese in Idaho.
demonstrated that the ores from the Cleveland area are amenable to beneficiation by several methods; however, the deposits are apparently rather small (Hubbard, 1935, p. 36).

Sporadic production of manganese has come from irregular deposits of manganese oxide minerals that occur in brecciated dolomite or limestone 450 feet above the Portneuf River near Lava Hot Springs (No. 2). These deposits are also in an area of hot springs activity which led Hewett and others (1963, p. 25) to conclude that manganese derived from hot spring waters was deposited in the breccia when the bed of the river was at the altitude of the deposits.

Several deposits of manganese oxides occur in an area about 15 miles long east of the Snake River in the vicinity of Sturgill Creek in northwestern Washington County (No. 3). Although these were some of the earliest known manganese deposits in the State, having been described by Livingston in 1919, they have yielded little ore. The latest recorded production from the area was in the mid-1950's for sale to the Government stockpile. The rocks in the area are mainly quartzite, schist, slate, and some marble. Manganese and iron oxides occur in quartz veins as wide as 15 feet that parallel bedding in slate or schist; only a few veins transect bedding. The veins contain 2 to 20 percent manganese and 1 to 20 percent iron (Livingston, 1919) but apparently no other metals. Livingston (1919, p. 35) postulates that the manganese oxides were derived from the weathering of rhodonite or rhodochrosite or both.

Many base and precious metal deposits of the State contain primary manganese-bearing minerals, mainly rhodochrosite or manganiferous siderite, which, upon near-surface oxidation, yield a black manganese oxide stain and in some places pockets enriched in manganese. Many occurrences of this type are shown in figure 27, but only the Lava Creek district (No. 4) has produced ore in recent years; that was in the mid-1950's for sale to the Government stockpile. For the most part, the grade of deposits of this type is low, and they are too small to have yielded much ore or to hold much promise for future production.

Deposits near Paris in southwestern Bear Lake County consist of pockets of manganese oxide minerals in conglomerate of early Tertiary age and of pebbles in the conglomerate with a coating of manganese oxides (Mainsfield, 1927, p. 349). Except that the host rocks are older, these occurrences are analogous to those at Cleveland, and they may also have been derived from hot springs water. However, there are base metal deposits nearby, and the possibility that the manganese was derived from the hydrothermal solutions that deposited the base metals cannot be ruled out.

Known reserves of manganese ore in Idaho are probably small (Hubbard, 1955, p. 37), and the possibility of significant production in the near future is slight.

MERCURY

(By E. H. Bailey, U.S. Geological Survey, Menlo Park, Calif.)

Mercury (quicksilver) is a heavy silvery metal having the unique property of being a liquid at room temperature. It also has several
other unusual physical and chemical properties—such as amalgamating with other metals, expanding uniformly on heating, and forming exceedingly poisonous compounds—that make it the "metal of a thousand uses." Some of its better known uses are in thermometers, in silver alloy dental fillings, or in ultraviolet lights. Much more, however, is used in various kinds of electrical apparatus, in fungicides and bactericides, in medicines, and in antifouling paint. In most cases the quantity used for a single piece of equipment or application is small, but large amounts are required, though not used up, in mercury boilers or caustic soda plants. About 2,000 tons is required annually by the U.S. economy. In the mercury industry this quantity would be referred to as about 55,000 flasks, as the worldwide unit of trade is a steel flask containing 76 pounds of the liquid metal. Domestic mines have in recent years yielded annually about 50,000 flasks, or half of the domestic consumption. The mercury deposits in Idaho, like many in other States, are generally mined only when the price per flask is unusually great; and owing to low prices, they have not been active since 1961.

The value of a flask of mercury is normally controlled by the price established by production from the Almaden mine in Spain or the Monte Amiata district in Italy. During war periods the price in the United States increases because of the difficulty of obtaining mercury from overseas. In both World Wars the United States became self-sufficient after the brief period required to get the domestic mines in operation. An initial, but small, recovery of mercury was made in Idaho during World War I. During the period of high prices brought about by World War II, Idaho produced in 1944–45 nearly 15,000 flasks of mercury; and from 1951, when the price rose owing to the Korean war, until 1961, an additional 16,000 flasks was recovered. The total production of Idaho through 1962 is 31,000 flasks, which is roughly 1 percent of the total U.S. production.

Cinnabar, the bright red mercuric sulfide, is the chief ore mineral for mercury and the only one found in commercial amounts in Idaho. Because cinnabar is normally unaffected by weathering, is heavier than most minerals, and is brightly colored, it is especially amenable to panning. However, in some siliceous rocks the cinnabar tends to be very finely divided and tightly held so that it cannot be concentrated by panning; and, furthermore, where such rocks are exposed to sunlight, as in outcrops, the cinnabar darkens rapidly to a blue-black color. Mercury ores of this type, some of which occur in Idaho, are not easily detected unless pieces are broken open to reveal their telltale pink color.

Mercury deposits are formed by the deposition of the ore minerals from aqueous solutions at shallow depths in the earth and at temperatures that are lower than for most other metallic ores. In at least one place in Idaho, at Boiling Springs in Valley County, mercury sulfide is probably now being deposited from hot water at the earth's surface (White, 1965, pp. 124–125). Because of their shallow environment of deposition, mercury deposits are likely to be found in almost any kind of rock, but they are also likely to be more erratic in distribution and therefore more difficult to develop than are most other metallic deposits.

Two mercury mines have shared equally in producing about 99 percent of the mercury recovered in Idaho. One of these is the Hermes
mine in Valley County near Yellow Pine and the other is the Idaho-Almaden mine in Washington County near Weiser (fig. 28). Minor production has been made from prospects in Cassia and Power Counties and other occurrences of mercury minerals have been noted in Blaine and Custer Counties (Hubbard, 1955, p. 59).

The Hermes deposit was discovered in 1902, but very little mercury was recovered from it until World War II. In 1941 the United Mercury Mines Co., which had held the property for many years, merged with the Bonanza Mines Co. and erected a plant containing two 75-ton rotary furnaces. Production began in January 1942 and continued into 1948, during which time about 10,700 flasks of mercury was recovered. From 1951–54 the mine was operated at a reduced rate, and in 1956 it was purchased by Holly Minerals Corp., which worked it until the plant was destroyed by fire in August 1956. In 1958 and early 1959, after installing a 200-ton-a-day flotation plant, leaching tanks, and electrolytic deposition equipment, an additional few hundred flasks of mercury was produced.

The Hermes ore bodies are within a roof pendants of Paleozoic (?) sedimentary rocks near the center of the Idaho batholith. The pendant rocks, consisting of steeply dipping quartzite and dolomitic limestone beds, are cut by dikes of splitite and granite, which are not genetically related to the ore. The ore bodies occur where cinnabar—accompanied by some stibnite, realgar, and orpiment—either replaces or fills fractures in the altered dolomitic limestone. They have been mined over a strike length of 300 feet, a width of 40 feet, and through a vertical range of about 150 feet.

The Fern deposit, which is a mile south of the Hermes mine but on the same structure, is believed to have yielded a little mercury during the early development of the district. The nearby Vermillion property is credited with a small production in 1927.

The Idaho-Almaden deposit, 11 miles east of Weiser, was apparently first discovered by a shepherd about 1936 (Ross, 1966, p. 79). Although the ore is scattered over a wide area on and near the surface, it remained unnoticed until this late date because of darkening of the cinnabar through exposure to the sun. The deposit was first mined from 1938 to 1942, yielding nearly 4,000 flasks of mercury. It remained idle from 1943 to 1954 when extensive exploration was begun by Rare Metals Corp. In 1955, after a large tonnage of low-grade ore had been developed, a 150-ton rotary furnace plant was installed (Lickes, 1957). From September 1955 through 1961, when this operation terminated, the mine was one of the major domestic producers, yielding during this period nearly 12,000 flasks of mercury.

The mine consists of several large openpits at the crest of a ridge known as Nutmeg Mountain. The mountain is composed of broadly arched beds of feldspathic sandstone and shale comprising a part of the Payette Formation of Miocene and Pliocene (?) age. Ore bodies are in flat-lying parts of this sequence that have been converted to rock composed largely of chalcedony, or locally opal, and termed "opalite." Cinnabar is in part minutely disseminated through the opalite, coloring it pink, and in part concentrated as coarser grains in veins. Nearly all of the ore was comparatively low in grade, and to maintain a furnace feed averaging about 3 pounds to the ton required extensive sampling by drilling in advance of mining, followed by selective mining.
Figure 28.—Mercury in Idaho.
In Washington County, north and west of the Idaho-Almaden mine, there are three other areas of mercury mineralization that have merit.

On the Consolidated property, a few miles due north of the Idaho-Almaden mine, cinnabar-bearing opalized sandstone much like that of Nutmeg Mountain has been prospected by an adit. At the John Coats prospect, 8 miles northeast of Weiser, a cinnabar-bearing opalized zone in sandstone and shale was prospected by pits and bulldozer cuts in 1941. Also in 1941, at the Virginia L group of five claims, on the east side of the Snake River about 25 miles north of Weiser, a short adit was driven to explore a zone containing narrow veinlets of cinnabar in phyllite.

At the Lucky Boy group, in northwestern Owyhee County, a little cinnabar occurs with opal along fractures in siliceous flows and tuffs. In the Black Pine Mountains, in southeastern Cassia County, cinnabar has been found in several places. At the Valentine mine, a little mercury has been recovered from a deposit at the top of a limestone bed and beneath shale. The cinnabar occurred in leached rock, coating barite and quartz, and it was coated by scorodite. One flask was recovered here about 20 years ago.

At the Juniper Hill mine, in Power County about 15 miles east of American Falls, a short shaft explores a fault zone in limestone in which a small pod of high-grade cinnabar ore was found. Cinnabar from this pod, and from a few scattered calcite veinlets, was retorted in the 1930's yielding one flask of mercury.

The other places shown on Figure 28 indicate occurrences of cinnabar in ores mined or prospected for other metals. Cinnabar is fairly abundant in the concentrates of the Ruby placer, 4 miles south of Burgdorf in Idaho County; and it also occurs with native mercury, monazite, and zircon in the Stanley Creek placer in Custer County. In Blaine County cinnabar and native mercury occur with pyrite, sphalerite, barite, and quartz in the Dockwell Tunnel of the Bonnie mine.

Some mercury is found with smelter stack products at the Bunker Hill smelter, presumably derived from ores of the Coeur d'Alene district. The amount is too small to be of economic importance.

The ore deposits of neither the Hermes nor Idaho-Almaden mines are exhausted of mercury-bearing rock, but unusually high prices for mercury will probably be required to stimulate their further exploitation. The other deposits mentioned herein have not come up to their developers' expectations, but they indicate mercury is widespread in southern Idaho and suggest still other exploitable deposits await discovery.

MICA AND ASSOCIATED PEGMATITE MINERALS


Mica, feldspar, quartz, and beryl are the principal pegmatite minerals that have any immediate economic importance in Idaho. Columbite is of minor potential importance, and other minerals such as tourmaline, garnet, apatite, and various phosphate and uranium minerals are of only mineralogical interest. Since 1888, when pegmatite mining began in Idaho, 2,200 tons of mica, a few tons of beryl, and a
ton or less of columbite have been produced with a total value of nearly $1 million. Most of the mica and beryl came from the Muscovite mine, Latah County. The columbite is from the Columbite mine in Boise County. Smaller deposits have been prospected in 10 other counties (fig. 29). Reserves of mica, beryl, and columbite are not large, and none of these minerals were mined in 1963. Resources of feldspar, however, may be large, and although none has been mined commercially in Idaho to date, feldspar probably has the largest potential for future production of any of the pegmatite minerals. In this chapter, emphasis is placed on feldspar and mica; beryl, columbite, and quartz are described in separate chapters.

Pegmatites are coarsely crystalline igneous rocks generally found as lenticular or tabular bodies in metamorphic rocks or associated with large granite intrusions. Individual mineral grains range in length from an inch or less to many feet, and a large variation in grain size within a single pegmatite body is common. Pegmatites are composed mostly of feldspar, quartz, and mica. The most common accessory minerals are garnet, tourmaline, apatite, and beryl; many other less common pegmatite minerals are rich in caesium, lithium, molybdenum, niobium, rubidium, scandium, tantalum, thorium, tin, tungsten, uranium, yttrium, zirconium, and the rare earths. The many rare and unusual minerals found in some pegmatites make them favorite collecting sites for mineralogists and rockhounds.

In many pegmatites, the minerals are more or less evenly distributed throughout, but in others the minerals are segregated into units. These units or zones can sometimes be selectively mined to recover certain minerals by hand sorting. Recent studies have increased the general knowledge of the occurrence, origin, and economic importance of pegmatite deposits (Cameron and others, 1949; Jahns, 1955), and studies made during World War II have helped improve techniques of prospecting and exploration (Stoll, 1950; Jahns and others, 1952; Page and others, 1953; Cameron and others, 1954; Norton and Page, 1958).

The principal mica minerals are muscovite (white mica), biotite (black mica), and phlogopite (amber mica). All have a perfect basal cleavage and form crystals that can be split into thin sheets having various degrees of transparency, toughness, flexibility, and elasticity. The micas are common minerals, but only muscovite is mined in the United States.

Two types of mica are sold: sheet mica, which must be relatively flat, free from most defects, and large enough so that it can be cut into specified shapes (Jahns and Lancaster, 1950); and scrap mica, which is all mica that does not meet sheet mica specifications and is generally ground to a powder. Sheet muscovite is an important insulating material in the electronic and electrical industries. Built-up micas made from very thin sheets and reconstituted mica made from scrap can be substituted for larger sheet mica for some uses (Skow, 1962, p. 11). The principal use of scrap mica is in the roofing, wall-paper, rubber, paint, and other industries.

Sheet-quality muscovite is obtained from the large crystals scattered throughout unzoned pegmatites or concentrated in certain units of zoned pegmatites. The value of sheet mica depends on the size, structure, and quality of the natural crystals. The manner in which
Figure 29.—Deposits of mica, feldspar, and associated pegmatite minerals in Idaho.
the crystals are obtained by mining and the care and skill of preparation are also important factors affecting the value. The erratic nature of most mica concentrations, the great range of quality of material, the expense of mining, and the large amount of hand labor needed for preparation limit sheet mica mining to periods of very high prices or to countries with low-cost labor. Since the end of the Government purchasing program in June 1962, little sheet mica has been mined in the United States. Most of the recent production of sheet mica has been from North Carolina, New Hampshire, and South Dakota. The total Idaho production of sheet mica may be as much as 2 percent of the total U.S. production.

Many pegmatite deposits contain only scrap mica, and a large amount of scrap is produced during the mining, trimming, and fabricating of sheet mica. Scrap mica is also recovered from mica schists and as a byproduct from the mining of feldspar and clay. Most of the mica mined in the United States is scrap mica, and much of the mica in Idaho pegmatites is of scrap quality. A mill was constructed near the Muscoire mine in the Avon district of Latah County to recover scrap mica and beryl from the mine dumps, but little material was produced.

Prices of sheet mica depend on the size of the sheet and in 1963 ranged from $0.07 a pound for sheets 1/4 inches across to $0.88 a pound for sheets 8 inches or more across. Scrap mica is valued at the mine at $0.20 to $0.30 per short ton. Most of the buyers of mica are in the Eastern United States.

Feldspar is the general name for a group of aluminum silicate minerals that contain varying amounts of potassium, sodium, or calcium. The feldspars are important rock-forming minerals and constitute nearly 60 percent of igneous rocks. The principal potassium feldspars are orthoclase and microcline, which have the same chemical composition (KAlSi3O8) but different crystal form. The sodium-calcium feldspars, called plagioclase, form a complete series of minerals that range in all proportions from pure NaAlSi3O8 (albite) to pure CaAl2Si2O8 (anorthite). Natural orthoclase and microcline generally contain 10 to 25 percent NaAlSi3O8, and plagioclase generally contains 5 to 1 percent KAlSi3O8. Intergrowth of orthoclase or microcline with albite are called perthite, a common pegmatite mineral.

The potassium feldspars and the more soda-rich forms of plagioclase are the types generally mined. Until recently, much of the feldspar produced was perthite, which is commonly concentrated as very large crystals in certain zones in pegmatite bodies. Today, finer grained pegmatite is mined in bulk, and a mixture of potassium and sodium feldspar is recovered by milling and flotation. In 1961, about 62 percent of the feldspar used was from flotation concentrates, 23 percent was from hand sorting, and 15 percent was from feldspar-rich sand (de Polo and Tucker, 1962, p. 543). In 1957, these figures were 42, 46, and 12 percent, respectively.

The average price of crude feldspar was $10.31 per long ton in 1961 and $9.51 in 1960 (de Polo and Tucker, 1962, p. 544). The average price of ground feldspar was $12.36 per short ton in 1961 and $13.40 in 1960. From 1956 to 1960, about 55 percent of the feldspar sold in the United States was used in glass, 32 percent in pottery, 5 percent in enamel, and 8 percent in other ceramic uses,光curring soaps, and abrasives. The United States is self-sufficient in feldspar production.
capacity. The major problems for a producer are the lack of a constant market, the high cost of production, and low-selling price. There is an increasing shortage of high-grade potassium feldspar, but there is also an increase in use of lower grade and finer grained materials through milling and flotation. The largest production comes from North Carolina and California. Other important producing States include Colorado, South Dakota, New Hampshire, Maine, Virginia, Georgia, and Connecticut, in order of recent production. There is no recorded production of feldspar in Idaho, although some feldspar-rich sands are mined near Emmett in Gem County (Kelly and others, 1958, p. 54).

FELDSPAR DEPOSITS IN IDAHO

Pegmatite deposits have been reported in 14 counties in Idaho (fig. 29). Most of the mica deposits have been described by Sterrett (1915, 1923), Anderson (1923), Forrester (1942a), and Stoll (1950), and the feldspar deposits by Fryklund (1951). Mica mining began in the Arvon district in Latah County in 1889 and was fairly continuous until 1919. Many mines were active again in 1942-45 and a few from 1952 to 1960.

Adams County.—Several mica-bearing pegmatite dikes are present in a belt of metamorphic rocks on the south flank of Council Mountain near the western edge of the Idaho batholith (Fryklund, 1951, p. 8). Development at the Mica Queen mine (fig. 29, No. 21) has exposed three tubular north-trending pegmatite bodies composed of medium-grained plagioclase, quartz, and muscovite with small amounts of microcline, biotite, and garnet (Stoll, 1950, p. 10-11). The wall rock is biotite-quartz schist and gneissic granodiorite. The mica is green to greenish-brown and generally bent, or cracked, and some is soft. Production from 1918 through 1944 is probably less than 7 tons of crude mica.

The Siles prospect about a mile west of the Mica Queen mine is on a pegmatite body 8 feet wide and 150 feet long that is one of a group of north-trending pegmatite dikes (Fryklund, 1951, p. 9). The pegmatite consists of fine-grained plagioclase, quartz, and muscovite. The area contains a large tonnage of fine-grained feldspar but little mica.

Some heavily stained muscovite is reported from two pegmatite bodies exposed in open cuts at the Clark prospects (No. 20) about 4 miles northeast of New Meadows (Stoll, 1950, p. 10). There is no recorded production.

A pegmatite largely composed of orthoclase has been reported at the Lucky Strike mine in the Seven Devils mining district (Kelly and others, 1956, p. 51), although Livingston and Laney (1920, p. 37-38), in the original description of this deposit, mention only a little feldspar in quartz veins that “resemble true pegmatites.”

Boise County.—Numerous small pegmatite bodies and probably some large ones are indicated by considerable pegmatite float in areas of granite rocks of the Idaho batholith in the Garden Valley district (Fryklund, 1951, p. 11-13). Several small prospects and mines are concentrated in the area on both sides of Wash Creek south of the South Fork of the Payette River. Largest of these is the Vaught Columbite mine (fig. 29, No. 6), which has been worked intermittently since 1900. According to Stoll (1950, p. 12), production from surface
pits amounted to about 500 pounds of columbite through 1944. Fryklund (1951, p. 12) reports that a crystal weighing 309 pounds and consisting of a core of columbite and an outer zone of samarskite was recovered. The pegmatite appears to be the lower part of an originally flat-lying lens-shaped body, about 250 feet long and 200 feet wide. The wall zone is graphic-textured perthite-quartz pegmatite; the intermediate zones are plagioclase-quartz-muscovite pegmatite and nearly pure microcline pegmatite (Fryklund, 1951, p. 11–21). A quartz core is exposed at the surface (Stoll, 1950, p. 12) and in a tunnel. The mica is pale green, crinkled, and mostly stained. Much of the mica is of scrap quality. The microcline feldspar is massive, buff to flesh colored, and relatively free of impurities. Columbite, samarskite, and monazite occur as scattered fine to coarse masses in the plagioclase-quartz-muscovite pegmatite.

The two pegmatites exposed at the Mica Dome claims (No. 27) have a fine- to medium-grained plagioclase-quartz-muscovite wall zone and a quartz core (Fryklund, 1951, p. 13–14). A small tonnage of plagioclase and scrap mica is present, and there are minor amounts of rare earth oxides.

At the Bowman prospects (No. 28), three prospect pits have been dug on small pegmatite bodies ranging from 3 to 15 feet in width (Fryklund, 1951, p. 14). The pegmatite is a fine-grained intergrowth of microcline, quartz, and muscovite. Minor amounts of columbite, samarskite, and euxenite are accessory minerals.

The Mirandelorde prospects (No. 29) contain some pits and short adits that expose narrow pegmatite bodies through a vertical distance of 300 feet (Fryklund, 1951, p. 14–15). The narrow wall zones are feldspar-quartz pegmatite and the cores quartz-muscovite-feldspar pegmatite with minor columbite and samarskite.

The Mica Slim prospect (sec. 22, T. 9 N., R. 5 E.) (No. 24) is on a pegmatite 8 to 12 inches wide and 15 feet long. The mica books are small and of poor quality (Fryklund, 1956, p. 15).

The Kingsley deposit about 3 miles east of Grimes Pass (No. 25) is reported to contain a 50-foot pegmatite dike with feldspar borders (Kelly and others, 1956, p. 92).

Bonner County.—Only a few pegmatites have been prospect ed in Bonner County. Near Berry Creek (fig. 29, No. 3), several tabular pegmatite bodies 1 to 5 feet thick contain microcline, quartz, and muscovite (Stoll, 1950, p. 13). On the west slope of Sundance Mountain (sec. 6, T. 50 N., R. 3 W.), two pegmatites containing medium-to coarse-grained microcline, quartz, and muscovite are exposed in road cuts at the Soldier Creek prospects (No. 2). Beryl is reported but is not abundant (Stoll, 1950, p. 13).

Boundary County.—Small mica-bearing pegmatites occur on the north flank of Kent Peak and the walls of Lion Creek valley (sec. 1 or 2, T. 62 N., R. 3 W.). At the Lion Head prospect (fig. 29, No. 1), a pegmatite 140 feet long and 12 feet wide is composed of coarse-grained microcline, quartz, biotite, and muscovite. Most of the mica is cracked and broken (Stoll, 1950, p. 14).

Cassia County.—Fine- to medium-grained pegmatites are associated with the Cassia batholith in the southern part of South Mountain (fig. 29, No. 34) near the Utah line (Anderson, 1931, p. 54). Prospecting for mica has been unsuccessful, but resources of feldspar are present.
The City of Rocks mine (sec. 11, T. 16 S., R. 23 E.) (No. 35) has four pegmatites in an area 300 by 500 feet. These range from 6 to 10 feet in thickness. At least two are zoned and have a graphic-textured wall zone of feldspar, quartz, and muscovite, an intermediate zone of coarse perthite and some plagioclase, quartz, and muscovite, and a quartz core. A few hundred pounds of feldspar have been recovered from several small cuts and a shallow shaft. According to Fryklund (1951, p. 16-17), the mine has moderate resources of mixed perthite and plagioclase.

Clearwater County.—The pegmatites of Clearwater County are related to the Idaho batholith and are found in both the granite rocks of the batholith and the metamorphic rocks adjacent to the batholith (Anderson, 1930b, p. 22; Hietanen, 1962, p. A-29, A-57). Pegmatites ranging from 1 to 20 feet in thickness accompanying the quartz diorite intrusives have plagioclase as the principal feldspar, and pegmatites associated with the more granite intrusives have perthite as the principal feldspar (Anderson, 1930b, p. 18, 22). Little prospecting has been done in the county, but according to Stoll (1950, p. 14-15) mica-bearing pegmatite is exposed at the Bob Creek prospect (fig. 20, No. 9) and in the area of the Partridge Creek prospect (No. 10). Mica-bearing pegmatite is also reported along lower Cedar Creek, a tributary of Oronico Creek (Anderson, 1930b, p. 60). According to Anderson (1930b, p. 54), pegmatite is abundant along the North Fork of the Clearwater River below the mouth of Quartz Creek.

Kelly and others (1956, p. 54) report that the Wild Rose pegmatite (No. 11) at Pierce City contains pink orthoclase, white quartz, and muscovite.

Elmore County.—A large number of small- and moderate-size pegmatites are in granite rock of the Idaho batholith in the northern half of Elmore County (Fryklund, 1951, p. 19). A fine-grained plagioclase-quartz-muscovite pegmatite has been prospected unsuccessfully at the Swenson prospect (fig. 20, No. 30) in sec. 11, T. 6 N., R. 9 E.

Idaho County.—Pegmatites occur in several areas of Idaho County, but little work has been done on them. A number of mica-bearing pegmatites are reported in granite near Woodland south of the mouth of Lolo Creek in the northwestern part of the county (Anderson, 1930b, p. 60). The nearby Myers mine (fig. 29, No. 13) in sec. 20 or 21, T. 34 N., R. 4 E., had a production of more than 300 pounds of sheet mica during World War II (Stoll, 1950, p. 16). The irregular pipe-like pegmatite has a plagioclase-quartz wall zone with some muscovite and biotite and a quartz core with some perthite. The mica is green to green brown and mostly bent and broken (Stoll, 1950, p. 16-17).

The southern part of the county near Allison Creek contains a number of pegmatites in secs. 11 and 14, T. 24 N., R. 2 E. (Fryklund, 1951, p. 19-20). A mica-bearing pegmatite 6 to 8 feet thick is exposed at the Hidden Fawn claim (No. 16), and a branching pegmatite several feet thick is present at the nearby Deer Ridge prospect (Stoll, 1950, p. 15-16). The mica is green, and the books contain crystal imperfections and black specks. Along the Allison Creek Road, several feldspar-rich pegmatites as much as 20 feet thick contain a fair tonnage of good quality perthite (Fryklund, 1951, p. 201). To the north in sec. 36 T. 25 N., R. 2 E., near the upper switchback on the Allison
Creek Road, three pegmatites 2 to 3 feet thick are exposed at the Hall-madge or Mica Lode prospect (No. 14). Clay-stained green muscovite occurs in 1-foot zones in two of the pegmatites, and a small amount of good grade perthite is also present (Fryklund, 1951, p. 20).

The O.K. mica prospect (No. 17) is on the west side of Lake Creek valley south of the Salmon River. Both stained- and clear-green mica of fair quality are reported (Stoll, 1950, p. 17).

Kelly and others (1956, p. 56) report that pegmatite dikes containing feldspar occur on the divide between the first and second creeks east of Jersey Creek, a tributary of the Salmon River, T. 24 N., R. 8 E. (No. 19).

Latah County.—The Avon district (fig. 29, Nos. 5-8) of Latah County is the most important pegmatite district in Idaho (Stoll, 1950, p. 17-54). Mining began in the district in 1888 and has been intermittent since then. About 18 mines and prospects are in an area of 3 square miles in sec. 22 and parts of adjacent sections in T. 41 N., R. 2 W. The principal producing mines are the Muscovite (No. 5), Doerr (No. 6), Steelsmith (No. 7), and Last Chance (No. 8). The country rock in most of the area is mica schist and gneiss of the Belt Series of Precambrian age. Along the eastern edge of the district, the metamorphic rocks are in contact with granodiorite of the Thisna batholith of Mesozoic age (Tullis, 1944, p. 143; Stoll, 1950, p. 18–19). About 100 pegmatite bodies 1 to 90 feet thick and as much as 1,000 feet long are irregularly scattered through the metamorphic rocks. The marginal parts of the batholith and the contact metamorphosed schist adjacent to the batholith are cut by numerous small dikes of pegmatite (Stoll, 1950, p. 19). The most productive pegmatites range in length from 30 to 275 feet. The pegmatite is composed principally of plagioclase, quartz, and muscovite. Microcline is not abundant. Tourmaline, beryl, garnet, biotite, apatite, graphite, vivianite, strengite, lithiumylite, metatorbernite, autunite, and fellingite are common to rare accessory minerals. Most of the pegmatite bodies are conformable to the bedding and foliation of the metamorphic rocks, and many of the productive bodies are zoned. The zones commonly found are a fine-grained border zone; a wall zone of feldspar, quartz, and sheet mica; intermediate zones of plagioclase and a little quartz, muscovite, and tourmaline; and a quartz core. Some bodies have a feldspar-quartz-muscovite core and some have discontinuous quartz cores. Some are not zoned.

The mica ranges in color from yellowish brown or “rum” to green. Much of the brownish mica is bent, warped, broken, and cracked. Some has mineral inclusions. During the Second World War, 1 to 9 percent of the rum-colored mica was recovered as sheet mica in pieces larger than 1 by 1 inch (Stoll, 1950, p. 19). The green mica is generally soft, broken, and has crystal imperfections. Most of the green mica is of scrap quality.

The Muscovite mine (No. 5) is the largest mica mine in Idaho and has one of the largest mica productions in the United States. Total production from 1888 through 1962 is probably about 1,300 tons of crude mica. Unfortunately, the average quality is low and much of the production was scrap quality (Skow, 1962, p. 48). Four or more pegmatite bodies have been mined in a large open pit, three or more adits, and several stopes. The lowest level is 280 feet below the orig-
inal outcrop. The East pegmatite is a complex of numerous closely spaced pegmatite bodies of various shapes separated by horses and septa of altered schist. The pegmatite is unzoned and consists of plagioclase, quartz, muscovite and accessory perthite, beryl, tourmaline, and apatite. The Central pegmatite has three branches and ranges from 35 to 50 feet in thickness. It has a narrow discontinuous border zone, a wall zone of quartz-plagioclase-muscovite-beryl pegmatite, and a core of plagioclase-quartz pegmatite. The West pegmatite ranges from 1 to 13 feet in thickness and is similar to the East pegmatite. A fourth or New pegmatite was discovered and mined in 1922-24 (V. C. Fryklund, written communication). It ranges from 8 to 30 feet in thickness and has a plagioclase-quartz-muscovite-beryl wall zone and a plagioclase-tourmaline core. The mica from all four pegmatites is rim colored and generally clear. Much of it is wavy, cracked, ruled, broken, and has crystal imperfections. The dumps contain a large tonnage of plagioclase feldspar and scrap mica (Fryklund, 1921, p. 22). Beryl production has been small, and only fine-grained beryl is left in the dumps.

The Doerr mine (No. 6) was located in 1914 and was worked intermittently up to 1945. No production records are available for the early years, but according to Stoll (1950, p. 26) total production must be nearly 100 tons of crude mica. Workings at the mine consist of six open cuts, several adits, and an unknown amount of stoping on several pegmatite lenses. The largest lens is over 60 feet long and 8 feet thick. It contains a quartz core, and a wall zone of plagioclase-quartz-muscovite. The mica is rim colored, flat, and hard.

The Steelsmith (Levi Anderson) mine (No. 7) was worked before 1910 and again in 1943-46 (Stoll, 1950, p. 51). More than a dozen pegmatite lenses and pipe-like bodies are exposed in five cuts, three adits, and several stopes. The total production may be as much as 30 tons of crude mica. The mica is pale purple to colorless. Some is bent and broken and some clay stained. The average quality is fair. Much of the feldspar on the dumps is fine-grained and intergrown with quartz, but some is coarse-grained (Fryklund, 1951, p. 23).

At the Last Chance mine (No. 8), five pegmatites are exposed in three cuts, two adits, and several stopes (Stoll, 1950, p. 28-30). Mining was started before 1910 and was resumed in 1944-45. The total production may be as much as 50 tons of crude mica. The largest pegmatite is a contorted tabular body 3 to 26 feet thick and 150 feet long. Pale purple mica is concentrated in the plagioclase-muscovite-quartz wall zone 1 to 4 feet thick. An intermediate zone of plagioclase-tourmaline-quartz contains green muscovite. The quartz core is discontinuous. The rim-colored mica is clear but badly cracked and warped; the green mica is finely cracked and warped. Much of the feldspar on the dumps is too fine-grained to be hand cobbled (Fryklund, 1951, p. 22), but feldspar from this mine was used by Wilson (1927, p. 8-10) and found to give good results as to color and fusibility in whiteware tests.

Lenahi County.—Mica-bearing pegmatite is exposed at the Glenan prospect (fig. 29, No. 15) in the Salmon River Valley 13.3 miles by road west of North Fork. Books of mica as much as 5 inches across are generally fractured and stained (Stoll, 1950, p. 54).

Shoshone County.—Several pegmatites are exposed near the end of the Marble Creek Road in secs. 19, 24, 26, and 50, T. 44 N., R. 8 and
The largest body exposed is 2 to 5 feet thick and contains 80 percent plagioclase, 10 percent quartz, and 10 percent muscovite. The mica is green, clear, generally small, and mostly bent, broken, and cracked (V. C. Fryklund, written communication, 1952).

Pegmatite dikes containing large quartz and feldspar crystals are reported near the mouths of Cornwall and Homestead Creeks, tributaries of Marble Creek in T. 43 and 44 N., R. 3 E. (Kelley et al., 1956, p. 22).

Valley County.—A pegmatite ledge as much as 600 feet long crops out at the Panther prospect (fig. 29, No. 23) on the east wall of Middle Fork Valley (sec. 14, T. 12 N., R. 5 E.). The pegmatite consists of perthite, quartz, plagioclase, and muscovite. The country rock is granodiorite of the Idaho batholith. The mica is green to brown, and stained (Stoll, 1930, p. 54). A pegmatite containing high-quality feldspar (No. 22) is reported south of Gold Fork, a tributary of the North Fork of the Payette River in T. 16 N., R. 3 or 4 E. (Kelly et al., 1956, p. 63).

OTHER SOURCES OF FELDSPAR

Although granitic pegmatites are the principal source of feldspar, certain fine-grained igneous rock are potential sources, and some arkosic sands and sandstones can also be used. Feldspar could be concentrated by flotation methods from the granitic rock of the Idaho batholith, but the varying proportions of ferromagnesian minerals and the changing potassium-sodium ratio of the feldspars provide a different metallurgical problem for each outcrop (Fryklund, 1951, p. 22). Some igneous rocks associated with the batholith and later intrusive rocks are feldspar-rich and contain only small amounts of ferromagnesian minerals. One such body of feldspar-rich igneous rock called perthosite has been mapped in the NW 1/4 sec. 2, T. 37 N., R. 4 W., about half a mile south of Pine Grove School, Latah County (fig. 37, No. 12). The rock consists mostly of microcline-microperthite and accessory magnetite, apatite, sericite, kaolin, and hematite (Tullis, 1944, p. 143, 146). It crops out along the road for 0.3 mile (Fryklund, 1951, p. 24).

