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Outline of the Geology of Idaho

by

CLYDE P. ROSS and J. DONALD FORRESTER

(Prepared in cooperation with the U.S. Geological Survey)

State of Idaho
ROBERT E. SMYLIE, Governor

Idaho Bureau of Mines and Geology
E. F. COOK, Director

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Clyde P. Ross

U. S. Geological Survey

and

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Formerly of the Idaho Bureau of Mines and Geology

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FOREWORD

An outline of the Geology of Idaho is designed to be an explanatory text for the Geologic Map of Idaho which was prepared by the same authors and published by the U. S. Geological Survey and the Idaho Bureau of Mines and Geology in 1947. Anyone who has a copy of the state map needs this present Bulletin for a comprehensive exposition of the geology of Idaho in terms of the units shown on the map. Copies of the map are available at $2.50 each from the Idaho Bureau of Mines and Geology, Moscow, Idaho.

Clyde P. Ross, of the U. S. Geological Survey, senior author of the Bulletin as well as the map, is the dean of geologists still active in Idaho; his first field work in the state was done more than 30 years ago and he is still actively mapping in south-central Idaho. C. P. Ross' contributions to the geology of Idaho have been many and varied; not the least among them is his share of the present publication.

Dr. J. D. Forrester, although his field work in Idaho extends over a somewhat shorter span than Mr. Ross', also has an intimate knowledge of the State, acquired largely during his tenure as Head of the Department of Geology and later Dean of the College of Mines of the University of Idaho and Director of this Bureau. He is the author of numerous papers on geology and mining and his textbook, Field and Mining Geology, is widely used.

Several additions have been made to this Bulletin to supplement the Ross and Forrester text and to make it and the geologic map more useful to the educated non-geologist:

(1) A glossary of geologic terms used in the text will be found on pages 65-68; the definitions have been made as simple as concern for accuracy will allow;

(2) A list of the mineral names mentioned in the text has been compiled and each name is defined on page 69;

(3) A similar list of definitions for rock names used in this publication is on pages 71-72;

(4) A chart showing formation names used in the publication plotted according to their relative age on the geologic time scale is shown on page 6;

(5) A rock cycle chart illustrating the way existing rocks are continuously being changed into other rocks by erosion and deposition, compaction and cementation, metamorphism and melting will be found on page 73;

(6) A chart showing the Idaho geologic formations, arranged according to their relative age, concludes this Bulletin on page 74.

These six items, designed to make the text more interesting and intelligible to the person who has not studied geology, have been compiled by the staff of the Idaho Bureau of Mines and Geology.

The Ross and Forrester text (pages 1-64) has been approved for publication by the Director, U. S. Geological Survey.

E. F. COOK
Director
Idaho Bureau of Mines and Geology

FIGURE 3 - THE OXBOW OF THE SNAKE RIVER, ON THE WESTERN BORDER OF IDAHO
---Courtesy, Idaho Power Co.

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OUTLINE OF THE GEOLOGY OF IDAHO

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PURPOSE AND SCOPE

The principal industries of Idaho are dependent in large measure on geology for their attainments and expectations of future growth. This report is a brief summary of present concepts as to the geology of the State, intended as a background for anyone interested in any phase of the subject. Many reports relating to the geology of Idaho have been published but most of these deal either with specific districts or other particular features. A bibliography essentially complete through April 15, 1941 is available (Ross, 1941). An up-to-date list of the publications of the Idaho Bureau of Mines and Geology is obtainable on request from the Director of that Bureau at the College of Mines, University of Idaho, Moscow, Idaho.

A number of very small scale geologic maps of Idaho have long been available. One of the earliest of these was prepared by Robert N. Bell (1904) at the beginning of his long career as State Mine Inspector. A somewhat more detailed map, but still so much generalized and on so small a scale that it fills only a single page, accompanies a report by one of the present writers (Ross, 1936). Other small maps have appeared but, although of value for the special purposes for which they were prepared, they are inadequate to portray present information in regard even to the broader aspects of the geology of the State. A map on a scale of 1:500,000, compiled by the present authors (Ross and Forrester, 1947), and available from the Idaho Bureau of Mines and Geology, Moscow, Idaho, in many respects does have sufficient detail for the purpose. This map is some 10 years old and, to that extent, is out of date. However, it still fairly well represents our knowledge of the geology of the State and forms the basis for the discussion that follows. The rock subdivisions described below are essentially those shown on this map so that the discussion herein constitutes an expansion of the map explanation. Some of the units are necessarily arbitrary and include rocks that would have been mapped separately if that had been practicable.

Both in the compilation of the map and in the preparation of the present report available published and unpublished reports by many persons have been supplemented by the results of much field work by the writers, a large part of which was undertaken solely to aid in compilation of the map. The index map that accompanies the geologic map shows the principal reports (published and unpublished) that were utilized in the compilation, the area covered by each, and the approximate standard of detail. In general, these citations are not repeated in the present report.

So far as was practicable when the State geologic map was compiled, the rocks belonging to each of the systems used in the geologic time classification (Wilmarth, 1925, p. 3-9, pl. 1; Geologic Names Committee, 1953) were distinguished on the map, and intrusive rocks were discriminated from stratified rocks. Several departures from this general scheme had to be adopted to fill special needs. In some areas insufficient data were at hand to permit the systems to be distinguished. It was necessary, therefore, to group together the rocks deposited in different eras rather than periods. On the other hand, some units of less than systematic rank were shown. The rocks of the Permian system, for example, fall into two such sharply different categories that it seemed wise to map them separately. The phosphate-bearing Permian rocks in southeastern Idaho were distinguished, therefore, from the dominantly volcanic rocks in the western and central parts of the State. The latter are regarded with different degrees of certainty as mainly of Permian age, but include some younger rocks that cannot everywhere be satisfactorily mapped separately on the basis of present data. In a few inadequately known areas in southern Idaho it was not possible to separate Permian from older rocks. Much work has been done on the phosphate-bearing rocks since the map was issued, but the reports that have resulted would introduce few changes in the State map.

The treatment of geologic units of Tertiary and later age on the State map also departs from the scheme of making map units correspond to systems in the conventional classification. This was necessitated partly because generally recognized formations of these ages transgress the systematic boundaries, and partly because most of the Tertiary and early Quaternary units mapped are comparable in areal extent and in thickness to the systematic units of earlier ages. Quaternary unconsolidated deposits, mainly alluvium, serve so well to emphasize topographic features that they were shown, where possible, even though they cover smaller areas, correspond to shorter time intervals, and are thinner than many of the other units mapped. Work done since the State geologic map was compiled has modified some of the concepts as to age and interrelations of the Tertiary and younger strata.

Intrusive rocks were shown in as great detail as possible because of their significance in connection with ore deposits, structure, and other geologic phenomena. Limitations imposed by scale and by the information available required some generalization in depicting the intrusive rocks but the trends and proportions shown on the map convey a correct picture in most respects. The principal deficiency is that rocks that should properly have been shown as constituents of border zones have not been distinguished in some places from the main mass of the Idaho batholith and similar masses. This is true mainly in areas known only on a reconnaissance basis. Even in areas where gneissic rocks were known to exist they were mapped with the batholithic masses if definite boundaries had not been established. If the compilations were made today, the tendency would be to do the opposite. That is, every attempt would be made to record the presence of gneissic material, even if boundaries were inadequately known.

GENERAL GEOLOGY

STRATIFIED ROCKS

Precambrian rocks

Precambrian(?) strata not correlated with the Belt series

Most of the Precambrian stratified rocks in Idaho belong to the Belt series. In places rocks had been assigned a Precambrian age with different degrees of certainty, but had not been correlated with the Belt series at the time the State map was made. Among these rocks are certain highly metamorphosed sedimentary rocks in the Pioneer Mountains east-northeast of Ketchum, Blaine County, and also in Cassia County and in northwestern Bannock County. There are also small amounts of ancient rocks, possibly both sedimentary and igneous, along the Montana boundary in northern Fremont County.

The area in Fremont County may contain the oldest rocks exposed in Idaho. It is the southern extension of a mass of metamorphic rock that crops out over large areas in southern Montana. In that State the mass consists mainly of gneiss and schist regarded as much older than the Belt series. Presumably those in Fremont County are similar in age and character.

The Precambrian(?) rocks in the Pioneer Mountains include the Hyndman formation, estimated to be 6,600 feet thick, and the East Fork formation, at least 1,560 feet thick. The Hyndman formation consists mainly of quartzite but includes green hornfels in the upper part and a schist member in its lower part. The East Fork formation consists largely of metamorphosed limestone but includes conspicuous interbedded quartzite masses. The two formations together crop out over an area of about 20 square miles along the southwestern border of a granite body. They are cut by many faults and are separated from all other sedimentary rocks in the vicinity by faults. As part--possibly a very large part--of the metamorphism that has affected these formations is related to the intrusion of the granitic mass nearby and thus is without significance in regard to the age of the rocks, the assumption that the Hyndman and East Fork formations are of Precambrian age is far from proved; it is equally possible that part or all of these rocks are faulted and metamorphosed fragments of Paleozoic rock units such as are plentiful in the surrounding region.

The postulated Precambrian(?) beds in Cassia County were first named the Harrison series (Anderson 1931) and later changed to the Albion Range group by Anderson (1934, p. 377). They are more than 9,000 feet thick and consist mainly of quartzite, with some schist and marble. Anderson suggests correlation between his Albion Range group and the Hyndman and East Fork formations on the basis of lithologic similarity. He thinks that the Albion Range group is different

from and probably older than the Belt series, in part because of resemblance to rocks in the Wasatch Range, Utah, which Blackwelder (1925, p. 132-133; 1935, p. 153-157) has shown to underlie strata which he regarded as of Algonkian age.

Rocks near Pocatello, Bannock County, include, according to Ludlum (1942, p. 85-95; 1943, p. 973-986) the Bannock volcanic formation of Anderson (1928; redefined by Ludlum, 1942) at the base, the Pocatello formation of Ludlum (1942), supposed to be largely of glacial origin, and the Blackrock limestone of Anderson (1928) at the top; the whole thought by Ludlum to be of Precambrian age but not to be correlated with the Belt series. As they are separated from overlying Cambrian strata only by an inconspicuous unconformity and have lithologic resemblances to parts of the Belt series or to formations in Utah (Crittenden, Sharp, and Calkins, 1952, p. 1-6) that similarly have resemblances to the Belt series, the rocks near Pocatello may well be allied to that series.

Belt series

Precambrian rocks correlated with the Belt series probably once covered all of central and northern Idaho. This series is still widespread in these areas, especially north of 46° 30' North latitude. Small parts of the rocks in Butte and Valley Counties included in undifferentiated Paleozoic sedimentary rocks on the State map are now regarded as belonging to the Belt series. Similar beds extend far into Montana. 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 included. In many places ripple marks, mud cracks, intraformational conglomerate and small-scale crossbedding testify to deposition in shallow water. Stromatolites (algal fossils), locally abundant in the series in Montana and present also in Idaho, strengthen this concept. The abundant evidence that the water was shallow, locally decidedly so, as well as some other features of the deposits, have led some geologists to regard the Belt series as of lacustrine origin but they are now commonly inferred to be marine. The exposures are distributed over an area of fully 65,000 square miles in Montana, Idaho, and eastern Washington and may once have had connection with the Arctic Ocean to the north and the Pacific Ocean across southern California.*

The rocks of the Belt series are thoroughly cemented and partly to completely recrystallized. Over large areas they are little, if any, more metamorphosed than the Paleozoic strata. Locally the Belt series is strongly metamorphosed but this is also true of younger rocks.