Another but smaller body of feldspar-rich igneous rock is exposed near the Yellowjacket mine (No. 19) about 34 miles southwest of Salmon, Lemhi County. The rock is called an albite pulaskite and consists mostly of albite, the sodium-rich plagioclase, minor orthoclase, and accessory quartz, hematite, apatite, magnetite, and sericite (Anderson, 1935, p. 9).

Several sills and dikes of feldspar-rich syenite, granite, and quartz monzonite are found in the alkaline igneous rocks of the Caribou Mountain intrusive area (No. 33) about 45 miles southwest of Caribou Falls (Anderson and Kirkham, 1931). Sills and dikes of norite contain 90 percent orthoclase, 3 percent quartz, 3 percent biotite, 2 percent diopside, and 1 percent other accessory. Two sills and a dike of granite contain 88 percent orthoclase, 8 percent quartz, 2 percent biotite, and accessory magnetite and zircon. A large sill of quartz monzonite porphyry on the west side of Mount Caribou contains 55 percent plagioclase, 37 percent orthoclase, and 8 percent quartz.
Arkose sands are found in the Payette Formation of Miocene to Pliocene age in parts of Gem and Washington Counties. (See fig. 48, Silica deposits in Idaho.) The Gem Silica Co. mines a large deposit of such sands near Emmett, Gem County (No. 51) and could probably recover feldspar of ceramic grade by flotation methods (Kelly and others, 1956, p. 54). Similar sands occur near Weiser, Washington County (No. 52). Tests have been made to treat the sands by attrition scrubbing and froth flotation to produce silica sand with 0.05 percent Fe₂O₃, and a mixture of potassium-sodium feldspar sands with 0.08 percent Fe₂O₃ (Kelly and others, 1956, p. 63).

MOLYBDENUM

(By R. U. King, U.S. Geological Survey, Denver, Colo.)

The metal molybdenum is of importance to our modern industrial economy, due chiefly to its versatility as an alloying element in the ferrous metal industry. Small amounts of molybdenum used in steel impart beneficial properties of hardness, toughness, and resistance to wear and corrosion. In these respects, molybdenum compares favorably with other alloy metals such as vanadium, chromium, tungsten, nickel, manganese, cobalt, and columbium.

Molybdenum is a silvery white metal somewhat softer than steel. It has a melting point of about 4750° F., which is higher than all other metals except tungsten, rhenium, osmium, and tantalum. It is ductile and is resistant to acids and to oxidation at ordinary temperatures.

About 75 percent of the molybdenum consumed in the United States is used in the manufacture of high-temperature alloy steels (Fischer and King, 1964), stainless steels, and castings. The rest goes into special alloys, metal products, metallic and nonmetallic refractories, chemicals, pigments, catalysts, lubricants, and agricultural products.

New uses for molybdenum are being developed in the nuclear power field, and in missile and aerospace industries, and these give promise of an ever-increasing demand for this versatile metal.

Molybdenum is widely distributed in rocks of the earth’s crust, the average content being about 2.5 parts per million (0.00025 percent). It also is present in trace amounts in soils; in ground water, oceans, hot springs; and in plant and animal tissues. It is never found in its pure or native state, but only in combination with nonmetallic elements such as sulfur and oxygen, and other metallic elements such as iron, calcium, tungsten, and lead. Its most common naturally occurring form, and the only one of current commercial importance, is in the mineral molybdenite (molybdenum disulfide, MoS₂). Other molybdenum minerals include wulfenite (lead molybdate), ferrimolybdate (hydrated ferric molybdate), powellite (calcium molybdate, often with tungsten), jordiite (amorphous molybdenum sulfide), and thiomolybdate (molybdenum oxysulfate). Several rarer minerals of doubtful economic significance are known in which molybdenum is combined with one or more of the following elements: bismuth, copper, magnesium, vanadium, cobalt, and uranium.
The marketable forms of molybdenum are either molybdenite concentrates (95 percent MoS₂) or molybdenum oxide (MoO₃), which is made by roasting molybdenite concentrates. Concentrates are not normally marketable in small or individual lots, thus limiting the economic potential of individual small molybdenum deposits.

Although the element molybdenum was identified in the latter part of the 18th century, it was not until the early part of the present century that its potential value to the metals industries was recognized and wide applications for its use were developed. Intensive search for the metal followed, which resulted in the discovery of high-grade deposits of wulfenite in Arizona, molybdenite in New Mexico, and the large but lower grade deposit of molybdenite at Climax, Colo.

Commercial production of molybdenum in this country began in 1888, but was relatively small and intermittent until 1914. Since 1914, production has increased yearly, with few exceptions, to a current annual rate of more than 60 million pounds. During the first quarter of this century, the United States contributed only a small portion to the world's molybdenum supplies, but since about 1925 between two-thirds and nine-tenths of the world's molybdenum has been produced in the United States.

Molybdenum deposits have been known in Idaho since early in the century, but the State's production of molybdenum has been insignificant to date. There are a number of deposits scattered over the central and northwestern parts of the State that appear to be too low grade or too small to be worked under present conditions but that constitute potential sources of molybdenum.

Molybdenum deposits can be grouped in five genetic types based on similarities of geologic and physical features: (1) "porphyry" or disseminated deposits, (2) contact metamorphic deposits, (3) quartz veins, (4) pegmatites and splites, and (5) bedded deposits in sedimentary rocks.

Molybdenum occurs in "porphyry" or disseminated deposits of molybdenite alone or in association with copper sulfides. The ore minerals are dispersed through relatively large volumes of altered and fractured rocks commonly in or near intrusive bodies of granite or porphyritic rocks. These deposits, although large, have low metal content and are amenable only to large-scale, low-cost mining methods. This type of deposit is by far the most productive of molybdenum in the United States and offers the greatest resource potential, as for example, the huge deposits at Climax, Colo., and at Bingham, Utah.

In the molybdenum-bearing contact metamorphic deposits, molybdenite is commonly associated with scheelite, powellite, or copper sulfides in zones of silicified limestone or tactite bodies near contacts with granitic rocks. Three deposits of this type are known in Idaho, but none have yielded molybdenum in commercial quantities, and probably none of them are mineable for their molybdenum content alone.

Small amounts of molybdenum (up to 0.05 percent) are present in the phosphorites and black vanadiferous shales of the Phosphoria Formation in the southeastern part of the State. The reserves of phosphate rock are large, and the total quantity of molybdenum therefore becomes significant, but because the molybdenum is not recoverable under present conditions it can only be considered as a potential resource.
In the extreme northern part of the State, vein deposits of molybdenite occur near the margins of the intrusive granitic rocks of the Kaniksu batholith (fig. 30). They have not been productive except for the deposits at the International Molybdenum Co.'s mine (fig. 30, No. 2), from which about 1,000 pounds of molybdenum was mined in 1958 from open-cut workings. The molybdenum occurs as molybdenite in pegmatitic quartz veins cutting granite. The yellow oxidation product, ferrimolybdate, occasionally is found associated with the molybdenite.

Molybdenite also occurs in pegmatitic quartz veins cutting granite at the American Girl prospect (No. 1) near Copeland, Moyie Yaak district, Boundary County. At the Hotchkiss (Hines) prospect (No. 3) just northwest of Nickelplate Mountain, Bonner County, molybdenite is associated with scheelite, powellite, and iron sulfides in quartz veins, and is disseminated sparsely in the country rocks. Although molybdenum ore of commercial grade may be present in these deposits, the deposits are likely to be too small for profitable mining.

Molybdenite is a minor constituent in quartz veins and stringers that cut dacite and granodiorite at the Petsite prospect (No. 4), Orogrande district, Idaho County. The molybdenum content of the veins is not known but is probably too small to be of commercial interest.

Molybdenite occurs in quartz veins cutting granite at the Spring Creek prospect near the Idaho-Montana boundary in Lemhi County (No. 5). Samples of the vein material are reported to contain from 0.12 to 1.27 percent Mo; little is known regarding the size of the deposit or the average molybdenum content of the veins.

Molybdenite occurs with copper and tungsten minerals in tactite at the Profile Gap mine (No. 6), in the Edwardsville district, Valley County. The molybdenite content is too low to be of economic interest.

At the Helena mine (No. 7) and at several other properties in the Seven Devils region of Adams County, molybdenite and powellite are associated with the scheelite and copper sulfides in tabular tactite bodies lying between limestone and granitic rocks. The molybdenite content of some of the ores runs as high as 1 percent, and significant tonnages of high molybdenite-tungsten ore are reported.

Molybdenite is associated with copper and iron sulfides in quartz veins cutting granitic rocks at the Virginia Beth prospect (No. 8), on Little Pistol Creek, Valley County. The deposits are reported to amount to a few thousand tons of ore with a molybdenum content of about 1 percent.

At the IXL mine (No. 9) in the Cuddy Mountain district of the Seven Devils region in Washington County, molybdenite is associated with copper sulfides in a disseminated deposit in fractured and altered granite. Country rocks are mineralized over an area 8,000 by 4,000 feet. No estimates of grade or tonnage are available, but such a deposit could contain many millions of tons of low-grade molybdenum-copper ore. It is reported that a major copper company has been engaged in exploration of this area.

Molybdenum is found with tungsten and other minerals at the Ima mine (No. 10) in the Blue Wing district, Lemhi County. The deposits are near the contact of quartzite of the Precambrian Belt Series with an elongate stock of granite, and are mostly in the quartzite. Two stages of mineralization have been recognized. The first con-
MOLYBDENUM LOCALITIES

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EXPLANATION

Granitic rocks of the Idaho batholith and other granitic plutons

Border zone of Idaho batholith

Porphyry or disseminated deposits

Vein deposits

Contact metamorphic zones and tactite bodies

Figure 30.—Molybdenum in Idaho.
sists of numerous irregular quartz-orthoclase veins with mica, pyrite, molybdenite, and some chalcopyrite. They are best developed in or near the granite. The second stage is represented by a series of more persistent and regular quartz veins with huebnerite, fluorite, rhodochrosite, and various sulfide minerals. The molybdenite is restricted almost wholly to the first stage. Although molybdenite is locally found in solid masses and dense disseminations, it is usually smeared in thin films over slickensided walls or around small fragments of vein or wall-rock material. The molybdenum content probably is insufficient to make recovery feasible (Hobbs, 1945, p. 6-7).

Molybdenite occurs in scattered quartz veinlets and as disseminated grains in quartzite near its contact with granite at the Boulder Creek prospect (No. 11), Custer County. The mineralized quartzite, containing as much as 0.1 percent molybdenum, covers an area a few hundred feet wide by more than a thousand feet along the contact. Although no molybdenum has been produced from this locality to date, a potential exists for a several-million-ton low-grade molybdenum deposit.

Small amounts of molybdenite occur in scattered veinlets and disseminations in a fractured zone in rhyolite and quartz monzonite at the Little Falls prospect (No. 12), Boise County. The mineralized fracture zone is about 500 feet wide and can be traced for over 1,000 feet on the surface, but the average molybdenum content is very low. No molybdenum has been mined from this prospect, but some exploration was recently done by a Denver company.

Molybdenite occurs in the ores of some of the mines in the Mackay district, Custer County. At the Empire mine (No. 13), molybdenite is associated with copper minerals in tactite, but has not been recovered to date, and its potential as a byproduct is not known. Molybdenite also occurs in the ores of the Phoenix and Vaught mines, but the quantity is small.

Molybdenite-bearing quartz veins cut quartz monzonite at the Walton (No. 14) and White Mountain (No. 15) prospects in Custer County. The veins are of varying widths ranging from stringers to over a foot wide. Molybdenite content ranges from a few tenths of a percent to several percent, and in the aggregate some tens of thousands of tons of molybdenum-bearing rock are probably present in the deposits. The molybdenum content is between 0.1 and 0.5 percent.

Two molybdenum prospects, the Rhinebold (No. 16) and the Decker-Hortenstein (No. 17) are known in the Rocky Bar (Roaring River) district, Elmore County. At these prospects, molybdenite is associated with copper and zinc sulfides, and beryl in quartz veins, aplite dikes, and brecciated zones in granite. Although high-grade samples of molybdenite-bearing material containing several percent molybdenite have been taken from the deposits, there has been no commercial production of molybdenum.

The Morning Mist (No. 19) is a deposit of molybdenum associated with copper, about 2 miles south of Idaho City in Boise County. Mineralization occurs in a wide fracture zone in granite rocks. The description of this deposit is similar to the description of the Little Falls prospect in Boise County.

According to Livingston (1919), molybdenum occurs on the South Fork of the Salmon River about 12 miles east of Warren in Idaho County in garnetized schist containing hornblende sills. The deposit
is located just opposite the mouth of Grouse Creek. For location purposes, this occurrence is called the South Fork deposit (No. 18). Livingston states that molybdenite, which in places forms as much as 1 percent of the rock, is found in a zone 150 feet wide by 2,300 feet long.

Molybdenite occurs in a deposit near the headwaters of West Eightmile Creek (No. 20) on the east side of the Lemhi Range (Livingston, 1919). The molybdenite is in a narrow chimney in an irregular pegmatite cutting granite. According to Livingston, several hundred pounds of molybdenite were shipped from this deposit.

From the above descriptions, it can be seen that the presently known vein- and contact-type molybdenum deposits in Idaho do not contain appreciable tonnages of ore that is mineable under existing conditions. On the other hand, potential sources of molybdenum are present in the disseminated type of molybdenum deposit, such as those at Boulder Creek (No. 11) and the IXL mine (No. 9) and perhaps others.

NIOBUM AND TANTALUM

(By R. L. Parker, U.S. Geological Survey, Denver, Colo.)

Niobium (columbium) and tantalum are two refractory metals that have become increasingly important in modern technology. These metals have certain physical properties which make them useful in electronic, nuclear, chemical, and high-temperature metallurgical applications. Both metals have important uses in the manufacture of vacuum tube elements, cryotrons, corrosive-resistant vessels and laboratory ware, high-temperature nonferrous alloys, and austenitic stainless steel. Niobium has special use as a cladding element for nuclear fuel. Tantalum has special application in capacitors, rectifiers, and surgical implants and as a catalyst in the manufacture of butadiene rubber (Miller, 1959; Barton, 1962).

Niobium and tantalum do not occur in nature as free metals but are commonly found together as constituents of minerals that are compounds of niobium, tantalum, and oxygen, with minor amounts of titanium, tungsten, iron, manganese, rare earths, uranium, thorium, sodium, calcium, and others. The most important ore minerals are: columbite-tantalite, \((\text{Fe, Mn})_2(\text{Nb, Ta})_2\text{O}_6\); pyrochlore, \(\text{NaCaNb}_2\text{O}_6\); microlite, \((\text{Na, Ca})_2\text{Ta}_2\text{O}_8(\text{OH, F})\); and euxenite, \((\text{Y, Ca, Ce, U, Ta})_2(\text{Nb, Ta, Ti})_2\text{O}_8\). Niobium and tantalum are also contained in various amounts in titanium minerals, sphene, rutile (ilmenorutile) and ilmenite (Palache and others, 1944).

Niobium is not an exceedingly rare element in the earth's crust; it is about as abundant as cobalt and more plentiful than lead. Tantalum is much more rare than niobium but still more abundant than antimony, silver, or gold. Compared with many other valuable elements whose crustal abundance is less than niobium or tantalum, deposits of niobium, and particularly tantalum, are scarce. They are largely restricted to granite rocks and pegmatites, alkalic rock complexes and carbonatites, and placers derived from these rocks.

Some granite bodies contain disseminated columbite-tantalite, euxenite, or other niobium-tantalum-bearing minerals as primary rock constituents, and in some places these minerals have been sufficiently concentrated by deep residual weathering and fluvial processes to
render them commercially extractable. Columbite-tantalite, euxenite, microite, and other rare niobium-tantalum minerals are concentrated in some granitic pegmatites, but these concentrations are commonly sporadically distributed within the pegmatites, are of small magnitude, and do not constitute a large source of supply.

In many parts of the world, large, low-grade deposits of niobium occur in alkaline rock complexes and associated carbonatites. Some multi-million-ton deposits are known in central Africa, southeastern Canada, Norway, and Brazil (Barton, 1962), and at least four smaller ones have been found in the United States. The niobium occurs in the mineral pyrochlore, disseminated in carbonatite. Also in some alkaline complexes, nepheline-bearing rocks contain pyrochlore as a minor accessory mineral. Many carbonatite deposits are under extensive development and are expected to be the principal source of the world's niobium in future years.

The United States is the world's largest consumer of niobium and tantalum, but it is a small producer (Barton, 1962). Except for the period 1956–59, domestic production of these metals constituted an exceedingly minor fraction of the domestic consumption (fig. 31). In 1958, domestic production reached an all-time high of nearly 12 percent of the domestic consumption, but since 1959, domestic production has been negligible. Imports for consumption of combined niobium and tantalum concentrates in 1962 were about 6,234,000 pounds.

Idaho has been the largest producer of niobium and tantalum in the United States. During the period 1956–59 production of these elements, principally from the Bear Valley placer deposit, Valley County, and to a minor extent from the Dismal Swamp placer deposit, Elmore County, accounted for as much as 90 percent of the U.S. production.

The Bear Valley placer deposit (fig. 32, No. 6) is about 28 miles northeast of Lewman in Valley County (Mining World, 1968: Savage, 1961a). Mining began at the deposit in 1955 under contract with the U.S. Government for the purchase of 1,060,000 pounds of concentrates containing 90 percent niobium-tantalum pentoxide. Mining continued into 1959, when operations ceased after fulfillment of the contract. The property has remained inactive since that time, apparently because of the absence of the Government price stimulus.

The Bear Valley deposit is surrounded by granitic rocks of the Idaho batholith, from which the deposit was apparently derived. Niobium and tantalum minerals, euxenite and columbite-tantalite, which occur in the placer, are found in place in nearby pegmatites and granitic rocks of the batholith. A typical sample from the placer contains the following quantities of heavy minerals in pounds per cubic yard of gravel: euxenite, 1; monazite, 0.5; columbite-tantalite, 0.2; zircon, 0.08; garnet, 13; ilmenite, 28; and magnetite, 7; totaling 49.75 (Mining World, 1968). The euxenite has the following composition:

<table>
<thead>
<tr>
<th></th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>U₂O₅</td>
<td>8.0-10.5</td>
</tr>
<tr>
<td>Nb₂O₅</td>
<td>23.0-26.0</td>
</tr>
<tr>
<td>Ta₂O₅</td>
<td>1.5-3.0</td>
</tr>
<tr>
<td>TiO₂</td>
<td>2.5-3.0</td>
</tr>
<tr>
<td>(Fe,Mg)₂O₃</td>
<td>24.0-28.0</td>
</tr>
</tbody>
</table>
Figure 31.—World and U.S. production and U.S. imports of niobium and tantalum concentrates, 1953–62.
EXPLANATION

- Blacksand placer areas with reported niobium-tantalum (after Savage, 1961)
  1. Clearwater
  2. Elk City
  3. Burgdorf-Warren
  4. Cascade
  5. Deadwood
  6. Bear Valley
  7. Boise Basin
  8. Dismal Swamp
  9. Stanley Basin-Yankeet Fork
  10. Wood River-Camas Creek

- Bedrock deposits of niobium-tantalum minerals
  11. Vaught columbite prospect
  12. Mineral Hill district

- Idaho batholith and other granitic plutons

- Border zone of Idaho batholith

**Figure 32.**—Niobium-tantalum in Idaho.
The columbite-tantalite contains 56 to 72 percent \( \text{Nb}_2\text{O}_5 \) and 5 to 22 percent \( \text{Ta}_2\text{O}_5 \).

The Dismal Swamp placer deposit (Armstrong, 1957) (No. 8) is about 8 miles northwest of Rocky Bar in Elmore County. About 2,000 pounds of columbite concentrates was marketed from this deposit in 1958. The placer lies in granitic rocks near the southern end of the Idaho batholith and is a product of local stream erosion and slope wash of weathered batholithic rocks. Heavy minerals in the placer are anatase, cassiterite, columbite, cyrtoelite, garnet, ilmenite, magnetite, monazite, rutile, samarskite, titaniferous magnetite, topaz, xenotime, zircon, and an unidentified mineral containing niobium, thorium, rare earths, and uranium. A weakly magnetic fraction of the placer concentrate contains most of the niobium-tantalum. This fraction amounts to 1.40 to 1.87 pounds per cubic yard averaging between 14 and 20 percent \( \text{(Nb, Ta)}_2\text{O}_5 \).

Other placer areas in central Idaho that are reported to contain niobium and tantalum minerals are the Boise Basin area, Boise County (No. 7); Wood River-Camas Creek area, Camas and Blaine Counties (No. 10); Deadwood area (No. 5) and Cascade area (No. 4), Valley County; Stanley Basin-Yankee Fork area, Custer County (No. 9); Burdet-Warren area (No. 3) and Elk City area (No. 9), Idaho County; and Clearwater area, Clearwater County (No. 1) (Savage, 1961a). Like the Bear Valley and Dismal Swamp deposits, these placers lie within the Idaho batholith or along its border and probably were derived from the batholithic rocks (fig. 32).

Niobium-tantalum minerals are also contained in carbonate bodies in the Mineral Hill district, Lemhi County, and in pegmatites near Garden Valley, Boise County. The Mineral Hill district (No. 12) (Kaiser, 1955; Anderson, 1960) is about 30 miles northwest of Salmon. Niobium in the mineral ilmenorutile (8 to 10 percent \( \text{Nb(Ta)}_2\text{O}_5 \)) is concentrated locally along with rare earth and thorium minerals in dike-like or vein-like bodies of carbonate rock. These bodies are enclosed in amphibolite or gneiss at the border of the Idaho batholith, and in many respects resemble carbonatites. No alkaline rocks with which they might be related have been found in the district.

The deposits of Mineral Hill district are small and the distribution of ilmenorutile is irregular. No commercial concentrations have yet been discovered.

Pegmatites containing niobium-tantalum minerals have been reported in the Garden Valley area (No. 11) (Stoll, 1950; Fryklund, 1951). A prospect known as the Vaught columbite prospect, about 8 miles southeast of Garden Valley, is said to have produced only about 500 pounds of columbite since 1900. The pegmatite is zoned and lies in granodiorite of the Idaho batholith. The columbite is found in the wall zone or along the contact between the wall zone and quartz core of the pegmatite. The columbite is a low tantalum variety.

Resources of columbium and tantalum in Idaho placer deposits are estimated at 30,000 tons of combined pentoxides—one of the largest potential sources in the United States (National Academy of Sciences—National Research Council, 1959, p. 65). Most of these resources are in the Bear Valley deposit and the remainder are in the Dismal Swamp and smaller deposits. Exploration by the U.S. Bureau of Mines and others has pointed up several potential blacksand placer
deposits, but the grades of these deposits are lower than that of the Bear Valley deposit.

The discovery of additional commercial placers is possible within the extensive area of the Idaho batholith with which most Idaho blacksand placers are related. Some placer deposits, which cannot operate on a basis of niobium and tantalum minerals alone, may in the future utilize the combined marketability of these and other mineral components of the gravels for commercial feasibility of the deposits.

The carbonate deposits of the Mineral Hill district and pegmatites of the Idaho batholith, because of the relatively small amounts and erratic distribution of niobium-tantalum minerals within them, offer little potential as resources of niobium and tantalum.

PEAT


Peat is semicarbonized vegetable tissue formed by partial decomposition of various plants in water. It is formed in the primary stage of the conversion of vegetable matter to coal. It contains varying amounts of the elements carbon, hydrogen, oxygen, and nitrogen in a ratio of about 80 percent water to 10 percent organic material.

Since about 1904, peat production has continued to grow in importance in the United States. The total value of the U.S. commercial sales of peat in 1962 was close to $5.2 million, a 12-percent increase over the year 1961 (Sheridan and Otero, 1963, p. 292). The average unit value of peat sold in the United States decreased, however, from $3.48 per ton in 1961 to $2.15 per ton in 1962. Locally, the packaging of small units of peat brings a premium price. World production of peat in 1962 was 189.7 million short tons.

The chief use of peat in the United States is as a soil conditioner, but it is also used as a filter in mixed fertilizer, as poultry and stable litter material, as packaging material, and in the processes of filtering and tanning. The acid or alkaline quality of peat is important to its use as a soil conditioner. The range of pH values in different samples of peat is from 3.5 to 8 (less than 7 is acid, more than 7 is alkaline). The acidity of some peat is thought to account in part for its antiseptic quality, a quality that is desirable for some uses; for example, as a packing material for vegetables and plants. For some uses, peat acts as a deodorizer. Peat is not used extensively for fuel in the United States as it is in many other countries such as Russia and Ireland.

Peat composition varies greatly because of the wide range of climates and environments in which it may form. It is sometimes classified according to its botanical content as moss peat, reed-sedge (fibrous) peat, shrub and tree (woody) peat, or peat humus (peat that is so decomposed that the plants are not identifiable). If the decomposed organic matter contains more than 40 percent mineral matter, it is referred to as "muck" (Sheridan and DeCarlo, 1957, p. 5-4). For many special uses, moss peat is the most desirable, but in 1962 production percentages of various types in the United States were as follows: Reed-sedge, 52; humus, 28; and moss, 19.
The climatic conditions that favor abundant plant life leading to peat accumulation are a lack of extreme seasonal air temperatures, high humidity, and abundant and well-distributed yearly rainfall. Peat formation is also affected by the topography of the land. The most ideal conditions are a flat to gently sloping surface with poor drainage, particularly a drift-covered, glaciated land surface with its deranged drainage. In Idaho, glaciated terrains occur only in the northern panhandle area and at higher elevations in the central part of the State.

The types of undrained land where peat may form are in (1) bogs, which are flat or gently sloping wet areas usually overgrown with low grasses and mosses and lacking trees; (2) marshes, which are open shallow basins or flat areas continually covered with water and overgrown with bog-type vegetation such as bulrushes and cattails; and (3) swamps, which are low, flat areas covered or saturated with water and overgrown with trees and often with smaller vegetation. Plants flourish in these types of areas; as the plants die, the organic material accumulates year after year and is covered either by subsequent layers of fallen plants or by water. The oxygen supply is decreased and the rate of decomposition is slowed down or stopped. The pressure created by burial leads to the compaction and solidification of this organic material and eventually forms layers of peat, which, given sufficient pressure and time may be converted to different types of coal. Peat accumulates slowly at an estimated average rate of 1/4 to 4 1/2 feet in 2,500 years where conditions remain fairly uniform (Soper and Osborn, 1922, p. 13).

In 1962, the U.S.S.R. was reportedly the leading peat producer, with about 95 percent of world output, whereas the United States ranked about fourth in world production. Minnesota, Wisconsin, and Michigan contain over 71 percent of the 14 billion tons of the known domestic reserves of peat. Many of the peat operations in the United States are small and employ less than three men. A large percentage of the peat consumed in this country is imported from Canada and West Germany. Idaho receives shipments from California, Washington, and Montana, and from British Columbia.

The commercial peat industry in Idaho is small and relatively new. The amount produced probably has been consumed mostly within the State and is insufficient to supply local demand. Production figures of peat in Idaho are not available because they are combined with production from other States. The combined production of Montana and Idaho jumped from 8,885 short tons in 1961 to 18,265 short tons in 1962, an increase of over 100 percent. Although the average value per ton of peat from these two States decreased from an average of $18.89 in 1961 to $10.37 in 1962, the volume of commercial sales increased over five times during the same period—from $83,054 in 1961 to $109,052 in 1962 (Sheridan and Otero, 1963, p. 299).

Peat in Idaho occurs principally in three areas: (1) Southeastern Idaho (relatively small deposits of reed-sedge and humus peat adjacent to some swampy river flats); (2) central Idaho (reed-sedge and shrub and tree peat in boggy meadows at high altitudes in glaciated sections); and (3) Boundary, Bonner, Kootenai, and Shoshone Counties (reed-sedge peat near ponds and lakes and along swampy portions of rivers).
Commercial production of peat has also come from bogs on Marsh Creek near Downey (fig. 33, No. 1) in Bannock County and from similar deposits along Teton River near Driggs and Victor (No. 2) in Teton County. Total production from these areas is unknown.

Some of the peat deposits in central Idaho are mentioned in publications on Idaho placer deposits; for example, Cappe (1940, p. 6 and 18) and Reed (1939, p. 11–15) briefly describe deposits of reed-sedge and woody peat, locally up to 20 feet thick, that occur in boggy meadows at elevations of over 7,000 feet in some places—the Florence (No. 3) and Newsome (No. 4) districts and in the Secesh Basin (No. 5). These deposits, for all practical purposes, may be dismissed as economically unfeasible for development in the foreseeable future. Deposits at Warren (No. 6), Dixie (No. 7), and Elk City (No. 8) are probably in the same category, for they too are inaccessible and remote from potential markets.

North Idaho has the largest reserves of potentially commercial peat in the State, but there has been little, if any, production. Peat deposits in the Idaho panhandle have not been thoroughly studied or mapped, but locally there are large accumulations of accessible reed-sedge peat. Most of these deposits are near enough to transportation and markets to be considered commercial. Extensive deposits are present along the Kootenai River Valley in Boundary County (No. 9), and in poorly drained bogs and meadows adjacent to ponds, lakes, and sluggish streams in Bonner (No. 10), Kootenai (No. 11), and parts of Shoshone (No. 12) Counties. In the Kootenai Valley, farmers burning stubble from the grain fields have accidentally started fires in the peat deposits that have burned underground for many months before finally being extinguished.

The outlook for peat in Idaho suggests continued rather rapid increase in consumption. Because of the increased demands for peat in the Pacific Northwest, there is a definite potential market for North Idaho peat. As in other parts of the United States, the principal use for peat in Idaho is as a soil conditioner, but uses for peat are expanding. Extensive investigations should be made to determine the possible use of Idaho peat in construction as an insulating material (bulk, compressed, or in blocks); as a possible cattle feed when blended with byproducts of the sugar industry; as a poultry and cattle litter; as a vegetable storage and shipping material, particularly in the potato industry; as a base for special fertilizers; and as a general packing material. Also, for many uses, Idaho peat should be able to compete regionally with foreign peat.

PETROLEUM AND NATURAL GAS

(By C. N. Savage, Idaho Bureau of Mines and Geology, Moscow, Idaho)

The use of natural gas and substances of petrolierous origin goes back over 6,000 years, but the petroleum and petrochemical industries as we now know them were launched at the time of the discovery of Drake's Pennsylvania oil well in 1859. Oil and gas now provide about 75 percent of the energy consumed in the United States. In 1962, the United States produced 2.6 billion barrels of crude oil and 13.8 trillion
EXPLANATION

- Peat production
- Known peat deposits (general area)

Peat Localities
1. Marsh Creek and adjacent areas
2. Driggs area
3. Florence
4. Newcomb
5. Spencer Basin
6. Wcreen
7. Dixie
8. Elk City
9. Kootenai Valley
10. Bonner County area
11. Kootenai County area
12. Keshock County area
13. Bear Lake area
14. Owyhee County area

Figure 32.—Peat in Idaho.
cubic feet of natural gas. Thirty-one States contributed to the crude oil production and 29 to that of natural gas. There is currently an excess domestic productive capacity of about 3 million barrels of crude oil per day, but a recent publication of Resources for the Future suggests that by the year 2000 the 1960 consumption of petroleum in the United States would be more than tripled, while natural gas consumption will be over 2½ times that of 1960. These requirements may exceed the available domestic supply from conventional sources.

A future supplementary source of liquid fuels is the vast resource of oil shales. These shales can produce all the products we now obtain from petroleum and natural gas plus some others. Such shales are found in 29 States but are best known in parts of Colorado, Utah, and Wyoming. Oil shales to be potentially commercial should average 25 gallons of oil to the ton of shale, and producing horizons should average at least 15 feet and preferably 25 feet in thickness. The Green River shales alone are thought to contain 500 billion to a trillion barrels of oil which meet these requirements (Duncan, 1958).

Of lesser importance are other domestic oil shales, such as those in the Phosphoria Formation in Montana, Wyoming, Idaho, and Utah, and others in the Upper Cretaceous rocks of the Great Plains. Data now available indicate that these shales would yield 15 gallons of oil or less per ton, and the producing horizons are 25 feet or less in thickness. They constitute a resource that will be exploited only in the distant future, if ever.

Commercial quantities of oil or natural gas have not yet been produced in Idaho. Large portions of the State are underlain by rocks that are not favorable either as source rocks or reservoir site for oil or gas. In the central and northern parts of the State, unfavorable areas include the granitic rocks of the Idaho and Kaniksu batholiths and the metamorphic argillites, siltites, and quartzites of the Belt, pre-Belt, and equivalent series. Paleozoic, Mesozoic, and Tertiary sedimentary rocks comprise the more favorable potential oil or gas sources and reservoirs (fig. 34).

Three States adjacent to Idaho—Montana, Wyoming, and Utah—have oil- and gas-producing fields in rocks that are equivalent in age to some formations in Idaho (table 8). There are also some lithologic similarities between rocks in these producing areas and rocks in Idaho.

The earliest recorded activities in the search for oil and gas in Idaho occurred in 1904 in the Boise region. Since then, short-lived, unsuccessful exploratory projects and promotional schemes have sporadically flared up and then died down. Greatest exploration efforts have been expended in the southwestern and southeastern parts of the State, but some investigations have been in south-central and northern Idaho. To date, roughly 55 holes have been drilled (fig. 34). Some information on these wells is available in open files at the Idaho Bureau of Mines and Geology at Moscow, however, in several instances little or nothing is known about the wells. Of the holes drilled, the average depth approximates 5,000 feet, and only six are known to have gone below 5,000 feet.