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*Ross, C. P., in prep., 1956, The Belt problem in Montana: U. S. Geol. Survey Prof. Paper.

The Belt series is broadly uniform in its lithologic characteristics nearly everywhere but has numerous variations in stratigraphic details. At present correlations throughout the State are impracticable and subdivisions of the series are not shown on the State map. For the narrow part of the state north of 47° North latitude, the stratigraphic column established long ago by Calkins (Ransome and Calkins, 1908, p. 22-44) is accepted by most geologists with modifications to fit conditions at particular localities. The maximum thicknesses of the units have been found to be much greater than those where Calkins' measurements were made. Detailed studies have shown that subdivisions are possible but formal designations of new formations have not yet been offered. Some changes proposed by Calkins were included in a stratigraphic correlation chart prepared by M. Grace Wilmarth and issued by the Federal Geological Survey in 1932. Figure 4, on the following page is adapted from that chart; with the correction, however, that the Monk formation, now regarded as of Cambrian(?) age, has been omitted. Certain obsolete series names quoted on the chart are also omitted here.

The first column in Figure 4 includes a number of Canadian stratigraphic names that have not come into general use in the United States. The term Purcell lava is used somewhat loosely as more than half of the unit so designated consists of conglomerate and other sedimentary rocks. The rest of the unit is calcic lava with some tuff, all distinctly metamorphosed. The Blacktail formation in the second column is a local term, convenient where the Revett and St. Regis formations of the Coeur d'Alene area are not discriminated. In recent studies of the Belt series, mainly in Montana, lateral variations have been shown to be so marked that groups, rather than formations, are emphasized in regional correlation (Ross, in prep.). On this basis, the Prichard formation remains the lowest recognized unit in the Belt series in Idaho; the Burke, Revett and St. Regis formations and their equivalents belong to the Ravalli group; the Wallace and its equivalents are correlated with the Piegan group; and the Striped Peak formation belongs to the Missoula group. The so-called Purcell lava of Kirkham and Ellis (1926) in Boundary County, Idaho, may also belong to the Missoula group.

Most of the formations of the Belt series of the Coeur d'Alene region are believed to have their counterparts in Clearwater County to the south. Most of this county and the adjacent part of Shoshone County are geologically little known and stratigraphic studies are hindered by intense metamorphism. Anderson (1930, p. 8-12) has given the name Orofino series to an assemblage of these highly metamorphosed rocks exposed near Orofino. He says the series cannot be correlated with any part of the Belt series farther north and must either be older than that series or belong to a part of the Prichard formation not exposed to the north. Anderson's Orofino series includes banded micaceous and hornblendic quartzite, schist and gneiss with intercalated beds of marble. Anderson estimates that the Belt series in Clearwater County, including his Orofino series, is over 20,000 feet thick. Recent work (Hietanen, 1956, p. 1-27) has called attention to the metamorphic rocks in the Belt series along the northern border of Clearwater County.

Figure 4

TENTATIVE CORRELATION CHART FOR THE BELT SERIES IN NORTHERN IDAHO

(Adapted from Tentative Correlation of the Named Geologic Units of Idaho, by M. Grace Wilmarth, U. S. Geological Survey, 1932)

Boundary County and Priest River National Forest, Idaho	Pend Oreille region, Idaho		Coeur d'Alene Mountains, Idaho and Montana
Eroded	Eroded		Eroded
Purcell lava of Kirkham and Ellis (1926) 11,000 feet	Striped Peak formation 3,500 feet		Striped Peak formation 1,000 feet+
Kitchener formation 4,500 feet	Wallace formation 6,000 feet		Wallace formation 2,500-4,000 feet
Creston formation 5,000 feet	Blacktail formation 8,300 feet	Ravalli group	St. Regis formation 1,000 feet+
			Revett quartzite 1,200 feet
	Burke formation 8,000 feet		Burke formation 2,000 feet
Aldridge-Prichard formation of Kirkham and Ellis (1926) 10,000 feet+	Prichard formation 7,000 feet		Prichard formation 8,000 feet - base concealed
Total 30,500 feet+	32,800 feet		17,200 feet+

In the vicinity of the Middle Fork of the Salmon River the Belt series includes the Yellowjacket formation, at least 9,000 feet thick, composed of dark argillaceous quartzite with some calcareous beds, overlain by the white Hoodoo quartzite, over 3,560 feet thick. These formations extend northwestward almost as far as 115° 30' west longitude and may include part of the rock designated as of Paleozoic age on the State geologic map. There is reason to think that similar units are included in the metamorphosed Belt series in the general vicinity of Buffalo Hump but available data are insufficient for correlation.

The Belt series in much of the mountainous part of Lemhi County and extending somewhat south of the limits of that county have, for the most part, not yet been subdivided. In the Lemhi Range south of Patterson the Lemhi and Swauger quartzites have been distinguished. The Swauger quartzite is exposed much farther south in the Lemhi Range than was appreciated when the State map was compiled and is present in the Lost River Range also. It is inadvisable at present to attempt correlations between the formations of the Belt series in the south central part of Idaho and those in the north.

Rocks of Paleozoic Age

Cambrian rocks

Cambrian sedimentary rocks have been recognized in several parts of Idaho. They are especially plentiful in Bannock and Bear Lake Counties, and are prominent in one locality in northern Idaho. Strata that may be of Cambrian age are present also in Custer County.

In and near Bannock and Bear Lake Counties, seven separate formations of Cambrian age are known. They are, in ascending order, the Brigham quartzite, Langston limestone, Ute limestone, Blacksmith limestone, Bloomington formation, Nounan limestone, and St. Charles limestone. These Cambrian strata aggregate nearly 6,000 to over 7,000 feet in thickness and locally may be much thicker.

Sedimentary rocks of supposed Cambrian age are exposed along the southern border of the State in Cassia County, but no diagnostic fossils have been found in them. Similarly small masses of unfossiliferous, somewhat metamorphosed sedimentary rocks, called the Bayhorse dolomite and Garden Creek phyllite, in one locality in Custer County are inferred to be of Cambrian age because they appear to underlie slate of Early Ordovician age. In northern Idaho limestone, shale, and quartzite containing undoubted Cambrian fossils have been mapped close to Pend Oreille Lake.

Ordovician rocks

The Ordovician rocks in southeastern Idaho are somewhat similar in character and distribution to the Cambrian sequence of that area, but are thinner. They include the Garden City limestone, Swan Peak formation and Fish Haven dolomite, whose variable thicknesses aggre-

gate close to 2,500 feet. In the central part of the State, Ordovician strata are much more widespread and thicker than those tentatively assigned to the Cambrian system; their age has been established by fossil evidence. Five formations have been distinguished but the Phi Kappa formation, largely argillaceous quartzite, and the unnamed argillite beneath it are together probably broadly equivalent to the Ramshorn slate, Kinnikinic quartzite and Saturday Mountain formation, largely calcareous, of other areas. The aggregate thickness of these Ordovician rocks is nearly everywhere large and in some localities is close to 10,000 feet. In addition to the areas in which they are shown on the State map, Ordovician rocks, especially the Kinnikinic quartzite, are known to be present in several of the mountain ranges in central Idaho where it has been necessary to group them among the undifferentiated Paleozoic sedimentary rocks on that map.

Silurian rocks

Silurian rocks are relatively scarce in Idaho. The thick sequence of Paleozoic age in the southeastern part of the State includes the Laketown dolomite which locally attains a thickness of 1,000 feet. In a few places in Custer County this formation is as much as 2,500 feet thick; it is known to be present in several other parts of south central Idaho. In addition, a little shale and sandstone of the Trail Creek formation has been identified in a few places in and near southwestern Custer County.

Devonian rocks

Middle and Upper Devonian beds belonging to the Jefferson and Three Forks formations are widespread in southeastern Idaho. They have a maximum aggregate thickness here of about 1,100 feet and consist mainly of limestone with some shale and sandstone. Devonian rocks have been mapped in several parts of south central Idaho, and evidence is increasing that they are both widespread and relatively thick in that region. Three units, the Jefferson and Grand View dolomites and the narrow but distinctive Three Forks limestone, have been definitely recognized, and it is possible that the lower part of the Milligen formation is also of Devonian age. The incomplete information at hand is sufficient to show that the maximum thickness of the Devonian sequence in south central Idaho is more than 3,000 feet. Dark dolomite predominates but the Three Forks limestone at the top commonly weathers to a bright yellow easily recognizable from a distance. This and the well-preserved fossils that it generally contains make the unit an especially valuable horizon marker. Its thickness ranges from less than 50 feet to about 350 feet.

Carboniferous rocks

Strata of Mississippian and Pennsylvanian age are among the thickest and most widespread of the Paleozoic rocks in Idaho. The Madison and Brazer limestones and Wells formation, which is largely arenaceous, together have a maximum thickness of about 6,000 feet in southeastern Idaho. They are prominent in Caribou County and adjacent parts of Bear Lake County and extend westward into eastern Cassia County although not everywhere separated from other Paleozoic rocks on existing maps.

North of the Snake River Plain, strata of these ages are at least equally plentiful. Here the dominantly argillaceous Milligen formation, up to 3,000 feet thick, is thought to be mainly of Mississippian age, though part of it may be Devonian. It is roughly comparable in stratigraphic position to the Madison limestone though lithologically quite different. The beds of metamorphosed coal in the Milligen formation, although of little economic value, are of interest because they seem to be older than most coal beds in the United States. The Milligen thins markedly eastward. Brazer limestone (Upper Mississippian), with a maximum thickness of over 5,000 feet in the Lemhi Range, overlies the Milligen in many places but is absent along the western borders of the Paleozoic rocks in south central Idaho. On the other hand, the Wood River formation (Pennsylvanian), which in a very general way may correspond to the Wells formation of southeastern Idaho, has a probable thickness of 8,000 feet along the eastern border of the Idaho batholith but appears to be absent east of the Lost River Range. Some geologists are inclined to regard as Permian the uppermost parts of the Wood River and Wells formations.

Permian sedimentary rocks (Phosphoria formation)

The only masses of dominantly sedimentary rocks at present regarded as of Permian age in Idaho belong to the Phosphoria formation. This formation, in the part of southeastern Idaho where it is best known, has a maximum thickness of about 730 feet and in most places is much thinner. The thickness, however, increases markedly westward into Cassia County according to information obtained since the State map was compiled. The unit, where most explored, consists of phosphatic shale overlain by limestone and chert with an upper phosphatic shale member in most places. Farther west carbonaceous mudstone and chert are dominant. The Phosphoria formation has been mapped nowhere in central Idaho north or west of the crescentic Snake River Plain. It does, however, crop out in Beaverhead County, Montana and a westward extension of these exposures has been recognized recently east of Leadore, Idaho.