The Idaho group and Payette formation of southwestern Idaho (table 8) have yielded traces of oil and gas, probably derived from organic materials buried in former marshy environments. The sediments are largely fluviatile, but include some lacustrine materials.
EXPLANATION

Oil and gas potential of underlying rocks

- Granitic rocks, batholiths, and stocks—no oil and gas potential

- Volcanic rocks, mostly flows—no oil and gas potential; may overlie potential reservoir rocks locally

- Metamorphic or other rock material not likely to contain oil or gas

- Sedimentary rocks with qualities which may be favorable to storage of oil and gas—some areas have better potential than others

Exploration wells

- Status unknown

- Dry or abandoned hole

- Gas showing, abandoned

- Gas and oil showing; abandoned

- Number refers to county hole number

Figure 34.—Oil and gas potential of Idaho rocks and location of exploration wells.
<table>
<thead>
<tr>
<th>Geologic units present in southern Idaho</th>
<th>Thickness range (ft)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cenozoic:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertiary and Quaternary:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pliocene and Pleistocene: Idaho and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Owyhee Lake group</td>
<td>1,000-8,000</td>
<td>May contain small local gas accumulations.</td>
</tr>
<tr>
<td>Owyhee and Pleistocene: Fayette and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Owyhee Lake group</td>
<td>1,125</td>
<td></td>
</tr>
<tr>
<td>Spinifex and Kewanee: Washoe group</td>
<td>1,800</td>
<td></td>
</tr>
<tr>
<td>Mesozoic:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cretaceous:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wasatch group: (Frontier formation)</td>
<td>3,200-4,000</td>
<td>Producing equivalents in Montana and Wyoming, Kansas, Thermopolis, and Mokoy formations.</td>
</tr>
<tr>
<td>Uinta formation: (Boulder formation,</td>
<td>2,100-3,200</td>
<td>Producing equivalents in Montana, Wyoming, and Utah—Moravia, Lakota, Fossil, Clovis, Dakota, Elk, and Vermillion Cliff formations.</td>
</tr>
<tr>
<td>Bear River Formation, Bear River</td>
<td>3,200-4,000</td>
<td>Producing equivalent in adjacent areas—Moravia, Curtis, Rutledge, Sandstone, Carquest, Nuxen, and Nuxen formations.</td>
</tr>
<tr>
<td>Jurassic:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Colorado Plateau)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jurassic:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ancestral group: (Wood Shale; Deadman Limestone; Bighorn Sandstone; Timothy Sandstone)</td>
<td>1,000-1,500</td>
<td>Producing equivalent (?) Chugwater formation.</td>
</tr>
<tr>
<td>Trislope (Fortino Limestone; Fort Hill formation; Rose Fork Limestone)</td>
<td>1,000-3,850</td>
<td>Producing equivalent (?) Chugwater formation.</td>
</tr>
<tr>
<td>Wasatch:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wasatch Sandstone; Wasatch Sandstone</td>
<td>1,175-2,000</td>
<td>Producing equivalents—Dinwoody and Flensburg, or &quot;Ember&quot; formations.</td>
</tr>
<tr>
<td>Wasatch Sandstone: Wasatch Sandstone</td>
<td>1,175-2,000</td>
<td>Producing equivalents—Dinwoody and Flensburg, or &quot;Ember&quot; formations.</td>
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<tr>
<td>Wasatch Sandstone: Wasatch Sandstone</td>
<td>1,175-2,000</td>
<td>Producing equivalents—Dinwoody and Flensburg, or &quot;Ember&quot; formations.</td>
</tr>
<tr>
<td>Paleozoic:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permian:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Redhorn Sandstone; Test member:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphoria formation (Herbert Shale Member; Clarity Shale; Red Shale; Moab Creek Shale; Lower Moab)</td>
<td>1,000-1,500</td>
<td>Producing equivalents in adjacent areas—&quot;Ember&quot; and Goodrich.</td>
</tr>
<tr>
<td>Park City Formation; (Bravay Member</td>
<td>1,000-1,500</td>
<td>Producing equivalents—Test, Jeep, Quad, Red, Weise, Morgan, and Goodrich.</td>
</tr>
<tr>
<td>Madison Canyon Formation; Lodgepole Limestone;</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Green River Formation; (Four Parks Lime-</td>
<td>1,000-1,500</td>
<td>Producing equivalents present in adjacent areas.</td>
</tr>
<tr>
<td>Green River Formation; (Jefferson formation)</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Wasatch Canyon Formation</td>
<td>1,000-1,500</td>
<td>Producing equivalents in adjacent areas.</td>
</tr>
<tr>
<td>Siltstone:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish Lake (Bighorn Dolomite)</td>
<td>1,000-1,500</td>
<td>Producing equivalent in Williston Basin.</td>
</tr>
<tr>
<td>Snake River Formation</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Green River Formation</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Snake River Formation</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Camas Creek</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>St. Charles formation (Bagen-Calapa)</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Goose Bay group:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noseau Limestone</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Bloomington formation</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Bachelors formation</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Ute formation</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Logan formation</td>
<td>1,000-1,500</td>
<td></td>
</tr>
<tr>
<td>Brigham Quarry</td>
<td>1,000-1,500</td>
<td></td>
</tr>
</tbody>
</table>

1 Stratigraphic nomenclature and correlations are not necessarily those used by the U.S. Geological Survey.  
2 When present.

(Savage, 1958 and 1961a). Although their presence has not been proved, rocks of Mesozoic and Paleozoic ages may lie beneath these Tertiary sediments and could conceivably contain petrolierous materials. A well that was drilled as early as 1908, about 10 miles north and 3 miles west of Emmett in Sand Hollow, reportedly produced some...
natural gas. Additional unsuccessful wells were drilled on the western Snake River Plain during the periods 1921-35 and 1955-66. Many of these were water wells that tapped small pockets of gas. Kirkham (1955) reported that the gas encountered in Payette-Weiser area sediments was "** characterized by high nitrogen, oxygen, and hydrogen sulfide, by relatively high methane and ethane, and high hydrocarbons." One well reportedly produced 75 million cubic feet of gas per day for a short time before it ceased to flow.

In the Weiser-Payette area, a typical gas analysis was as follows (Kirkham, 1955, p. 287):

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>0.2</td>
</tr>
<tr>
<td>Oxygen</td>
<td>4</td>
</tr>
<tr>
<td>Methane</td>
<td>72.4</td>
</tr>
<tr>
<td>Ethane</td>
<td>26.9</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>4</td>
</tr>
</tbody>
</table>

Reportedly, some of the gas in this area has been used for domestic purposes, but in all cases exploratory wells have been short lived even when they came in as "gushers," blowing debris 100 to 150 feet into the air. Pressures in initial stages reportedly have ranged from 300 to 1,000 pounds per square inch. Temporarily, some wells yielded up to 100,000 cubic feet of gas per day. Buwalda (1925) expressed the opinion that "** the chances of securing a paying gas well do not appear good, even if somewhat better than the chances for securing a producing oil well."

Youngquist and Kjilsgaard (1951) concluded that the younger rocks of the Snake River Plains were not potential oil and gas reservoir rocks because of the many thick impervious extrusive igneous rocks, and because of a "** general lack of proper regular structure in both the sedimentary and volcanic rocks." It might be noted that porous volcanic rocks in central Washington have produced small quantities of gas, used for domestic purposes, probably derived from interbedded Tertiary lacustrine deposits similar to the Idaho and Payette formations.

There are few good arguments why the Cenozoic rocks of the Idaho part of the Snake River Plain should contain oil and gas, and overwhelming arguments why the rocks should not contain commercial quantities of these substances. The lithologic, structural, and environmental conditions of deposition are all generally unfavorable over the area. Widespread volcanism and faulting of the rock materials is incompatible with the accumulation of oil and gas. Furthermore, these Tertiary deposits are fluviatile and lacustrine in origin and not marine, as in the case in larger producing fields. Although some lake deposits constitute our largest reserve of oil shales, their environment of deposition was somewhat different from that of the Payette formation and Idaho group.

The general basinal structure of the western Snake River Plain is a natural trap for ground water rather than oil and gas. Ground water intakes lie on the flanks of the eroded structure and water movement is down-dip into the beds and basin. Except for minor flexures
which have locally trapped natural gas, any larger quantities of petrolierous material might be expected to have been flushed up and out of the intake beds at their surface outcroppings. Until deep drilling has been done to establish what rocks underlie the Payette formation and Idaho group, no statement can be made of the potential of the older rocks for oil and gas. In a recent publication, Newton and Corcoran (1963) summarize existing knowledge of the petroleum geology of the western Snake River Plain, including both the Oregon and Idaho sections. Where available, previous drill hole data are included. A strong case is presented for the possible presence of commercial quantities of gas in the region, particularly in the Oregon section. Further drilling exploration is advocated by the authors.

Kirkham (1922, 1923, 1924, 1928a, 1928b, and 1935) concluded that within the State the southeastern part had the best potential for oil and natural gas occurrences. Among the reasons for optimism about southeastern Idaho, as previously stated, is the fact that commercial-scale oil and gas production occurs in formations of similar age in adjacent States, from 70 to 300 or more miles distant. However, several unsuccessful exploratory wells have been drilled in southeastern Idaho (fig. 34).

In southern and southeastern Idaho, there are over 25,000 feet of exposed sedimentary rocks, with perhaps two times this thickness actually composing the entire sedimentary section. Of the total thickness, close to 12,000 feet of rock may have characteristics that would make them good reservoir rocks. Furthermore, it is a fact that many of the exposed strata have a fetid oil-like odor when freshly broken, and petrolierous substances in some rock fragments will burn. However, no good oil seeps are known to exist in the area. Some of the strata have excellent porosity because of the presence of porous sandstones, cavernous limestones, and faulted and jointed rock units. Some formations, however, are less permeable than one might expect because they are dolomitized or because their grains have been closely cemented, producing impermeable orthoquartzites (Savage, 1961b). The presence of numerous unconformities, faults, and folds is favorable to migration and accumulation of oil and gas. Anticlinal and synclinal structures, in many instances, are expressed topographically as ridges and valleys, respectively. On the other hand, some potentially good reservoir rocks are too highly folded and broken to make good traps for oil and gas.

Some oil shales are known to underlie southeastern Idaho; however, they are very low grade by comparison to others farther east in Wyoming and Colorado, and southeast in Utah. Winchester (1926, p. 76-78) records tests of the Phosphoria formation in southeastern Idaho, noting that one sample, taken in Palisades Creek, southeast of Idaho Falls, yielded only 3 gallons of oil per ton. Samples of Cretaceous rocks in western Teton County and Quaternary (?) rocks 4 miles south of Soda Springs in Caribou County yielded 32 and 20 gallons of oil per ton, respectively. However, these oil shale beds are thin and of limited areal extent. Gardner (1944) concluded that the Phosphoria formation in Idaho appears to be notably deficient in oil.

Upon the basis of our present knowledge of the lithology and structure of exposed rocks in Idaho, the future possibility of oil and gas production in commercial quantities seems poor indeed. Extensive
recent volcanism in much of the State, extensive metamorphism, and intense faulting and folding of potential reservoir rocks locally—all are important reasons for pessimism. All this pessimism could be changed, however, by one successful well producing only a few barrels of oil per day.

Further deep exploratory holes, strategically located in southern Idaho, seem to be the next step in exploration. By most standards, much of the previous exploratory drilling in Idaho has been timid, ill advised, or by inexperienced persons with insufficient funds. A few holes have been drilled competently, but most of the drilling has been relatively shallow. By comparison to producing areas, exploration in more favorable parts of the State may be said to have been most inadequate. The lack of thorough exploration reflects in part the opinion of many competent geologists, that there are no attractive exploration possibilities for oil or gas within the State.

In the opinion of other geologists, the complete absence of oil and gas in Idaho has yet to be demonstrated. These men feel that further well-directed exploratory drilling is warranted. Largely because of the latter viewpoint, the State of Idaho has recently established an oil and gas commission and devised regulatory measures which became effective in July 1963. Copies of these regulations are available (at $1 each) from the Secretary of the Commission at Moscow (Oil and Gas Conservation Act and General Rules and Regulations of the Idaho Oil and Gas Conservation Commission, 1963).

PHOSPHATE ROCK

(By W. C. Gerè, U.S. Geological Survey, Denver, Colo.)

In 1963 the United States, the world's largest producer of phosphate, mined 19,389,000 long tons of marketable phosphate rock valued at $134,304,000, averaging $6.93 per ton (Lewis and Tucker, 1963); about 42 percent of world production. The Florida field produced about 72 percent of this amount, followed by the western phosphate field (16 percent) and Tennessee (12 percent). Idaho as of 1963 had produced a total of about 29,150,000 long tons of phosphate rock valued at $91,211,572. Idaho ranks annually with Tennessee for second place in phosphate output. The largest reserves of phosphate rock in the Nation are contained in the western phosphate field of eastern Idaho and in adjacent parts of Montana, Wyoming, and Utah (see fig. 35), an area of about 150,000 square miles.

There is presently an international search for phosphate resources, either to locate new deposits or extend the known reserves. The expanding world population, with attendant increasing requirements for fertilizer and industrial phosphate products, contributes to the importance of this commodity. About 70 percent of world production is used in agriculture as fertilizer products.

The major occurrence of phosphate in nature is in the form of the mineral fluorapatite (CaF) _Ca_5(PO_4)_3(F,OH) and other phosphate minerals disseminated in igneous rocks. Through the process of weathering, the phosphorus is released, part of which is transported to the oceans by streams and rivers. In certain marine environments, carbonate
Figure 35.—Phosphate rock deposits in Idaho.
fluorapatite phosphate minerals are precipitated through biologic and other chemical activity, and concentrations of marine deposits of economic interest have resulted. The phosphatic strata maintain a rather uniform phosphate content and thickness over many square miles. Such phosphate deposits were formed in ancient oceans that transgressed portions of present land areas and were buried beneath younger accumulations of sediments. Through later regression of the seas and uplift and erosion, the ancient marine phosphate rocks are now exposed at the surface in many parts of the world, including Idaho, and are now available for exploitation.

Igneous rocks, guano, and secondary deposits, formed by the leaching and redeposition of phosphorus in rocks, are utilized in worldwide production of phosphorus, but the greatest reserves and resources are the marine phosphate deposits.

In the western phosphate field, upper Paleozoic marine rocks of both Mississippian and Permian age are phosphate bearing. The phosphatic zones are in the Brazer Limestone and equivalent units of Mississippian age, and in the Meade Peaule and Retort phosphatic shale members of the Permian Phosphoria formation. The phosphatic rocks in the Mississippian and Permian rocks are similar in lithologic types and appearance, and they are related in origin. The only known concentrations of phosphate in Mississippian rocks that warrant consideration as future resources are in northern Utah.

The great phosphate deposits in the Permian rocks were discovered in northern Utah in 1899 by gold prospectors (Jones, 1907). Subsequent studies of the origin, nature, and extent of the phosphate deposits and related rocks have provided valuable information for exploration and development of this resource area. Noteworthy publications not otherwise cited in this report are: Davidson and others, 1953; Deiss, 1949; Enigh, 1958; Lowell, 1952; Mansfield, 1922; McDittivit, 1956; McKelvey, 1963 and 1947; McKelvey and others, 1959a, 6, c, d; O'Malley and others, 1958; Smart and others, 1954; and Swanson and others, 1956.

The Permian phosphate deposits are in two shale units in the lower and upper parts of the Phosphoria formation and equivalent rocks: the Meade Peak and Retort phosphatic shale members, respectively (McKelvey et al., 1959, pp. 22-26, 29-39, pl. 3). The phosphatic members consist of oolitic, peletal, biologic (skeletal), and nodular phosphorite, nodular and bedded chert, siltstone, claystone, limestone, dolomite, and mixtures of these rock types. Phosphate zones are usually found near the base and top of each member. The cyclic deposition, sequence, and relationships of the various lithologies are described by Sheldon (1963, p. 124). The configuration of the basin of deposition changed frequently, resulting in interruption of cyclic sequences and producing differences in rock types and phosphate content, and only in places are the phosphate beds rich enough to warrant development. The reducing conditions in the Permian sea caused the preservation of large amounts of organic material that contributes to the darker colors of the rocks. The accumulation of significant to trace amounts of vanadium, chromium, uranium, zinc, and many other elements is associated in part with the carbonaceous matter (Gulbrandsen, 1960, pp. 82-86). Shoreward, the carbonaceous content decreases so that a halo of lighter colored phosphorites and related sedimentary
rocks appears accompanied by a decrease in phosphate and trace element content, with few exceptions. In southeast Idaho, the two phosphatic shale members are separated by chert and cherty mudstone of the Rex Chert member of the Phosphoria formation. North of the Snake River, owing to a lateral facies change from chert to carbonate rock and sandstone, the phosphatic members are separated by and interdigitate with the Franson and Ervay carbonate rock members of the Park City formation and the upper and lower members of the Shoshoni Sandstone (McKelvey et al., 1959, pl. 5). The westward limit of the phosphate basin is exposed southwest of Oakley in Cassia County as a 2-inch bed of dark phosphorite in a chert sequence as much as 1,000 feet thick.

The phosphate production in Idaho comes from the Meade Peak phosphatic shale member, the lower phosphatic unit. Although the Retort phosphatic shale member is well developed in Idaho, especially north of the Snake River, it contains only one to three thin phosphorite beds. Phosphate is concentrated in the Retort member in southwestern Montana, and is mined.

Phosphate rock is a term used in commerce for rocks of sufficient grade and composition to permit their use, either directly or after concentration, in the manufacture of commercial products, and the ore is classified according to grade amenable to processing by industry. Phosphate content is calculated and expressed either as tricalcium phosphate, Ca₃(PO₄)₂, also referred to as bone phosphate of lime (BPL), or more commonly as phosphorus pentoxide, P₂O₅. (One percent P₂O₅ equals 2.18 percent BPL). High-grade (acid-grade) rock contains a minimum of 31 percent P₂O₅, and medium-grade (furnace-grade) requires 24 percent. Low-grade rocks, containing an average of at least 18 percent P₂O₅, may be utilized by blending or beneficiation. Most phosphate rock, including the Idaho deposits, must be processed to free the phosphorus from the fluorine in theapatite to form a water-soluble fertilizer product.

The application of sulfuric acid (also nitric acid) to high-grade phosphate rock to make fertilizer products is the most widely used procedure today. This process yields a fertilizer containing about 20 percent available P₂O₅. Triple superphosphate is made by the use of additional acid, which forms phosphoric acid, and the phosphoric acid is used to treat phosphate ore resulting in a product containing 40 to 50 percent available P₂O₅. Because of the lower transportation cost per unit of P₂O₅, triple superphosphate or phosphoric acid are more competitive products for shipment outside the area of local consumption. Phosphoric acid is also combined with potassium and ammonium compounds to form potassium and ammonium phosphates.

Electric and blast furnace operations require ore averaging about 34 percent P₂O₅. The rock is roasted with coke and siliceous flux producing elemental phosphorus, ferrophosphorus, and calcium silicate slags. During the process, the phosphorus is volatilized, condensed, and collected. The product is utilized by the chemical, drug, and food industries, and part is also used to produce triple superphosphate. The purity of the product results in the lowest freight cost per unit of P₂O₅, although the cost and operation of a furnace installation is more expensive.
The value of the ore depends not only on the grade but also on the amount and kinds of contained impurities. The organic material is removed by calcining. Carbonate content is held to the minimum to avoid excessive acid consumption and, although the western shales are self-fluxing in part, high carbonate content also requires the extra cost of additional silica in furnace operations. Iron oxides and aluminas, and for some uses magnesites, contribute to an unstable or inferior fertilizer product. Iron oxide content also causes loss of phosphorus to the heavy ferrophosphorus slag.

A number of byproducts are available for recovery in the processing of the phosphate ore. Some uranium has been recovered from plants processing Florida phosphates, and fluorine is removed to prevent pollution and recovered as a fluosilicate (see section on fluorine, p. 79.) The Anaconda Copper Mining Co. recovered vanadium from the Phosphoria phosphatic rocks at the Conda mine north of Soda Springs during the early 1940’s (Rubey, 1943). McKelvey and Strobell (1885) give data on the Paris-Bloomington Canyon locality. Ferrophosphorus slag provides a concentration of vanadium, chromium, and other metals. Additional roasting of ferrophosphorus slags from Idaho furnace plants has yielded concentrations of \( V_2O_5 \) as high as 15 percent, 10 percent \( Cr_2O_4 \) and 40 percent \( P_2O_5 \). Slag from Idaho was processed for a short time during 1962 at the Susquehanna Minerals mill west of Salt Lake City and is processed presently at the Vitro Chemical Co. plant, also in the Salt Lake City area. Recently Kerr-McGee Minerals constructed a vanadium plant at Soda Springs, Idaho, to recover vanadium from phosphate operations. Concentrations of selenium, zinc, molybdenum, nickel, and zirconium in the phosphatic zones are greater than in most common rock (Gulbrandsen, 1960, pp. 82-86), but potential recovery of these metals as byproducts is highly speculative at present. Large quantities of hydrous calcium sulfate are formed during the manufacturing of the superphosphate fertilizers, which is usually discarded as waste.

Phosphate rock has a relatively low unit value, ranging from $1 to about $8 per ton. Local consumption of phosphate products would not support a large industry, and, therefore, Idaho deposits must compete with other domestic and foreign sources for markets outside the State. Thus, the costs of mining, transportation, and processing are very critical. Exploration geologists should acquire a thorough knowledge of the stratigraphy of the Permian rocks and the nature and extent of the various types of phosphorite in order to locate competitive deposits.

Reserve estimates are purposefully conservative because the available analytical data are from samples that have mostly been collected from surface trenches. Weathering agents leach the lime from phosphate rock, thus yielding \( P_2O_5 \) analyses higher than will be found in rock below the weathered zone. This difference may vary as much as 6 percent \( P_2O_5 \). One of the advantages of strip mining is the recovery of most of the ore from the enriched weathered zone. However, the reserves amenable to strip mining are a small percent of the total, and the major production will ultimately be recovered by underground methods.

Idaho has produced phosphate rock each year since 1906, except 1916 (fig. 36). The early history of development and production of
the Idaho deposits is described by Mansfield (1927, p. 292-301). Many companies were organized to exploit phosphate rock, but few have survived. The San Francisco Chemical Co. started operations in 1906 and is presently one of the major operators in the Western field; most of its Idaho production came from the Montpelier Canyon area. The Anaconda Copper Mining Co. opened the Conda mine north of Soda Springs in 1928 and maintained annual production until sale of the property to the J. R. Simplot Co., present operator. Since 1934, phosphate production has increased rapidly (fig. 36), especially with the start of the J. R. Simplot Co. operations in the Fort Hall Indian Reservation, and the construction of electric furnace plants by the Food Machinery & Chemical Co. at Pocatello, the Monsanto Chemical Co. at Soda Springs, and the Central Farmers Fertilizer Cooperative in Georgetown Canyon.

**IDAHO PHOSPHATE DEPOSITS**

The richest phosphate deposits in the Western field are in southeast Idaho (Swanson and others, 1953, figs. 8-11). Available reserve esti-
mates of phosphate rock in Idaho reflect only a very general appraisal. The published reserves in southeast Idaho are from Mansfield (1922, 1925, 1927, and 1929) and Sheldon (1935). Mansfield's calculations are very conservative and are based on limited sample data and geologic mapping. Since 1935, the U.S. Geological Survey has gathered considerable data on the phosphate content and distribution of the Permian rocks. Final compilation of this material is in progress, but as yet only the reserve figures for Teton and parts of Caribou and Madison Counties are available, and these show tonnages by grade above and below entry level (Sheldon, 1935).

Bannock County.—In sec. 18, T. 5 S., R. 38 E., within the Fort Hall Indian Reservation, phosphate rock is exposed and underlies part of the area to the north (Mansfield, 1920, p. 102-103) (fig. 35). Several million long tons of high-grade rock are present at a depth of 5,000 feet or less.

Bear Lake County.—Phosphate rocks crop out at only a few places in this county, although they underlie much of the eastern and northern parts at depths less than 5,000 feet (Mansfield, 1927, p. 248-282). Mansfield's very conservative estimate is about 69.2 million long tons of high-grade rock.

The Union Pacific Railroad crosses the richest part of the Western phosphate field through Bear Lake and Caribou Counties. Because of the nearness of rail transportation, most of the Bear Lake County deposits were explored soon after the discovery of the Western phosphate field. Mineral claims were located covering major areas prior to the enactment of the Federal mineral leasing regulations. These include the Hot Springs locality on the northeast side of Bear Lake, the Paris-Bloomington Canyon area, and Montpelier and Georgetown Canyons (fig. 35). A large tonnage has been produced from the Montpelier Canyon deposits by the San Francisco Chemical Co. The Central Farmers Fertilizer Cooperative has constructed an acid plant and electric furnace installation in Georgetown Canyon for processing rock from their mine. Several companies, including Potash Co. of America, have mined rock in the Bloomington-Paris Canyon area.

Bingham County.—The Meade Peak phospathic shale member of the Phosphoria formation crops out in the eastern part of the Fort Hall Indian Reservation, 17 to 20 miles east of Fort Hall (fig. 35), and in the Wolverine Canyon area. The J. R. Simplot Co. and Food Machinery Corp. hold Indian leases on extensive areas. The Simplot Co. has recovered large tonnages from the Gay mine, utilizing the high-grade ore in their acidulation plant northwest of Pocatello, and furnishing medium-grade rock to the Food Machinery & Chemical Corp. electric furnace plant, also at Pocatello. Assuming a high-grade bed at the base of the Meade Peak ranging from 2 to 6 feet in thickness, Mansfield (1920 and 1929), estimated the reserves at about 763.8 million long tons.

Bonneville County.—The Meade Peak phospathic shale member of the Phosphoria formation is exposed on both sides of the Snake River, in the Caribou and Snake River Ranges, in the eastern part of the county (fig. 35). The richest deposits are in the Caribou Range southwest of Swan Valley, extending from Bear Creek northwesterly to beyond Pritchard Creek. The deposits in the Snake River Range are exposed in northwest-striking complex folds and thrust fault
structures, and the deposits are more or less continuous from the Wyoming State line to the Teton County line. The lower zone in the Meade Peak is not well developed; however, a rather unique bed of phosphate fossil detritus at the top of the Meade Peak is apparently widespread in the county. At Bear Creek in the Caribou Range, this unit is more than 12 feet thick but thins rapidly to the northwest within a mile along strike. In the Snake River Range, this unit is over 3 feet thick in North Fork Rainey Creek and 4 feet thick at Pine Creek. It can be traced northwesterly into Madison County. Considerable prospecting has been done in the Caribou Range, and the deposits in the northwestern part are in a Federal lease. Sheldon (1965, p. 154, and pl. 12) has estimated that for this area there are 89.1 million tons of high-grade, 223.7 million tons of medium-grade, and 603.4 million tons of low-grade rocks above entry level; and 88.1 million tons of high-grade, 213.9 million tons of medium-grade, and 540.6 million tons of low-grade rock less than 5,000 feet below entry level.

Caribou County.—The bulk of the deposits of the western Permian phosphate field are in Caribou County, mainly in the eastern and central parts (fig. 35). The phosphate rocks are repeatedly exposed along the large folds that trend north to northwesterly in an area bounded by the Webster Range on the east and the Aspen Range on the west, and continuing through the Chesterfield Range to the northwest. Phosphate zones are at both the base and upper part of the Meade Peak phosphatic shale member. The Conda locality, a few miles north of Soda Springs, has been mined since 1920. Underground methods were mainly used by the Anaconda Copper Mining Co. for much of the production until the late 1940's, when strip mining was initiated and this method has been continued by the J. R. Simplot Co., present operator. The Monsanto Chemical Co. has developed a large strip mine about 15 miles north of Soda Springs, Idaho; the Ballard mine, to furnish ore for their electric furnace plant north of Soda Springs. Strip mines in the Lower Valley area, by J. A. Terteling & Sons, and at Diamond Gulch, by San Francisco Chemical Co., have also produced ore. This county has been prospected since 1910. Patented claims cover a few areas of outcrops, and much of the remaining area is controlled by Federal and State leases.

Mansfield (1927, pp. 229-236, and 1929, pp. 69-88) estimated about 4,618.7 million long tons of high-grade ore to depths of as much as 5,000 feet. This is a very conservative estimate and is based on a zone at the base of the Meade Peak phosphatic shale member from 4 to 8 feet thick. Later work has shown that in part of Caribou County the lower zone is over 15 feet thick and that the upper zone is as much as 10 feet thick. The reserves of high-grade rock are possibly 2 to 4 times Mansfield's estimate, and reserves of medium- and low-grade rock must be more than 40 billion tons. It is probable that reserves in three or four townships in Caribou County are equal to the combined total of the known reserves of Montans, Wyoming, and Utah.

Detailed mapping in the Dry Valley quadrangle (Cressman and Gulbransen, 1955), Johnson Creek quadrangle (Gulbransen et al., 1956), and the Snowdrift Mountain quadrangle (Cressman, 1987) presents pertinent information on certain parts of the county.

Cassia County.—The Meade Peak member of the Phosphoria formation is present in a southeast-plunging synclinal structure in the
western part of the Sublett Range in eastern Cassia County (fig. 35). The known area of exposure is confined to T. 13 S., R. 29 E. The shale unit contains only 6.4 feet of medium-grade and 9.5 feet of low-grade deposits. It is possible that other areas of outcrop will be found when this locality is studied in greater detail. Near the divide and along the upper parts of Trapper and Trout Creeks, southwestern Cassia County, the Meade Peak is exposed for about 6 miles in a north-south direction. The phosphatic zone consists of a thin bed of phosphorite about 2 inches thick overlain by a few feet of slightly phosphatic rock. This is the westward margin of the phosphate area in this part of Idaho (fig. 35). Reserve estimates for Cassia County are not available.

Clark County.—The Permian phosphate rocks are exposed in the Centennial Range in the northeastern corner of the county (Honka, 1932) (fig. 35). High-grade bioclastic phosphorite beds in the Meade Peak phosphatic shale member of the Phosphoria formation have an average thickness of 6 feet. Ore reserves have not been calculated, but Honka (1932, p. 18) states that “...it is probably safe to say that they involve scores of millions of tons of acid-grade (high-grade) phosphate rock.” The J. R. Simplot Co. holds a Federal phosphate lease and has mined from the Centennial deposits. The Retort phosphatic shale member (upper phosphatic unit) contains 1 to 2 feet of high-grade beds usually separated by slightly phosphatic shales, but the deposits in this member are not considered to have economic significance.

Fremont County.—In Fremont County, the Permian phosphatic rocks are exposed along the south slope of the Centennial Range and north and south of Howard Creek west of Targhee Pass (fig. 35). Little is known concerning the deposits west of Targhee Pass except for a brief discussion by Condit and others (1928, p. 395). The deposits in the Centennial Range near the Clark County line should contain a high-grade bed 4 to 5 feet thick near the base of the Meade Peak phosphatic shale member.

Lehi County.—The Permian phosphate crops out along Hawley Creek on the west slope of the Beaverhead Mountains (T. 16 N., R. 27 E.) (fig. 35). Phosphatic rocks are present, but the grade, thickness, and reserves are not known. Some prospecting has been done under a Federal prospecting permit.

Madison County.—A band of the Meade Peak phosphatic shale member is exposed in the extreme southeast corner of the county (fig. 35), crossing Burns Creek in a northwesterly direction. To the northwest, the shale is covered by Tertiary volcanic rocks. The phosphatic zone at the base is not well developed, but a bed of high-grade bioclastic phosphorite at the top of the shale interval should average 3 feet in thickness. From the data of Sheldon (1963, p. 154, and pl. 12), it is estimated that Madison County contains at least 4 million long tons of high-grade phosphate rock, 6.5 million tons of medium grade, and 11.5 million tons of low grade, more than half of which should be above entry level. Part of the surface has been prospected, and a Government phosphate mineral lease covers much of the Coalmine Creek and Argonaut Ridge areas west of Burns Creek.

Teton County.—Phosphate rocks are exposed as erosional remnants along the lower part of the western slope of the Teton Mountains and
in the Big Hole and Snake River Ranges (fig. 35). The deposits are mostly medium to low grade (Gardner, 1944). From the reserve figures of Sheldon (1965, p. 153–154, and pl. 12), it is estimated that 7.5 million long tons of high grade, 940.4 million (tons) of medium grade, and 123 million (tons) of low grade are present in the county, mostly above entry level. Some of the phosphatic sandstones above and below the Retort phosphatic shale member (upper shale member) of the Phosphoria formation contain as much as 18 percent P₂O₅. These rocks have a potential for furnace feed ore, and should be considered as part of the Idaho phosphate resources. Geologic maps covering parts of the Teton area are available (Albee, 1964; Staatz and Albee, 1965). Some prospecting has been done in the county, and a Federal lease has been issued on a small area east of Victor.

Phosphate rock will continue as one of the major mineral industries of Idaho, and gradual growth seems assured. Most of the major chemical and fertilizer companies have made and are making economic studies in the western field, and established producers of western rock are increasing their reserve holdings. To date Idaho has mined approximately 20.1 million tons from reserves of about 6,697 million tons of high-grade rocks, half of which should be above entry level. The great majority of phosphate rock deposits remain to be exploited. In addition to research conducted and supported by industry, the Federal Geological Survey and Bureau of Mines and the Idaho Bureau of Mines and Geology have made and will continue research studies on the nature, distribution, and processing of the resources of the western phosphate field, all of which will aid the future exploitation of Idaho phosphate rock.

REFRACTORIES (HIGH ALUMINA)

(By L. S. Prater, Idaho Bureau of Mines and Geology, Moscow, Idaho)

Refractories have been defined as "materials having the ability to retain their physical shapes and chemical identities when subjected to high temperatures" or as "nonmetallic materials suitable for the construction or lining of furnaces operated at high temperatures" (Clark and McDowell, 1960). Of the different types of refractories, the more important are—

(1) Fire clay refractories.
(2) High alumina refractories.
(3) Silica refractories.
(4) Basic refractories.

All are commonly supplied as brick or other shapes having fixed dimensions, but they also have such applications as cements, mortars, and ramming mixtures.

Refractories are manufactured from Idaho fire clay and are discussed on page 58. Silica refractories are made from relatively pure silica or quartz and the silica deposits of Idaho are described on page 174. Basic refractories are manufactured from magnesium and chromium compounds. No commercial deposits of chromite or magnesite are known in Idaho, but extensive beds of dolomite are present in the State, as described in the section on limestone. These may be exploited in the future for the production of dead-burned dolomite. The special
refractories include such items as those manufactured from zirconia, silicon carbide, fused alumina, graphite, etc. They are not discussed further in this report.

Although no production has yet been recorded, Idaho has significant deposits of minerals from which the high alumina refractories are made. These include kyanite, sillimanite, and andalusite. These three minerals have identical chemical formulas (aluminum silicate, Al₂SiO₅) and in commercial usage are commonly grouped together under the term "kyanite." They differ from each in crystal form. Dumortierite (an aluminum silicate containing some boron) and topar (an aluminum fluosilicate) are usually included with the high alumina refractories, but neither of these minerals is known to occur in Idaho in significant quantities. All of these minerals convert to mullite and siliceous glass at temperatures ranging from 1,832° to 2,322° F. (Klinefelter and Cooper, 1961). Mullite is a stable compound having a low coefficient of expansion up to temperatures of approximately 3,990° F., and its refractory properties are superior to products made from fire clays but inferior to those made from fused alumina and some of the special refractories. The glass manufacturing and metallurgical industries consume about 90 percent of the mullite refractories for furnace linings. The remaining 10 percent is used mainly for kiln furniture in the ceramics industry with minor quantities of uncalcined kyanite being used for making electrical and chemical porcelain.