The State geologic map depicts the Phosphoria formation as well as was possible at the time of compilation. The unit is smaller than most of those mapped but was shown because of the aid it gives in picturing structure and because it is the principal source of rock phosphate in this part of the United States. Interest in rock phosphate has increased in recent years and extensive investigations of it have been undertaken (Swanson, McKelvey, and Sheldon, 1953).

Permian and Triassic volcanic rocks

The central and western parts of Idaho contain several areas in which volcanic rocks distinctly more metamorphosed and older than the Tertiary flows are abundant. The most widely known area of this sort is the Seven Devils region and the rocks of this kind have been named the Seven Devils volcanics. This formation is exposed at intervals from T. 12 N., R. 7 W. in Washington County northward in the mountains east of the Snake River into Idaho County. It has been traced as far as 46° North latitude near Harpster, in north central Idaho County.

Farther west small areas of similar rock have been mapped as far north as Deary, Latah County. A similar and possibly equivalent assemblage occupies extensive areas in Custer, Lemhi and Valley Counties on both sides of the Middle Fork of the Salmon River. This assemblage is known as the Casto volcanics, from the quadrangle in which it was first recognized. From the area near the Middle Fork it has been traced northwest as far as the southern border of Idaho County in the vicinity of Chamberlain Creek.

The Seven Devils and Casto volcanics are similar to each other in their relations to other rocks and in their lithologic characteristics. Both consist mainly of andesitic flows, agglomerates, and tuffs.

The Seven Devils volcanics have long been known to contain fossils of Permian age. The volcanics also contain fossils that range in age up to late Triassic (Cook, 1954) but it has not proved feasible to separate the younger volcanic rocks in mapping. The inclusion of the Casto volcanic rocks in the Permian system is tentative. This formation has yielded no fossils but underlies the Challis volcanics of Tertiary age and is cut by the Idaho batholith.

Rocks of Mesozoic age

Triassic sedimentary rocks

Triassic sedimentary strata are widespread in southeastern Idaho and are also present farther west in association with the volcanic rocks just described. In the southeastern corner of Idaho the Triassic rocks seem to be confined to several areas in Bear Lake County. The zone in which they are exposed extends northward and increases somewhat in width to the vicinity of 43° 30' North latitude. North of this place Tertiary and later rocks conceal the older rocks over large areas. Triassic strata reappear in small areas in the mountains along the Montana boundary. The rocks of Triassic age in southeastern Idaho include the Dinwoody formation and the overlying Thaynes limestone, with an aggregate maximum thickness of over 5,000 feet, overlain successively by the Higham grit, Deadman limestone, and Wood shale which have a combined thickness of 550 feet (Kummel, 1954, p. 165-188).

In western Idaho sedimentary strata regarded with varying degrees of assurance as of Triassic age extend interruptedly from T. 13 N., R. 7 W., Washington County, to near Grangeville in Idaho County. Argillaceous rocks, in part schistose, predominate but limestone, sandstone, and conglomerate are also present.

Jurassic sedimentary rocks

Jurassic strata have a distribution in Idaho similar to that of the Triassic rocks just described. In the southeastern part of the State they include, in ascending order, the Nugget sandstone, Twin Creek limestone, Preuss sandstone, and Stump sandstone, with a com-

FIGURE 5 - SEVEN DEVILS VOLCANICS FORMING THE WALLS OF HELLS CANYON
---Courtesy, Idaho Power Co.

bined thickness of about 6,700 feet. Most of the formations of Jurassic age are separated from each other by unconformities, whereas most of the formations of Triassic age are mutually conformable. Jurassic strata have been reported along the western border of Idaho also but have not been mapped there (Livingston, 1932, p. 33-34).

Cretaceous sedimentary rocks

Sedimentary rocks of probable Cretaceous age are abundant in southeastern Idaho. They extend interruptedly from northern Bear Lake County to beyond 43° 30' North latitude, and reappear in small masses in the mountains along the Montana boundary. No stratified rocks thought to be of Cretaceous age have been reported from any other part of Idaho.

The Gannett group has recently been shown definitely to be of Early Cretaceous age (Mansfield, op. cit., p. 42, 43). This group includes the Ephraim conglomerate, Peterson limestone, Bechler conglomerate, Draney limestone, and Tygee sandstone, with a combined maximum thickness of about 2,000 feet. Above this assemblage is the Wayan formation, about 11,800 feet thick. The fossils of both the Gannett group and the Wayan formation, unlike those from other Mesozoic strata in the region, indicate that most of the rocks were laid down in fresh water.

Rocks of Cenozoic age

Introductory note

The Tertiary and later rocks present some difficulties in delineation not shared by the older units. As they are less intensely deformed and have been subject to erosion for shorter time intervals than the pre-Tertiary rocks, preservation of each unit is more nearly complete. Hence units of formational rather than systemic rank are represented on the State map. Some of these units are very thick. Most of them were originally defined on the basis of inadequate information as to extent, limits, and age. Consequently, the definitions that have received official recognition by the Federal Geological Survey are loose and overlapping. For example, the Snake River basalt as officially defined (Wilmarth, 1938, p. 2017) would include much of the basalt in western Idaho that is grouped with the Columbia River basalt by most geologists. As knowledge has accumulated, more restricted usage than is implied by the official definitions has come to be accepted by most geologists familiar with Idaho. It is proposed to define the different units in the descriptions that follow in terms that will so far as possible bring them into accord with present usage. In this the writers have been guided by the results of studies of fossil plants by R. W. Brown, in part unpublished, and by information gathered during reconnaissance mapping done for the purpose of completing the State map. A number of geologists are engaged in studies that will subdivide Cenozoic units in the State and modify present concepts as to age relations.

Many of the Tertiary and younger rocks in Idaho are lava flows and other products of volcanism, and even the sedimentary beds include considerable quantities of volcanic material, in part the direct product of explosive volcanism. Further, the sedimentary rocks are of subaerial origin and include deposits formed in ephemeral streams and lakes, as well as hill wash and alluvial fans. In consequence of these modes of origin the rocks are highly variable both lithologically and in thickness. They interfinger in irregular and locally complex fashion. Fossils in rocks of this character are, in most places, neither abundant nor closely diagnostic. These factors, coupled with still incomplete information for many areas, add much to the difficulties in establishing a consistent nomenclature.

Each of the different volcanic units has interbedded with it some material of sedimentary or mixed sedimentary and tuffaceous origin. Beds of this kind have been mapped separately from the volcanic rocks wherever possible. However, in many places this has been impossible either because of inadequate information or because of limitations of the map.

In any discussion of the different Tertiary stratigraphic units in Idaho it should be clearly realized that such names as Payette and Latah have come to be applied by many geologists to rocks with certain lithologic characteristics and within certain rather broad age limits. Neither term applies to a single, originally coextensive stratigraphic unit now separated into different masses as a result of the accidents of erosion and deformation. Instead each applies to an aggregate of lenses and more irregular masses that never were united and that have appreciably different stratigraphic relations.

Wasatch formation

The Wasatch formation has so far been mapped only in small areas in the southeastern corner of the State, where it constitutes northward and westward extensions of a formation which is more extensively displayed in Wyoming and Utah. Further work may show that the Wasatch formation is more widely exposed in Idaho than is now realized.

The formation has a maximum exposed thickness of 1500 feet and consists largely of conglomerate with some limestone. No diagnostic fossils have been found in it in Idaho but there seems little doubt that the strata mapped as the Wasatch formation in that State are to be correlated with those in nearby Wyoming that have been proved to be of Eocene age. Certain strata in Wyoming are regarded by some as of Paleocene age and, in the opinion of some geologists, it is possible that the lower part of the Wasatch in Idaho is of that age.

Challis volcanics and associated rocks

The name Challis volcanics was applied (Ross, 1934, p. 46) originally to the thick and diverse assemblage of Tertiary volcanic rocks in the part of Idaho that centers around Challis, Custer County.

The Snake River basalt was specifically excluded and the Columbia River basalt was recognized to be different from and probably younger than the Challis volcanics, even though some basalt flows are included in the latter. (Later work has confirmed the fact that the Challis volcanics as thus defined constitutes a logical and distinctive stratigraphic unit.) The principal source of uncertainty remaining is in the correlation of some of the silicic volcanic rocks associated with the Snake River basalt. Certain of the rocks of this kind that underlie the basalt resemble silicic strata in the upper part of the Challis volcanics. The original definition of the Challis volcanics is sufficiently broad so that all such silicic rocks in the mountains of south central Idaho might well be considered components of that unit. On the assumption that they are petrographically different and may be much younger than the main body of the Challis volcanics, certain relatively silicic rocks along the border of the mountains were distinguished on the map.

South and east of the Snake River Plain there are a few small areas of andesitic rocks that occupy a lower stratigraphic position than the other Tertiary volcanic rocks of the vicinity. These rocks have been given the same designation as the Challis volcanics on the State map, although precise equivalence with the Challis volcanics north of the Plain is not regarded as established. One such area north of Twin Falls, through a drafting error, is incorrectly labelled Qal on the State map.

North of the westward flowing stretch of the Salmon River, rocks that resemble the Challis volcanics are rare. The only rocks there grouped with the Challis volcanics are the Kamiah volcanics of Anderson (1930, p. 25). These rocks are andesitic and latitic flows, erosion remnants of which constitute buttes in a small area in northwestern Idaho County. They are surrounded and overlapped by Columbia River basalt. In composition and relationships these rocks so closely resemble the Challis volcanics in south central Idaho that they may represent a northward extension of the same assemblage.

The Challis volcanics of south central Idaho attain a maximum thickness of over a mile. Most of them are of intermediate composition. Some basalt, and, especially near the top, extensive flows of rhyolite are included. In the Bayhorse region in western Custer County, the formation has been divided into five members; the latite-andesite member, Germer tuffaceous member, basalt and related flows, Yankee Fork rhyolite member, and travertine. In the Bayhorse region, the rhyolitic member itself has three subdivisions that have been distinguished in mapping on the basis of differences in lithology. The formation is susceptible of at least equally numerous subdivisions in most areas in which sufficient of it is preserved. Lateral changes are so marked, however, that few such subdivisions retain their precise identities far from the localities where first recognized.

The Germer tuffaceous member of the Challis volcanics in and near its type locality near Challis, Custer County, has been mapped in some detail and thus was distinguished on the State map without difficulty.

Clastic beds, mostly water-lain and in large part tuffaceous, are known to be associated with the Challis volcanics in numerous places in south central Idaho, but have been mapped in only a few places. These are shown on the State map with the same map symbol as the Germer tuffaceous member. The largest masses so shown are in and near the valley of Lemhi River, eastern Lemhi County; but lenses are mapped near Hailey, Blaine County, and elsewhere. Tuffaceous beds are known to be abundant near Bonanza, western Custer County, and also in eastern Valley County, but these were not on the State map.

Commonly, clastic strata are more plentiful in the upper than the lower part of the Challis volcanics in each locality. Nearly all are water-laid, but most are tuffaceous and a few are the direct products of volcanic eruption. Much of the welded tuff, which resembles lava in the field, is grouped with the lava on the map. In Germer Basin and a few other localities the clastic beds constitute almost the whole of the Challis volcanics present, and have thicknesses as great as 2,000 feet. In each of these localities, however, lava flows are plentiful in the neighborhood. Clearly, all the different masses of clastic strata, mapped and unmapped, are not at exactly equivalent stratigraphic horizons. All are, however, embraced within the age range of the Challis volcanics. Thus they are younger than the Wasatch formation and older than most or all of the sedimentary strata of Cenozoic age. One such mass, near Salmon, has recently been designated the Carmen formation by Anderson (1956, p. 28–31). This mass is probably somewhat younger than the beds in and near Germer Basin.

Beds on the Montana boundary in and near T. 17 N., R. 27 E., somewhat similar lithologically to the Germer tuffaceous member of the Challis volcanics, and the Carmen formation of Anderson, have been shown on the basis of unpublished studies of R. W. Brown and others to be middle Miocene or younger. These are grouped on the State map with the Salt Lake formation of Pliocene age and associated strata.

The age of the Challis volcanics of south central Idaho is still under study, although the position of the formation with respect to other units of Tertiary age is now established fairly closely. A review of the then-available information led Ross (1937, p. 65-68) to the opinion that "The Challis volcanics are possibly, if not probably, of Oligocene age and that they can hardly be younger than early Miocene." Since then, additional fossil evidence has been accumulated, mostly by R. W. Brown. Decision as to whether some of the fossil collections are best regarded as of late Oligocene or early Miocene age has not yet been finally reached by Brown. It seems, however, increasingly clear that the fossils from the Germer tuffaceous member near Challis represent a lower horizon than those from the Carmen formation recently named by Anderson near Salmon. The latter fossils come from strata that, on the whole, are less tuffaceous than the Germer. It seems entirely possible that the lower part of the Challis volcanics is of Oligocene age while some of the beds high in the sequence may be as young as early Miocene.

The single, hitherto unpublished, age determination on zircons, by the Larsen method now available implies that the Challis volcanics were erupted earlier in the Tertiary period than is indicated above. This determination was made from a sample of the granite that intrudes the Challis volcanics near the Middle Fork of the Salmon River. The age indicated is 59 million years which would be near the beginning of Tertiary time, (as currently accepted) much earlier than the fossils suggest. More data are needed on this point but an assignment of the Challis volcanics to an earlier date than has been given them would have little effect on concepts regarding geologic events in the region.

Columbia River basalt

In early geologic studies in the northwestern United States such names as Columbia lava and Columbia River basalt were applied to the great mass of dominantly basaltic rocks in the region drained by the Columbia River. As originally defined (Russell, 1893, p. 20-22) this unit included the Snake River basalt. The Geological Survey at present recognizes Columbia River basalt as a convenient blanket term, covering basalts of Eocene, Miocene, and Pliocene(?) age in the broad region described by Russell (Wilmarth, 1938, p. 494-495). Current usage in Idaho restricts the term to a unit that consists mainly of flows of basaltic and kindred composition that extend interruptedly from the vicinity of South Mountain, Owyhee County, through western Idaho at least as far north as Kootenai County. Some, perhaps many, of these flows are slightly less calcic than true basalt and might more precisely be termed calcic andesite. The maximum thickness of lava in the unit as thus limited is estimated by Kirkham (1931, p. 571-577) to be probably more than 3,000 feet. The flows are associated with sedimentary beds which in places reach thicknesses in excess of 1,000 feet (Kirkham, 1931, p. 232). These sedimentary beds include strata that in southern Idaho have been referred to the Payette formation (Miocene and Pliocene(?)) and others farther north that contain flora typical of the Latah formation (middle or upper Miocene). Recent unpublished studies show, according to R. W. Brown, that the flora from the Payette formation near Weiser, Washington County, and from similar beds near Idaho City, Boise County, is essentially the same as flora from the Latah at Spokane, Washington, and distinctly younger than the flora in the Challis volcanics. On this basis the Columbia River basalt in Idaho would seem to be of Miocene age and much, perhaps all, of it not older than middle Miocene. This conclusion is in accord with available information as to the relation of the Columbia River basalt to other rocks and to the history of the development of land forms in the region. Recent, mostly unpublished, studies of invertebrate fossils by Dwight Taylor and of diatoms by K. E. Lohman suggest the Payette formation may be younger than Brown's work would indicate. Whether of Miocene or Pliocene age, it seems clear that the flows in western Idaho commonly called Columbia River basalt and the sedimentary rocks intercalated in them are younger than the Challis volcanics and older than most of the volcanic and sedimentary rocks that floor the Snake River Plain. Numerous changes in nomenclature and age assignment for the Cenozoic strata in Idaho are to be expected as a result of studies now in progress.

In most localities in Idaho the Columbia River basalt, in the restricted sense here proposed, is easily recognized. Some problems and border cases, however, remain. For example, although most of the Columbia River basalt in Owyhee County is distinctly older than the silicic flows there and in adjacent parts of Twin Falls County, flows that seem lithologically indistinguishable from the Columbia River basalt are locally interbedded in the silicic rocks. Where these have been mapped, as in the vicinity of Jordan Creek, they have been given the same designation as the Columbia River basalt on the State map, but detailed studies might require other treatment.

Payette formation and related strata

The rocks shown on the State map as Payette and related strata include beds that, although having many resemblances, have a considerable range in age. The rocks so grouped have affinities to the Payette formation (commonly regarded as Miocene) the Latah formation (middle or upper Miocene), and the Idaho formation (Pliocene). The Idaho formation, according to some geologists, includes some Pleistocene beds. The Payette formation and related strata are exposed principally along the borders of the western part of the Snake River Plain, but continue at intervals and in relatively smaller masses into northern Idaho. Strata that belong with this assemblage are known to be present in many places in this region where they cannot be shown on the State map, either for lack of information or because they are so intercalated in lava as to be exposed in strips too small to show on the scale used. Lack of adequate information led to a somewhat arbitrary separation in which the unit that includes the Payette formation is mostly west of 114° West longitude, whereas that which includes the Salt Lake formation is east of that meridian. This corresponds essentially to the current usage but some components of the two assemblages are nearly equivalent to each other. Part of the rocks here grouped together belong to what has been called the Payette formation. This formation is the product of deposition of sand, clay and gravel, mingled in places with the products of ash showers. Diatomaceous beds are present in several localities. Many of the clay beds are carbonaceous and locally contain lignite, generally of inferior quality. Some of the strata of the Payette formed in local and in part ephemeral lakes, but a large part of the material was deposited in alluvial fans and along the course of ephemeral streams. The maximum thickness of the unit is probably much more than 1,000 feet.

The early concept that the Payette and Idaho formations represent two successive stages of a large lake, with the division between them at some horizon not definitely fixed, within the sedimentary succession above the Columbia River basalt (Lindgren, 1898a, p. 632-637) is so much at variance with facts now known that it must be abandoned.

Kirkham (1931, p. 232) desired to restrict the Payette to sedimentary rock that "generally occurs interbedded with the Columbia River basalt," commonly about 600 feet below the top of the basalt

unit--a suggestion that has much to commend it in the areas in which he worked. He has mapped the formation on this basis in an area in southwestern Idaho comprising T. 1 S., to T. 13 N., R. 5 W. to R. 1 E., inclusive, and the area within the bend of the Snake River northwest of Weiser. Such details as are now available suggest that there is much local variation in the stratigraphic positions of sedimentary rocks associated with the Columbia River basalt and that in places it is still difficult to distinguish these from similar but younger rocks nearby. Also, isolated exposures, such as those of Boise Basin, cannot be satisfactorily correlated at present. Those in Boise Basin are grouped with the Payette formation on the State map, but may be older.

Uncertainty remains as to the precise stratigraphic relation between strata of Payette age and those in northern Idaho that contain a Latah flora. Most of the rocks of Latah affinities in Idaho (Kirkham and Johnson, 1929, p. 484-504) are in rather small masses, relatively few of which have been delimited on any geologic map.

In a general way the term Idaho formation is applied to those Cenozoic sedimentary rocks in and near the western part of the Snake River Plain that have broad lithologic and genetic resemblances to the Payette formation but are younger. The strata of the Idaho formation as thus limited are, on the average, somewhat finer grained and less firmly consolidated than the Payette but this distinction is not sufficient to be readily used in mapping. The unit, probably several thousand feet thick, is the most extensive of those grouped as Payette and related strata on the State map. It is interbedded with Snake River basalt and overlies silicic and older rocks, in many places with appreciable unconformity. The name Idaho formation has not been applied in eastern Idaho although similar rocks exist there. In those places in which modern, detailed work has been done, the tendency has been to assign local names to strata of Idaho affinities. The best example of this is the name Hagerman lake beds. This name is essentially synonymous with Idaho formation for the area in which it has been applied, but has the advantage that it is tied to upper Pliocene fossils whose stratigraphic relations are known definitely. These show that the Hagerman lake beds appear to be continuous with the Idaho formation of areas farther west but detailed relationships remain to be determined.

The silicic lava flows and welded tuffs that lie under the Snake River basalt in places contain many intercalated sedimentary beds which locally include tuffaceous material. These are especially abundant in parts of Twin Falls and Cassia Counties. In the latter county it is possible to map them separately from the flows and welded tuffs. As they seem more nearly equivalent to strata of the Payette formation and are surely older than certain somewhat similar rocks with which they are in contact in northeastern Cassia County, they have been included in the Payette formation and related strata on the State map.

Salt Lake formation and associated strata

The rocks designated the Salt Lake formation and associated strata are exposed mainly in and near the eastern part of the Snake River Plain. They include all the sedimentary deposits of Tertiary age other than those mapped as the Wasatch formation in this region. Similar rocks in eastern Custer County are included in this unit.

Both the Salt Lake formation and the subordinate units, mostly unnamed, here grouped with it consist largely of sand, silt, and gravel, generally rather poorly consolidated, of lacustrine and fluviatile origin. Some fresh-water limestone and tuffaceous beds are included. Rhyolitic material, largely welded tuff and basalt are intercalated at several horizons. These are shown separately, so far as information permits. The sedimentary beds are commonly several hundred and in places well over 1,000 feet thick. G. R. Mansfield and his associates (Mansfield, 1952, p. 44-46) believed them to include beds of Pliocene and probably also of Pleistocene age; the Salt Lake formation is considered to be of Pliocene age by the U. S. Geological Survey. These studies show convincingly that many of the rocks, particularly in and near Bonneville County, must be regarded as not older than the Idaho formation (Pliocene) of western Idaho, and that probably most of them are younger. It has been suggested that the association of rhyolitic material with the Salt Lake formation is a basis for correlation of that unit with the Payette formation. Some of the youngest of the rocks in Bonneville County, however, are interbedded with rhyolitic material, and this association is an insecure basis for correlation. The rhyolitic rocks require much additional study before they can be safely used as horizon markers outside of limited areas where their stratigraphic relations are known.

Silicic rocks associated with the Snake River basalt

All of the volcanic rocks that are associated with the Snake River basalt, but that are decidedly silicic in composition and have a field resemblance to rhyolitic lava, are here mapped as a unit. Most of these rocks underlie the basalt but some are at higher horizons. Silicic volcanic strata are exposed at intervals along the borders of the Snake River basalt all the way from the vicinity of Yellowstone National Park to the Oregon State boundary, and are also revealed here and there in canyons that have cut through the basalt. The largest exposed masses are in Ts. 2 to 15 N., Rs. 32 to 46 E., between the Montana boundary and 44° latitude, and on both sides of the Snake River Plain from near 114° longitude westward into Oregon. Most of the numerous scattered exposures of similar rocks in and near Bonneville and Bingham Counties are at higher horizons, and generally in far smaller individual masses.