The kyanite minerals occur almost exclusively in metamorphic rocks, where they form by recrystallization of rocks of appropriate composition under the influence of heat and pressure. Generally, only one of the Al₂SiO₅ minerals is found in a given deposit, but it is not uncommon for two of them to occur together, and all three are found in a few deposits (Espenshade and Potter, 1960, p. 6). Which mineral forms depends partly on temperature-pressure relationship at the time of formation. In Idaho, the kyanite minerals are found in mica schists and similar rocks comprising the contact zone between the Idaho batholith and the older argillaceous and siliceous sediments of the Belt Series. Kyanite is resistant to weathering and consequently rocks containing high percentages of it may form ridges or features of high relief. It may be concentrated in boulders of "float" material on hilltops or as finer sands in river placer deposits.

All of the known U.S. deposits of kyanite are the disseminated type in which the kyanite mineral is more or less uniformly distributed through the host rock. The minerals most commonly associated with the kyanite are quartz, feldspar, and mica. Other minerals often present in smaller amounts include garnet, magnetite, pyrite, and rutile. Lump kyanite, which can be quarried in marketable form, is found in some foreign deposits, particularly those in India. Mullite made from lump kyanite is superior to that made from concentrates recovered from disseminated ores.

The commercial deposits of kyanite are near the surface and world production is virtually all from open pit mines. Some blasting is generally required for breaking the rock. Milling of massive kyanite is usually restricted to no more than crushing and screening. The product may or may not be calcined prior to marketing, depending upon its final use. Kyanite expands appreciably when fired, but the
other minerals of the group do not exhibit this property to the same extent. Because of this, some markets require precalined kyanite. Disseminated ores of kyanite require more elaborate processing to concentrate the kyanite, usually accomplished by flotation.

Market specifications for kyanite are lacking. Consumers select material largely on the basis of chemical analysis, grain structure and strength, pyrometric cone equivalent (PCE), hot and cold load tests, spall tests on bricks, etc.

There are only two companies producing kyanite in the United States at the present time, one in Virginia and one in South Carolina. Both companies mine disseminated ores and both properties include flotation as part of the concentration process. Small massive deposits of andalusite and dumortierite in Nevada and California were mined from 1924 to 1945, but these operations are idle now.

Worldwide (except U.S.S.R.) production of kyanite and related minerals for 1960 is reported by Cooper and Tucker (1962, p. 769) as follows:

<table>
<thead>
<tr>
<th></th>
<th>Short tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>71,992</td>
</tr>
<tr>
<td>India</td>
<td>31,801</td>
</tr>
<tr>
<td>Australia</td>
<td>1,707</td>
</tr>
<tr>
<td>United States</td>
<td>(†)</td>
</tr>
</tbody>
</table>

† Almost all from Union of South Africa.
*Figures withheld to avoid disclosing individual company data.

Idaho’s kyanite resources are still largely unknown but reconnaissance work indicates that they may be substantial. All known occurrences are of the disseminated type. The deposits on the south slope of Goat Mountain in Shoshone County (fig. 37, No. 1) just north of the Clearwater-Shoshone County boundary have received the most attention to date (Abbott and Prater, 1954; Hietanen, 1956, 1962). The original claims and leases are in secs. 9, 15, and 16, T. 42 N., R. 5 E., but rocks containing varying amounts of the kyanite minerals occur over much of the Boebls Butte quadrangle (Hietanen, 1956). Outcrops are obscured by vegetation, depths of deposits are unknown, and the kyanite content varies. Estimates range from 25 to 35 percent on outcrop material (Hietanen, written communication, 1964). A sample on which beneficiation tests were run was found to contain 18.8 percent kyanite by sink-float separation (Abbott and Prater, 1954). No estimate of tonnage has been made, for there has been little development work to establish continuity or grade. Even less work has been done on the sillimanite deposit near Troy (No. 2) but estimates of the grade indicate that the sillimanite content is lower than the kyanite of Goat Mountain. Samples examined under the microscope ranged from zero to a high of 18.4 percent, with roughly two-thirds of the samples being under 5 percent (Forrester, 1949).

A. L. Clark, in an unpublished University of Idaho thesis (1963), describes the occurrence of sillimanite in the metamorphic rocks of the Clarkia area, approximately where the Benawah-Latah County boundary intersects the western boundary of Shoshone County (No. 3). This location is some 20-30 miles west and a little north of the Goat Mountain deposits, about the same distance northeast of the Troy deposit. Metamorphic rocks of the same general type are predominant over this entire area and it is possible that there are other deposits of the kyanite minerals present, which have not been reported because of ground cover or other reasons.
Figure 37.—Kyanite, sillimanite, and andalusite deposits in Idaho.
Kyanite has been reported in the sands of the Middle Fork of the Selway River and also associated with quartz and tourmaline veins in secs. 27 and 34, T. 22 N., R. 21 E., about 4 miles northwest of Salmon (Klinefelter and Cooper, 1961). No quantitative information is available on either of these occurrences. Sillimanite pebbles that are valued by “rock hounds” are found in the gravels along the Clearwater River (Blake, 1956). Many of these have attractive color combinations and polish nicely for jewelry mountings.

Imported kyanite and domestic kyanite not only compete against each other, but both must compete against synthetic mullite manufactured from Bayer Process alumina and silica. Increasing production of synthetic mullite in recent years has had a more adverse effect on imports than it has on domestic kyanite. The synthetic material is suitable for all of the uses now made of imported massive kyanite and in a time of emergency all imports could be supplanted by synthetic material. Since 1952, there has been a gradual decrease in imported kyanite and an increase in the volume of synthetic mullite manufactured in the United States. Also, since 1952 domestic kyanite production has exceeded imports due to gradual depletion of foreign sources and improvement of beneficiation methods for disseminated ores (Klinefelter and Cooper, 1961).

The trend to higher temperatures in furnaces should increase the use of mullite refractories. From 1950 to 1955 the annual consumption of mullite refractories in the United States increased 60 percent (Klinefelter and Cooper, 1961) and it seems likely that this trend will continue. There is some question, however, as to what effect this will have on making the Idaho deposits of economic value. Much of the demand will be filled by synthetic material. The kyanite concentrated from the disseminated ores is suitable for refractory cements, mortars, and ramming mixtures, but it is less satisfactory for block refractories than massive kyanite or synthetic mullite. As mentioned previously, there are only two companies mining kyanite in the United States at the present time, whereas there are six companies manufacturing synthetic mullite; this may perhaps indicate the way the industry is heading.

Kyanite has only a moderate price ($44-$55 per short ton for 35-200 mesh material E. & M.J. listing for November 1963). To be of potential commercial value, a kyanite deposit should have large reserves, possibly in the order of a million tons or more and a grade of at least 10-percent kyanite and preferably 20 percent or more. Although unproven at present, there is good reason to believe that the Goat Mountain deposits might meet both of these specifications. Their location with respect to markets is not as favorable. The area is remote from transportation and has severe winters and heavy snowfall. Mining, milling, and transportation would all be expensive under these conditions.

SALT

(By E. H. Walker, U.S. Geological Survey, Boise, Idaho)

Production of salt in Idaho is mostly of historic interest, although it had considerable importance during frontier days. Production be-
gan in the 1860’s, increased for two decades, but declined abruptly after the early 1880’s, when railroads were built and salt produced more cheaply elsewhere was brought into the region; however, the deposits of salt that supported the business still remain and possibly may be exploited in the future.

Salt was produced in the valleys of Stump, Tygee, and Crow Creeks (fig. 38), close to the Idaho-Wyoming border in southeastern Idaho, in what is now Caribou County but was originally part of Oneida County. The easiest access to the area is by unpaved road from the upper Star Valley in Wyoming. The Lander Cutoff, which was a principal immigrant road, extended up the valley of Stump Creek and crossed a low pass to descend westward. This road is now only an unimproved forest trail.

Salt was produced by evaporation of water from salt springs along the valley floors of Stump, Tygee, and Crow Creeks, from the beginning of production until 1902. In 1866 B. F. White and J. M. Stump formed the Oneida Salt Works to extract salt from a spring on Stump Creek along the Lander Cutoff (Hayden, 1872, p. 161). The Oneida

![Figure 38. Former salt-producing area in Idaho.](image-url)
Salt Works appears to have been the principal producer for a long time, but various individuals and groups began producing salt from other local salt springs before the end of the 1860's. The salt springs, as described by Breger (1910, p. 5), occurred on the valley floors in areas of stony clay or gravel made soggy and barren of vegetation by the salty water. Pits dug in such places filled with brine strong enough to have a viscous appearance. Only the simple equipment of evaporating troughs over fires of native wood was needed.

The salt sold readily to emigrants traveling westward on the Lander Cutoff. It was also distributed by wagon to the growing market as far west as Boise and north into Montana. Salt was required not only for table and stock needs, and commercial pickling and preserving, but also in the mining industry—the extracting of silver and gold from complex ores was then accomplished by roasting the ores with salt to form soluble chlorides that could be leached out with water.

Rock salt was discovered in 1902 by James Splawn and H. Hokanson while they were excavating a salt spring on the east side of Crow Creek (Breger, 1910). Their excavation exposed 20 feet of rock salt mixed with clay. The rock salt could be produced far more cheaply than the "boiled salt" and was satisfactory for stock though too impure for table or preservative uses.

The graph showing production of salt in the district (fig. 39) has been compiled from data from several sources. Figures collected by Hayden (1872, p. 161) show the rapid rise in production during the first years after operation began in 1866. A production of 750 tons in 1880 is reported in an article in the Blackfoot Register (May 21, 1881), and a production of 800 tons in 1884 is reported in Federal Mineral Statistics Reports. It is uncertain if these figures refer to production for the whole district or just for the Oneida Salt Works; if the latter, then the total production of the district in the early 1880's may have reached 1,000 tons a year.

![Graph showing production of salt](image)

**Figure 39.**—Production of salt in southeastern Idaho, 1866-1924.
No production data are available from 1884 to 1906; the production was small in comparison with that of major salt-producing districts and apparently no effort was made to keep statistics.

It is known that the production began to decline in the late 1880's, after railroads entered the region where the salt had been marketed. Some boiled salt was produced as late as 1924, but none is produced now. The salt produced by evaporation was selling for about $30 a ton in 1871 (Hayden, 1872, p. 161), but rock salt mined in Utah in 1885 was sold for $3.50 a ton at the mine. Production of salt in the Idaho valleys always was hampered by the high costs of supplying firewood for evaporating the brines.

The discovery of rock salt in 1902 did little to halt the decline in production that is shown by figures for 1906-24 (Mansfield, 1927, p. 339). At present a few truckloads of salt are mined yearly for local stock use. The rock salt is impure and there are expenses for draining water from the pits.

Bedrock in the area consists of sedimentary formations of Mesozoic age. These formations have been folded, faulted, and eroded to form the mountains and valleys of northerly trend. The trace of a large low-angle fault, the Bannock overthrust, emerges at the surface in the valleys of Stump, Tygee and Crow Creeks. The Salt Lake Formation, a valley fill of Pliocene age ranging from clay and silt to conglomerate, occurs widely in the lowlands. Alluvium of Pleistocene and Recent age lies on the valley floors; probably it is not more than a few tens of feet thick.

All the springs, as Mansfield (1927, p. 322) noted, occur along the zone of the Bannock overthrust and probably are related to it. The fault plane presumably acts as a barrier beneath which the ground water emerges as springs and seeps, but detailed fieldwork would be necessary to determine the actual relations.

The rock salt found on the east side of Crow Creek is in valley-filling deposits of clayey and bouldery material. The salt may have been deposited by evaporation of saline spring water while the valley-filling sediments were accumulating. The actual nature of the geological conditions and the extent of the rock salt could be determined by test drilling.

The primary source of the salt in this district is bedded salt in the Preuss Sandstone of Late Jurassic age. An oil test drilled in 1922 to a depth of 456 feet in the valley of Tygee Creek, about 3 miles south of the junction with Stump Creek, penetrated 96 feet of salt in six beds that ranged in thickness from 6 to 29 feet (Mansfield, 1927, p. 340). The salt beds are interstratified with beds of conglomerate, shale, "gray lime" which may be anhydrite, and gypsum. This assemblage indicates deposition in a closed basin under dry climatic conditions that probably were local because the Preuss Sandstone is not known to be salt bearing elsewhere.

Probably no one will exploit the salt springs again because their flow is too small to support economic operations. The rock salt in the valley floor probably will be exploited only by noncommercial operators for local use, because the salt is too impure (before refinement) for most uses and there is little evidence of the presence of enough salt to support an operation of economic size.
Exploitation of the beds of rock salt in the Preuss Sandstone is not likely to begin under present conditions. Salt can be mined more cheaply at many localities in the Nation. Features weighing against exploitation of the salt beds are: (1) they are undercover and folded in different degrees; (2) they are likely to pinch and swell or to be cut off altogether from place to place by the faults; and (3) they are distant from railroad transportation. The geologic features make it probable that any exploitation in the future may be by circulating water through drill holes and dissolving the salt rather than by underground mining.

SAND AND GRAVEL AND QUARRY ROCK FOR HIGHWAY CONSTRUCTION

(By B. G. Charboneau, Idaho Highway Department, Boise, Idaho)

The abundance of naturally occurring construction materials in Idaho is generally never realized, nor is their importance appreciated. Sand and gravel production comprises the largest mineral industry in the United States in terms of tonnage and is fourth largest in dollar value (Weis, 1963). Production of sand and gravel in the United States in 1962 was estimated at 776,701,000 short tons with a net value of $794,725,000 (Cotter and Mallory, 1963). In 1961 Idaho produced approximately 7,305,000 short tons valued at $6,703,000, and in 1962 produced 14,321,000 short tons valued at $13,029,000 (Fulkerson and others, 1963).

The Idaho Department of Highways, under an accelerated highway construction program, is the largest consumer of natural and manufactured aggregates in Idaho. In 1961 production for department use by State forces or by contract amounted to approximately 3,588,000 tons of aggregates with an estimated net value of $8,500,000. Production and cost of the material are shown graphically in figure 40, A and B. In these charts sand and gravel, including both pit-run and processed material, are considered as a single unit. Quarry material is mostly basalt with minor amounts of quartzite, limestone, sandstone, and andesite. It also includes cinder production.

Major uses of sand and gravel and crushed quarry rock by the department are for subbase, base, surfacing, concrete, and embankment materials. Since 1958, 23.6 million tons of sand and gravel have been used by the department. During the same period, only 2.9 million tons of quarry rock have been used.

Sand and gravel constitute a low-cost product. Average prices range from generally less than $1 to $1.25 per short ton for material meeting department specifications. Surfacing materials have a wide variety of ranges but average from $3.30 to $4 per unit. The accessibility of production sites to construction and maintenance projects is reflected in local costs. Major gravel pit and quarry sites are shown in figures 41 and 42.

Materials utilized in Idaho are many and varied. In District 1 (fig. 41), production is primarily from alluvial gravels. These are broadly classified as Marsh and Bear Valley gravels (mostly quartzite with minor amounts of limestone), Portneuf gravels, generally asso-
Figure 40-A. Idaho Department of Highways statewide pit and quarry production.

Figure 40-B. Idaho Department of Highways statewide cost of producing aggregate.
Figure 41.—Major sources of sand and gravel in Idaho.
Figure 42.—Major quarry sites in Idaho.
ciated with the overflow channels of Pleistocene Lake Bonneville (primarily quartzite with minor amounts of basalt and limestone), and Snake River gravels (quartzite with minor amounts of basalt and limestone). Quarry production is minor and is confined principally to Snake River basalt flows. A number of cinder pits are utilized.

In District 2 (fig. 41), major production is from alluvial gravels with units described by localized names, i.e., Salmon River, Raft River, etc. Such sources as the Snake River gravels have been well exploited. Quarry production is minor and is confined principally to andesite. Cinders and scoria are utilized principally as subbase materials.

In District 3 (fig. 41), major production is confined to sand and gravel including the Ten Mile gravels, the Caldwell-Nampa sediments (Savage, 1958), and Melon, Crowsnest, and Sugar Bowl gravels (Molde and Powers, 1962). Quarry production is minor and is from the Idaho Volcanics, Bruneau Formation, Snake River Group, and the Columbia River Basalt. Cinder production from the Bruneau and Snake River is a minor item.

Seventy-one percent of the production of District 4 (fig. 42) is quarry rock from the Columbia River Basalt. Degradation of the rock is prevalent and selection of sound rock requires careful source evaluation and petrographic study. The sand and gravel produced is from present-day streams.

In District 5 (fig. 41), 85 percent of the aggregate produced is sand and gravel, most of which is of glacial origin from the Wisconsin Glaciation. The gravel is generally clean with little or no alteration. Quarries are principally in basalt of the Columbia River flows. Alteration of the basalt is extensive in some flows and selective subsurface exploration is required. Quarries from the St. Regis and Revett Formations are also utilized but problems resulting from mechanical disintegration (degradation) of the rock restrict their usage.

Principal production in District 6 (fig. 41) is from sand and gravel deposits which are classed in the field as Snake River gravels. They are tentatively called the North Fork and South Fork deposits. Lacustrine and glacial gravels are also used. Production from quarries is minor but several excellent cinder sources, associated with the Snake River Group, are available.

In summary, sand and gravel sources in Idaho are principally of alluvial or glacial origin. They are found within the network of the major stream and river valleys and exhibit many diversified engineering problems for their full utilization in highway maintenance and construction.

Wisconsin continental glaciation has contributed vast amounts of gravel in northern and south-central Idaho which have not been fully exploited. Lacustrine materials are minor and these are used principally as sources of sand.

Quarries are confined principally to the Columbia River basalt. Only minor amounts of quartzite are used. Use of cinders is also minor, but vast reserves near proposed highway alignments probably will be utilized more in the future.
SILICA


Silica (SiO₂, silicon dioxide) is the most abundant chemical compound in the earth's crust. It occurs both as pure silica minerals of the quartz group and, in combination with other elements, as a host of silicate minerals that form most of the major rock types. Concentrations of commercial value occur as the quartz veins and irregular masses of primary hydrothermal origin and as the quartz core of some pegmatites. Secondary concentrations of silica are formed from the weathering and erosion of quartz-bearing rocks, veins, and pegmatites and are found as deposits of sand and gravel, sandstone, and quartzite. Silica also occurs in the hydrous form as opal, chert or flint, diatomaceous earth, and tripli. Of all the sources, sand, sandstone, and quartzite are most common, provide the greatest resources, and are generally considered together as "silica sand deposits" or "industrial sands."

The uses of silica and especially those of high quality "industrial sands" are myriad and continually growing. Silica is the chief constituent in the manufacture of glass. It is also used in large amounts as a metallurgical flux, as hydraulic sands, abrasives, molding sands, in ferroalloys, in ceramics and refractories; and in lesser amounts as a paint extender, mineral filler, insulation, and in fertilizers and insecticides. Silica is the source of metallic silicon used in semiconductors of electronic instruments. It is also used for the manufacture of silicones, a group of plastics with many unusual properties, that are being put to ever-increasing uses.

Specifications vary greatly according to use. For some purposes, the physical properties of the raw material are most important. For others, the chemical composition of a deposit is the chief concern. Certain other purposes require both high chemical purity and specific physical properties. For example, glass sand should contain 95 percent silica and less than 0.06 percent iron; more tends to color the finished product. Uniformity of grain size is also important in the glass industry, as coarse material is more difficult to melt and extremely fine material produces "seeds" in the glass and creates dust problems (Carter and others, 1962, p. 3). Grain sizes ranging from 20 to 100 mesh have proved to be most satisfactory.

Purer quartz sands, ranging from 98.5 to 99.7 percent SiO₂, are required in the manufacture of silicon carbide. The alumina content must be closely controlled, for it will color the product. For example, 0.04 percent Al₂O₃ is the maximum allowed for "green grit" SiC. Any more makes a lower grade "black grit" silicon carbide, for which the allowable maximum is 0.20 percent Al₂O₃. Iron, calcium, and magnesium oxides are each limited to less than 0.10 percent.

The manufacturers of silicon metal, ferrosilicon, and other silicon alloys also require great purity (99 percent SiO₂ or more). Material containing a maximum of 0.07 percent Fe₂O₃ and 0.25 percent Al₂O₃ may be used in making silicon metal, while that containing 0.30 percent Fe₂O₃ and 0.15 percent Al₂O₃ or less is suitable for ferrosilicon. Generally massive quartz or quartzite, crushed to fragments ranging from 6 inches to one-half, is considered to be the most desirable raw material.
Hydraulic sand must be composed of tough, well-rounded grains so that it may be packed into artificial openings in producing rock horizons of oil wells to insure maximum porosity and thereby promote recovery. Impure sands with angular grains are screened or crushed to specific sizes for abrasives, plaster, and other purposes.

Mining of silica throughout the United States is usually a mechanized operation employing open-pit and quarrying methods. Because of the large tonnages involved and the relatively cheap prices which the raw materials command, most of the deposits considered minable are, by necessity, near railroads and not far distant from centers of manufacture and consumption. Two of the main obstacles facing the exploitation of Idaho silica deposits are (1) the inaccessibility of some occurrences and (2) the distance to silica markets.

"Industrial sand" production in the United States in 1962 totaled over 20 million short tons at a value of over $67 million (Cotter and Mallory, 1962, p. 1050). Of this, glass sand production (approximately 7.2 million short tons) provided over one-third the quantity and value of the "industrial sand" industry. Molding sand production was second (approximately 6.2 million short tons) and followed by grinding and polishing sand (0.9 million short tons), blast sand (0.5 million short tons), and fire or furnace sands (0.4 million short tons). Principal production came from near industrial centers in the Eastern and Midwestern States, where the Oriskany and St. Peter sandstones contain most of the raw material. In the West, California was the largest producer.

Markets for industrial sands in the Pacific Northwest are in the major population centers of Oregon and Washington. A list of consumers, their locations, and their products is included in table 9. Annual consumption during the mid-1950's amounted to about 300,000 short tons per year. Of this, 90 to 75 percent was produced from local Northwest deposits. About 70,000 short tons were used by glass producers, and 180,000 short tons were used by producers of silicon and silicon alloys. Major production during this period came from the Denison silica deposit near Spokane, Wash., which, when depleted in 1957, reduced total production to 80,000 short tons. This loss was largely overcome in 1959 with the opening of the Quartz Mountain silica deposit, Spokane County, Wash., but this deposit has not been worked since 1961. Production from this deposit since that time has been of stockpiled material.

Table 9.—Principal companies consuming significant volumes of high-grade industrial silica in the Pacific Northwest (after Carter and others, 1962) 1, 2

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonaceous Co.</td>
<td>Vancouver, Wash.</td>
<td>Silica refractories</td>
</tr>
<tr>
<td>Eastern Metalurgical Co.</td>
<td>Everett, Wash.</td>
<td>Glass and ceramic</td>
</tr>
<tr>
<td>Kootek Electric Mica Co.</td>
<td>Springfield, Ore.</td>
<td>Glass and ceramic</td>
</tr>
<tr>
<td>National Metaphysical Corp.</td>
<td>Seattle, Wash.</td>
<td>Glass and ceramic</td>
</tr>
<tr>
<td>Northwest Union Co.</td>
<td>Portland, Ore.</td>
<td>Glass and ceramic</td>
</tr>
<tr>
<td>Ohio Ferroldyke Co.</td>
<td>Tacoma, Wash.</td>
<td>Glass and ceramic</td>
</tr>
<tr>
<td>Owens, Illinois</td>
<td>Portland, Ore.</td>
<td>Glass and ceramic</td>
</tr>
<tr>
<td>Philadelphia Quartz Co.</td>
<td>Tacoma, Wash.</td>
<td>Glass and ceramic</td>
</tr>
</tbody>
</table>

1 Irving (1952, written communication) shows that during the early 1950's the principal consumers were U.S. military installations, mainly naval shipyards, using sand for blasting purposes. Construction companies purchased fine sand for plaster.

In Idaho, the search for and development of sands for industrial purposes have taken place since World War II. Prewar resource studies by Hodges (1938, p. 88–99) in connection with market studies for the Columbia River Hydroelectric Power System showed that Idaho silica resources, although present, were undeveloped at that time.

Since the war, high-grade silica deposits, including those of sand, sandstone, quartzite, and quartz-core pegmatites, have been reported in 19 counties. Of these, only eight counties (Bonner, Nez Perce, Latah, Gem, Bannock, Power, Caribou, and Bear Lake) have deposits that are known to have been worked. Principal production has been for glass sand, foundry sand, blast sand, plater sand, roofing granules, ferrosilicon, and metallurgical flux. Approximately 88,000 short tons of special sands, railroad ballast and sand and gravel used for miscellaneous purposes, were produced in 1962 and had a value of about $92,000 (Fulkerson and others, 1963, p. 382).

**SAND AND SANDSTONE**

Sand and poorly consolidated sandstones, mainly in the southwestern part of the State, provide the largest, most accessible, and most easily mined silica resources in Idaho.

The first silica sand operation was that of the Gem Silica Co., which began in 1946 to mine extensive deposits of the Idaho Group of Pliocene and Pleistocene ages from a low range of hills 3 to 4 miles south of Emmett in Gem County (fig. 45, No. 1) (Savage, 1958 and 1961).

The deposits, approximately 900 feet thick, consist of poorly consolidated medium- to fine-grained, arkosic sand. The sand averages 50 to 55 percent silica, 35 to 40 percent feldspar, and contains some clay. When washed and screened to about 0.8 mm size, the product yields 85 percent SiO₂. Chemical analyses of the sand mined from the Emmett area are included in table 10.

**Table 10.—Chemical analyses of silica sand deposits in Idaho**

<table>
<thead>
<tr>
<th>Locality I</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>Na₂O</th>
<th>TiO₂</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Idaho group, Emmett, Gem County</td>
<td>62.21</td>
<td>3.73</td>
<td>0.39</td>
<td>0.90</td>
<td>0.60</td>
<td>≤0.01</td>
<td>0.01</td>
<td>2.14</td>
</tr>
<tr>
<td>2. Idaho group, Weiser, Washington County</td>
<td>64.78</td>
<td>5.47</td>
<td>0.06</td>
<td>0.00</td>
<td>0.06</td>
<td>≤0.01</td>
<td>0.01</td>
<td>2.36</td>
</tr>
<tr>
<td>3. Latah Formation, Nez Perce</td>
<td>78.65</td>
<td>9.06</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>≤0.01</td>
<td>0.01</td>
<td>2.14</td>
</tr>
<tr>
<td>4. Dechutes County</td>
<td>96.40</td>
<td>0.50</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>≤0.01</td>
<td>0.01</td>
<td>2.14</td>
</tr>
<tr>
<td>5. Cedar-County, (A)</td>
<td>94.38</td>
<td>0.86</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>≤0.01</td>
<td>0.01</td>
<td>2.14</td>
</tr>
<tr>
<td>6. Clearwater County, (B)</td>
<td>96.30</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>≤0.01</td>
<td>0.01</td>
<td>2.14</td>
</tr>
<tr>
<td>7. (B)</td>
<td>96.30</td>
<td>0.61</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>≤0.01</td>
<td>0.01</td>
<td>2.14</td>
</tr>
</tbody>
</table>

I Numbers refer to locations shown on fig. 43.  
II Samples of washed sand.  
III Samples of washed sand.

**Early production involved a simple screening process from which the coarser fractions were shipped in bulk or bags for foundry sand and blast sand. The finer material was sold for plaster sand. In 1952, bulk and bagged sand was shipped to 10 different purchasers in Utah, Montana, California, Oregon, and Washington. (Irving, 1952, p. 382)**
Figure 43.—Silica deposits in Idaho.
written communication). The largest consumers were U.S. Government agencies, principally U.S. naval shipyards. Experimental treatment of the sands indicated that by a washing and flotation process the clay could be removed and feldspar separated, thereby raising the grade of the silica to glass sand specifications (Kelly and others, 1956, p. 5a).

In 1956, the Gem Silica Co.'s operations were taken over by the Sand Division, Del Monte Properties, Inc., San Francisco, and plant improvements were made to increase production and upgrade the product. Since then, the Del Monte Properties Co. has steadily increased production of high-quality sand for plaster, glass, and abrasives. The feldspar coproduct is used by the ceramic industry within the State.

A deposit similar to that near Emmett has been described near Weiser in Washington County (No. 2). Experimental attrition scrubbing and froth flotation by the U.S. Bureau of Mines produced silica with 0.03 percent Fe2O3 and potash-soda-rich feldspar with 0.08 percent Fe2O3, with white clay as a secondary product. No commercial production from the deposit has yet been recorded. Deposits near Boise (No. 3) in Boise County and Owyhee (No. 4) in Ada County indicated by Hubbard (1955, p. 74) are of the same type of material, but the sand tends to be cemented.

Silica sands are also known to be associated with clays (halloysite) of the Latah formation of Tertiary age (Kirkham and Johnson, 1929, p. 499) near Troy (No. 5) and Bovill (No. 6), Latah County (Hos-terman and others, 1960, pp. 27-28). The clays have been exploited for the manufacture of firebrick by the Idaho Fire Brick Co. and, more recently, by the A. P. Greene Fire Brick Co. The deposits cover some 2,000 acres, range in thickness from a few inches to 20 feet, and are the residual product of decomposition of granite. Experimental studies showed that physical separation of the silica and clay could be accomplished by washing, tabling, and magnetic separation to produce a high-grade silica sand for glass and potters' flint (Wilson and Zvanut, 1936). Typical chemical analyses of head samples of the washed sand are given in table 10.

In 1960, large-scale production of high-grade container-glass sand began at the Bovill, Idaho, silica deposit (No. 6) (Carter and others, 1962). This operation, run by the J. R. Simplot Co., also exploited the Latah Formation of Tertiary age, separating the clay and sand particles into a clay product and a silica sand product. The clay is used in the paper industry and the sand coproduct for glass. Probably because of its high titanium content, the clay was found unsuitable as a filler but satisfactory as a coating for high-glass paper (J. W. Hosterman, oral communication). In 1963, the J. R. Simplot Co. shipped a small quantity of sand for foundry use, but the production of silica sand fell off sharply from the total of the previous year (Fulkerson and others, 1963).

Special high-quality sands used for plaster, filter, and abrasive purposes have also been mined and prepared by H. P. Terteling a few miles east of Lewiston on Coyote Grade in Nez Perce County (No. 7). These sands contain much decomposed feldspar and may be correlated with the Latah formation. The deposits are not extensive.

Significant unexploited resources of sand and sandstone of the quality and quantity required of glass sand have been described in the Kelly-Cedar Creek area (No. 8) of eastern Clearwater County by
Carter and others (1962, pp. 14-19). These deposits are accessible by good gravel logging roads but are about 35 miles from the nearest railroad at Superior, Mont. Assays of the sand reported by Carter and others (1962) are included in table 10. These analyses indicate that the sand will require some beneficiation to remove clay and other impurities before it can be used as glass sand. It is doubtful if the deposits will be developed in the foreseeable future.

Other small sand and sandstone deposits have been indicated by Hubbard (1955) near Salmon (No. 9) and Reno (No. 10) in Lemhi County, near Burley (No. 11) and Cotteral (No. 12) in Cassia County, at the mouth of the Deadwood River (No. 13) in Boise County, and near Paris (No. 14) in Bear Lake County.

**QUARTZITE**

Quartzite, a light-gray to white, hard, granular, layered rock consisting largely of quartz, crops out in many places as resistant ledges and ridges in the north and southeastern parts of the State (fig. 43). Although quartzite is more difficult to mine than sand and sandstone and often is contaminated by too much iron, it constitutes a significant source of silica and, locally, has been periodically worked for road metal and metallurgical flux and as a source of silica in making ferroalloys. Elsewhere, it has also been used in refractories and for other purposes.

In southeast Idaho, the Brigham Quartzite (Walcott, 1906, p. 8), Swan Peak Quartzite (Richardson, 1913, pp. 407-409), the upper and lower portions of the Nugget Sandstone, and an upper member of the Wells formation provide significant reserves of silica for local uses. Quartzite has been mined for road metal at Worm Canyon (No. 18) in Franklin County west of Bear Lake (Mansfield, 1929). The geology of that area is described by Coulter (1956), who believes the mined quartzite is probably from the Brigham Quartzite (Coulter, oral communication). Recently, similar quartzite deposits have been mined by Wells Cargo, Inc., from the Kit quarry in Power County (No. 16) west of Pocatello (80 to 90 percent SiO₂). At Soda Springs, Caribou County (No. 17), the Swan Peak formation has been mined by the Monsanto Chemical Co. for use as a flux in electrical furnaces producing elemental phosphorus at plants owned by the FMC Corp. and Monsanto, respectively. The Swan Peak formation at this quarry has the following average analysis (percentage):

<table>
<thead>
<tr>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>98.90</td>
<td>0.37</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Annual production is about 100,000 short tons.

A quarry near Georgetown, Bear Lake County (No. 18), has also been worked for furnace flux (Baker and others, 1960). Quartzite is also quarried at Inkom, Bannock County (No. 19), by both the Morrison-Knudsen Co., Inc., and Wells Cargo, Inc.

To the north, in the Idaho panhandle, Hodge (1958, pp. 88-91) suggested that silica might be obtained from quarries of the Burke and Revett formations of the Precambrian Belt Series, which crop out over a large area (fig. 43). An analysis of the quartzite in the Revett formation from an exposure a few miles west of Clark Fork on U.S. Route 10A (No. 20) showed 96.6 percent SiO₂ and 3.4 percent Fe₂O₃ and Al₂O₃ combined. Fairly pure quartzite may also be found in the Striped Peak and Prichard formations.
At the south end of Pend Oreille Lake in Bonner County, the Cambrian Gold Creek Quartzite (Sampson, 1928) (No. 21) locally has possibilities as a source of silica. Chemical analysis showed 97.5 percent SiO₂, 1.3 percent Fe₂O₃, and 1.4 percent Al₂O₃. However, in some places the quartzite contains up to 4 percent Fe₂O₃.

In the Coeur d'Alene district, the Belt Series totals over 20,000 feet in thickness, and of this, the Burke and Revett formations comprise approximately 25 percent of the sequence. If this same percentage extends throughout the entire area underlain by the Belt Series, the quantity of silica is enormous. However, in general, Precambrian quartzites are probably low grade and too high in iron for use as high quality silica rock. Two specific localities have been mentioned as possible sources of the silica. One is in Canyon Creek at Burke, northeast of Wallace (No. 22), and the other near Mullan (No. 23) in Shoshone County (Hodge, 1938, pp. 88-99). No production, however, has yet been reported from these areas.