All of these rocks have commonly been called rhyolite, and the larger masses include much lava to which this name is strictly applicable; however, there is considerable variation in composition and appearance among them. Quartz latite, latite, dacite, and andesite have been recognized, and in addition much of the material,

especially among the rocks of conspicuously glassy character is now known to be welded tuff rather than lava (Mansfield and Ross, 1935, p. 308-321; Stearns, Crandall, and Steward, 1938, p. 35-42).

Basalt is associated with the rhyolitic rocks at various horizons. It has been mapped separately where possible, though in some areas, such as southern Twin Falls County, flows of this or similar composition have been noticed but not yet distinguished on a map.

The silicic rocks have a wide range in thickness in different localities, depending in part upon their stratigraphic position. Those that underlie the Snake River basalt probably average 1,000 feet in thickness and are reported to be locally nearly 2,000 feet thick. In scattered exposures in Bonneville County, however, many of the young silicic strata, largely welded tuff, are less than 50 feet thick and none is more than a few hundred feet thick.

The rocks of this unit probably have a considerable range in age and will be further subdivided when information permits. The oldest and largest part of this group comprises rocks that underlie the Snake River basalt. They can hardly be younger than Pliocene; the basal portion may be at least as old as middle Miocene because part is associated with the uppermost horizons of the Challis volcanics, and, in Owyhee County, rhyolite is interstratified with basalt resembling the Columbia River basalt. This conclusion is strengthened by the fact that in Malheur County, Oregon, near the Idaho boundary, beds that overlie rhyolite contain fossils regarded as of middle Miocene or slightly later age (Gazin, 1932, p. 37-86). As noted above, the youngest of the sedimentary rocks with which rhyolitic material is associated may be as young as Pleistocene.

Snake River basalt

The term Snake River basalt is generally applied to the flows of basaltic composition that underlie most of the Snake River Plain and to similar, closely related, rocks in neighboring areas. The rhyolitic rocks discussed above and all older strata are excluded from the Snake River basalt by most geologists. As thus restricted, this basalt extends from Fremont County south and west across Idaho into Oregon and Nevada, a total area of more than 10,000 square miles. Where detailed studies have been made local names have been applied to parts of this great basaltic aggregate or to clastic units interbedded with the basalt. Most of these local units have not been shown individually on the map. Where available information and the scale of the map permit, sedimentary units have been shown. Those masses of basaltic lava that have been recognized as much younger than the greater part of the Snake River basalt have also been mapped separately. They constitute the uppermost members of the formation.

Probably most of the flows that make up the Snake River basalt are strictly of basaltic composition but insufficient petrographic work has yet been done to determine how much calcic andesite is present. Some rock of even more silicic composition has been grouped

with the basalt locally, but it seems probable that future work will show that this rock belongs more properly with other units. As large parts of the Snake River Plain are relatively undissected, the maximum thickness of the basalt is unknown. It is certainly as much as 700 feet and may be much greater.

The Snake River basalt, as here restricted, ranges in age from Pliocene to Recent. According to Stearns (Stearns, Crandall, and Steward, op. cit., p. 56), who has made widespread studies of the rocks of the Snake River Plain, all the volcanic and sedimentary material laid down there from the end of deposition of the Hagerman lake beds to the end of the deposition of the older alluvium is of Pleistocene age. On this basis probably much the greater part of the Snake River basalt is Pleistocene. Studies now in progress by Howard Powers and others suggest that the proportion that is of Pleistocene age is even greater than has been supposed. The distinction between the Snake River basalt and the supposedly Miocene flows termed Columbia River basalt in the present report is, in most places, easy to make on the basis of degree of alteration and relations to other rocks. Similarly the part of the Snake River basalt that is of Recent age can be distinguished from the rest of the formation wherever detailed mapping has been done.

Glacial deposits

The mountainous parts of the State have been subjected to glaciation to some degree, and the topography of parts of them has been profoundly modified by the action of the numerous glaciers. Most of the glacial deposits that remain are in narrow mountain valleys. They are so mingled with alluvium that they have been grouped with alluvial deposits on the map, where large enough to be shown at all. However, in a few places, notably in Fremont, Bonner and Kootenai Counties, the glaciers reached the larger valleys between mountain masses and left moraines and outwash deposits so extensive that they have been mapped as such. Although patches of perennial ice may still remain in some of the higher mountains, it is probable that all of the glacial deposits large enough to appear on the map are of Pleistocene age. They formed in several stages.

Young lake sediments

In some areas in eastern Idaho there are such widespread deposits of unconsolidated lake beds that they can be shown readily on the State map. The silts of this character that floor valleys in Oneida County constitute northward extensions of deposits that occupy wide areas in Utah. Most of them were laid down in Pleistocene Lake Bonneville, which in periods of maximum expansion reached far into southeastern Idaho. The lacustrine deposits near American Falls appear to have resulted from the damming of the Snake River by basalt at some time during the Pleistocene epoch. The lake deposits mapped farther north, in Jefferson County and adjacent areas, are related, for the most part, to Mud Lake, to Market Lake, and to streams that issue from the surrounding mountains. There seem to have been lakes

here at least as long ago as the early part of the Pleistocene, but most of the deposits now at the surface are much more recent. Indeed, deposition is still in intermittent progress as the lakes fluctuate in response to changes in the weather and in the needs of agriculture.

Alluvial deposits

Except for the glacial and lake deposits just described, unconsolidated materials have been somewhat loosely grouped as alluvial deposits on the State map. Most of them are floodplain and fan deposits along modern streamways; some are terrace deposits. The largest of the terrace deposits are along the Snake River west of Boise and have been called the Upper and Lower Mesa gravels by Kirkham (1931, p. 235-265). Landslide debris, which in a few places forms relatively large masses--some near Grangeville for example--has been grouped with the alluvium on the map.

In some places, particularly in and close to the Snake River Plain, deposits laid down by the wind are widespread. Where these form merely a thin surface layer of shifting sand, rarely more than a few inches thick, they have been ignored in mapping. Dunes and the thicker bodies of wind-blown sand are grouped with alluvial materials. The greater part of the unconsolidated material here considered is of Pleistocene and Recent age, but some Pliocene material may be included.

INTRUSIVE ROCKS

Precambrian intrusive rocks

The Belt series of northern Idaho contain sills, dikes, and irregular masses of igneous rock, most of which are believed to have been intruded prior to the deformation that affected these rocks near the end of the Proterozoic era. Most of the intrusions consist of gabbro and diabase but dioritic and granitic differentiates are present locally. Many of the sills are hundreds of feet thick and some are as much as 2,000 feet thick. Genetic relations between these sills and the Purcell basalt have been suggested. The more calcic and smaller of the intrusive masses are somewhat similar to small intrusive bodies in the same region that are known to be younger, so that there is a possibility of confusion in identity.

South of 45° North latitude Precambrian intrusive bodies are both scarce and small. Small metamorphosed diabase dikes and sills in northwestern Lemhi County and in Valley County appear to be Precambrian. The granitic gneiss in Fremont County has already been mentioned.

Intrusive rocks of Mesozoic age

All of the granitic rocks and their associates in Idaho that cannot be clearly demonstrated to be of Tertiary age are grouped, for convenience, as Mesozoic intrusive rocks. The Idaho batholith is by far the largest single mass of such rock, but parts of another big

batholith occupy large areas in northern Idaho. Stocks or small batholiths are plentiful, and there are numerous dikes and other satellitic intrusions so small that they are not shown on the State map.

The Idaho batholith

The Idaho batholith is exposed from southern Elmore County northward through the center of Idaho into Montana. It has a relatively flat top; is about 250 miles long and 90 miles in maximum width. Its surface is inclined so that it is highest towards the south. Within the zone accessible to observation, the sides are rather steep and flare outward. No evidence of a floor or of contraction in depth has been recorded. Most of the rocks intruded by the batholith, especially in north central Idaho, belong to the Belt series. Paleozoic strata are invaded along the southeastern border, and on the west side rocks as young as Triassic and possibly Jurassic have been cut. Much of the batholith is overlapped unconformably by Tertiary rocks, some of which may be as old as Oligocene.

The main mass of the batholith consists largely of rather calcic quartz monzonite but locally rocks as silicic as true granite and, on the other hand, as calcic as granodiorite and even quartz diorite are included. As now mapped, the batholith also includes in its outer parts various gneissic and associated rocks that genetically belong more properly with the border zone than with the main body of the batholith. In reconnaissance work the tendency has been to group with the batholith rocks of granitoid appearance and to map separately only those masses in which distinctly stratiform material is abundant. This tendency has been encouraged by the fact that most of the rock of the batholith, even in the interior of the mass, has a faint gneissic structure.

It seems that the greater part of the Idaho batholith was intruded as a unit or as a number of large, intimately related units. Changes in fabric and composition are fairly common but in many places the different varieties merge into each other without mappable boundaries. These changes record movement in the magma, combined with some differentiation and late-stage modifications during the long time required for so large a mass to come into position and consolidate. However, a number of discrete masses are known within the area of the batholith and more will be discovered as detailed studies progress.

The border zone

The gneissic border of the Idaho batholith is an incomplete, complex outer shell of metamorphic and igneous rocks. It contains intruded and infiltrated igneous material, darker and more calcic than the main mass of the batholith and cut by offshoots of the latter. Gneissic material that has similarities with the main mass and, at least locally, grades into that mass (Ross, 1952; Hamilton, 1953, p. 1531; Hietanen, 1956, p. 3-22) is also present. The shell includes masses of sedimentary rock now so intimately penetrated and replaced

by igneous material as to be scarcely recognizable. Along the northern part of the batholith on both flanks most or all of the sedimentary rock involved belongs to the Belt series. South of latitude 46° on the western border of the batholith much of the sedimentary rock in and near the border zone is of Permian, Triassic, and possibly also Jurassic age. Along those parts of the eastern border, south of Challis, where the batholith is in contact with folded rocks of known Paleozoic age the gneissic border zone is absent. The Paleozoic rocks, which include much limestone, were locally so metamorphosed as to be largely replaced by silicates but so little igneous material was injected into them that gneisses have not been mapped. However, certain outliers of the batholith in this region are in part gneissic or have gneissic borders.

Nearly everywhere, the igneous gneiss includes and is associated with distinctly stratified rock which, however, has the mineral composition and closely approximates the texture of igneous material. In places, notably along the Salmon River near Shoup, the border zone consists almost exclusively of stratified rock of this character. Dikes and irregular masses of aplite, lamprophyre, pegmatite, and other diverse igneous rocks cut the gneissic border zone in numerous localities. Some of the latter are offshoots of the main batholith and are similar to it in composition, showing that the border zone formed in large part before the main mass consolidated; yet, in many places the contact between the outer zone and the main interior mass is gradational. Probably the zone includes a medley of rock consolidated from molten magma and rock produced by intrusion and permeation of originally sedimentary material both by magma and by more tenuous emanations of igneous material. In places these hybrid rocks grade outward into obviously sedimentary material, mostly belonging to the Belt series, altered by contact metamorphism. Evidence is accumulating that there have been late-stage changes in the rock of the Idaho batholith, perhaps especially in the gneissic border zone.