**QUARTZ VEINS AND PEGMATITES**

Veins and irregular masses of quartz and the quartz cores of some pegmatites constitute smaller, but often quite pure, reserves of silica. Deposits of this type have received periodic attention during the past 25 years.

The Freeman Lake quartz vein in Bonner County (No. 94), a few miles east of Newport, Wash., was described by Hodge (1938, p. 29) and was once quarried by Pacific Northwest Alloys, Inc., to provide silica for its former ferroalloy plant in Spokane. The quarry is now idle, and the commercial silica is nearly exhausted. A similar but much larger deposit has been described at Boulder Mountain (No. 25) west of Priest Lake in Bonner County. Percentages of silica in this deposit range from 97.7 to 99.6, while iron ranges from 0.06 to over 1 percent. A brief report (Gammell, written communication, 1943) on the Hollenbeat quartz deposit (No. 28), 4 miles southeast of Riggins in Idaho County described widespread quartz float along a ridge south of Captain John Creek. Kilsgaard (1951, written communication) examined the Jacobs quartz crystal property on Jug Handle Mountain southeast of McCall in Valley County (No. 33) and suggests that small tonnages of massive quartz remain to be mined. A silica deposit is reported (personal communication) by W. W. Staley of the Idaho Bureau of Mines and Geology at the Thorson property, No. 36, in Washington County, about 20 miles north of Weiser. The silica is said to occur as a large ovoid body of coarsely crystalline quartz in granodiorite. It is overlain in part by basalt. Preliminary exploration suggests a very large tonnage of high-grade silica.

Quartz-feldspar pegmatites have been mentioned by Kelly and others (1936) at Cornwall and Homestead Creeks (No. 27) in Benewah County; at the Kingsley deposits in Grimes Pass area (No. 29) in Boise County; at South Mountain 18 miles from Oakley (No. 29) in Cassia County; at the Wild Rose pegmatite at Pierce City (No. 30) in Clearwater County; near Jersey Creek (No. 31) in Idaho County, the Avon district (No. 32) of Latah County; and near Gold Fork (No. 34) of the Payette River in Valley County. Fryklund (1951, p. 11) describes the quartz core of a gently dipping pegmatite as 175 feet long and 50 feet wide at the Columbine mine (No. 35) of the Garden Valley district, Boise County. Most veins and pegmatites, however,
are either too remote from existing rail transportation and markets or too small to be considered as minable reserves of silica at the present time except, possibly, for local use.

RESERVES AND POTENTIAL RESOURCES

Idaho’s resources of low-grade silica are virtually unlimited, but known deposits capable of producing high-purity silica for specialized use in the electrochemical industry are not so abundant. The most accessible, largest, and probably the most valuable deposits are the sand and sandstone of the Idaho Formation in the southwestern part of the State. The deposits are easy to mine, and some of them can produce high-purity silica, although most of the material requires treatment and beneficiation. With the depletion of high-grade deposits in Washington, they may become an important source of high-grade silica to supply the needs of the electrochemical industry of the Pacific Northwest.

Quartzite of the Prichard, Revet, and Striped Peak formations underlies much of the northern part of the State, while the Brigham, Swan Peak, and other quartzites are found in the southeastern corner. While these deposits constitute an enormous silica resource, they are lower in grade and harder to mine and process. Future exploitation will probably be restricted to local use as metallurgical flux, and, possibly, in refractory brick.

Many quartz veins and pegmatites, found mainly in the north and western parts of the State, contain high-grade quartz, but mostly they are small, inaccessible, and costly to mine. Their future use is probably limited, although a few deposits may be found that are large enough and sufficiently pure to be of interest.

Other rock types that contain a high percentage of silica include deposits of pumicite (volcanic ash) and diatomite (diatomaceous earth) that are found and mined in significant amounts in southern Idaho. As they are used mainly for other special purposes, they are treated separately in other chapters of this report.

SILVER, LEAD, AND ZINC


Silver, lead, and zinc ores are closely associated geologically, and most Idaho deposits that contain one of these metals also contain the other two. The three metals, therefore, are discussed together in this report. All three metals are widely used industrially, and the income derived from mining and processing each of them is of great importance to the economy of the State. Idaho is one of the great silver-, lead-, and zinc-producing States in the Nation, and during recent years has ranked first in the output of silver, second in the output of lead, and second or third in the output of zinc. This output is of prime importance to the mineral economy of the Nation. Further information on national production and values of these metals and on their uses may be obtained from the annual U.S. Bureau of Mines minerals yearbooks.

Development of the State of Idaho is linked very closely to its mining history. Bolino (1961) notes that mining of quartz veins for gold and silver started in the Boise Basin during the early 1860's.
Prospectors quickly spread from this basin to areas throughout central Idaho and other gold-silver deposits soon were found, including the silver-rich deposits in the Silver City region of Owyhee County. During the early 1890's, silver-lead deposits were discovered in the Wood River region, others in the Bayhorse area along the Salmon River, and others west and northwest of Arco. Still other silver-lead deposits were discovered near the headwaters of the Lemhi River, in Lemhi and Clark Counties, and all of these were quickly brought into production (Ross, 1963). Most of the rich ore from these mines was treated at small local smelters or was sorted and freighted by wagon for considerable distances to railroad shipping points. The “booming” mining camps created employment for great numbers of miners and others who worked at construction, at transporting ore and supplies, and at countless other tasks. The need for food speeded the settlement of irrigable lands in the valleys and the construction of roads and railroads to such ore-shipping points as Hailey, Ketchum, Arco, Mackay, and Leadville.

Shenon (1961) points out that lead-silver deposits were known in the vicinity of Burke and Mullan, Shoshone County, as early as 1884. The following year lead ore was found in Milo Gulch, near the town of Kellogg, at the site of the present Bunker Hill mine. These discoveries marked the beginning of silver-lead mining in the famous Coeur d'Alene mining region, which has been, by far, the largest producer of silver, lead, and zinc in Idaho, and which is one of the great mining areas of the world. Production from this region, during the period 1884 to 1964, according to the U.S. Bureau of Mines totals:

<table>
<thead>
<tr>
<th>Metal</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold (fine ounces)</td>
<td>438,658</td>
</tr>
<tr>
<td>Silver (fine ounces)</td>
<td>669,306</td>
</tr>
<tr>
<td>Copper (short tons)</td>
<td>109,140</td>
</tr>
<tr>
<td>Lead (short tons)</td>
<td>4,700,445</td>
</tr>
<tr>
<td>Zinc (short tons)</td>
<td>2,270,812</td>
</tr>
<tr>
<td>Value of total metal product</td>
<td>$1,970,430,420</td>
</tr>
</tbody>
</table>

Aside from the Coeur d'Alene region, the more productive silver-lead-zinc deposits in Idaho are in the Yankee Fork, Bayhorse, Texas, Warm Springs, Mineral Hill, DeLamar, and Carson (Silver City) districts. Some of these, such as Yankee Fork and Silver City, and a number of less important gold-silver districts, were most actively mined during the early days of mining before the turn of the century, but have been more or less idle since then. Others, such as the Texas and Warm Springs districts, were active until relatively recently but are currently not productive.

State output of silver, lead, and zinc from 1863 to 1962 is shown in figure 44. This illustration shows that output of silver has increased steadily, with an all-time high during the late 1930's, during a period influenced by the bringing into major production of the rich Sunshine mine in the Coeur d'Alene region. An earlier peak represents output during World War I, whereas a later peak, starting in the late 1940's, was influenced by the output from the Galena and Lucky Friday mines, both of which also are in the Coeur d'Alene region and both of which also were brought into major production during the latter peak period.

The high point of lead production from Idaho came during World War I. Since then, lead output has decreased, although it continues at a high level.
Zinc is a relative newcomer in Idaho production. Zinc minerals had been known in the Idaho deposits since the deposits were discovered; however, during early days of mining zinc was regarded as a nuisance metal that had no value and was either sorted and discarded or left unmined. Not until the early 1900's, when concentration equipment was developed to separate zinc minerals from other minerals did production begin, and not until the 1920's, when the flotation cell was perfected to separate zinc sulfides from silver and lead sulfides, did zinc production become significant. Since World War II, as deeper and more zinc-rich ores were mined in the Coeur d'Alenes, the output of zinc and lead has been nearly parallel.

Location of the more significant mining districts is shown on figure 45, as modified from McKnight and others (1962a, 1962b), and pertinent data on these districts are given in table 11. Both the illustration and the table show the relative size of the districts with respect to production of metal and estimates of potential reserves. Production figures from individual districts are not given as they are difficult, if not impossible, to determine for some districts, especially for those that produced gold and silver during early mining days when production figures were scantily kept, if kept at all.
Figure 45.—Principal sources of silver, lead, and zinc in Idaho (numbers refer to mining districts listed in table 11).
<table>
<thead>
<tr>
<th>No.</th>
<th>District</th>
<th>County</th>
<th>Magnitude in rank</th>
<th>Silver</th>
<th>Lead</th>
<th>Zinc</th>
<th>Type of occurrence</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pothill</td>
<td>Boundary</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Bedded replacements and veins in PreCambrian quartzite of the Belt Series.</td>
<td>Kirkham and Bills, 1928.</td>
</tr>
<tr>
<td>3</td>
<td>Pend Oreille</td>
<td>Shoshone</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Vein in PreCambrian quartzite and argillite of the Belt Series.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>4</td>
<td>Lakeview</td>
<td>do</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Veins along show zones in PreCambrian argillite of the Belt Series.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>5</td>
<td>Summit (Murray)</td>
<td>Shoshone</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins along show zones in PreCambrian argillite of the Belt Series.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>6</td>
<td>Cour d'Alene (a region composed of several districts)</td>
<td>Idaho</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Veins and replacements along veins in quartzites and argillites of the Belt Series.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>7</td>
<td>Elk City</td>
<td>Idaho</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins in PreCambrian, quartzite and greisen, and in quartz monzonite of the Idaho batholith.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>8</td>
<td>Florence</td>
<td>do</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins in granite rock of the Idaho batholith.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>9</td>
<td>Marshall Lake</td>
<td>do</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins in PreCambrian muscovite and granite next contact with Idaho batholith.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>10</td>
<td>Warm Springs</td>
<td>do</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins in granite rock of the Idaho batholith.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>11</td>
<td>Yellow Pine</td>
<td>Valley</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Disseminated minerals and vein along shear zones in quartz monzonite of Idaho batholith.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>12</td>
<td>East Fork</td>
<td>Custer</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins and replacements in PreCambrian quartzite and argillite of the Idaho batholith.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>14</td>
<td>North Fork</td>
<td>Lemhi</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins and replacements and veins in Paleozoic intrusives.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>15</td>
<td>Salmon</td>
<td>Boise</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins in granite rocks of the Idaho batholith, replacements in Paleozoic intrusives.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>16</td>
<td>Deadwood</td>
<td>Valley</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins in sheared zones in granite rock of the Idaho batholith.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>17</td>
<td>Pahoa Fork</td>
<td>Custer</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins in Chalcopyrites of Tertiary age.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>18</td>
<td>Boyhorns</td>
<td>do</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Replacements and veins in Paleozoic dolomites rocks and dikes.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>19</td>
<td>Blue Wing</td>
<td>Lemhi</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Veins in PreCambrian quartzite, new igneous intrusives.</td>
<td>Hancock, 1941.</td>
</tr>
<tr>
<td>20</td>
<td>Junction</td>
<td>do</td>
<td>3</td>
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Under the classification, magnitude of rank, as used in Table 11, rank 1 refers to districts in which production plus potential reserves total more than 50 million ounces of silver, or more than 1 million tons of lead, or more than 1 million tons of zinc. Rank 2 applies to districts in which production plus potential reserves total 5 to 50 million ounces of silver, or 50,000 to 1 million tons of lead, or 50,000 to 1 million tons of zinc. Rank 3 includes those districts in which production plus potential reserves total 100,000 to 5 million ounces of silver, or 1,000 to 50,000 tons of lead, or 1,000 to 50,000 tons of zinc. Each district is ranked according to the individual metal, and districts whose output of any of the three metals is not of third rank are shown by a dash "-" thus it will be noted that several districts are of third rank with respect to silver, but not of third rank with respect to lead and zinc. Districts whose known output of all three metals and whose estimate of potential reserves are less than third rank are not shown on the map or listed in the table.

Lead and zinc occur in many different minerals, but in primary ores the most common occurrences are as the lead sulfide, galena, and the zinc sulfide, sphalerite. Silver is a minor constituent in many lead-zinc ores, most commonly as "argentiferous galena" or as minute inclusions of one or more silver-bearing minerals in lead or zinc minerals. Silver also occurs as the sulfide, argentite, or as its oxidation products and as complex sulfosalts with arsenic and antimony. Silver values in primary ores vary widely from silver-rich ores to lead-zinc ores in which silver is only a coproduct, and to some gold ores that contain silver as an impurity.

Many deposits of primary silver, lead, and zinc sulfides are oxidized to varying depths below the ground surface, the oxidation usually extending to or near the level of the underlying ground water table. Within the oxidation zone, galena is converted to a number of secondary minerals, the more common of which are anglesite and cerussite. This conversion takes place without any appreciable migration of the lead minerals. Removal of the more soluble minerals from the deposit by migrating meteoric water during oxidation generally results in enriched concentrations of the secondary lead minerals. Primary ores of silver are dissolved during oxidation, and the silver is precipitated as secondary silver minerals in an enriched zone that may be either at the site of the original primary ore or downward from it. Below the zone of oxidation, the grade of lead and silver in primary ores usually is less than in overlying enriched secondary ores. Oxidized deposits of enriched lead and silver ores commonly occur together and as such accounted for much of the early-day production in the Wood River region (Fig. 45, Nos. 33 and 34), the Bayhorse district (No. 18), Texas (Gilmore) (No. 21), Nicholais (No. 14), and several other areas. Oxidized silver minerals formed from the rich ores in the Carson (Silver City) and DeLamar districts (Nos. 39 and 40), the Lava Creek district (No. 37), Yankee Fork district (No. 17), Mineral district (No. 23), and several others.

Sphalerite differs from galena and silver sulfides in that during oxidation the zinc is dissolved by acidified meteoric water and transported until precipitated as secondary zinc minerals as the solutions become neutralized. These secondary zinc minerals form massive irregular replacements or disseminated bodies, usually away from the
site of the original primary ore. Oxidized zinc ore bodies, therefore, rarely occur together with oxidized ores of lead and silver. Secondary zinc ore has not been widely mined in Idaho, although it has been produced at the White Knob mine in the Alder Creek district (No. 36) and at the Homestake mine in the Warm Spring district (No. 33).

Silver, lead, and zinc deposits are widely scattered in Idaho, as may be seen in figure 45. These deposits are of many different types, but the most productive have been veins and replacements in metamorphosed rocks and replacements and veins in sedimentary rocks. There appears to be a spatial relationship between most of the deposits and intrusive granitic rocks, the principal mass of which is the Idaho batholith. Many early students of Idaho geology related the deposits genetically to the batholith, but later work has shown that this relationship is subject to question. Rather, the evidence suggests several periods of mineralization, the more prominent of which is of Tertiary age and which is associated with Tertiary igneous rocks that have intruded rocks of the batholith, as well as other rocks. For simplified descriptive purposes, the deposits are classified into the four following types:

1. Veins and replacement deposits in Precambrian metamorphosed rocks;
2. Replacement and vein deposits in sedimentary rocks;
3. Precious metal veins:
   a. Silver-gold veins;
   b. Gold-silver quartz veins;
4. Contact metamorphic deposits.

Veins and replacement deposits in Precambrian metamorphosed rocks are the important and most productive type of deposit in the State. They are typified by deposits in the Coeur d'Alene region (No. 6) and by others in the Lakeview (No. 4), Pend Oreille (No. 3), Clark Fork (No. 2), and Porthill (No. 1) districts (Continental mine), and other areas. The Coeur d'Alene region is approximately at the intersection of a major westerly trending fault (the Osburn fault) with a northerly trending arch in the Precambrian rocks. These folded Precambrian rocks were intruded by monzonitic stocks of Late Cretaceous age prior to deposition of the ore. Common host rocks of the ore deposits are quartzites and argillites of the Belt Series. The veins are chiefly in linear belts, one concentration of which is north of the Osburn fault and the other south of it. Galena, sphalerite, and tetraedrite are the common ore minerals and these are concentrated in ore shoots, many of which have been mined to great depths. Siderite and ankerite are common vein minerals.

Crosby (1961, p. 9) states that about one-half of the Coeur d'Alene ore has come from mineral belts north of the Osburn fault, which follow trends of east-southeast faulting. A total of 44 mines have produced ore from this area, the aggregate tonnage from which—through 1960—was about 45 million tons of ore averaging 4.2 ounces silver, 7.5 percent lead, and 3.1 percent zinc. The Morning, Star, Frisco, Dayrock, Hercules, Tamarack, Sherman, and Lucky Friday are but a few of the productive mines in this area.

Of the deposits south of the Osburn fault, the Bunker Hill mine has been the principal producer and is the largest mine in the district. According to McConnel (1961, p. 17), this mine produced about 25.3
millions of tons of ore, containing about 93.1 million ounces of silver, 2,078,000 tons of lead, and 286,000 tons of zinc between 1896 and 1961. The ore is mined from a number of northwest- and northeast-trending veins that are chiefly in argillites and argillaceous quartzites of the St. Regis Formation of the Precambrian Belt Series.

A number of mines east of the Bunker Hill mine are in a mineralized area known as the Silver Belt, which extends for about 10 miles in the area between Kellogg and Wallace, and which contains a number of prominent mines including the Crescent, Sunshine, Polaris, Silver Summit, and Galena. Ores from these mines are characteristically rich in silver. The common ore mineral is freibergite, the silver-bearing variety of tetrahedrite, in which the silver content varies considerably. Average grade of Silver Belt ore is not known to the writer, although Colson (1961, p. 34) states that the Sunshine mine, from 1904 to 1905, produced about 61 million tons of ore, from which was recovered 187,500,311 ounces of silver, 61,599 tons of lead, and 26,429 tons of copper.

West of the Bunker Hill mine is another prominent producer, the Page mine. The Pine Creek area is southwest of the Page, and it contains many small mines that have operated intermittently during the present century but which were closed in 1964 because of economic conditions.

Replacement and vein deposits in sedimentary rocks have been the main lead, zinc, and silver producers in the southern part of the central Idaho region, especially in the Mineral Hill (No. 34), Warm Spring (No. 35), Bayhorse (No. 15), Junction (No. 20), Texas (Gilmore) (No. 21), Nicholau (No. 14), Birch Creek (No. 22), Boulder Creek (No. 45), Abler Creek (No. 36), and Dome (No. 38) districts. Deposits of this type have many geologic features in common. They are in folded and faulted sedimentary rocks—usually limestone or dolomite—and all are spatially close to Tertiary intrusive rocks, either stocks or dikes, to which they appear to be genetically related. They characteristically are localized by faults that appear to have served as feeding fissures. Locally, ore has been deposited along these faults to form vein deposits. Replacement deposits may be along or adjacent to these veins, or have replaced favorable beds of the host rocks and may extend some distance away from the veins. Some ore bodies are pipe-like bodies formed at the intersection of faults and favorable host rocks. The deposits tend to be irregular, and not as continuous as ore shoots along veins in the Precambrian rocks. They usually are oxidized near the surface, and many were worked for secondary lead and silver ores during early days of mining but have been relatively inactive since then.

Typical of these are most of the deposits of the Warm Spring (No. 35) and Mineral Hill (No. 34) districts in the Wood River region of Blaine County. This region has produced more silver, lead, and zinc than any other area in Idaho, excepting the Coeur d'Alene region. The Triumph mine, including the old North Star and Independence mines, has been the principal producer; however, reserves at this mine were exhausted in 1927 and the mine was abandoned. Other prominent mines include the Minnie Moore and Silver Star-Queens, which were productive during the early part of the century, then abandoned but reopened in 1949 and active since.
Most of the ore in this region has been mined from veins and from associated replacements of calcareous rock of the Milligen Formation of Mississippian and Devonian (1) age. This is especially true of the Triumph mine, Minnie Moore and Silver Star-Queens mines. Elsewhere, as in mines of the Bullion Gulch area, ore has come from veins in quartzite rocks of the Wood River formation of Pennsylvanian and Permian age. Some ore has been mined from veins in diorite, which presumably is part of the Idaho batholith.

During early days of mining, much oxidized silver-lead ore was produced from this region, and at later periods oxidized zinc ore was mined at the Homestake mine on Lake Creek, but most of the values have come from sulfide ore. Argentiferous galena and sphalerite have been the dominant minerals, although tetrahedrite is common, as were ruby silver minerals in the upper workings of the Triumph mine.

The Bayhorse district (No. 18) in Custer County also is one of the famous mining districts of the State. Large amounts of silver, lead, and zinc have been produced from irregular replacements and veins in dolomite rocks and slate of Cambrian and Ordovician age. Of the many mines, the Clayton Silver, Beardsley, Excelsior, Pacific, Red Bird, Riverview, Last Chance, Ramsborn, and Skylark have been the principal producers. All of the deposits have been oxidized and most of the early-day ore—produced during the most active period in the history of the district—was high-grade oxidized silver-lead ore. During recent years, the Clayton Silver has been the only active mine in the district, and it produces silver and lead from sulfide ores.

The Texas (Gilmores) (No. 21) district in Lemhi County has been an important producer of lead-silver ore. The Pittsburg-Idaho, Latest Out, and Allied Gold mines have been the principal producers. These mines were active during the early 1900's, but aside from minor exploratory work and small sporadic shipments from leaseholders the district has been idle in recent years. The ore is in veins in Paleozoic limestone. Locally, ore has replaced selected beds of limestone, and these irregular replacements may extend many feet away from the veins. Almost all of the ore has been oxidized, although lead-zinc sulfide ore is reported on the lowest level of the old Pittsburg-Idaho mines.

The Viola, Weimer, and Scott mines in the Nichola (No. 14) and Birch Creek (No. 22) districts are reported by Anderson and Wagner (1944, p. 14) to have been among the most important lead-silver producers in the State during the period 1881 to 1890. They have been mostly idle since then, although some mines were active during World War II. All deposits but one are irregular replacements in Paleozoic limestone. Aside from small scattered bunches of sulfides, all of the ore mined has been oxidized.

Throughout central Idaho, there are a number of districts that have been mined for the precious metals gold and silver. Veins in these districts are classed as epithermal deposits, or deposits that formed at relatively shallow depths below the surface of the ground. These veins follow faults or zones of shearing, usually forming belts of veins more or less oriented in the same direction. They cut or else are cut by intrusive rocks of early to middle Tertiary age and are considered to be genetically associated with these rocks. The
wall rocks of these veins are highly altered, and the material within
the veins usually is brecciated and silicified. Textures of quartz
within the veins range from finely laminated chalcedony to coarse
crystals that frequently line cavities. The primary ore minerals con-
sist of silver sulfosalts (chiefly ruby-silver minerals) and gold,
usually in thin mineralized bands parallel to the vein walls. Lead,
zinc, and copper sulfides occur in minor amounts and only rarely in
ore quantity. Ore shoots within the veins extend only a few hundred
feet below the surface, but they often contain extremely high-grade
ores especially in the upper parts. With depth, the ore shoots become
smaller and too lean to be profitably worked.

In most of these deposits, the amount of silver present exceeds
that of gold. For example, Piper and Laney (1926, p. 64) note an
average ratio of 30 ounces of silver to 1 ounce of gold in the Silver
City region, and in the Yankee Fork district (No. 17) the ratio may be
calculated as 40 ounces of silver to 1 ounce of gold. Gold has a
higher value than silver, however, and many of the deposits are
valued more for the gold output; consequently they are known as gold
mines rather than silver mines.

On the basis of known metal output, the precious metal deposits
are classified in this report as (a) silver-gold veins and (b) gold-
silver-quartz veins.

Silver-gold veins.—Silver-gold veins have been mined in the Silver
City region and in the Yankee Fork (No. 17), Rocky Bar (No. 29),
Mineral (No. 23), and Vielma (No. 30) districts.

In the Silver City region—which includes the DeLamar, Carson
(Silver City), and Flint districts (Nos. 39, 40, and 41)—in Owyhee
County, the principal properties include the Golden Chariot, Ida
Elmore, Morning Star, Oro Fino, Poorman, DeLamar, Black Jack,
Trade Dollar, and Rising Star-Peace River mines. The initial period
of mining activity extended from 1863 to 1876, when the mines were
closed because of depressed financial conditions. A more productive
period of mining began in 1889 and continued to 1914, when reserves
were exhausted and mining ceased. The region has been more or less
idle since. During early days of mining, incredibly rich bonanza
bodies of oxidized ore and of ruby-silver minerals were mined in this
region.

In the Yankee Fork district (No. 17) in Custer County, the more
productive mines included the General Custer, Lucky Boy, Gray
Eagle, Montana, McPadden, Charles Dickens, and Golden Sunbeam,
although there were many smaller mines. The district was most pro-
ductive during the period 1875-90, when extremely high-grade ore
was mined, some so rich it was transported from the district in sacks.
Mining has continued intermittently since; the last significant produc-
tion came from the Lucky Boy mine, which was closed during World
War II. Aside from small sporadic exploratory efforts and a few
shipments of hand-sorted ore, the district has been idle during recent
years.

Silver ores were found in the Atlanta district in 1864, and much of
the shallow and richer ore had been mined by 1870. Subsequently,
the district was mined intermittently during several periods, the latest
of which started in the late 1930's and continued into the early 1950's.
Since then, only small sporadic mining ventures have been attempted.
Anderson (1939, p. 23) notes the ratio of silver to gold, by weight, in early-day mining was as much as 200 to 1; however, gold has been by far the most valuable metal produced from the district. The silver and gold ores are in extensively fractured and sheared zones in quartz monzonite of the Idaho batholith. The ores consist chiefly of various ruby-silver minerals and native gold. Most of the rich silver ores were within 200 feet of the surface of the ground. All of the ore was in ore shoots, which were not commercial below a depth of 500 feet from the surface.

**Gold-silver quartz veins.**—These gold-silver deposits are essentially quartz veins worked for gold but in which is silver that is recovered as a byproduct. Typical are most of the deposits in the Pearl-Horsecshoe Bend (No. 24) district, the Quartzburg (No. 25), and Grimes Pass (No. 26) districts of the Boise Basin, the Warren (No. 10), Marshall Lake (No. 9), Florence (No. 8), and Elk City (No. 7) districts. These districts were actively worked during early days of mining but have been more or less idle for many years. Some, like the Golden Anchor mine in the Marshall Lake (No. 9) district, and the Belshazzar and Gold Hill mines in the Quartzburg (No. 25) district were active to the late 1890's or early 1940's but have been idle since.

These deposits are mostly along shear zones in granitic rocks of the Idaho batholith, but they are considered to be genetically related to younger Tertiary dikes and stocks that have intruded the batholith. Ore shoots within the veins have been discontinuous and small to moderate in size. Few of the ore shoots have extended more than 500 feet below the surface. Resumption of output from these districts could be expected, but only under greatly improved economic conditions.

Contact metamorphic deposits are not common in Idaho, but there are some that have been productive. These ore bodies generally are enriched in zinc and copper, and they form irregular pipelike bodies in metamorphosed limestone near to or adjoining intrusive masses of igneous rocks. Typical are those in the South Mountain district (No. 42), in Owyhee County, where a large mass of Paleozoic limestone has been intruded by a stock of granodiorite. The deposits are pipelike bodies that have been sporadically worked, the latest period during the 1850's.

In the Alder Creek district (No. 36), Custer County, contact metamorphic deposits at the Empire mine have been worked for copper, but they also contain appreciable amounts of zinc. These pipelike bodies are in limestones of Mississippian age, which is intruded by a granite stock of early Tertiary age. Intruding the granite are dikes and porphyritic rocks of a later Tertiary age, and the ore is believed to be related to these later rocks.

**RESOURCES AND OUTLOOK**

Estimate of lead and zinc reserves in Idaho, as of the end of 1962, indicated there was a supply available that was adequate to maintain the 1962 rate of production of the metals for at least 10 years. Of the reserves, 98 percent of the lead and 93 percent of the zinc are in deposits of the Coeur d'Alene (No. 6) region. Geologic possibilities of finding and developing new reserves in the Coeur d'Alene area are considered excellent, however, and there also are likely to be additional potential resources that should sustain mining for many years to come.
Elsewhere in Idaho, vein and replacement deposits in Precambrian rocks, similar to those in the Porthill (No. 1), Clark Fork (No. 2), Pend Oreille (No. 3), and Lakeview (No. 4) districts are geologically favorable for finding new sources of ore, and these areas may be expected to be further explored.

In southern-central Idaho, there are a number of replacement and vein deposits in sedimentary rocks that contain potential resources, that may be expected to be further explored, particularly under more favorable economic conditions. All of the ore mined in the Warm Spring (No. 35) and Mineral Hill (No. 34) districts has been from mines that have been worked within a few hundred feet of the surface. The nature of the ores from these deposits, however, is not typical of shallow epithermal ores but of deeper ones. The problem of whether the deposits contain ore at greater depths has not been resolved.

Reserves in the Bayhorse district (No. 18) are limited and are confined largely to the Clayton Silver mine. The district, however, is considered one of the more favorable areas in the State for potential resources of silver, lead, and zinc. It contains many replacement deposits in dolomitic rocks, some of which have been inadequately explored. The district needs to be mapped geologically in greater detail to determine structural and stratigraphic guides to ore and, more especially, whether the replacement deposits are mostly restricted to any particular bed or series of beds.

The Junction (No. 20), Texas (Gilmore) (No. 21), and districts along Birch Creek (Nos. 14 and 22) have been worked only in the oxidized zone for ore that could be produced quickly and with a minimum of expended capital. The sulfide zones in these districts have not been adequately explored, and until this is done the potential of these areas will remain unknown. The deposits are of the type that may be expected to continue to greater depths, and while they may not be as high grade in the sulfide zone as they were in the oxidized zone, they may contain material that will be profitable to mine. Much of the same can be said of other deposits in the Dome (No. 85), Alder Creek (No. 36), Lava Creek (No. 37), and South Mountain (No. 42) districts. Sulfide ore has been mined in some of these districts, but none of them can be considered as worked out and unworthy of further exploration.

The precious metal deposits, such as those worked in the vicinity of Silver City (Nos. 39 and 40), Atlanta (No. 28), Yankee Fork (No. 17), and those in the Boise Basin (Nos. 25, 26, and 27) pose another problem. Deep exploration under shallow epithermal deposits of this type, in other parts of the country, has been largely unrewarding. There is, however, the possibility of finding other similar deposits in areas now covered and concealed by alluvium, Recent valley fill, or by volcanic rocks that were poured out of the surface after the deposits had formed.

The outlook for continued output of silver, lead, and zinc from Idaho is encouraging. The State has a rich history of past production, and there is no reason why it should not continue to produce in the future. Mining activity will be affected by economic conditions, which have not been too favorable in recent years, and by the tendency for more and more lead and zinc ore to be mined from large lower grade replacement deposits such as are mined in Missouri and Tennessee. Many of
Idaho's deposits will be adversely affected by the higher cost of mining and transportation in relatively remote areas and by the increasing depth of some of its mines. A favorable factor, however, is the relatively high silver content of most of Idaho's lead-zinc ores. Silver is a metal which is now, and is likely to remain for some time, in short supply. Idaho has the potential to overcome the problems which her lead-zinc industry must face, and it is probable that there will be at least as much ore mined from the State in the future as there has been in the past.

SMELTER BYPRODUCTS


Several elements are present in minor amounts in the base and precious metal deposits of Idaho and may be recovered as byproducts or co-products in the smelting or recovery of such principal metals as zinc, lead, copper, silver, and gold. In addition to antimony, which is described in a separate section, the elements arsenic, bismuth, cadmium, germanium, selenium, and tellurium are present in many of the ore deposits of Idaho. Production figures for these metals are not readily available, as some of the ores containing them are processed in the State, and others are shipped to smelters in other States.

ARSENIC

Arsenic occurs chiefly in the minerals arsenopyrite, enargite, realgar, and orpiment, associated with ores commonly mined for their gold, silver, copper, lead, and zinc content. Most of the arsenic produced in the United States is recovered from smoke as an oxide (white arsenic). Arsenic is toxic and volatile, and is used primarily in insecticides and pesticides. Its minor uses include wood preservation, weed control, and as a constituent of glass and lead shot. Its toxic uses have declined in recent years due to the substitution of other chemical compounds. Realgar and orpiment serve as paint pigments and the former is used in leather tanning.

Arsenic occurs in a variety of minerals in the ore deposits of Idaho. Arsenopyrite is the most common arsenic-bearing mineral and is an accessory in lead, zinc, gold, and antimony veins. The arsenic content complicates the treatment of ores from these veins, and usually a penalty is assessed against arsenical ores by smelters. Deposits containing arsenopyrite and other common arsenic-bearing minerals are found in the districts listed in Table 12.

Nickelite and sulfidrite, nickel and cobalt arsenides respectively, occur with other cobalt-nickel minerals in the Blackbird district (fig. 46, No. 18), Lemhi County. Cobaltite, a cobalt sulfarsenide, is the most important ore mineral of cobalt in this district. Danait, the cobaltiferous variety of arsenopyrite also occurs here. Gersdorffite, a nickel-cobalt iron sulfarsenide, occurs at several localities in Shoshone County, including the Sunshine mine in the Coeur d'Alene district (No. 7).

The copper sulfarsenide, enargite and tennantite, occur in the Yankee Fork district (No. 22), Custer County, and in the Saint Charles
<table>
<thead>
<tr>
<th>District and index number on fig. 46</th>
<th>County</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boise (27)</td>
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<td>Do</td>
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<tr>
<td>Butte (28)</td>
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<td>Do</td>
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<tr>
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<td>Elmore (31)</td>
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<td>Idaho (33)</td>
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<td>Do</td>
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<td>Lemhi (34)</td>
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<td>Do</td>
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<td>Blaine (35)</td>
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<td>Do</td>
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<td>Bonner (36)</td>
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<tr>
<td>Custer (37)</td>
<td>Do</td>
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<tr>
<td>Kootenai (38)</td>
<td>Do</td>
<td>Do</td>
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<td>Owyhee (39)</td>
<td>Do</td>
<td>Do</td>
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<tr>
<td>Shoshone (40)</td>
<td>Do</td>
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<td>Butte (41)</td>
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<td>Butte (42)</td>
<td>Do</td>
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<tr>
<td>Custer (43)</td>
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<td>Lemhi (44)</td>
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<td>Owyhee (45)</td>
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<td>Shoshone (46)</td>
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<td>Do</td>
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<tr>
<td>Washington (47)</td>
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<tr>
<td>Valley (48)</td>
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<td>Do</td>
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<tr>
<td>White (49)</td>
<td>Do</td>
<td>Do</td>
</tr>
</tbody>
</table>

1 Many different ruby silver minerals occur in these districts, but the common arsenic-bearing one is piromorphite.

district (No. 49), Bear Lake County. Realgar is associated with copper, zinc, and antimony in the Black Pine district (No. 41), Cassia County. Native arsenic is reported by Shannon (1916) to occur as a narrow vein in granite parallel to a galena-bearing vein in a prospect on Vulcan Hill (No. 4), two miles south of Lakeview, Bonner County.

Arsenic is a ubiquitous element in many deposits and there are considerable potential resources of it in Idaho. Previous output has been entirely as a smelter byproduct, and relatively small amounts have been produced. Penalties are levied on base metal concentrates that contain high amounts of arsenic; thus high arsenic-bearing ores usually are left unmined or else they are discarded. Furthermore, mining at many deposits in which arsenic occurs has been depressed during recent years, and most of the mines have been idle. More arsenic could be produced under favorable economic conditions.

BISMUTH

The United States is the world's largest producer and consumer of bismuth. Almost all of the bismuth produced is a byproduct of the smelting and refining of lead and copper. Two companies produce bismuth in the United States—American Smelting & Refining Co. and the U.S. Smelting Lead Refinery, Inc. Bismuth is resistant to corrosion by acids, has a low melting point, expands on solidification,
Figure 48.—Occurrences of ores containing arsenic, bismuth, cadmium, germanium, selenium, and tellurium in Idaho.
and has a lower thermal conductivity than any other metal except mercury. It is used in low melting point alloys for safety devices, as a flux in the paint, glass, and ceramic industries, and improves the machinability of aluminum alloys and malleable iron and steels. Because of its smooth texture, it is used in pharmaceutical chemicals. One of the newer uses being investigated for bismuth is as a coolant for nuclear energy production piles (Howe, 1954).

Bismuth minerals are rare in most deposits. Where found, they generally are in vein or contact metasomatic deposits, and almost always associated with igneous rocks. Primary bismuth minerals usually are sulfides; more rarely bismuth occurs as native metal. Although some bismuth minerals have been found in many deposits in Idaho—particularly in gold veins—significant quantities of bismuth have not been produced, nor is there reason to expect much output in the future.

Disseminated native bismuth is found in quartz at the Empire property in the Washington Basin, east Fork district, Custer County (fig. 46, No. 33). It is also found in quartz veins at a contact between granite and slate on Beauty Bay Creek, Beauty Bay district (No. 5).

The bismuth sulfide, bismuthinite, is associated with copper ores in the Seven Devils district, Adams County (No. 11) and the Heath district, Washington County (No. 12). Anderson (1947, p. 281) has described galenobismuthite and bismuthinite at the Belshazzar mine in the Quartzburg district, Boise County (No. 27).

Minor amounts of bismuth have been reported from ores from the Copper Basin district, Custer County (No. 35); Calera mine, Blackbird district (No. 18); Triumph mine, Warm Spring district, Blaine County (No. 34); and Pend Oreille (Talache) district, Bonner County (No. 2). It has been found in several placer deposits, including those in the Quartzburg district, Boise County (No. 27), Dixie district, Idaho County (No. 15), and Elk City district, Idaho County (No. 10). Bismuth has been found at several mines in the Coeur d’Alene district, Shoshone County (No. 7) (Kaiser and others, 1954, p. 49–54).

CADMIUM

Cadmium is a relatively rare metal that is associated with zinc ores. It is recovered as a byproduct in the treatment of lead and zinc ores at the Bunker Hill Co. smelter and the electrolytic zinc plant in the Coeur d’Alene district (fig. 46, No. 7) (McConnell, 1961). Cadmium is resistant to atmospheric, galvanic, and alkaline corrosion, is toxic, and has a low melting point. Most of the cadmium metal produced in the United States is used as a protective coating for iron, steel, and, sometimes, copper for auto, aircraft, and marine engine parts. It is also used in solders and low-temperature fusion alloys for safety devices and in nickel-cadmium storage batteries. Cadmium sulfide is used as a coloring agent, and cadmium halides are used in photography. Some interesting but minor uses of cadmium include the Weston Standard Cell, which is the working standard for the United States in maintaining the value of the volt, and in control and shield devices in atomic reactors (McCutcheon and Musgrave, 1954).

Greenockite is the common ore mineral of cadmium, and it occurs chiefly as a stain on the zinc sulfide, sphalerite. Cadmium is recovered
from most of the zinc ores mined in Idaho, the principal source being mines in the Coeur d’Alene district, Shoshone County (No. 7). The Warm Spring (No. 84) and the Mineral Hill (No. 36) districts in Blaine County also have produced considerable zinc ore (Kaiser and others, 1954), from which cadmium is believed to have been recovered. The cadmium content in zinc ores varies from mine to mine and district to district; however, a regional average of Western ores is about 0.23 percent. Calculating this percentage against known reserves and potential resources of zinc ore in Idaho indicates that potential cadmium should aggregate at least 5,000 tons of metal.

Minor amounts of cadmium are found in the ore from the White-delf mine, Clark Fork district (No. 3), Bonner County, and in the Bayhorse district, Custer County.

GERMANIUM

Germanium, which is a byproduct of base metal production, was produced in the United States for the first time in 1944. It is considered a metalloid with properties somewhere between those of a true metal and a nonmetal. Its most significant use is as a semiconductor component in electronic devices. Most of the germanium produced in the United States is recovered by the Eagle-Picher Co. at Henryetta, Okla., from ores of the Tristate district of Missouri, Kansas, and Oklahoma (Harner, 1954).

Germanium is commonly associated with and occurs as minute quantities in sphalerite and also with a number of other minerals, including coal. The more important germanium-bearing minerals are germanite, a copper-iron-germanium sulfide; argyrodite, a silver-germanium sulfide; canfieldite, a silver-tin-germanium sulfide; and renierite, a copper-iron-germanium sulfide.

Minor amounts of germanium have been reported in zinc-lead ores from the Viola mine, Nicholla district (fig. 46, no 29), and from the Amazon, Morning, Frisco, Tamarack, Page, and Blackhawk mines, all in the Coeur d’Alene district (No. 7) in Shoshone County (Kaiser and others, 1954). Minor amounts also occur in garnet sand concentrates from the Emerald Creek placer district (No. 8) near Fernwood, Benewah County.

The potential value of germanium as a semiconductor material is uncertain, as it is subject to substitution by other, more economic, materials. Under more favorable economic conditions, the value of germanium as a mineral resource in Idaho would be increased.

SELENIUM AND TELLURIUM

Selenium and tellurium are almost entirely byproducts of electrolytic copper refineries, with additional small amounts recovered from lead-smelter flue dusts and from treatment of gold telluride ores. The Western copper ores are the most important source of selenium, whereas gold and silver ores are the principal sources of tellurium. Some forms of selenium exhibit the properties of a metalloid while others, those of a true metal. In most of its compounds it displays the properties
of a nonmetal. Tellurium may be thought of as having the properties of a metal in most of its forms (Stone and Caron, 1954).

Because of the similarity in properties of these toxic elements, they are interchangeable in some of their uses. Selenium, however, has gained wider acceptance in many industries than tellurium. Most of the copper producers that recover one also recover the other. Both metals increase the machinability of stainless steel and copper, are used in dry-plate metal rectifiers, act as coloring agents in glass, porcelains, enamels, and paints, and have been used as vulcanizing agents in the rubber industry. More recently selenium has replaced tellurium in this capacity; it also promotes rubber's resistance to heat, oxidation, and abrasion, and increases its resilience. Selenium is also used as an oxidizing agent in the preparation of the drug cortisone, in photoelectric cells, in toning baths in photography, in activating charcoal, and, in one form, is one of the most powerful solvents known for glue, resins, paint, and varnish. The inkless printing process, xerography, is based on the electrical properties of selenium. One of the newer uses of tellurium is in thermoelements for space vehicles (Fisher, 1960).

The distribution of selenium and tellurium in the ore deposits of Idaho is not yet known in detail. The common association of tellurium with gold in many of the Western ore deposits is not so apparent in Idaho. Sylvanite, a silver-gold telluride, has been reported to occur in the Warren (fig. 46, No. 14) and Marshall Lake (No. 13) districts, Idaho County, on the Deer Creek property, Nez Perce County (No. 9), and to a small extent in the Coeur d'Alene district (No. 7). Petzite, another silver-gold telluride, has been found in the Dixie district, Idaho County (No. 15). Tetradymite, a bismuth-tellurium sulfide, has been reported in ores of the Empire group of claims (No. 83), Custer County. Tellurium minerals also are reported from the Seven Devils district (No. 11), Adams County, the Quartzburg district, Boise County (No. 27), and a property on Trail Creek, Boundary County.

A number of selenium-bearing minerals have been found in Idaho, none of them in significant amounts. The silver selenides, naumannite and aguilharite, have been found in the Tertiary gold and silver ores of the Yankee Fork district, Custer County (No. 22), and naumannite in the Gravel Range (No. 20) and Parker Mountain (No. 21), Lemhi County, and the DeLamar (No. 38) and Silver City (No. 39) districts, Owyhee County. Clausthalite, the lead selenide, has been found in the Hypotheek mine in the Coeur d'Alene district, Shoshone County (No. 7). Selenium also has been detected in the antimony deposit at the Meadow Creek mine, Yellow Pine district, Valley County (No. 10), and in phosphate deposits of Permian age in southeast Idaho (Anderson, 1961). Davidson and Gulbrandsen (1957, p. 1714) state:

The Meade Peak Phosphatic Shale Member of the Permian Phosphoria formation in Idaho, Wyoming, Utah, and Montana contains some of the most seleniumiferous sedimentary rocks known, and the most seleniumiferous of these are in southeastern Idaho and western Wyoming.

The phosphate deposits (found in portions of Bear Lake, Bannock, Bingham, Bonneville, and Fremont Counties) contain by far the largest potential resources of selenium in the State.
STONE AND CONSTRUCTION MATERIALS
(By R. R. Asher, Idaho Bureau of Mines and Geology, Moscow, Idaho)

Stone and construction materials are highly important commodities in the United States. For example, crushed stone is exceeded only by the fuels, iron ore, and cement in value of annual production. Dimension stone, of lesser importance than crushed stone, has a much higher unit value; in 1961 only 0.3 percent of all stone produced in the United States was dimension stone, but it contributed 9.2 percent of the total value (Cotter and Jensen, 1962). Other stone and construction materials of importance are slate, pumice, pumicite, volcanic cinder, diatomite, and naturally expandable materials such as bloating clays and shales, perlite, and vermiculite. The value of pumice, pumicite, and volcanic cinder produced in 1961 was in excess of $6 million; volcanic cinder, of much lower unit value than pumice or pumicite, accounted for 62 percent of the tonnage produced but only for 38 percent of the gross value (Hartwell and Schreck, 1962a). The total value of crude perlite produced in the United States in 1961 was $1.3 million; the corresponding figure for expanded perlite was $12 million (Hartwell and Schreck, 1962b). It is obvious that stone and construction materials contribute significant amounts to the economy of the United States.

 Crushed stone, pumice, and volcanic cinder are produced in Idaho, and until 1969 perlite was produced. There are large deposits of pumicite but there has been no production; slate occurs but its economic potential is not known; dimension stone has been produced in the past but is now an insignificant industry. Such materials as expanded clay and shale or vermiculite are not important in Idaho and they are not discussed in this chapter. Diatomite is covered in a separate chapter of this report.

 Crushed stone is used in the construction industry for road stone and concrete aggregate; dimension stone finds use in building construction as interior and exterior trim and facing stone, base plates, and structural stone; it is also used for monuments and statues. Slate is used for roofing and for other specialized applications. Natural and expanded lightweight materials are used as aggregate in lightweight masonry concrete, plaster, stucco, and mortar and as aggregate in precast concrete products; they also find application as loose fill insulation, and as ingredients of manufactured wallboard and acoustical tile. In addition, pumice and pumicite are used as pozzolans and volcanic cinder is used as aggregate, road metal, and railroad ballast.

 The above commodities are not only important in the construction industry; they are used in many other fields. The lightweight materials mentioned above can be used as inert mineral fillers, filter aids, paint extenders, abrasives, soil conditioners and for many other uses (Otis 1960a, 1960b). Crushed stone, particularly limestone, the most important raw material of the crushed stone industry, has a wide range of application. Limestone is a basic ingredient in cement manufacture, and it is important to agriculture and the chemical and metallurgical
industries. Because of its importance, limestone is discussed in a separate chapter of this report.

In general, almost any type of rock is suitable as crushed stone for construction uses as long as it is relatively strong, abrasion resistant, and chemically inert (Severinghaus, 1960). The size and shape of the deposit and the amount of overburden are important cost items in quarry site selection (Key 1960). Once a quarry is developed, distance from point of use is generally the limiting economic factor. Because raw materials are readily available at many localities and portable crushing plants can be readily moved to new sites, a quarry is generally abandoned and a new one established when the distance from a construction site becomes excessive. In some applications, such as limestone or quartzite for chemical or metallurgical uses, chemical composition may be more important than the physical characteristics of the product. The availability of chemically suitable stone may strongly influence the selection of a site for the development of an industrial plant.

Like crushed stone, almost any type of rock may be used for dimension stone, but deposits are much more restricted because of the rigid specifications covering uniformity of texture and grain size, constant color or color patterns, and freedom from impurities that cause staining or deterioration. Porous rocks are unsuitable because of adverse effects on durability. Because relatively large blocks are required, stone with closely spaced joints or other planes of weakness are unacceptable (Bowles, 1960). The limited availability and the expense in mining, handling, and shipping these heavy, bulky products make dimension stone uncompetitive in many applications. Substitute materials such as concrete products and other manufactured items have largely replaced it in the construction market (Key 1960), but the use of ornamental and decorative stone is an important market that has been increasing in recent years. Stone possessing some unique quality may be highly valued for special monumental or architectural applications and it can then be shipped long distances.

Slate, like dimension stone, has a limited market. Roofing slate was at one time very popular, but manufactured products have now largely displaced it from the roofing market. Slate is used in the manufacture of billiard and other table tops, electric panels, blackboards, and flagstones. Crushed slate is used for roofing granules. Slate expanding processes have been developed and expanded slate is used for lightweight aggregate (Key, 1960).

Pumice, pumicite, and volcanic cinder are frothy, cellular volcanic ejecta produced by explosive volcanic activity. They are composed chiefly of volcanic glass and characterized by a low bulk density because of their cellular nature. These materials are found in areas characterized by recent volcanic activity on the slopes of volcanic cones, as bedded deposits resulting directly from ash falls, often interbedded between lava flows or welded tuff sheets, and as sedimentary deposits associated with clays, sands, and silts. Pumicite may be carried long distances by air currents following an eruption and
be deposited some distance from its source. Commercially valuable deposits of these glassy volcanic materials older than Tertiary are rare as volcanic glasses tend to devitrify rapidly.

Pumice and pumicite are acidic in composition, similar to rhyolite; pumicite is the fine material produced by violent volcanic activity and pumice is the coarser fraction. Cinders are the basaltic or basic equivalent of pumice.

The chief use of pumice is for lightweight aggregate, and as such it must be composed of strong, clean granules or fragments with small, evenly distributed vesicles that are not interconnected. Proper size gradation of the material to be used for aggregate is important, and crushing and screening may be required to produce a suitable product. Freedom from reactive chemical impurities and from soil, humus, clay, and the like are other requirements. Pumice must produce a workable mix with a low water requirement and produce concrete with a high strength-to-weight ratio in order to be used.

Volcanic cinders to be used for aggregate must possess qualities similar to those given for pumice. For road aggregate or railroad ballast, the chief uses of cinders, the particles must be strong and of the proper size and shape.

The chief use of pumicite is for pozzolan. A pozzolan is a siliceous, or siliceous and aluminous substance, used as a partial replacement of the cement (10 to 30 percent) in a concrete mix. It imparts certain desirable features to the mix and to the concrete. The material used for pozzolan must occur as extremely fine particles or grinding will be required; calcining may be necessary to induce or increase the pozzolanic activity of a material and the optimum calcining temperature must be determined. The pozzolan should effectively control alkaline-aggregate reactions between cement and alkalis, improve workability, reduce heat generation, thermal volume change, bleeding, and permeability of concrete. It should not greatly increase the water requirement in the mix, contain any exchangeable alkalis, or materially affect the strength or setting time of the concrete (U.S. Bureau of Reclamation, 1955).

Perlite, like pumice, is a variety of acidic volcanic glass, but it lacks the cellular structure of pumice and contains from 2 to 5 percent combined water. In general, perlite is thought to be produced through the hydration of obsidian, a variety of volcanic glass containing up to 1 percent combined water, but the source of the chemically combined water in perlite and the mechanism of its introduction are not well understood (Sharps, 1961). Because volcanic glass results from the rapid cooling of magma, perlite deposits are associated with acidic lava flows, volcanic domes, and intrusive bodies emplaced at shallow depths. Because volcanic glass is unstable and devitrifies rapidly, exploitable deposits older than Tertiary are seldom found.

In petrography the term "perlite" refers to a peculiar oninskin or concentric strain pattern developed in volcanic glass. This texture
is diagnostic of perlite. Commercial perlites, when heated beyond a certain temperature, expand to yield a lightweight, frothy product that is used as aggregate in gypsum plaster and concrete, as a filter aid, and for other uses; but the presence of perlite structure does not necessarily indicate an expandable material.

In evaluating a perlite deposit, the softening temperature and fuel requirements must be considered as well as the expansion characteristics of the material; percent decrease in bulk density when expanded, chemical and physical variations of the material in the deposit, and the amount of included nonexpandable material are important considerations. The body strength of the expanded particles is important, and light-colored, spherical particles with thick cell walls are desirable.

It should be pointed out that in all of the commodities discussed above, distance from markets and transportation facilities are extremely important economic factors. These are low unit value products that cannot be profitably exploited if excessive transportation costs are encountered. Thus, even though stone and construction materials of excellent quality may be found, they are of little value in remote localities. The materials used in the construction industry are in a highly competitive market and a deposit with an economic disadvantage cannot compete.

World production figures are incomplete for the stone industry, but in 1961 the United States was well ahead of any other country for which figures are available.

In 1961 Idaho ranked about 40th among the States producing stone with a reported production of 1.9 million tons, all crushed stone. Approximately 81 percent was basalt and granite for construction uses and 20 percent was limestone and quartzite for cement manufacture, construction, metallurgical, and industrial uses. There was no reported production of dimension stone but it is likely that there were a few small local quarries operating intermittently in the State that produced an unreported tonnage.

The recorded production of stone in Idaho goes back many years, the amount varying in response to demands by the construction, cement, and other industries. Dimension stone has been produced at various times but there has never been a significant, sustained production. The greatest demand for crushed stone in Idaho occurred in 1954 during construction of Palisades Dam in the southeastern part of the State. The accompanying graph (fig. 47) shows the production of crushed stone in Idaho for the period 1951-63. Production figures were taken from the U.S. Bureau of Mines Minerals Yearbooks for the various years.

Table 13 summarizes the important features of Idaho's stone industry. The map number is the number following the location of a deposit; it refers to the corresponding number on figure 48 to aid in locating the deposit. Many of the deposits and quarries can be located only approximately.
Figure 47.—Stone production in Idaho, 1951-62.
### Table 13: Important features of Idaho's stone industry

<table>
<thead>
<tr>
<th>Rock type</th>
<th>Uses</th>
<th>Location of deposits and map No.</th>
<th>Remarks</th>
</tr>
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<tbody>
<tr>
<td>Basalt</td>
<td>Aggregate and roadstone; used in past as building stone locally.</td>
<td>Widespread; outcrop areas of Snake River Group and Columbia River Basalt. Fig. 46 shows area extent of basalt in Idaho.</td>
<td>Quartz too numerous to plot individually. Located near areas where basalt is available. Most basalt suitable for most uses, but most void stones. In one instance, black, or contain reactive chemical ingredients. Many of the granite areas in Idaho are remote and are not well suited for quarrying. Pitting, weathering, and desilication make much of the granite unsuitable. Rocks occurring in extensive border zones of Idaho batholiths have potential value as trim and facing stone. Toh-oc-ah quarried and worked; they have on prolonged exposure (Bolton, 1934, p. 59). Few rocks potentially valuable as trim stone because of attractive colors and intricate flow patterns. Sandstone of Idaho Formation from Table. Rock quarry important in early Idaho, used in construction in California, Nevada, Colorado, Oregon, and Washington. (Gassaway, 1903). Other localities only of local importance.</td>
</tr>
<tr>
<td>Granite</td>
<td>Aggregate and roadstone; building and monumental stone in past.</td>
<td>Outcrop in Tertiary siliceous rocks and associated tuffs; some rocks of southern Idaho, see Fig. 6. Locations of individual deposits are shown on the Geological Map of Idaho (Du-32).</td>
<td></td>
</tr>
<tr>
<td>Rhyolite, Tuffs, and Andesites</td>
<td>Used for building stone in past.</td>
<td>Outcrop in Tertiary siliceous rocks and associated tuffs; some rocks of southern Idaho, see Fig. 6. Locations of individual deposits are shown on the Geological Map of Idaho (Du-32).</td>
<td></td>
</tr>
<tr>
<td>Slate, Marble, Sandstone, Quartzite, and Slates</td>
<td>Building stone; industrial and metal-work uses.</td>
<td>Building stone, Bonner County, from rocks of Balsam Series (B-1). Quartzite for industrial use, southeastern Idaho, one quarry located near Soda Springs, Caribou County (Q-4); location of other quarries not accurately known. Quartz quarried in Box Elder County, Utah (Q-1); state of Montana (Q-2).</td>
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</table>
FIGURE 48.—Stone and construction materials in Idaho.
Idaho has sufficient reserves to satisfy demands for crushed stone for many years. Consumption will probably increase in the future as there are several federal highway construction projects, dams, and other construction jobs now underway and planned in the State. There is little chance that a large, prosperous dimension stone industry will develop in Idaho. A market could be developed for many of the sandstones, rhyolites, and tuffs with pleasing colors and unusual textures for trim, facing, and ornamental stone, however. There are small areas of shale and slate in the State that have potential value in the manufacture of expanded products for lightweight aggregate; this use has never been evaluated.

Idaho ranks about seventh among the States producing pumice, pumiceite, and volcanic cinder. In 1946 Idaho was in first place as a producer of pumice but since then Idaho production has generally decreased while overall U.S. production has increased. The graph in figure 49-A shows Idaho production of pumice, pumiceite, and volcanic cinders from 1946 to 1962 and it points out how the annual tonnage and value of these products has declined. The data for the graph were taken from the U.S. Bureau of Mines Minerals Yearbooks for the various years. Prior to 1963 volcanic cinders were not included in the annual figures prepared by the U.S. Bureau of Mines, and the portion of the graph representing the years 1946 to 1953 shows only pumice and pumiceite. There is an unknown quantity of cinders produced in Idaho each year that are not reported in the U.S. Bureau of Mines for inclusion in their annual figures. A less drastic decline in Idaho production would be indicated by the graph if these unrecorded cinders could be included.

Figure 49-B is a table comparing total U.S. production and Idaho production of pumice, pumiceite, and volcanic cinders. This table shows that while U.S. production has been increasing yearly, Idaho production has generally decreased, especially since 1958. Cinders contribute significantly to overall U.S. production but many of the cinders produced in Idaho are unrecorded; thus figure 49-B is not a true picture of the situation, but it is indicative. Loss of out-of-State markets to producers more favorably situated and to competing products has caused Idaho pumice production to decline. Increasing freight rates, coupled with a decreasing unit value for pumice and depletion of easily accessible deposits close to rail facilities, are also adverse factors affecting production.

There has been no significant production of pumiceite in Idaho. This material is widely available and a potential market exists for it as a pozzolanic material and for other uses. Cinders are an important commodity; they are used largely by noncommercial firms such as Federal, State, and county agencies for road aggregate. Only two commercial cinder pits are known in the State.

Pumice and pumiceite are associated with the Salt Lake and Payette formations, and Idaho group of southern Idaho. The areal extent of these units is shown on figure 48. Cinders are associated with the Snake River basalts and cinder cones are abundant on the Snake River Plain and in adjacent areas. Water-laid cinders are found interbedded with sediments in Ada, Canyon, and Bonneville Counties. Because cinders and pumiceite are so widespread and abundant, only the more important and extensive deposits are shown on figure 48.
Table 14 is a general summary of the features of the known pumice deposits in Idaho and of selected, representative deposits of pumice and cinders.

Reserves of pumice, pumiceite, and volcanic cinders are abundant and sufficient to meet demands for many years. Economic factors hinder development of the deposits.

The Oneida Perlite Corp., with a deposit about 25 miles north of Malad in Oneida County (Fig. 48), mined, milled, and expanded...
<table>
<thead>
<tr>
<th>Commodity</th>
<th>Area of occurrence</th>
<th>Important deposits and representative occurrences</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumice (most deposits contain associated pumice)</td>
<td>Southeastern Idaho; associated with Salt Lake Formation and with Tertiary andesitic volcanic rocks.</td>
<td>1. Pothole east of Ammon, Bonneville County; part of Salt Lake Formation. (P-1.)</td>
<td>1. Ammon and vicinity most important producing area in State; product sells for $1.00 to $2.50 per ton.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Magic Reservoir pumice; associated with Tertiary extrusives; probably near a volcanic vent. (P-2.)</td>
<td>2. Deposit discovered in 1914 and 1922; production ceased in 1933; 300,000 tons produced; used as cement; reserves estimated at 250,000 tons.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Tetonia pumice, near village of Tetonia in Teton County; Salt Lake Formation. (P-3.)</td>
<td>3. Similar to pumice mined near Ammon.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. About 30 miles north of Maida, Oneida County. Salt Lake Formation. (P-4.)</td>
<td>4. Associated with andesitic and rhyolitic flows.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Between Carey and Pioche, Carson County; interbedded in Chalkie volcanics. (P-5.)</td>
<td>5. Production ceased in 1927; 2000 tons produced; used as concrete.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. East Bank of Owyhee Mountain; Goose Creek Basin, Owyhee County. Salt Lake or Payette Formations.</td>
<td>6. Associated with andesitic extrusives.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interbedded with andesitic extrusives. (P-6.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>South of Murphy, Owyhee County, along Rabbit Creek; Idaho Group. (P-7.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Along Reynolds Road, southeast of Walters Ferry, Owyhee County; Idaho Group. (P-8.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. North of Runnem, Gem County; Idaho Group. (P-9.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Near Rockland, Power County; Salt Lake Formation. (P-10.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Near Idaho, Bannock County; Salt Lake Formation. (P-11.)</td>
<td></td>
</tr>
</tbody>
</table>

**Pumice**

Southeastern Idaho; associated with sediments of Payette Formation, Idaho Group and Salt Lake Formation.
<table>
<thead>
<tr>
<th>Commodity</th>
<th>Areas of occurrence</th>
<th>Important deposits and representative occurrences</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volcanic cinders</td>
<td>Southern Idaho; cinder cones are abundant on Brandy River Plateau.</td>
<td>1. L. Freiberg's Pit, about 10 miles south of Nampa, Owyhee County, was the largest cinder cone. Cinders are 120 feet above sea level. Deposited by L. Freiberg's cinder cone.</td>
<td>1. Pit developed to waterlain cinders in recent sediments. Deposits are 120 feet above sea level. Deposited by L. Freiberg's cinder cone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Near Soda Springs, Caribou County; cinder cones numerous on Blackfoot lava field.</td>
<td>2. Several State and county cinder pits developed. One commercial pit operation, cinders sold in Utah markets as lightweight aggregate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Numerous State and county pits at many places in southern Idaho, too numerous to mention individually.</td>
<td>3. These cones are used generally in eastern Idaho for cinders.</td>
</tr>
</tbody>
</table>
perlite from November of 1960 until 1963; no figures are available on the quantity produced during this period. A mill is maintained at the mine; an open-pit operation and expanding facilities are located on the railroad at Malad (Staley, 1962). The deposit is associated with Tertiary silicic volcanic rocks overlying the Salt Lake Formation that locally contains pumice. Perlite has not been produced from any other deposit in Idaho, and none of sufficient size is known. Small lenses of perlite glass can be seen in the Tertiary silicic volcanic rocks at several places in southern Idaho but these occurrences are not of commercial interest.

A report on the volcanic construction materials in Idaho is being prepared by the Idaho Bureau of Mines and Geology. The report will include more details on the location, geology, quality, and quantity of the various materials within the State.

THORIUM AND THE RARE EARTHS

(By A. L. Anderson and C. N. Savage, Idaho Bureau of Mines and Geology, Moscow, Idaho)

Thorium and the lanthanide series of elements ("rare earths") have similar chemical properties and commonly occur in the same minerals. Thorium is not quite as plentiful in the earth's crust as lead and molybdenum but is more plentiful than uranium. It is radioactive, and its possible use as a nuclear energy fuel might significantly increase demand for thorium ores. The rare earths are not radioactive but are somewhat like aluminum and are essentially basic in character. Their future lies in their remarkable versatility. Some of these little-known elements are as plentiful as copper, lead, and zinc, and others, although scarce, are more abundant than mercury, silver, and selenium. Markets for the thorium and rare-earth minerals are now relatively small. In part, this reflects the relatively high unit cost of production of limited quantities. If larger markets existed, volume production techniques might substantially lower unit costs. Potential uses are being developed that may create increased demand, which, in turn, should lead to lower prices and foster further expansion.

At present, thorium (Th) is used primarily as thorium dioxide (ThO$_2$) containing 1 percent cerium dioxide (CeO$_2$) for use in the incandescent gas mantle devised by Welsbach for kerosene and gasoline lanterns. Other uses of thorium and its compounds are as catalytic agents in the petroleum and chemical industries; as ingredients in special glasses, medicinal compounds, and polishing compounds; as a refractory; as an alloying material with magnesium, and in electronic devices. The potential use of thorium as a source of atomic power, although still in the experimental stage, has some advantages over uranium according to some investigators. Thorium cannot be used directly in nuclear reactions but can be converted to fissionable U$^{233}$ in so-called breeder reactors, and the U$^{233}$ is then used as a source of atomic energy. Experimental reactors using thorium cores are now in operation, while research is being done all over the world to further the use of thorium as a source of energy.
The lanthanide or rare-earth series consists of two groups, one of which is named after yttrium, technically not a true rare earth:

**Cerium group:**
- lanthanum (La)
- cerium (Ce)
- praseodymium (Pr)
- neodymium (Nd)
- promethium (Pm)
- samarium (Sm)
- europium (Eu)

**Yttrium group:**
- yttrium (Y)
- gadolinium (Gd)
- terbium (Tb)
- dysprosium (Dy)
- holmium (Ho)
- erbium (Er)
- thulium (Tm)
- ytterbium (Yb)
- lutetium (Lu)

Difficult to separate, the rare earths are often used as a mixture called misch metal. Misch metal consists of the following (percentages):
- Cerium, 50; neodymium, 18; praseodymium, 5; samarium, 1; and lanthanum and others, 24 to 28. Salts of cerium, lanthanum, and neodymium seem to be in greatest demand. There is a growing broad-base use for rare earths, however, in the following industries: Electrical, electronic, nuclear, alloy, ceramics, glass, and chemical. Recently (Parker and Tucker, 1962), it was reported that rare-earth materials are being used at an increasing rate in glass polishing and in steel alloying. Investigations of potential uses are also being stepped up by several interested groups.

Rare earths have recently been priced as follows (average per pound in dollars):

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Monazite concentrates (55 percent grade, massive, imported)</td>
<td>0.14</td>
<td>0.14</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Alloy, mixed metal, ingot</td>
<td>2.25</td>
<td>2.25</td>
<td>2.50</td>
<td>2.80</td>
</tr>
<tr>
<td>Metal, cerium, high purity</td>
<td>27.00</td>
<td>27.00</td>
<td>27.00</td>
<td>27.00</td>
</tr>
</tbody>
</table>

Because thorium and the rare earths tend to associate and enter into the same minerals, there are few minerals which may be regarded separately as thorium or as rare-earth minerals; either thorium or the rare earths may predominate. Over 200 minerals are known to contain rare earths, including allanite, cerite, monazite, euxenite, bastnaesite, brannerite, cyrtolite, fergusonite, hnejmite, polycrase, priorite, samarskite, xenotime, and gadolinite. Rare earths may constitute 45 to 50 percent by weight of the mineral monazite, which may also contain thorium; this accounts for monazite's widespread use as a commercial source of both thorium and rare earths.

Monazite (Ce-La-Y-Th)PO₄ from placer mineral deposits is one of the principal sources of commercial thorium and rare earths produced in the State. Euxenite (Y-Ca-Ce-U-Th) (Cb-Ta-Tl)₃, which has been produced chiefly for its columbium and tantalum content, from deposits in Bear Valley, has been a much smaller source of thorium and rare earths. Thorite (ThSiO₄), although not yet exploited, is probably the largest potential source of thorium in Idaho. In some deposits, it is associated with rare earths. Other less important minerals include allanite, a cerium-bearing variety of epidote, uranothorite (thorite containing more than 15 percent uranium), and samarskite.

Thorium and rare-earth minerals are widely distributed in Idaho, not only as hydrothermal veins and as local masses in pegmatite, but also as accessory grains in igneous rocks—principally the granitic.
rock of the Idaho batholith and also in some metamorphic rocks. Where plentiful, veins and masses of these minerals may be treated as lode deposits, but the widely distributed grains are valueless unless they have been concentrated by natural processes into commercial-sized heavy mineral placer deposits. These placers differ in quantity and type of minerals because of differences within adjacent source rocks. The most productive in central Idaho have been monazite and euxenite-rich placers.

Rich concentrates of thorite in hydrothermal veins, with lesser amounts of monazite and allanite, may have great potential. These vein deposits, plus the monazite placer deposits, give Idaho a huge resource of thorium and rare-earth minerals. Accessibility to most of the vein deposits is excellent; accessibility to the known placer deposits is good to fair. Placer deposits at higher altitudes present some seasonal operational problems.

Except between 1887 and 1911, when monazite was recovered from stream placers in North and South Carolina, the United States has depended on monazite imports from India and Brazil for thorium and rare earths. The Indian Government placed an embargo on the export of monazite in 1946, followed by Brazil in 1951. Fortunately, the discovery in 1949 of large bastnasite (rare-earth carbonate) deposits in the Mountain Pass district, California, ended any shortage of rare earths in terms of present market conditions. However, bastnasite is deficient in thorium, and discovery of these deposits had no effect upon the supply of thorium in this country.