Outlying intrusions

On all sides of the Idaho batholith and at varying distances from it there are stocks and batholiths. Most of such masses in Idaho except those clearly of Tertiary age are commonly regarded as related in a broad way to the Idaho batholith. This opinion rests merely on general similarities in character and structural relations and on propinquity. If adequate evidence were available, appreciable age differences would probably be found to exist. The large granitic mass that extends from south of Pend Oreille Lake northward into British Columbia and westward into Washington is intermediate in position between the Idaho batholith on the south and the Nelson batholith on the north. Because of this position, the harmonious trends of the three batholiths, and other similarities, close relationships between them seem indicated. Similarly the different granitic masses in Owyhee County may be akin to the Idaho batholith. They might even be connected with it beneath the cover of younger rocks that now separates them.

The granitic rocks in Cassia County are regarded by Anderson

(1931, p. 55-56) as related to the Idaho batholith, but these masses are farther from the central batholith and differ somewhat from it petrographically. Peripheral portions are reported to consist mostly of granite, with granodiorite as the core. The granite of the outer zone is regarded by Anderson (1934, p. 376-392) as the product of impregnation and replacement of quartzite by igneous emanations.

There are several other granitic masses in Idaho, mostly smaller than those referred to above; they are mapped with Mesozoic intrusive rocks. They range in composition from soda granite to calcic quartz diorite; a few masses have other compositions. A few, particularly some of those that cut the Seven Devils volcanics, are sufficiently metamorphosed to suggest that they are older than the rest. A considerable number of the larger ones consist mainly of quartz monzonite and granodiorite that closely resemble the normal rock of the main batholith. So far as can be judged from analyzed material, however, the average composition of the outlying masses is somewhat less silicic than that of the main batholith. The comparatively large mass northeast of Ketchum, Blaine County, has a granodiorite core surrounded by a marginal zone of dioritic and gneissic rocks. During the original examination of this area (Umpleby, Westgate, and Ross, 1930, p. 45-49) the concept that the gneissic rocks of the marginal zone might be of sedimentary origin was rejected with some hesitation. However, in view of the fact that sedimentary rock so thoroughly impregnated with igneous material that its sedimentary origin is scarcely recognizable is now known to exist in other parts of Idaho, it is probable that the more strikingly laminated parts of the gneisses northeast of Ketchum may be metamorphosed sedimentary rocks.

Age relations

The age of the different rocks here grouped as Mesozoic intrusive rocks is susceptible of proof by the methods of field geology only within rather wide limits. This is to be expected in view of the fact that most of the rocks were exposed only after deep erosion obliterated many clues to their age. Further, the various steps that led to the final consolidation of such widespread intrusive units, some of which are exceptionally large, must have occupied a long time interval. The age range of the group as a whole is roughly limited by the fact that in places Triassic and possibly Jurassic rocks are invaded and that other rocks thought to be as old as Oligocene rest on the eroded surfaces of granitic masses. Closer dating depends mainly on inference in regard to the geologic history of Idaho and neighboring regions.

It is unlikely that the Idaho batholith came into place before the Early Cretaceous, or at most the Late Jurassic epoch and it is possible that its main mass did not consolidate before the middle of the Cretaceous. Some, perhaps most, of the intrusions west of the Idaho batholith may be somewhat older than the batholith. The small, metamorphosed intrusive masses in the western part of the State probably should be correlated with the early Mesozoic intrusions of eastern Oregon (Gilluly, 1937, p. 27-41). The Boulder batholith in west-

ern Montana has been thought by those who have studied it to be of early Eocene age and surely not older than Late Cretaceous. This batholith, although close to the easternmost part of the Idaho batholith, differs from the latter in trend, petrographic details, and the character of the associated ore bodies.

In recent years field methods of age determination have been supplemented by the Larsen method (Larsen, Keevil, and Harrison, 1952 p. 1045-1052). Most of the determinations so far made by this method on samples from the Idaho batholith give consistent results. Their average (Faul, 1954, p. 262-266; Larsen, Gottfried, Jaffee, and Waring, 1954, p. 1277) indicates an age of about 103 million years, which agrees with the geologic age previously deduced by field methods. Only one sample from an outlier of the batholith has been studied by the Larsen method. The result, hitherto unpublished, indicates an age of 111 million years. This sample is from a somewhat complex mass south of Hailey (Hewett, 1930, p. 211-214). Some indication of the age of the isolated intrusive masses in the Coeur d'Alene region of northern Idaho is afforded by two determinations cited by Faul. These are from monzonite near Wallace. One determination indicates 90 million years, the other 115 million years, thus suggesting that the rock is not far different in age from the Idaho batholith.

A number of geologists have postulated that there may have been an eastward migration of batholithic activity from near the Pacific coast into Montana. This concept is not borne out by determinations by the Larsen method because, as shown by the determinations cited by Faul, the southern California batholith is about 102 million years old and the Sierra Nevada batholith about 103 million years. Thus the batholiths near the Pacific coast seem to be of the same age as the Idaho batholith. The Boulder batholith, with an age of about 68 million years is, as previously supposed, younger than the Idaho batholith. There was recurrence of igneous activity across the region containing the Idaho batholith in Cenozoic time. The intrusive bodies introduced during the Cenozoic may have had little direct, genetic relation to the Idaho batholith.

Intrusive rocks of Tertiary age

Granitoid masses and related dike zones of Tertiary age have been mapped in several parts of Idaho. The largest assemblage of such rocks is along the middle reaches of the Middle Fork of Salmon River; another large zone of intrusive masses and dikes extends across the northwestern part of Boise Basin, Boise County, and continues to the vicinity of Pearl, Gem County. The area between the Middle Fork of the Salmon and Boise Basin has not yet been mapped in detail but it probably contains dikes that constitute connecting links between these two assemblages of Tertiary rocks. In and south of southern Custer County, near Mackay, Martin, and Ketchum, Tertiary intrusive rocks are exposed in several areas. Smaller groups of dike rocks are present in other parts of the State. All the different volcanic rocks in the State necessarily have intrusive feeders, but few such feeders have been definitely recognized.

The Tertiary intrusive rocks can be divided into those of granitic texture and those sufficiently fine-grained so that components of the groundmass are not readily distinguished by eye. The granitic rock along the Middle Fork of the Salmon has a roughly domelike upper contact and has at least part of a floor, so that it resembles a highly irregular laccolith. The other granitic bodies are less adequately exposed but some are sufficiently steep sided to suggest stocklike rather than laccolithic form.

The finer grained intrusive bodies have diverse shapes. Like the principal intrusive mass northwest of Ketchum, Custer County, that is exposed over more than 10 square miles, some are fully as large as some of those with granitoid texture. This body and others nearby have numerous apophyses whose connections with the main bodies have not yet been exposed by erosion. Probably most of the finer grained Tertiary intrusions are dikelike. They are irregular in many ways and the larger ones are lenticular in horizontal cross section. Some of the smaller ones, in bedded rocks, are sill-like.

The Tertiary granitic rocks of central Idaho range in composition from granite to diorite, and may include even more calcic varieties. Most of the larger masses consist of true granite, generally pinkish, coarse grained, and are without the faintly gneissic structure characteristic of much of the Mesozoic granitic rock in Idaho. A few are miarolitic. Microcline-microperthite commonly makes up nearly half of the components of the Tertiary granites. Quartz is abundant and dark minerals generally form less than 10 per cent of the whole and locally are almost absent. Small amounts of micropegmatite are fairly common. The more calcic varieties of Tertiary granitic rocks are somewhat less readily distinguished from the older rocks than the pinkish granite but many of them contain some micropegmatite and they are rarely gneissic. None of the masses here regarded as of Tertiary age has a gneissic border zone like that of the Mesozoic intrusions. However, in one locality on the Middle Fork of the Salmon River the pink, Tertiary granite has added somewhat to the metamorphism of material already injected and otherwise modified by the Idaho batholith. Tongues, dikelets, and even lit-par-lit injections of pink igneous material are present in the gneiss, and sporadic pink pseudophenocrysts of microcline and minor quantities of a second generation of plagioclase occur in the less thoroughly modified quartzite of the Belt series nearby.

The dike zones that are represented in somewhat generalized fashion on the State map include a wide variety of fine-grained rocks. Many of them show relationship to the granitoid rocks by the presence of micropegmatite and other intergrowths. Granophyres and porphyritic rocks that include granitic, monzonitic, dioritic, dacitic, and andesitic varieties are included, as are also a few lamprophyre dikes.

The different Tertiary intrusive rocks are for the most part allied to one another not only petrographically but also structurally. They are grouped in complementary systems of northwesterly

and northeasterly trends. They tend to be transverse to structural features in the older rocks but occupy the cores of uplifts in the Challis volcanics. The best example is along the Middle Fork of the Salmon River where Tertiary intrusive rocks are in the core of a broad, much faulted dome of northeasterly trend that involves the Challis volcanics. Similarly near Martin, Butte County, they are in a faulted dome of northwesterly trend.

Tertiary intrusive rocks cut the Challis volcanics both along the Middle Fork of the Salmon and at various localities from the head of Wood River in Blaine County, south to the border of the Snake River Plain. Some of them are probably genetically related to the lavas, especially to the rhyolitic flows in the upper part of the sequence. It has even been suggested in an unpublished report by Stewart Udell, then of the Idaho Bureau of Mines and Geology, that volcanic necks of Challis age are recognizable north of Muldoon, Blaine County. In one locality in western Idaho the intrusions were thought by Kirkham (1931, p. 578-579) to cut the Payette formation while in another locality nearby they appear to be unconformably covered by the Payette (Anderson, 1934, p. 12). In Shoshone County there are diabase and lamprophyre dikes of undetermined age. For convenience these were shown on the State map as belonging to the Tertiary intrusive rocks, although probably not synchronous with those rocks in south central Idaho.

Most of the Tertiary intrusive rocks in central Idaho are so similar in character and geologic setting that they can readily be supposed to have been intruded during a single episode. For those genetically related to the Challis volcanics this must be the case. Anderson (1947, p. 134-150; 1948, p. 91-92; 1952, p. 255-265) advocates the concept of two periods of intrusion, one very early in the Tertiary, the other in middle Tertiary time. Age determinations by the Larsen method are too few as yet to give a definite answer to this question but do suggest a considerable range in age. Of the three age determinations at hand, hitherto unpublished, from rocks that seem clearly of Tertiary age, one from a diorite in the mountains north of Boise Basin gives an age of 90 million years, one from pink granitic rock on Camas Creek near the Middle Fork of the Salmon an age of 59 million years, and one from a granite porphyry on the South Fork of the Payette west of Lowman one of 33 million years.

Bonneville County, in the southeastern part of the State, contains some peculiar intrusive rocks that are entirely different from any of those described above. They contain conspicuously abundant potassium feldspar and belong to the rare group of igneous rocks that has been termed the Highwood type (Anderson and Kirkham, 1931, p. 51-68), from the locality in Montana where they were first recognized. The age of the rocks in Bonneville County has not been determined closely, but as they are probably Tertiary they are mapped as a part of the group of small Tertiary intrusions.

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GEOLOGIC HISTORY

PROTEROZOIC ERA

Little record remains of the complex events of early Proterozoic time in Idaho. A time of marine sedimentation is represented by most of the exposed Precambrian rocks. Later Precambrian deposition took place on a sea floor that sank at about the rate that the sediments accumulated. There was little igneous activity, except in a few areas. In most of Idaho and Montana the deposition of Precambrian rocks ended with uplift and broad folding in contrast to the intense deformation that marked some later periods.

The earliest recorded events in western Montana included the invasion of a thick assemblage of sedimentary rocks by abundant igneous material, producing a basal complex that consists largely of gneiss and schist. It is now believed that very little of this basal complex is exposed in Idaho. Most of the gneissic material there formerly regarded as belonging to the basal complex is thought to have formed during the intrusion of the Idaho batholith and later igneous rocks.

With the exception of the small areas of basal complex, the rocks now supposed to be the oldest exposed in Idaho belong principally to types laid down in moderately deep seas. Neither the age of these rocks nor the areas originally covered by them has been established with certainty. Locally, glaciation and also volcanism took place in Proterozoic time and some think these events occurred early in that era. It is at least equally probable that they took place during the time in which the Belt series was being deposited.

The record for the latter part of the Proterozoic era is clearer. Much of Idaho and larger areas in neighboring regions were flooded by seas so shallow that at frequent intervals broad expanses of mud were exposed to the air. As the sediments in these shifting seas accumulated, the earth's crust slowly sank until many thousands of feet of sedimentary material--now known as the Belt series--had been laid down. Most of Idaho was little affected by igneous activity during this time, but in some northern areas extensive intrusions took place. Differentiation or some other process produced unusual variations in the composition of those intrusions that penetrated along bedding planes in sheetlike masses. Some of the igneous material found its way to the surface in one of the first of the numerous outbursts of volcanism that have been recorded in Idaho. Toward the close of the Precambrian the sediments, now consolidated into very competent rock masses, yielded to lateral compression. With the exception of a few areas where late Precambrian deformation may have been intense, the rocks of the Belt series were thrown into broad, open folds which contrast with the more intricate, close folds in the rocks of Paleozoic age. The Belt series became further cemented, and, in much of Idaho, as more highly metamorphosed than similar

material farther east. As a result of the widespread crustal movements near the close of the Proterozoic era, central Idaho appears to have risen somewhat higher than most of the rest of the State. In all subsequent history central Idaho continued to be an area that tended to rise more than surrounding regions, especially those immediately east of it.

PALEOZOIC ERA

The Paleozoic era resembled the late Precambrian in that marine sedimentation was dominant. Little igneous activity took place except in a few localities. In general, the seas were deeper and the shorelines shifted more than those of Belt time. During much of the era large parts of the State stood above sea level. The record is somewhat easier to read than that of the Precambrian because many of the Paleozoic rocks contain fossils that help to date them, and many of the rock units are both more distinctive lithologically and more restricted in extent than most of the Precambrian units.

Early in the Paleozoic era marine waters reentered parts of the State. The principal Cambrian deposits are in southeastern Idaho where in their present, much compacted, form they are more than a mile thick. Probably the sea lapped against the eastern shore of a land mass that occupied central Idaho, and extended northward into Canada. The extent to which this sea fluctuated during the period is indeterminate. The shore was so irregular that in places it projected into what is now Montana and at other points swung westward far enough so that at times it crossed what is now the narrow northern part of Idaho and entered Washington. In the closing years of Cambrian time at least part of these areas appears to have again become dry land.

In the next period, the Ordovician, the seas along the eastern side of Idaho seem to have spread out somewhat. In central Idaho they spread so far to the west that they may have lapped against the area later to be occupied by the granitic rock of the Idaho batholith. There were marked shifts in the shorelines, depth of water, and character of the deposits, but in one place or another rocks representative of most of the Ordovician period were laid down. This was so long after the Precambrian uplift that much of the land in central Idaho that had remained above sea level since that uplift had been deeply weathered and reduced to low relief by erosion. Masses of conglomerate, however, show that in places, hills remained high enough to permit exceptionally coarse rock debris to be deposited along the beaches. Neither the crustal movements that made the Cambrian seas retreat temporarily nor the numerous other disturbances that affected the rocks during the Paleozoic era appear to have been violent or to have given rise to large mountains. These crustal movements are known to have occurred because they modified the kinds of sediments being deposited and at different times and places temporarily halted sedimentation. The Cambrian and later Paleozoic rocks show marked lateral variations in character and thickness within short distances.

Marine deposits of Silurian age have been mapped in the southeastern part of the State and also in a few places in south central Idaho. They are now known to exist in several places not indicated on the map. On the whole, however, the Silurian period seems to have left relatively little impress on the State. Probably most of Idaho was above sea level during the Silurian and all of it may have been dry land during the early part of Devonian time, for Lower Devonian rocks have not been recognized.

InMiddle and Late Devonian time seas again invaded the eastern side of Idaho. They probably did not reach northern Idaho, although farther east they are thought to have stretched northward into Arctic regions. In and near Custer and Lemhi Counties in east-central Idaho the Middle and Upper Devonian rocks are especially thick and include at least one formation--the Grand View dolomite--not found elsewhere. In parts of east-central Idaho the division between Devonian and Mississippian rocks is still uncertain. Locally the transition from one period to the other may have taken place without any interruption in the deposition of sediments.

In east-central and southeastern Idaho the Carboniferous rocks are especially widespread and thick. Some of them, particularly in Blaine and western Custer Counties, contain plant remains that were extensively broken up during deposition, and, locally, abundant conglomerate that was laid down in stream channels and along steep shores. These and other evidence show that in east-central Idaho the shoreline in Carboniferous time was close to the east boundary of present exposures of the Idaho batholith and that the land where the granitic rock of this great mass now crops out was then more rugged than it was during most of the earlier Paleozoic. Apparently the late Paleozoic seas did not extend north of 45° latitude within Idaho. Along the southern border of the State rocks of late Paleozoic age are exposed in the same longitudes as those just referred to, but few, if any, other Paleozoic rocks extend as far west as this in southern Idaho.

During much of the several hundred million years of Paleozoic time, most of the seas that invaded Idaho were parts of large water bodies that extended far beyond the limits of the State. The Permian seas were comparatively small and may not have extended far south of the present state boundary. At times, however, there may have been connections with seas to the north and west. The marine sedimentary rocks of Permian age in Idaho are thin and, except for the southeastern region, scattered. In southeastern Idaho they include chert and valuable phosphate beds. It has been suggested that these rocks may have some genetic connection with volcanism, but no Permian rocks of definitely volcanic origin are present in or near southeastern Idaho. It is unlikely that Permian seas extended across any part of Idaho to join those in the southeast with those near the western border, where volcanic deposits are plentiful. If a connection existed, it was probably along a more circuitous route, conceivably through Nevada.

The facts outlined above imply that the late Paleozoic was a time of crustal uneasiness in which the crustal movements were gentle undulations, that neither crumpled nor broke the rocks. The surface rose and fell, but over most of the State uplift predominated. However, the Permian is the first period since the close of the Proterozoic era that has left definite evidence of seas within the limits of western Idaho.

MESOZOIC ERA

Marine deposition continued in parts of Idaho during the Mesozoic era, but it was overshadowed in most areas by the large-scale igneous activity and crustal movements that marked the era. If disturbances at all comparable to these had ever before affected Idaho, all record of them has been obliterated. Much of Idaho's mineral wealth resulted from the Mesozoic igneous activity, and many of the underlying factors that control the State's agriculture and its scenic features were created during that era.

Marine invasion was intermittent. In western Idaho marine deposits of Upper Triassic and Jurassic age are associated with the products of volcanism which had begun in the Permian and continued with some interruptions at least through the greater part of the Triassic period. Central and northern Idaho appear to have been above sea level throughout Mesozoic time. They were largely mountainous and still rising. The highlands probably extended as far east as the present Montana boundary and southward to the vicinity of latitude 43°30'. The sea withdrew from southeastern Idaho in Middle Triassic time and that area became a semiarid land with one or more extensive lakes. Parts of it were occupied temporarily by a sea during the Late Cretaceous epoch.

After deposition ceased in western Idaho the rocks were compressed into narrow folds of northeasterly trend. Intrusion accompanied or closely followed the folding and locally contributed to the deformation of the rocks. The intrusive masses then formed were of small to moderate size and on the whole more calcic in composition than subsequent intrusions of similar coarse texture. They are also more metamorphosed, possibly as a result of intrusion during emplacement. Some of the Mesozoic intrusions may be older than the Triassic sedimentary rocks.

Farther east the great central area that had remained relatively high since the uplift near the close of the Proterozoic era probably rose sharply. This part of Idaho was then made up mainly of the dominantly quartzitic Belt series. They were disturbed by movements in igneous reservoirs below but were sufficiently resistant to lateral compression to escape close folding and fracture.

The rocks of Paleozoic age that had accumulated to a maximum thickness of about 30,000 feet immediately east of the central raised mass constituted a structurally weak unit, and were compressed into long moderately open folds. This probably took place before the

intricate deformation in south central Idaho. As the major deformation in southeastern Idaho cannot be older than Cretaceous the early folding presumably took place late in the Jurassic period. The absence of marine strata of Mesozoic age in central Idaho makes it difficult to date Mesozoic and early Tertiary events there.

The Idaho batholith and those other intrusive masses that are related to it reached their present positions after the first folding of the Paleozoic rocks. Probably the persistent upward tendency of the earth block of central Idaho which contains the Idaho batholith was related to the processes that finally brought about batholithic intrusion, somewhat more than 100 million years ago. When intrusion did take place, the main batholith was introduced into the central positive block. Protuberances from the batholith extend westward and cut sharply across some of the folded rocks in the Seven Devils Mountains. South of latitude 45° offshoots, many of which may have been emplaced later than the main batholith, also extend eastward into the thick, folded Paleozoic rocks of the region between the main batholith and longitude 112° 30'.

That part of the gneissic border zone that is cut by the main mass of the Idaho batholith or by related rocks represents an early stage in the batholithic activity, or, conceivably, more than one such stage. On the other hand, that part of the gneissic material that is gradational with the main granitoid mass must have been formed at essentially the time that mass was introduced.

The Idaho batholith was intruded with force enough to affect the rocks on its eastern flank for as much as 50 miles from the exposed portion of the batholith. The already folded rocks along the intrusive boundary were twisted and broken to conform to the shape of the batholith. At greater distances from that boundary new folds of different trends were superimposed on those already existing; and the rocks were contorted, overturned, and broken. Some features of the folds in the Lost River Mountains and the Lemhi Range suggest that part of the deformation may have resulted from plastic flow of limestone under slight cover.

Some of the related masses of granitic rock east and north of the Idaho batholith are surrounded by or otherwise closely associated with fractures of different kinds. In northern Idaho faulting predominated over folding during and immediately after the batholithic activity. Some of the faults have vertical displacements of many thousands of feet, and some are reported to show horizontal shifts measurable in miles. In several of the mining districts complex fault systems have been mapped.