After 1947, because of the thorium shortage, monazite prices rose to between $500 and $400 per ton. By 1951, placer deposits in Idaho and Florida were meeting the demand for this product. However, high-grade vein deposits of monazite were discovered in South Africa in 1949, and by 1955 monazite from this source was being imported by the United States. After 1955, dredging for monazite ceased in Idaho. Some placer monazite continued to come from the euxenite placers in central Idaho, which were being dredged for columbium and tantalum minerals. In 1959, when the Government contract for the columbium-tantalum minerals was filled, this operation also ceased and went into a standby phase awaiting more favorable market conditions.

Past production figures on rare earths are obscure because their minerals contain fissionable materials that were formerly under security regulations. More recently, certain statistics have become available. Domestic mine shipments of rare-earth minerals in 1961 totaled about 23,5 times those for the preceding year, and about 2,902 short tons of monazite concentrate and other thorium ores were purchased from the Union of South Africa, Australia, Canada, and Mabha (Parker and Tucker, 1962). Domestic consumption of rare-earth elements in 1961 amounted to about 2,150 short tons. Cerium metal and cerium alloy were imported in small quantities.

Idaho production figures for rare-earth metals concentrates are unavailable prior to 1957 because they were formerly classified or confidential company data. Production figures since 1957 are as follows (short tons):

<table>
<thead>
<tr>
<th>Year</th>
<th>1957</th>
<th>1959</th>
<th>1960-62</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957</td>
<td>408</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1959</td>
<td></td>
<td>602</td>
<td>692</td>
</tr>
</tbody>
</table>

*None produced or shipped.*
Production over these years was chiefly from the Bear Valley euxenite placers and from Cascade-Long Valley placers (shipped from stocks at Boise). A little production came from the Lemhi Pass vein deposits.

Thorite veins in the Lemhi Pass area, Lemhi County, in eastern Idaho and at Hall Mountain, Boundary County, in northern Idaho (fig. 50), hold what are probably the greatest known resources of thorium in the United States. These were new discoveries which resulted from the search for uranium in the late 1940's and early 1950's. The potential of these deposits, however, was not recognized until later exploration and development had revealed their size and number.

The Lemhi Pass thorium veins occupy complex fissure and fracture zones in the impure quartzitic rock of the Belt Series. They may range up to 40 feet thick and 1,000 feet long with high-grade shoots a few inches up to 10 feet thick and a few tens up to several hundred feet long (Anderson, 1958, 1961a, 1961b). In addition to thorite, these veins contain variable amounts of feldspar, barite, siderite, quartz, specular hematite, and monazite; in some cases, euxenite and allanite are also present. The euxenite is found in only a few of the veins along with somewhat more abundant thorite, but the allanite is restricted to a single property, where it is accompanied by monazite but not by thorite. Some of the veins locally contain as much as 20 percent thorium dioxide (ThO₂), but in more promising veins the average grade is closer to 1 percent and in many veins it is between 0.5 and 1 percent. Low-grade, but commercial, ores are apparently very large in volume. Much of the ore may be amenable to open-pit production methods.

In its annual report to Congress in 1961, the Atomic Energy Commission credited the Lemhi Pass area with 100,000 tons of thorium dioxide. This is ore of probably commercial grade at current prices ($1.75 to $2.75 per pound of ThO₂ in 20 to 30 percent thorium concentrates) (Blake and Tucker, 1962). As there has been little underground development, the reserve estimate is based largely on exposures in bulldozed cuts and in drill holes.

Other less well-known areas of mineralization in Lemhi County are mentioned. One of these is on Diamond Creek northwest of Salmon (fig. 50). The deposits which have been described by Anderson (1958, pp. 74-78) are in many respects similar to those in the Lemhi Pass area. Another area of interest is the Mineral Hill district below North Fork of the Salmon River Canyon (fig. 50) (Kaiser, 1956). In the Mineral Hill district, monazite and other rare-earth minerals, together with niobium-bearing rutile (ilmenorutile) and other thorium and rare-earth minerals, are found in a belt 1.5 to 2.5 miles wide and 18 miles long, which extends northwesterly from the Salmon River into Montana. These minerals are distributed sporadically in bodies of carbonate rock, which are enclosed in amphibolite or gneiss at the border of the Idaho batholith. The deposits have been regarded as replacements of marble beds or products of metamorphic differentiation, but they have some of the characteristics of carbonatites (Anderson, 1960).

In addition to the above, there are unconfirmed reports of thorite veins in the Lemhi Range west of the Lemhi Pass area.
EXPLANATION

**Placer Deposits**

- □ Significant potential
- □ Small or unevaluated

1. Boise Basin
2. Garden Valley
3. Dismal Swamp
4. Wood River-Camas Creek
5. Deadwood River
6. Bear Valley
7. Stanley Basin-Gold and Pigtail Creeks
8. Cascade-Long Valley area
9. Salmon-Tendoy region
10. Burgdorf-Warren districts
11. Florence
12. Dixie
13. Elk City-Newsome area
14. Pierce area
15. Elk River area

**Vein deposits**

- □ Significant potential
- □ Small or unevaluated

A. Lemhi Pass
B. Diamond Creek
C. Mineral Hill
D. Hall Mountain

- Idaho batholith and other granitic plutons
- Border zone of Idaho batholith

**Legend**

- Purcell sills

---

**Figure 50.**—Thorium and rare earths in Idaho.
The thorite veins in the Hall Mountain area near Porthill, Boundary County, were discovered in 1955. They have been described by Weis and others (1958, pp. 35–36) and by Lemoine (Newton and others, 1960, pp. 18–22). On the west side of Hall Mountain, granitic rocks of the Kaniksu batholith intrude rocks of the Precambrian Belt Series, which are also cut by Precambrian Purcell sills. A number of northwesterly trending faults and associated breccias are the dominant structural elements in the region. The thorium-bearing bodies are composed chiefly of quartz, calcite, and thorite (Newton and others, 1960, pp. 19–22) and are found in steeply dipping quartz veins within the sills, in some of the breccia zones, and as replacements in the quartzite overlying the sills. The best known occurrences are at the Golden Sceptre mine and in the Wa Wa and TMU groups, but other occurrences have been reported.

The potential of Idaho's blacksand placer deposits of thorium and rare earths is impressive and may equal or exceed that of the lode deposits. Alluvial deposits are widespread in central Idaho adjacent to the Idaho batholith (fig. 50). Many of these placers were previously worked for gold, but 50 or more types of heavy minerals are known to occur in the deposits. More recently commercial amounts of columbium, tantalum, and rare earths have been recovered. The presence of more than one mineral commodity enhances the value of these placers. Among others, the potentially valuable metals present in different quantities are: niobium, tantalum, gold, yttrium, zirconium, hafnium, uranium, thorium, titanium, and the rare earths.

The best known placers, some of which have been partially exploited, are described in considerable detail by Savage (1961a). Among these are deposits in the following areas: (1) Boise Basin, (2) Garden Valley, (3) Dismal Swamp, (4) Wood River-Camas Creek area, (5) Deadwood River lower drainage, (6) Bear Valley area, (7) Stanley Basin-Gold and Pigtail Creek deposits, (8) Cascade-Long Valley region, (9) Salmon-Tetoloy region, (10) Burgdorf-Warren districts, (11) Florence, (12) Dixie area, (13) Elk City-Newsome area, (14) Pierce area, and (15) Elk River area (fig. 50).

In these placers, the most common of the rare-earth minerals is monazite. On an overall basis, monazite appears to run from 0.08 to 1.8 pounds per cubic yard of placer material. Locally, the yield may be slightly higher. In the Cascade-Long Valley area alone, drilling in 1955 indicated over 87,000 tons of recoverable monazite are available (D. M. Schwarze, written communication). The drilling was not exhaustive, so the reserves are probably much larger.

According to Lund (1963), stockpiled atomic weapons should soon reach national objectives, thereby releasing more uranium for energy purposes. This would imply that unless thorium from Idaho deposits can be proved cheaper or more suitable for energy production it will not replace uranium to any great extent. If this is the case, any marked increase in use of thorium will come through increased non-energy uses. This could conceivably be brought about by vigorous research, especially into metallurgical uses for the product.

The future for Idaho rare-earth deposits is much less optimistic. According to Lund, there is currently a heavy stock of mixed rare earths, built up as byproducts of the heavy production of thorium for sales to the AEC in the 1950's. When these have been consumed,
the California bastnaesite deposits (reportedly containing 5 million tons of rare-earth oxides) are ready for stepped-up exploitation.

One of the more favorable facets to the situation in Idaho is that her placer deposits contain several potentially valuable mineral commodities. Increased demand for any one of them might make it feasible to operate the placers. Such a circumstance, however, is not foreseeable in the immediate future.

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**TITANIUM, ZIRCONIUM, AND HAFNIUM**

(By C. N. Savage, Idaho Bureau of Mines and Geology, Moscow, Idaho)

Titanium, zirconium, and hafnium are relatively new to the industrial metals trade. Since about 1918, titanium dioxide has been used extensively for making paint pigments, but use of titaniun metal started as recently as 1948. By 1962, over 90 percent of the production of this metal, known for its good strength-to-weight ratio, went into the construction of aircraft, space vehicles, and missiles. Both titanium and zirconium metals have excellent resistance to corrosion and desirable physical properties at high temperatures. Hafnium has similar qualities, but it is also used for its ability to absorb neutrons. Zirconium and hafnium nearly always occur together in nature, and hafnium is a byproduct of zirconium production.

Titanium, zirconium, and hafnium have been the subject of vigorous research programs conducted by Government, company, and university scientists with a continued expansion of the use of these materials, and the accumulation of sizable bibliographies on the subject (Abshire, 1957 and 1958; Fullerton and Gray, 1962; Hess, 1962; Jaffe, 1958; Lawthers and Mark, 1957; and Miller, 1957). In the United States, titanium products were valued at $18 million in 1962 (U.S. Bur. Mines, 1963). Titanium metal uses in 1961, by percentages consumed, were as follows (Stapler, 1965): military aircraft, 66; commercial aircraft, 13; missiles and space vehicles, 17; chemical industry, 3; and ordnance, 2. The success of titanium metal in electrochemical applications is remarkable. Titanium is also used in paints, paper, floor coverings, coated fabrics, printing ink, rubber, ceramics, roofing (granules), siding, artificial gem stones, titaniferous chemical, and plastics. In Idaho, ilmenite has been shipped for use in high-density concrete and cement.

The two principal titanium minerals, ilmenite and rutile, sold for $25 to $26 per long ton (99.5 percent titanium dioxide) and $50 per long ton (94 percent titanium dioxide), respectively, in 1961. At the same time, several forms of titanium metal were available at the following prices per pound (Stapler, 1962):

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sponge, grade A-1</td>
<td>$1.00</td>
</tr>
<tr>
<td>Sponge, grade A-2</td>
<td>$1.50</td>
</tr>
<tr>
<td>Wire</td>
<td>$5.00</td>
</tr>
<tr>
<td>Sheet</td>
<td>$7.50</td>
</tr>
<tr>
<td>Forging billets</td>
<td>$3.10</td>
</tr>
<tr>
<td>Strip</td>
<td>$6.75</td>
</tr>
<tr>
<td>Hot rolled bars</td>
<td>$3.10</td>
</tr>
<tr>
<td>Ferrotitanium</td>
<td>$25.00 - $27.00 per short ton</td>
</tr>
</tbody>
</table>

Titanium slag is made from ilmenite smelted in the presence of carbon. The slag contains about 70 percent titanium dioxide, and sells for approximately $36 per short ton. In 1962, the lowest price for any grade titanium metal was $1.52 per
dioxide pigments ranged from $200 to $380 per short ton (10 to 29
cents per pound) (Stamper, 1962).

In the past, zircon has had the following major uses:

- **Metals industry.**—reactor-grade (hafnium-free) zirconium;
  body replacements in surgery; alloys for resistance furnaces; lin-
  ings for engines using high-temperature propellants; and in al-
  loys for toughness, strength, and corrosion resistance.

- **Chemical industry.**—pigments and rubber; fabric industry as
  mordants, and water repellants; and for medical uses as phos-
  phates and carbonates.

- **Ceramics industry.**—refractories requiring a very high melting
  point (zirconium carbide has a melting point of over 6,000° F.)
  and as electrical insulators.

By 1962, uses for zircon in percentages consumed were as follows
(U.S. Bur. Mines, 1963): foundry sand, 50; refractories, 20; chemicals,
abrasives, and ceramics, 20; and metal and alloys, 10. Recently, an
atomic reactor built at Hanford, Wash., was constructed with zirconi-
um alloy tubes and used fuel coated with zirconium. Zirconium metal
has been used in the construction of nuclear-powered merchant and
naval vessels, and in reactors at Shippingport, Pa.; Dresden, Ill.; and
Arco, Idaho.

Hafnium is used in carbide for cutting tools, in the production of
fluorescent powders, and in control rods for nuclear reactors. Hafnium
is available as sponge and metal powder; and in many compounds,
such as oxides, borides, fluorida, chlorides, sulfates, and nitrates.

The price of the mineral zircon is usually stable, ranging in 1962
from $40 to $50 per short ton, with some as high as $75. High-hafnium
zircon from Nigeria sells for about $150 per short ton (U.S. Bur.
pound (Stamper, 1962).

Titanium, zirconium, and hafnium rank 9th, 19th, and 35th, respec-
tively, in abundance of elements in the earth's crust. Hafnium is pre-
ent with zirconium with an average abundance index of 4.5 grams per
ton of zirconium minerals (Hess, 1962). All three elements are more
abundant than uranium, mercury, silver, and gold; titanium and zir-
conium are more abundant than vanadium, nickel, lead, and zinc.

Only the minerals ilmenite (FeTiO₃) and rutile (TiO₂), theoretically
containing 53 and 100 percent titanium dioxide, respectively, are
currently considered commercial sources of titanium. Other titanium
minerals such as anatas, leucoxene, and brookite are commonly asso-
ciated with ilmenite and rutile, and may often be included in commer-
cial shipments. Still other titanium minerals such as sphene, perov-
skite, and pyrophanite are locally abundant, but have not yet been
used commercially for technological reasons.

Although there are 21 known minerals carrying over 10 percent of
zirconium dioxide, zircon (ZrSiO₄) and baddeleyite (ZrO₂, theoreti-
cally), are the principal commercial sources of zirconium. Zircon may
contain 0.5 to 2.0 percent hafnium dioxide (HfO₂), but altered zircon
may contain from 2.5 to 17.0 percent. Altered forms of zircon such
as alvite and cyrtoite are the richest known sources of hafnium.
These altered mineral complexes also may be rich in uranium, thorium,
rare earths, beryllium, and phosphorus (Hess, 1962).
Lode-type occurrences of ilmenite and rutile are found associated with iron deposits, particularly in anorthosites and related rocks, or in schists and gneisses. One of the largest known deposits of this type of ilmenite is intergrown with hematitic iron ore in Quebec. Zircon may occur in some pegmatites and nepheline syenites as large zircon crystals, but these are not yet considered sources of commercial zirconium. Many titanium-, zirconium-, and hafnium-bearing minerals are widespread as accessory minerals in igneous, metamorphic, and sedimentary rocks. Commercial deposits of these minerals are found as naturally concentrated detritals in some stream, beach, and dune deposits. Most of the commercially produced titanium and zirconium minerals, such as rutile, ilmenite, and zircon (hafnium bearing), come from such multiple-mineral placers. At the present time, this type of deposit is the most important known source of titanium, zirconium, and hafnium in Idaho (see also chapter on thorium and rare earths in this publication and Savage, 1961a).

The United States has been the world's largest producer and consumer of ilmenite, and Australia has been the largest producer of rutile. Consumption of ilmenite was 920,000 tons in 1961, of which about 95 percent was used for pigments. As the leading titanium metal producer in the free world (about 6,811 short tons in 1962), we have become progressively more dependent upon Australian rutile concentrates. Concentrates have also been imported from India and Malaya. During the past few years, surplus agricultural products have been bartered for rutile from Australia, and titanium metal sponge from Japan. Titanium slag and sponge have also been imported from Canada. In 1961, the United States imported over $7 million worth of titanium and titanium products (Stamper, 1962).

In 1961, according to Stamper (1962), U.S. production of zirconium sponge was 1,697 short tons. About 58.7 tons of hafnium oxide was produced, and some hafnium sponge was also shipped. Zirconium ingot production was 1,406 short tons; zircon oxide amounted to 5,731 short tons; zircon and zircon refractories, 20,737 short tons; and zirconium powder, 16.7 short tons.

The United States imported 32,805 short tons of zircon concentrate in 1961, and an estimated 29,800 short tons in 1962 (U.S. Bureau of Mines, 1963). The bulk of these imports came from Australia, but some came from the Republic of South Africa and Nigeria. Exports of zircon metal were small, amounting to approximately 100 short tons in 1962, but zircon concentrate exports amounted to about 1,700 short tons for the same period.

Known commercial and potentially commercial deposits of titanium, zirconium, and hafnium in Idaho are in black-sand placers found, for the most part, in central Idaho adjacent to the Idaho batholith (fig. 51). Some of these deposits were worked for gold as early as the middle and late 1800's. By 1949, interest in their potential content of radioactive, rare earth, and other minerals resulted in more recent extensive surveys and laboratory studies by the Idaho Bureau of Mines, the U.S. Bureau of Mines, and several private companies (Savage, 1961a and 1961b; and Storch and Holt, 1963).

From 1946 to 1948, Baumhoff and Marshall Co. and Idaho-Cana
dian Dredging Co. dredged parts of Boise Basin for gold; at this time, ilmenite, zircon, and monazite (rare earths) were among the recovered minerals that were stockpiled.
EXPLANATION

- Ilmenite, Mg-Magnesite, G-Garnet: 5 lb. or more per cu yd
- Zircon, Monazite: 0.5 lb. or more per cu yd
- U-Th-Pb minerals in probable economic quantities
- Unusually high concentrations of uranium, thorium, or thorium-bearing minerals
- Significant tonnage and variety of minerals
- Metamorphic and granular rocks
- Mineralized areas
- Known mineral deposits

1 - Ilmenite, Mg-Magnesite, G-Garnet: 5 lb. or more per cu yd
2 - Zircon, Monazite: 0.5 lb. or more per cu yd
3 - U-Th-Pb minerals in probable economic quantities
4 - Metamorphic and granular rocks
5 - Known mineral deposits

Figure 51.—Ilmenite, zirconium, and barium placer deposits in Idaho.
During the period from 1950 to 1959, bucket-line dredges operated in several places in central Idaho producing coproduct minerals from the black-sand placers. From these operations Baumhoff and Marshall Co., J. R. Simplot Co., and Porter Bros. Corp. recovered ilmenite, zircon, monazite, magnetite, garnet, and complex minerals called radioactive blacks, including columbium and tantalum. The major recovery operations were in the Cascade, Long Valley, Gold Fork, and Bear Valley placer areas. At the present time, no major recoveries of black-sand minerals are being made although some small quantities of stockpiled materials are still available.

Titanium production statistics for Idaho, as reported in U.S. Bureau of Mines Minerals Yearbooks from 1953 to 1965 are as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Short tons</th>
<th>Year</th>
<th>Short tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953</td>
<td>1,065</td>
<td>1954</td>
<td>1,884</td>
</tr>
<tr>
<td>1955</td>
<td>1,065</td>
<td>1956</td>
<td>1,127</td>
</tr>
<tr>
<td>1957</td>
<td>1,403</td>
<td>1958</td>
<td>1,223</td>
</tr>
<tr>
<td>1959</td>
<td>1,223</td>
<td>1960</td>
<td>1,065</td>
</tr>
<tr>
<td>1961</td>
<td>1,223</td>
<td>1962</td>
<td>1,127</td>
</tr>
<tr>
<td>1963</td>
<td>1,065</td>
<td>1964</td>
<td>1,223</td>
</tr>
<tr>
<td>1965</td>
<td>1,065</td>
<td>1966</td>
<td>1,223</td>
</tr>
<tr>
<td>1967</td>
<td>1,065</td>
<td>1968</td>
<td>1,223</td>
</tr>
</tbody>
</table>

- Sold for roofing granules or high-density cement.
- Not revealed.
- Sold to National Lead Co., St. Louis, Mo., probably for paint pigment.

The above shipments were largely ilmenite, and not all shipments have been revealed, as noted. Early shipments sold for about $5.90 per short ton, while later prices were about three times that figure (Idaho placer ilmenite is about 45 percent titanium dioxide). Total shipments from 1953 through 1962 probably amounted to a total value of over $500,000 (estimated).

Zircon has been stockpiled consistently at several Idaho placer operations, but the only record of sales were by Baumhoff-Marshall Co. in 1958. Reportedly the zircon was used as foundry sand. Some Idaho ilmenite and zircon have been used as blasting sand.

Idaho placers contain about 50 or more types of heavy minerals. In most cases the source of these minerals, including ilmenite and zircon, is the accessory minerals from local weathered bedrock of the Cretaceous Idaho batholith (Savage, 1961a). This bedrock is composed of quartz monzonite, granodiorite, diorite, aplite, and pegmatite. Locally, specific mineral types may dominate in any one placer deposit; however, ilmenite and zircon seem to be ubiquitous.

Samples of Idaho zircon, checked by the U.S. Bureau of Mines, yielded from 0.84 to 1.8 percent hafnium dioxide (Hess, 1962). The average is a little less than 1.5 percent. Deposits at Dismal Swamp contained as much as 4.6 percent hafnium dioxide. However, the Dismal Swamp deposits are probably too small to be commercial. Imported hafnium-rich Nigerian zircon contains about 2.5 to 4.5 percent hafnium dioxide.

Lode deposits of ilmenite and rutile have been reported in Idaho, but so little is known about these deposits that they are not discussed further in this report.

Thirty-three placer deposits of ilmenite, zircon, and other heavy minerals are shown on figure 51. Reportedly, ilmenite, magnetite, and
garnet in all these placers are present in quantities of 5 pounds or more per cubic yard of material; zircon and monazite are present from one-half pound or more per cubic yard. Radioactive black minerals are noted if present in near-commercial quantities. Niobium and tantalum minerals are included with the radioactive black minerals.

It should be emphasized that Idaho placer deposits show a considerable range of mineral content both vertically and horizontally. Inasmuch as some of the placers shown on figure 51 were sampled only by reconnaissance methods, more reliable data on mineral quantity should be acquired before any attempt is made to develop a specific area. Deposits that have been more thoroughly investigated such as those at Elk City, Cascade-Long Valley, and Bear Valley are known to contain commercial quantities of one or more minerals, provided a market exists. Of the areas tested, the placers listed in table 15 appear as the better ones (Storch and Holt, 1963; Reid, 1960; and Savage, 1961a).

<p>| Table 15.—Selected black sand placers, yields and estimated yields in pounds per cubic yard of placer material |
|-------------------------------------------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Index No. on fig. A1</th>
<th>Ilmenite</th>
<th>Zircon</th>
<th>Monazite</th>
<th>Magnetite</th>
<th>Garnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Thorn Creek (tributary Little Salmon River)</td>
<td>2-45</td>
<td>Tr.-3</td>
<td>0-1-0.5</td>
<td>Tr.-5</td>
<td>Tr.-2</td>
</tr>
<tr>
<td>24. Ketch Creek (tributary Middle Fork Payette River)</td>
<td>5-18</td>
<td>Tr.-1</td>
<td>0.2-0.5</td>
<td>Tr.-1</td>
<td>Tr.-1</td>
</tr>
<tr>
<td>35. Boise Boulders</td>
<td>1-1</td>
<td>Tr.-1</td>
<td>0.2-0.5</td>
<td>Tr.-1</td>
<td>Tr.-1</td>
</tr>
<tr>
<td>43. Circle Creek (tributary Raft River)</td>
<td>17-20</td>
<td>Tr.-1</td>
<td>0.2-0.5</td>
<td>Tr.-1</td>
<td>Tr.-1</td>
</tr>
<tr>
<td>55. High Butte area</td>
<td>17-30</td>
<td>Tr.-1</td>
<td>0.2-0.5</td>
<td>Tr.-1</td>
<td>Tr.-1</td>
</tr>
<tr>
<td>7. Elk City area</td>
<td>2-10</td>
<td>Tr.-1</td>
<td>0.2-0.5</td>
<td>Tr.-1</td>
<td>Tr.-1</td>
</tr>
<tr>
<td>8. Hixson Place</td>
<td>1-3</td>
<td>Tr.-1</td>
<td>0.2-0.5</td>
<td>Tr.-1</td>
<td>Tr.-1</td>
</tr>
<tr>
<td>13. Lenoreg and area</td>
<td>1-3</td>
<td>Tr.-1</td>
<td>0.2-0.5</td>
<td>Tr.-1</td>
<td>Tr.-1</td>
</tr>
<tr>
<td>16. Cascade-Long Valley area</td>
<td>1-3</td>
<td>Tr.-1</td>
<td>0.2-0.5</td>
<td>Tr.-1</td>
<td>Tr.-1</td>
</tr>
<tr>
<td>21. Bear Valley placers</td>
<td>1-3</td>
<td>Tr.-1</td>
<td>0.2-0.5</td>
<td>Tr.-1</td>
<td>Tr.-1</td>
</tr>
<tr>
<td>32. Florence</td>
<td>1-3</td>
<td>Tr.-1</td>
<td>0.2-0.5</td>
<td>Tr.-1</td>
<td>Tr.-1</td>
</tr>
</tbody>
</table>

1 Traces 0.5 pound or less.
2 Probably quite similar to Elk City.

Note: Interesting, although perhaps of not much practical value, is the overall average for 7 to 8 major placer regions in pounds per cubic yard of material:
- Ilmenite = 6.0
- Magnetite = 1.4
- Monazite = 1.2
- Zircon = 0.8

The Cascade, Long Valley, Gold Fork, and Bear Valley placer areas in Valley County constitute a large, well-defined resource of ilmenite, zircon, monazite, and magnetite. In 1967, Robert Lothrop—then employed by Porter Bros. Corp.—stated that drilling investigations showed known placer reserves in the Bear Valley area that were sufficient to last 30 years at a production rate of 2.5 million yards of gravel per year (personal communication).

In the Cascade-Long Valley area, drilling in 1955 revealed a known reserve of nearly 508,000 short tons of recoverable ilmenite and over 17,000 short tons of recoverable zircon. The area was not completely drilled out and it is likely that these figures are much too conservative to indicate the extent of the regional resource. For Valley County, Fullerson and Gray (1962, p. 35) cite a figure of 983 million tons of ilmenite-bearing placer deposits, containing “an average recoverable grade of 0.2 percent” titanium dioxide.
The Leesburg placers in Lemhi County; and Hoodoo, Elk City (Reid, 1960), and Florence placers in Idaho County apparently comprise still further extensive resources of blacksand minerals. Of these areas, the Hoodoo placers are handicapped by being remote and inaccessible. The other deposits are reasonably accessible, but transportation costs for placer commodities are unfavorably high because of their distance from present markets.

Miller (1957, p. 38) points out that the clay deposits of North Idaho yield ilmenite containing up to 8 percent titanium dioxide (see chapter on clays). One source indicates that the clays of Idaho and Washington contain over a million tons of TiO₂. Commercial development of these clays could yield titanium as a coproduct along with silica and feldspar.

Future extensive production of titanium, zirconium, and hafnium minerals from Idaho placer deposits will probably have to await further research and expansion of uses, and thus new markets for these and other blacksand minerals. Fulkerson and Gray (1962) point out definite advantages for the development of titanium sponge plants in the Pacific Northwest, and at the same time call attention to the fact that Idaho ilmenite is slightly low in titanium dioxide content (by contrast with imported varieties). This problem of low-grade material might be remedied by development of methods of upgrading preliminary placer concentrates, perhaps by producing a high-titanium slag, and by using ilmenite, titaniferous magnetite, and other titanium minerals for this purpose. Iron recovered from such upgrading processes might also be sold, along with several other mineral coproducts.

Unless sizable new markets for titanium, zirconium, iron, rare-earth, abrasive, and other materials found in black sands are developed in the Northwest, or unless there is an appreciable decrease in the imports of several of these commodities, the Idaho blacksand deposits will probably continue to lie in reserve. Any profitable future development of these resources should be (1) a venture that operates on a large enough scale and with upgrading including slag-making processes to make such a venture profitable, and (2) an operation with multiple-mineral recovery and marketing. An interesting aspect of future use is the possibility of an export market in the Far East.

TUNGSTEN

(By S. W. Hobbs, U.S. Geological Survey, Denver, Colo.)

Tungsten is a metal of high strategic value whose importance depends mainly on the physical and mechanical properties of the element, its alloys, and certain special compounds. In its pure form, tungsten is a white, ductile metal whose melting point of 3,410°C is higher than that of any other metal. It has unusually high density, low-vapor pressure, and favorable electrical and thermionic properties. Tungsten alloys and carbides are notable for their extreme hardness and wear resistance, and particularly for retaining hardness at elevated temperatures. Industrial uses of tungsten result from these special properties.
Pure, or substantially pure, tungsten metal is important in electric lighting, electronics, and electrical contact application. The familiar tungsten filament in the electric light bulb illustrates a use of the properties of ductility, high melting point, low-vapor pressure, and electrical resistivity. However, the greatest uses of the metal are in alloy tool steels and in tungsten carbide used for cutting edges, dies, drill bits, wear-resistant machine parts, and other applications where extreme hardness is desirable. Over 70 percent of recent consumption has been for tool steel and tungsten carbide.

Tungsten minerals are widely distributed in rocks of the earth’s crust, but for the most part, concentrations of economic importance seem to be genetically associated with igneous rocks of granitic composition. Only about 11 minerals contain tungsten as an essential component, and of these, 2 minerals (or mineral series) account for nearly all of the world production of the metal: scheelite (calcium tungstate), either pure or containing varying amounts of molybdenum, and the wolframite group (iron-manganese tungstate) that ranges in composition from ferberite (iron tungstate) to huebnerite (manganese tungstate). These tungsten minerals occur in a variety of geologic environments but main economic concentrations are in quartz veins, in tactite (a metamorphic rock at or near the contact of igneous rocks that have intruded limestone or impure limestone), in shear zones, and in igneous and metamorphic rock as low-grade disseminations often associated with other metals. One hot-spring deposit has been mined for its tungsten content in Nevada. Scheelite is found in all of the above environments; wolframite is found in all but the tactite.

Most of the important deposits in the Northwestern United States are related spatially and, for the most part, in time to the widespread intrusive granitic bodies of Cretaceous and early Tertiary age (Lemmon and Tweto, 1969, p. 1). Areas where tungsten mineralization is widespread can be considered tungsten provinces in which the likelihood of the discovery of economic ore bodies is much greater than elsewhere. However, the proclivity of many ores—and tungsten in particular—to form as erratically disposed single mineral grains, as small concentrations of ore-grade material and, frequently, as discrete and widely separated but usually small pockets of nearly pure mineral should caution against overoptimism as to the long-range potential of any one occurrence. Whereas the small high-grade pocket may prove to be a momentary economic windfall, the difficulty of locating others in the immediate area often more than offsets the initial gain. Major production has always come from those rarely discovered deposits of good size and grade or from very large deposits of lower grade that prove economic because of size and favorable mining conditions. Much more than a single crystal of scheelite or wolframite is needed to make a mine; nor is the occurrence of several single crystals any assurance of an ore body nearby.

The United States has, in general, imported tungsten in amounts that exceed domestic production. Although the U.S. tungsten mining industry has operated continuously (except for 1921 and 1922) for over 50 years, the rate of production has ranged widely because of various economic factors and particularly the Government stockpiling program. Only a few domestic producers have been able to compete
consistently on the open market with foreign producers (Holliday, 1960, p. 914). However, a large domestic productive capacity was demonstrated twice in the last two decades under conditions of special necessity—in 1943–45 to fill heavy demand of the war effort and between 1950–56 under the influence of the price incentive of the Government stockpiling program. In 1955, production reached an all-time peak that was nearly four times the average annual production of the immediate postwar period 1946–50. Subsequent to the end of Government stockpile purchases in December 1956, the price dropped drastically and, consequently, production from many mines was stopped or radically reduced. In 1956, nearly 600 mines in the United States reported some production (Holliday and Burke, 1958, p. 1227); in 1958, only two producers were active (Holliday and Burke, 1959, p. 1091). These facts illustrate dramatically the tungsten resource situation of the United States. There is a substantial supply of tungsten available at the present time if the need warrants paying the price to extract it.

The first recorded occurrence of tungsten in Idaho, and perhaps the first from any mining district in the United States, is a description of scheelite from a specimen of high-grade gold ore from the Charity vein in the Warren mining district, Idaho County, published in 1877 by Benjamin Silliman. As with numerous other minerals, the discovery of tungsten minerals was in many places a “byproduct” of the search for gold and silver by the early prospectors who combed the western United States for precious metals in the late 1800’s. In the Warren district of Idaho County, in the Murrays and Coeur d’Alene district of Shoshone County, and elsewhere, the recovery of gold in sluice boxes and in amalgam plates was often hampered by the collection of a heavy gray- or flesh-colored “spar.” Even when recognized for what it was, the scheelite was cast aside as deleterious to the overriding objective of gold recovery. It was several decades before technology for production of tungsten and the development of uses of the metal encouraged the search for tungsten minerals for their own value. Later decades saw many of these early “discoveries” re-visited and carefully examined for their tungsten potential at times when tungsten was a critical and strategic metal.

Idaho has been one of the leading tungsten-producing states—particularly during the last 30 years. Although small, sporadic shipments of tungsten ore were made from a few properties in the early years of this century, significant production started in 1936 when the Ina mine began its long period of nearly steady production. The Ina mine and Yellow Pine tungsten ore body (which was discovered in early 1941) have accounted for the great bulk of Idaho’s tungsten production. Both properties are now closed.

Since 1900, Idaho has provided nearly 10 percent of all the tungsten produced in the United States. In the critical war period, 1942–45, it accounted for 40 percent of the national production, mostly from the Yellow Pine mine. In the years from 1948 to 1957, Idaho was either the fifth or sixth State in amount of tungsten produced (U.S. Bureau of Mines Minerals Yearbooks and U.S. Geological Survey Mineral Resources Volumes). Table 16 shows data relative to this period. Since 1958, production has been small, owing to the decline in the price of tungsten and the closing of the two principal mines. Table 17 gives
production data from the principal mines in south-central Idaho through 1955 and illustrates the overriding importance of the two major deposits. It also illustrates a continuing potential by virtue of the production from newly discovered or reopened properties in the years 1952-55.

**Table 16.** Shipments of tungsten ore and concentrate from Idaho mines

<table>
<thead>
<tr>
<th>Year(s)</th>
<th>Short ton units WO₃</th>
<th>Rank among States</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950-52 (total)</td>
<td>1,307,760</td>
<td>4</td>
</tr>
<tr>
<td>1949-52 (average)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1950</td>
<td>1,307,760</td>
<td>4</td>
</tr>
<tr>
<td>1949</td>
<td>1,346,115</td>
<td>4</td>
</tr>
<tr>
<td>1951</td>
<td>1,268,120</td>
<td>4</td>
</tr>
<tr>
<td>1952</td>
<td>1,268,120</td>
<td>4</td>
</tr>
<tr>
<td>1953</td>
<td>2,150,200</td>
<td>4</td>
</tr>
</tbody>
</table>

1 Short-ton unit equals 20 pounds WO₃.


**Table 17.** Production figures for principal tungsten mines in south-central Idaho

<table>
<thead>
<tr>
<th>Mine</th>
<th>Production period</th>
<th>Tons milled or shipped</th>
<th>Units WO₃ produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow Pine</td>
<td>1953-54</td>
<td>14,305</td>
<td>2,377</td>
</tr>
<tr>
<td>Ima</td>
<td>1953-54</td>
<td>10,881</td>
<td>2,135</td>
</tr>
<tr>
<td>McQuillen</td>
<td>1954-56</td>
<td>3,600</td>
<td>3,380</td>
</tr>
<tr>
<td>Thompson Creek</td>
<td>1954-56</td>
<td>725</td>
<td>104</td>
</tr>
<tr>
<td>Rupel</td>
<td>1954</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>Buffalo Mountain</td>
<td>1963</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>Hixson</td>
<td>1963</td>
<td>11</td>
<td>18</td>
</tr>
</tbody>
</table>

1 Includes 11,602 tons of tailings remilled, from which 503 units of WO₃ was recovered. Source: Data from Cook, 1956, p. 37.

Figure 52 shows the location and relative rank of 31 mines and prospects for which data and information are available, and that warrant description either because of production or economic potential or to illustrate a mode of occurrence that may have bearing on future discoveries. There are other localities, some of comparable nature, that for lack of information or other reasons were not included. Much of the data for this map were derived from U.S. Geological Survey Mineral Investigation Map MR-25 (Lemmon and Tweto, 1962). The outline of the Idaho batholith and the satellite igneous bodies that are thought to be related to it are also indicated to illustrate the special relation of the tungsten ore deposits to this unit.

Table 18 which is keyed to the map (fig. 52), gives the salient information on the localities—location, name, rank, and geologic set-

1 The relative importance of the deposits is indicated by three ranks with the following production plus estimated reserves:
1. 0 to 500 short tons of tungsten metal (63,000 to 1,260,000 short-ton units of WO₃).
2. 500 to 10,000 short tons of tungsten metal (63,000 to 1,260,000 short-ton units of WO₃).
3. 10,000 to 63,000 short tons of tungsten metal (63,000 to 1,260,000 short-ton units of WO₃).
Figure 52.—Tungsten in Idaho (numbers referred to districts or deposits listed in table 18).
<table>
<thead>
<tr>
<th>Locality No. on fig. 33</th>
<th>County</th>
<th>District and mines</th>
<th>Rank</th>
<th>Manner of occurrence</th>
<th>Remarks</th>
<th>Selected references</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Boundary...</td>
<td>Kootenai-Yakko district (Queen Mountain); M. and F. mines (Chief Joseph-Tungsten; Bull Run Mine group).</td>
<td>2 Schistite in several quartz veins that also carry small amounts of galena, pyrite, scheelite, paratellurite, and freibergite. Schistite locally saturated with incongruent veins of tuff with associated belite. Nearby carbonate may be present in veins.</td>
<td>Pocky-like distribution of schistite in veins makes evaluation difficult.</td>
<td>Livingston 1919, Kirkham and Ellis 1930.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Bonner...</td>
<td>Finkle Oreille district; Talcesh Blackshale mine.</td>
<td>3 Hanksite occurs sparsely in the quartz veins and is concentrated in small vein-like bodies. Other minerals in veins include pyrite, marcasite, sphalerite, and pyrrhotite.</td>
<td>Principal product of mine has been silver.</td>
<td>Sampson 1928.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Shoshone...</td>
<td>Murray district; Golden Chest mine, Mother Lode Mine, Four Square (Golden Winters) mine, Old Dutch mine.</td>
<td>1 Schistite in gold quartz veins that contain minor amounts of pyrite, marcasite, pyrrhotite, and scheelite. Schistite locally affected by veins of quartz and pyrite.</td>
<td>Principal product has been gold.</td>
<td>Livingston 1919, Unagah 1923, Husmann and Talbot 1926, Husmann 1950, Husmann and Hrusick 1950.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4...do</td>
<td>Pine Creek district (Yakko mining district); Big Hill mine.</td>
<td>3 Schistite in quartz veins and stringers to rhyolite porphyry dikes.</td>
<td></td>
<td>Jones 1929.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Kootenai...</td>
<td>Beauty Bay (Elk Mountain) district.</td>
<td>3 Schistite and wollastonite in minor quantities in gold-quartz veins that also contain small amounts of pyrite, marcasite, pyrrhotite, clinozoisite, paratellurite, and molybdenite.</td>
<td></td>
<td>Anderson 1981.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Idaho...</td>
<td>Tenmile district.</td>
<td>3 Schistite and wollastonite in minor quantities in gold-quartz veins that also contain small amounts of pyrite, marcasite, pyrrhotite, clinozoisite, paratellurite, and molybdenite.</td>
<td>Principal production in gold.</td>
<td>Shannon and Boyd 1944, Shannon 1955.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. Silver, and withal, known to occur in a number of gold-quartz veins in quartz monzonite of the Idaho batholith.

8. Shen. – Seven Devils district: Alaska Tungsten and Lockwood mines.

9. Valley – Big Creek district: McAlpine mine, Red Devil and Copper Bluff mines (Joe Tvis), Morn- ing Star claims, and Smith Creek deposit.

10. – Nezperde Gap deposit.

11. Quartet Creek deposit.

12. Oberhiltz deposit.


1. Silver associated with gold-antimony ore in wide extensive shear zone (Meadow Creek fault) in quartz monzo- nine of Idaho batholith. Ore includes gold and antimony minerals, with lesser pyrite and galena. Silver occurs as small disseminated flakes in quartz and as native silver on shear zone walls.

2. Shenatite containing high percent of pyrite molecule in values along core of large block of marbles engulfed in quartz monzonite and pyroxene schist of the Idaho batholith.

3. Shenatite and quartz-monzonite known to occur in a number of gold-quartz veins in quartz monzonite of the Idaho batholith.

4. Principal production in gold-quartz vein district with minor production in the Tungsten and Lockwood mines. Shenatite known to occur in the one occurrence of tungsten noted from Idaho. District noted for copper production mainly from deposits other than the tungsten mine.

5. Shenatite and quartz-monzonite known to occur in a number of gold-quartz veins in quartz monzonite of the Idaho batholith.

6. Shenatite and quartz-monzonite known to occur in a number of gold-quartz veins in quartz monzonite of the Idaho batholith.

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12. Shenatite and quartz-monzonite known to occur in a number of gold-quartz veins in quartz monzonite of the Idaho batholith.

13. Shenatite and quartz-monzonite known to occur in a number of gold-quartz veins in quartz monzonite of the Idaho batholith.

Principal production in gold-quartz vein district with minor production in the Tungsten and Lockwood mines. Shenatite known to occur in the one occurrence of tungsten noted from Idaho. District noted for copper production mainly from deposits other than the tungsten mine.

Other minor occurrences of tungsten minerals reported from near Big Creek. Shenatite and quartz-monzonite known to occur in a number of gold-quartz veins in quartz monzonite of the Idaho batholith.

Small production in part from deposits noted in the image, with minor production in the Tungsten and Lockwood mines. Shenatite known to occur in the one occurrence of tungsten noted from Idaho. District noted for copper production mainly from deposits other than the tungsten mine.

Principal production in gold-quartz vein district with minor production in the Tungsten and Lockwood mines. Shenatite known to occur in the one occurrence of tungsten noted from Idaho. District noted for copper production mainly from deposits other than the tungsten mine.
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<tr>
<th>Locality No. on fig.</th>
<th>County</th>
<th>Districts and mines</th>
<th>Rank</th>
<th>Manner of occurrence</th>
<th>Remarks</th>
<th>Selected references</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 Valley............</td>
<td>Yellow Pine district: Spring</td>
<td>2 Schellels in pyrrhotite-bearing tectonite in granite rock of</td>
<td>Part of production from tailings from</td>
<td>1906.</td>
<td>Cook, 1906.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Field tungsten mine.</td>
<td>Idaho batholith.</td>
<td>tailings from tailings from</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 White Hawk Meadows...</td>
<td>Deadwood mining district: Mary Blue mine.</td>
<td>3 Wulfenite and scheelite in quartz veins localized by jasper and associated lenses in mesothermal veins of Idaho batholith. In addition to quartz, the main veins contain pockets and streaks of fluorite, limonite after pyrite, wulfenite, and minor molybdenite.</td>
<td>Represented one mode of occurrence that may be periods in the general geologic environment of the deposit.</td>
<td>1906.</td>
<td>Cook, 1906.</td>
<td></td>
</tr>
<tr>
<td>17 Breezy</td>
<td>3 Flow-banded scheelite in shears and disseminated in breccia and stockwork veins. Other minerals include pyrrhotite, chalcopyrite, pyrite, galena, and native gold. Mineralization tends to be more concentrated on fractures but is also present in a disseminated aureole around them. Scheelite occurs sporadically disseminated throughout, but most is found in quartz veins.</td>
<td>Mine operated by gold and silver values. Possible scheelite recovery by by-product only.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 Breezy</td>
<td>1 Hecla district:</td>
<td>26 most important tungsten production in Idaho. Production in excess of 300,000 units. Mine closed in 1937.</td>
<td></td>
<td></td>
<td>Callahan and Lemon, 1941; Anderson, 1946.</td>
<td></td>
</tr>
<tr>
<td>19 Custer</td>
<td>Haynes district: Thompson Creek and Buckskin mines.</td>
<td>2 At Thompson Creek mine the scheelite is in tectonite and in altered granite along a shearing contact of an outlying body of granite. At the Buckskin mine the scheelite is in tuffaceous sediments of the Hemingford Formation and in the Buckskin mine the scheelite is in tuffaceous sediments of the Hemingford Formation.</td>
<td>Production in the district has been generally from the Thompson Creek mine.</td>
<td></td>
<td>Cook, 1906; Ross, 1937.</td>
<td></td>
</tr>
</tbody>
</table>
of argillite and limonite lenses. Both argillite and limonite have been converted to tuffly-limy beds. Replacement of the sandstone along the fracture zone and outward from it is accomplished by the greater development of tuffly beds. Quartz monzonite of Idaho batholith is exposed within a quarter of a mile south and southeast of the mine.

Schistose, associated with metallic sulfide minerals in replacement deposits in marble beds in the Millen Formation. The Millen Formation is predominantly argillite. The marble bed near the veins is altered to light-colored siliceous rock. Neither dike nor intrusive contact appears to be closely related to the occurrence of copper. Schistose, associated with metallic sulfide minerals in the Millen Formation, is exposed within a quarter of a mile south and southeast of the mine.

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</thead>
<tbody>
<tr>
<td>25</td>
<td>Yuba</td>
<td>Altache district (Yuba mining district)</td>
<td>2</td>
<td>Small amounts of scheelite associated with gold in wide shear zones in granite rocks of the Idaho batholith. Ore consists principally of scattered bleached brocktonite, argentopyrite, molybdenum, and pyrite.</td>
<td>Schellie produced only as by-product of gold mining. No tungsten concentrates have been made in recent years.</td>
<td>Anderson, 1929; Kiddermore, 1942.</td>
</tr>
<tr>
<td>26</td>
<td>Blaine</td>
<td>Bridge Creek deposit; Eagle Island mine</td>
<td>3</td>
<td>Schellie in quartz veins in structurally disturbed formations of the Wood River Formation near a quartz monzonite porphyry stock.</td>
<td>Schellie in textural veins formed by the intrusions of quartz monzonite (quartz monzonite) and other volcanic rocks and replacement of hydrothermal breccias and porphyritic tuffs. Schellie veins are present in textural veins only where cut by later elukhite dikes.</td>
<td>Do.</td>
</tr>
<tr>
<td>27</td>
<td>Blaine</td>
<td>Melones area (Little Wood River mining district); Bearpaw mine</td>
<td>3</td>
<td>Small amounts of schellie in textural veins formed by the intrusion of quartz monzonite (quartz monzonite) and other volcanic rocks and replacement of hydrothermal breccias and porphyritic tuffs. Schellie veins are present in textural veins only where cut by later elukhite dikes.</td>
<td>A number of occurrences are scattered over the general area.</td>
<td>Do.</td>
</tr>
<tr>
<td>28</td>
<td>Blaine</td>
<td>Canons district; Gray Creek deposit</td>
<td>3</td>
<td>Small amounts of schellie in textural veins formed by the intrusion of quartz monzonite (quartz monzonite) and other volcanic rocks and replacement of hydrothermal breccias and porphyritic tuffs. Schellie veins are present in textural veins only where cut by later elukhite dikes.</td>
<td>Schellie in textural veins formed by the intrusion of quartz monzonite (quartz monzonite) and other volcanic rocks and replacement of hydrothermal breccias and porphyritic tuffs. Schellie veins are present in textural veins only where cut by later elukhite dikes.</td>
<td>Do.</td>
</tr>
<tr>
<td>29</td>
<td>Butte</td>
<td>Mineral Hill mining district; Midnight deposit</td>
<td>3</td>
<td>Schellie in narrow chlorocarbonate veins in breccia.</td>
<td>Of a number of narrow veins, only a small amount of scheelite has been produced.</td>
<td>Umpleby and Westgate, 1933. Cook, 1966; Livingston, 1969.</td>
</tr>
<tr>
<td>30</td>
<td>Butte</td>
<td>Cuppa Creek deposit (Solder Mountain deposit)</td>
<td>3</td>
<td>Schellie in narrow chlorocarbonate veins in breccia.</td>
<td>Of a number of narrow veins, only a small amount of scheelite has been produced.</td>
<td>Umpleby and Westgate, 1933. Cook, 1966; Livingston, 1969.</td>
</tr>
<tr>
<td>31</td>
<td>Butte</td>
<td>Lava Creek district</td>
<td>3</td>
<td>Schellie in narrow chlorocarbonate veins in breccia.</td>
<td>Of a number of narrow veins, only a small amount of scheelite has been produced.</td>
<td>Umpleby and Westgate, 1933. Cook, 1966; Livingston, 1969.</td>
</tr>
</tbody>
</table>
ting. The references are not intended to be complete but to list only the more important or the most recent one.

Idaho has been a leading tungsten-producing State, and the future outlook for a renewal of activity depends in good part on demand and economic factors. Resources of considerable size are at least partially delineated in several of the mining districts and could be mined as in the past under favorable economic conditions. Furthermore, possibilities are excellent for discovery or development of additional deposits. Of the 31 deposits shown on figure 52 and table 18, several important ones were discovered in the last 15 years, and others in the preceding 10 years. Clearly, discovery can still go on.

As figure 52 shows, the known deposits are scattered over a broad area in or near the southern part of the Idaho batholith, and in the northern part of the panhandle. The Idaho batholith clearly constitutes a tungsten province and thus constitutes a promising field for further study and prospecting, with a reasonable chance for important new discoveries. A zone in south-central Idaho in which many of the tungsten deposits are found has been very effectively delineated by Cook (1956). The occurrence of major deposits well outside this zone, however, emphasizes the existence of resource potentials throughout the entire region at or near those places where the igneous rocks of the Idaho batholith and its related offshoots intrude the sedimentary rocks. With the exception of the Ima mine, the deposits in quartz veins are relatively small and spotty, but other deposits could exist and should be sought. Recent discoveries of scheelite ore in tactite on Thompson Creek and at the Wildhorse mine are encouraging signs that this mode of occurrence is more widespread in Idaho than was previously thought. Of added significance is the fact that the tactite type of deposit is usually amenable to larger scale and thus cheaper mining operations with the production of larger tonnages.

URANIUM

(By F. C. Armstrong, U.S. Geological Survey, Denver, Colo.)

Uranium, the heaviest common element, is a hard, silver-white metal. Naturally occurring uranium is a mixture of three semi-stable radioactive isotopes, U238, U235, and U234, that have relative abundance of 0.0068, 0.71, and 99.28 percent, respectively. U235 can be converted to plutonium (Pu239), by bombardment with neutrons. When U235 or Pu239 is bombarded with neutrons, each undergoes fission (a splitting of the nucleus of the atom) accompanied by release of a large amount of energy. Under proper conditions, fission can start a chain reaction. Uncontrolled chain reactions provide the immense destructive power of the atomic bomb and the triggering mechanism for the even more powerful hydrogen bomb. Controlled chain reactions in nuclear reactors provide heat for the generation of electricity and provide radioactive isotopes for the military, industry, and research. In addition to the above major uses, small amounts of uranium and its compounds are used, as they have been in the past, in the ceramic, chemical, and electrical industries.
The abundance of uranium in the crust of the earth, where it is preferentially concentrated in rocks of granitic composition, is about equal to that of arsenic or boron and many times the abundances of such well-known metals as gold, silver, platinum, cadmium, bismuth, and mercury. In nature, uranium occurs in two valences, U4+ and U6+. Uranium is moderately soluble in ground water and is chemically reactive; as a result it is mobile under natural conditions and forms a major constituent in a large number of minerals that occur in many different types of rock. Uranium is removed from ground water by adsorption on many different substances. These characteristics promote geologic dispersion of uranium rather than concentration of it in rich ore deposits. Consequently, in prospecting for uranium a great many radioactive occurrences are found that have no potential value as ore deposits.

The most important uranium mineral is the oxide uraninite, a variety of which is called pitchblende. Many other uranium minerals are known; they can be grouped broadly as multiple oxides, often called radioactive blacks, hydroxides, phosphates, arsenates, uranates, carbonates, silicates, and sulfates, many of which are derived by alteration from uraninite. In nature, uranium does not occur native, that is as the metal, and does not form such compounds as sulfides, arsenides, and tellurides.

The largest sources of uranium in the United States are deposits in nonmarine sandstones, arkoses, and conglomerates. The ore minerals occur as fillings and impregnations in openings between the individual grains of the rock. Similar deposits occur in limestones and in breccias in sedimentary rocks. Next in importance are deposits in veins and near contacts of granitic igneous rocks. Many coals and coaly sediments contain small amounts of uranium, and locally they contain enough uranium to be ore. Marine black shales and phosphorites, such as the Permian Phosphoria formation in Idaho, also contain small amounts of uranium; in Florida uranium has been recovered as a byproduct of phosphate mining. Uranium minerals occur in pegmatites, but seldom in sufficient concentration to be mined. Some granites contain accessory uranium minerals. Placer deposits derived from uranium-bearing granites and pegmatites have been the source of a small amount of uranium as a byproduct or coproduct.

In recent years, the United States has been the free world’s principal producer and consumer of uranium. Although radioactive mineral occurrences in Idaho have been known for a long while (Shannon, 1926) and many new occurrences have been found and investigated in more recent years (Weis and others, 1958), Idaho has not been an important producer of uranium. Uranium has been mined from bedded and vein-type deposits in Lemhi and Custer Counties. In 1955, a small test shipment of ore was mined in Lemhi County; in later years ore was mined in Custer County. Production data are given in table 19.

In late 1955, a blacksand dredging operation was started at Big Meadow in Bear Valley, Valley County, under a special contract with the Atomic Energy Commission which called for delivery by the end of 1959 of 1,000,000 pounds of niobium-tantalum pentoxide concen-
trate containing 50 percent (Nb,Ta)_2O_5. A euxenite (one of the mul-
tiple oxide radiometric blacks) concentrate was made from which ni-
obium-titanium oxide, uranium oxide, and thorium, rare-earth, and
titanium residues were recovered. This development was the world's

<table>
<thead>
<tr>
<th>Table 19.—Production of uranium in Idaho from bedded and vein-type deposits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short tons ore</strong></td>
</tr>
<tr>
<td><strong>Bedded</strong></td>
</tr>
<tr>
<td>deposits</td>
</tr>
<tr>
<td>1954</td>
</tr>
<tr>
<td>1955</td>
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<tr>
<td>1956</td>
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<td>1969</td>
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<td>1970</td>
</tr>
<tr>
<td>1971</td>
</tr>
<tr>
<td>1972</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

2. Calculated using Chase's (1962) average grade, 0.05 percent UO_2.
3. In percent of 1965 production.
4. In percent of 1965 production.

first exploitation of placer deposits principally for the recovery of
radioactive blacks. The (Nb,Ta)_2O_5 content of the concentrate ranged
from 22 to 30 percent, and the UO_2 content ranged from 6 to 10 per-
cent. The (Nb,Ta)_2O_5/UO_2 ratio thus ranged from 2.2 to 5. The
amount of uranium recovered is not known. An estimate of the
uranium content of the euxenite concentrate can be made, however, by
comparing the (Nb,Ta)_2O_5 content of the concentrate produced to the
range in the (Nb,Ta)_2O_5/UO_2 ratio. (See Table 20.)

<table>
<thead>
<tr>
<th>Table 20.—Estimated range of uranium content in euxenite concentrates, Big Meadow, Bear Valley, Idaho</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pounds UO_2 in euxenite concentrate</strong></td>
</tr>
<tr>
<td><strong>(Nb,Ta)_2O_5</strong></td>
</tr>
<tr>
<td>1956</td>
</tr>
<tr>
<td>1957</td>
</tr>
<tr>
<td>1958</td>
</tr>
<tr>
<td>1959</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

3. Included in this figure is a small but unspecified amount of niobium-titanium oxenite from Elmore County.

Several different types of uranium occurrences are shown in figure
53, and listed below:

| 35-220 O-44—16 |
Near Stanley, Custer County, uraninite-quartz veins and uraninite stringers fill fractures in the granitic rocks of the Idaho batholith (Kern, 1959). In the same area bedded uranium deposits occur as replacements in nonmarine carbonaceous claystone, siltstone, arkosic sandstone, and conglomerate in the basal part of the Challis Volcanics of Tertiary age. In the bedded deposits, uranium minerals fill spaces between grains of the rock (Chote, 1962). At Williams Creek prospect south of Salmon in Lemhi County, secondary uranium minerals coat the walls of joints and shears in the Challis Volcanics (Weis and others, 1958, p. 13). It is from these deposits in Custer and Lemhi Counties that the ore production recorded above has come.

In the Gibbonsville area, Lemhi County, uraninite and zircore have been found at the Garm-Lamoreaux property, autunite on the Surprise prospect, and torbernite at the Moon claim. The uranium minerals occur in quartz veins that occupy faults in schistose micaeous quartzite of the Precambrian Belt Series (Trues and Tooker, 1953; Weis and others, 1958). In the Camas mining district near Hailey, Blaine County, large quartz veins in faults cut quartz monzonite of the Idaho batholith. In these veins, sooty uraninite and torbernite were found on the Rustler claims, and abnormal radioactivity was found at the Camas mine (Weis and others, 1958). In the Coeur d'Alene mining district, Shoshone County, uranium occurs at the Galena, Coeur d'Alene, Sunshine, Crescent, Bunker Hill, and Page mines. Uraninite veins and veinlets fill fractures in the St. Regis and Wallace Formations of the Precambrian Belt Series. In only a few places are the uranium-bearing veins closely associated with the lead-silver-zinc veins of the district. Wall rock bordering veins is stained red by iron oxide (Weis and others, 1958).

**FIGURE 53.—Uranium in Idaho (numbers refer to deposits listed in text).**

**Vein and veinlike occurrences:**
- A1 Garm-Lamoreaux
- A2 Surprise
- A3 Moon
- A4 Rustler
- A5 Camas
- A6 Williams Creek prospect
- A7 Stanley area
- A8 Galena mine
- A9 Coeur d'Alene mine
- A10 Sunshine mine
- A11 Crescent mine
- A12 Bunker Hill mine
- A13 Page mine

**Uranium-bearing pegmatites:**
- B1 Bonner County
- B2 Mica Mountain and Last Chance mines
- B3 Garden Valley
- B4 Howard and Casner Creeks
- B5 Whitehawk Mountain
- B6 Kelley and Stanley Creeks
- B7 City of Rocks

**Uranium in carbonateous shale, lignite, or coal:**
- C1 Goose Creek area
- C2 Fall Creek area

**Uranium-bearing placer deposits:**
- D1 Bole Basin
- D2 Bear Valley
- D3 Deadwood area
- D4 Diser Swamp
- D5 Gold Fork
- D6 Kelley and Stanley Creeks
- D7 Warm Springs Creek
- D8 Gold and Williams Creeks
- D9 California Creek
- D10 Warren Meadows
- D11 Robbins and Grouse Creeks
- D12 Dixie
- D13 Elk City area
- D14 City of Rocks

**Uranium and thorium-bearing placer deposits:**
- R1 Blaine-Camas area

**Bedded deposits in Challis Volcanics:**
- F1 Stanley area
Pegmatites containing uranium-bearing minerals have been found in many counties, among which are Custer, Cassia, Valley, Boise, Latah, and Bonner (Cook, 1957; Weis and others, 1958). Except as possible sources of placer deposits, however, these occurrences are of minornologic rather than economic interest.

The Permian Phosphoria formation, which crops out over a wide area in southeastern Idaho, contains a low concentration of uranium. Phosphorite beds within the Meade Peak member of the Phosphoria formation average 0.01 percent UO₂.

Low-grade uranium-bearing carbonaceous shale and lignite beds are found in the Goose Creek district in Cassia County. The lignite and carbonaceous shale are interbedded with fresh water limestone, shale, and bentonite in the Idavada Volcanics of Tertiary age. One of the beds contains as much as 0.09 percent uranium across a few inches of thickness. Somewhat similar occurrences have been reported from Payette and Twin Falls Counties but are not shown on the map. Uraniferous coal and carbonaceous shale are found in beds of Cretaceous age in the Fall Creek area of Bonneville County east of Idaho Falls. A foot of one of the coal beds averages about 0.045 percent uranium (Cook, 1955, p. 15).

The Idaho batholith, which underlies a large part of central Idaho, is a granitic mass that is cut by numerous pegmatite dikes. Uranium-bearing radioactive black minerals, such as euxenite, brannerite, sanaraskite, and feugusonite, occur sparingly in the pegmatites and also occur locally as accessory minerals in the granitic rocks of the batholith. Under the influence of mechanical weathering, the granite and pegmatites have been disaggregated into separate minerals to form soft crumbly outcrops which supply unaltered monomineralic grains to streams and basins. Radioactive blacks are brittle. They break down readily under chemical weathering and are easily ground up in stream transport. Under favorable conditions of abundant supply and short transport, however, radioactive blacks can be concentrated in placer deposits. At Big Meadow in Bear Valley, Valley County, glacial damming combined with a wet-meadow past environment to promote natural beneficiation of the radioactive black sand deposits. Other placer deposits that contain radioactive blacks are known in Boise, Cassia, Custer, Elmore, Idaho, and Valley Counties. In Camas and Blaine Counties are placer deposits that contain uranophorite and thorite, which minerals were probably derived from the nearby Idaho batholith (Savage, 1961).

Future production of uranium in Idaho, as elsewhere will depend upon future demand and cost. The search for uranium by the citizens and Government of the United States in the past dozen years has been so successful that for the present uranium is not in short supply. The Atomic Energy Commission—at present the sole buyer—established an allocation system under which annual quotas (in pounds of U₂O₅) through 1966, later modified and extended through 1970, were assigned to individual mines and companies. Ore found on new properties after November 28, 1958, is not eligible for inclusion in the allocation system. Under the system, the Atomic Energy Commission will pay $8 a pound for U₂O₅, through 1966, and under certain cir-
cstances through 1968; in 1969 and 1970 a maximum of $6.70 a
pound will be paid. As the military demand for uranium has leveled
off, an increase in the price paid for uranium will depend upon its
greater use for other purposes in the future, such as widespread use
of it in nuclear reactors for the production of electricity. It is possible
that thorium minerals may be used as a substitute for uranium for
this purpose, thereby substantially decreasing the demand for uranium
in the future.

Known uranium-bearing deposits in Idaho may be divided into
deposits with low-cost, short-term reserves and those with high-cost, long-
term resources. Low-cost, short-term reserves are in deposits that
with a moderate increase in the price of uranium and/or improved
technology can be expected to be mined within the next few decades.
Most important of these are the radioactive black sand placer deposits
of central Idaho. Improved technology for the recovery of several
coproducts at less cost might make these deposits economic under pres-
ent conditions. Higbie (1968, p. 389) estimated that more than 8,000
short tons of (Nb,Ta)₂O₅ are contained in the euxenite of the placer
deposits in Bear Valley, Valley County. Using the same ratios as
were used in estimating the amount of uranium contained in the con-
centrates produced from Bear Valley, the euxenite-bearing placers in
Bear Valley are estimated to contain between 3 million and 7 million
pounds of U₃O₈. The total uranium content of all radioactive black-
sand and uraninite placer deposits in Idaho may be several times as much.

The only other known low-cost, short-term reserves are contained
in the bedded and vein deposits of Custer County and in the uraninite
veins in the Sunshine mine, Coeur d'Alene mining district, Shoshone
County. The known deposits in Custer County are small; at the
largest one yet found, ore mined and all reserves as of the end of 1968
totaled less than 7,000 tons (Choate, 1969, p. 40). In Choate's opinion,
a higher price for uranium would be necessary to support profitable
mining from known deposits in this area. The uraninite veins at the
Sunshine mine contain a few thousand tons of ore that could be
mined in time of need.

Idaho's known high-cost, long-term uranium resources are contained
in large low-grade bedded deposits of phosphate rock and coal, lignite,
and carbonaceous shale. Without a manifold increase in the price of
uranium, which is not now foreseeable, it cannot be expected that these
deposits will be mined solely for uranium within the next several
decades. It is reasonable to expect, however, that uranium will be
recovered as a byproduct of other mining when it becomes economic
to do so. Idaho's largest uranium resource is contained in the phos-
phate rock of the Phosphoria formation. Cook (1957, p. 5) esti-
mated that in the phosphate ore that eventually will be mined there
are about 224 million pounds of U₃O₈. As of the end of 1968, uranium
had not been recovered from Idaho phosphate ore. Although uranif-
erous coal, lignite, and carbonaceous shale in Idaho are neither as
high grade nor as plentiful as they are elsewhere in the United States,
the uranium oxide content of certain Idaho coal, lignite, and carbo-
naceous shale beds probably is measurable in tens of millions of pounds.
If it becomes economic in the future, this uranium probably will be
recovered from the ash of coal burned by large industrial users.
VANADIUM

(By R. P. Fischer, U.S. Geological Survey, Denver, Colo.)

About 2,000 short tons of vanadium have been consumed annually in the United States in recent years. Three-quarters of this has gone into special engineering, structural, and tool steels, where it is used as an alloy to control grain size, impart toughness, and inhibit fatigue. The other principal domestic uses have been in nonferrous alloys and chemicals (Busch, 1960; Busch, 1961).

The bulk of domestic supplies of vanadium and nearly half of the world supplies have come from deposits of vanadium- and uranium-bearing sandstone in southwestern Colorado and the adjoining parts of Utah, Arizona, and New Mexico. The other principal sources of vanadium have been a deposit of vanadium-bearing asphaltite in Peru, vanadate minerals from the oxidized zones of some base-metal deposits in Africa, and vanadium-bearing iron deposits in Europe and Africa. These iron deposits and similar ones in many parts of the world contain very large resources of vanadium. Probably they will become increasingly important as sources of vanadium in the future.

None of these four geologic types of productive vanadium deposits are known to occur in commercial amounts in Idaho. However, mineralogic occurrences of carnottite, a vanadium ore mineral in southwestern Colorado and adjoining States, have been reported in the State, and sparse amounts of vanadate minerals have been found in a few base-metal deposits in Idaho.

Although Idaho has not yielded any vanadium ore, about 1,000 tons of vanadium in vanadium pentoxide have been recovered as a byproduct from phosphate rock mined in Idaho. This represents about 1.5 percent of the total U.S. production of vanadium through 1963. Most of this was recovered during the 1941-54 period at the fertilizer plant at Anaconda, Mont., from phosphate rock mined at Conda, Idaho. Since 1961, a small amount of vanadium has been recovered in Utah from ferrophosphorus slag obtained from elemental phosphorus furnaces in Idaho. According to a preliminary report by the U.S. Bureau of Mines on the Mineral Industry in Idaho in 1963 (area report B-106), Kerr-McGee Oil Industries, Inc., completed constructing a 750-ton-per-day vanadium pentoxide \((V_2O_5)\) recovery plant near Soda Springs, Carbon County. Because of the relatively low vanadium content of the phosphate rock, vanadium can only be recovered as a byproduct, so its possible rate of production will be limited by the size of the phosphate-mining operations and the metallurgical processes used in treating the phosphate rock.

The phosphate rock mined in Idaho comes from the Phosphoria formation of Permian age (McKelvey, 1949). Most of that from which vanadium has been recovered averages between 0.2 and 0.3 percent \(V_2O_5\). Resources of phosphate rock are very large (see section on phosphate), and the total vanadium content of this material is undoubtedly large, but sampling of this rock for vanadium has not been adequate to obtain a quantitative appraisal of the vanadium resources. Outcrops of the Phosphoria formation are shown in figure 35. (Phosphate rock deposits in Idaho.)
In addition to the large resources of vanadium in the phosphate rock, even larger quantities of vanadium occur in beds of shale associated with the phosphate rock. One layer in particular, commonly referred to as the "vanadiferous zone," is about 3 feet thick and averages about 0.7 to 0.9 percent V₂O₅ in several places where it has been sampled in southeastern Idaho and western Wyoming. This zone occurs near the middle of the Meade Peak phosphatic shale member of the Phosphoria formation (Galbraith, 1950). Because of metallurgical difficulties of treating shale, it is unlikely that these shale beds will be exploited for vanadium alone in the foreseeable future. In places, however, these shales also contain unusual concentrations of other elements—chromium, molybdenum, selenium, and zinc; ultimately two or more of these metals might be profitably recoverable as coproducts from these shales.

In the last few years, vanadium has been discovered in Idaho blackshales at several localities, according to C. N. Savage of the Idaho Bureau of Mines and Geology (verbal communication). Content of V₂O₅ ranges from 0.05 to 0.42 percent in the fairly large number of samples which were checked. No large tonnages of commercial values have yet been proved, but V₂O₅ content approaching commercial values has been found in samples from (a) Boise Basin, (b) Warren district, (c) Rexburg dune sand deposits, (d) Cascade-Long Valley area, and (e) lower Deadwood River basin and reservoir area.

SELECTED REFERENCES


—1941, A copper deposit of the Ducktown type near the Coeur d'Alene district, Idaho: Econ. Geology, v. 36, no. 6, 641-657.


1947c, Structural control and wall-rock alteration at the Wilbert mine, Dome district, Butte County, Idaho: Econ. Geology, v. 42, no. 4, p. 386-393.


MINERAL AND WATER RESOURCES OF IDAHO