The folding and fracturing of the great mass of sedimentary rocks of Paleozoic and Mesozoic age in southeastern Idaho did not begin until Cretaceous sedimentation in that area had ceased. This indicates that the folds of that region are somewhat younger than, although similar in trend to those in central Idaho. Possibly the eastward progress of deformation outward from the locus of intrusion was so gradual

that the folds related to the emplacement of the Idaho batholith merged without interruption with those of southeastern Idaho. The wide expanse of Tertiary and Quaternary rocks in the Snake River Plain now separates the two provinces and conceals their mutual relations. Some information on this subject is to be expected when southwestern Montana is studied in detail.

CENOZOIC ERA

Idaho has been well above sea level since the dawn of the Cenozoic era. It has been subjected to repeated outbursts of volcanism on a grand scale. The rocks have been broadly warped and have been fractured, largely along old lines of weakness. Many of the State's mineral deposits were formed during one or more of the periods of intrusive activity in the Cenozoic era.

The period of folding, fracture, and uplift that began in later Mesozoic time did not cease until after the earliest of the Tertiary sedimentary rocks in regions to the east had been deposited. These movements left much of the State mountainous and therefore subject to vigorous erosion by streams. Part of the material carried off by the mountain torrents was deposited in semiarid lowlands near the eastern border of the State.

Erosion continued during early Tertiary time until much of Idaho had been reduced to a fairly level region, with only subdued remnants of the former mountain ranges remaining. As most of the major structural features that control the topography today were already in existence, many of the uplands of that day were in much the same position as the principal modern ranges.

The early Tertiary erosion cycle was interrupted by renewed uplift or some other change that gave fresh power to the streams in much of central Idaho. Consequently by the time that eruption of the Challis volcanics began, nearly 30 million years ago, the total relief was great, although large parts of the comparatively level areas formed earlier had not yet been destroyed by stream attack. The lava flows of the Challis volcanics spread widely, filling valleys and burying interstream areas, including all but the highest summits in Blaine, Butte, Custer and parts of Lemhi and Valley Counties. Some of the numerous vents from which the lavas came were fissures; others may have been conical volcanoes. At times, especially near the end of the eruption of the Challis volcanics, the molten material surged to the surface with such explosive violence that ash showers swept over much of the region, blanketing the landscape and mingling with stream and lake sediments. These deposits consolidated to form tuff and in certain localities filled deep topographic depressions. Some of these depressions are situated along zones of structural disturbance that affected the volcanic rocks over wide areas and may have formed as a result of local crustal subsidence during the eruptions. There were pauses in the ash falls long enough to permit the growth of redwood trees 10 to 15 feet in diameter.

One of the principal zones of disturbance affecting the Challis volcanics extends from eastern Gem County through the vicinity of the Middle Fork of the Salmon River and across Lemhi County, a distance of more than 150 miles. Near the Middle Fork this zone is marked by a broken arch in the volcanic rocks. The granitic mass near the axis of the fold was intruded during the arching of the rocks. Beyond the limits of the Challis volcanics the zone is marked by fractures, many of which are filled by igneous rock. Other zones of fracture, mostly marked by similar intrusive rocks, are widely distributed in the State. They are grouped into sets with average trends of roughly N. 40° to 50° E. and N. 40° to 50° W.; a less prominent set trends nearly north.

The deformation was followed by prolonged erosion. At the time that the Columbia River basalt invaded western Idaho the topography was sufficiently subdued so that the flows were able to spread over extensive areas and in places to extend into the central part of the State. The parts of Idaho where the Columbia River basalt is especially thick, notably the Clearwater Plateau, sank so that the flows at the base of the formation are now well below sea level. At the same time central Idaho, in keeping with its long-retained role as a rising block, was again uplifted. These changes were brought about partly by broad warping, partly by faulting.

Most of Idaho north and west of the Snake River Plain has been free from volcanism since late Miocene time. In southern Idaho, however, volcanic activity has continued intermittently to Recent time. The eruption of rhyolitic material began in the Miocene or Oligocene and continued until much of southern Idaho was covered by rhyolitic material before the flows of Snake River basalt began. Toward the southwest the rhyolitic rocks were especially widespread and extended beyond the borders of Idaho into Nevada and Oregon. The Snake River basalt which followed was almost equally widespread but the thickest accumulations were in an area of subsidence corresponding approximately to the present Snake River Plain. Subsidence may have begun during the eruption of the Columbia River basalt, that is, prior to eruption of the Snake River basalt. Locally the rhyolitic rocks were warped along the borders of the plain before the deposition of the Snake River basalt began; in the Owyhee Mountains, the western part of the Minidoka National Forest, and other places they were raised into arches against which the basalt flows lapped. In the central parts of the plateau areas, in and near Owyhee County, the rhyolitic rocks remain little deformed. The eruption of basalt through fissures has continued in the Snake River Plain intermittently until Recent time, the youngest flows being probably no more than a few thousand years old. In parts of eastern Idaho, along the borders of the Snake River Plain, rhyolitic eruptions mainly of the explosive type may have continued on a small scale until very recently. Although the subsidence or downwarp of the Snake River Plain area was well advanced before most of the Snake River basalt was erupted, sinking probably continued as the load of lava and interbedded sediments increased, and as the crust beneath was weakened by withdrawal of lava from underground reservoirs. As a result the base of the Tertiary accumulations under the Snake River Plain, particularly near the Oregon boundary, is now far below sea level.

While these events were taking place in the Snake River Plain the more mountainous parts of the State were undergoing crustal movements and erosion was active. The principal features of the complicated erosional history reflected in the present topography are summarized below.

GEOMORPHOLOGY

GEOMORPHIC PROVINCES

According to Fenneman (1931, p. 150-273) much of Idaho is in the western part of the Northern Rocky Mountain Province although he suggested that the Middle Rocky Mountain Province extends into the State along the boundary with Wyoming; the valley of the Snake River and adjacent areas lie in the Columbia Plateau Province; and the northern end of the Basin and Range Province includes part of southeastern Idaho. Anderson (1941, p. 206-222) proposed a revision of Fenneman's unit designations in Idaho. He classified the entire crescentic area of the Snake River Plain into a single section of that name; set the southwestern part of the State aside as the Owyhee section; and divided the part of Idaho north and west of the Snake River Plain into the Seven Devils and Craig Mountain sections. Anderson also suggested modifications in details of the province boundaries throughout the State. Freeman (1940, p. 12-20; 1942, p. 59-79; 1942, p. 65-78; Caldwell, 1942, p. 79-87; Forrester, 1942; p. 80-96) has made proposals in regard to the Columbia Plateau Province that differ from those of Anderson and, more recently, Freeman together with Forrester and Lupher (1945, p. 53-75), has suggested a more specific and thorough definition of that part of the so-called Columbia Intermontane Province that lies in and near Idaho. The province and section boundaries on their map are reproduced on figure 1 of the present report with minor differences. The changes in the boundaries are based mainly on the geologic map of Idaho. Minor changes in the names of some of the sections are also indicated on figure 1.

The general east-west sweep of country that includes the Snake River Plain across southern Idaho and extends westward across much of Oregon was called the High Lava Plains subprovince by Freeman, Forrester, and Lupher (1945). It, in turn, included the Snake River Plain section on the east and the Malheur-Boise Basin section in western Idaho and eastern Oregon. For present purposes their Malheur-Boise Basin section is termed the Malheur-Boise-King Hill section and the section east of it becomes the Eastern Snake River Plain section. These changes avoid confusion with the well-known topographic features called Boise Basin and Snake River Plain. Other names are not changed. The Owyhee Upland to the southwest is a separate subprovince and the Wallowa-Seven Devils and Tristate Uplands of the major Central Mountains Subprovince are respectively the essential equivalents of Anderson's Seven Devils and Craig Mountain sections.

The Northern Rocky Mountain Province is sharply bounded on the south by the High Lava Plains Subprovince of the Columbia Intermontane Province. The western border extends northerly from near Boise, Idaho, separating the hills and valleys of the Wallowa-Seven Devils and Tristate Upland sections to the west from the higher mountains to the east. Farther to the north in the vicinity of Headquarters and Elk River, the border swings westerly and then continues along a north-south line almost coincident with the Idaho-Washington state

line. On the east and northeast, the province extends into Montana and, to the extreme northwest, it reaches into Washington.

Within Idaho, the Northern Rocky Mountain Province comprises a mass of mountains, carved mainly on massive rocks, with somewhat accordant summit levels and an irregular stream pattern. The topography of this region is the product of several incomplete erosion cycles, and the streams have been controlled, in large part, by geologic structure.

Southeast of this mountain mass, but still within the Northern Rocky Mountains, there are several distinct mountain ranges, separated by elongated valleys. These ranges differ little in general structure from those lying south and east of the Eastern Snake River Plain section, which are assigned to the Middle Rocky Mountain Province by Fenneman. The northwestern part of the Northern Rocky Mountain Province is characterized by wide glaciated valleys, some of them occupied by lakes. These striking geomorphic features have no counterpart elsewhere in Idaho unless northern Long Valley and the Payette Lakes can be so considered.

The small part of the Basin and Range Province that falls within the boundaries of Idaho might, with almost equal propriety, be grouped with the area immediately east of it and regarded as part of the Middle Rocky Mountain Province. The ranges are more isolated and the detritus-floored valleys broader. The numerous normal faults also ally this area with the Basin and Range Province.

The Eastern Snake River Plain section is underlain mostly by lava with only a local and thin cover of sedimentary material. It is a wide lowland, dotted in places by hills and trenched by the canyons of the river and some of its tributaries. West of an irregular line near 115° longitude is the Malheur-Boise-King Hill section which is so largely underlain by young sedimentary rocks that the topography is more diversified. The Owyhee Upland Subprovince is in the extreme southwest portion of the State. In the Wallowa-Seven Devils area, mountains composed of deformed and metamorphosed older rocks are surrounded by Tertiary deposits that have been block-faulted. Farther north, the Tristate Uplands section is an extensively eroded plateau carved mainly on Columbia River basalt that has been warped and faulted.

The Palouse Hills section is conspicuous in Washington but only a small portion of it enters Idaho. This section is characterized by fertile, rolling hills covered with deep soil probably of eolian origin, concealing the bedrock. Figure 1 includes part of the Channeled Scablands section but this is entirely within Washington. This section contains interlacing channels carved in bare lava that surround remnants of rolling, undissected hills composed largely of loess like that of the Palouse Hills.

GEOMORPHIC HISTORY

Throughout the more mountainous parts of Idaho remnants of an ancient surface that originally possessed low to moderate relief have been recognized by many observers. This surface has been given different names and age assignments in different regions but in many areas constitutes the summit peneplain or more properly partial peneplain, and was in existence fairly early in the Tertiary period. In those areas in which the Challis volcanics now cover much of the country it constitutes the flatter parts of the surface on which that formation was laid down. This surface of subdued topography, however, had been cut into extensively before deposition of the Challis volcanics began, and the volcanics locally fill deep valleys thus produced.

The topography must have been rugged when the uplift and faulting near the end of Challis time subsided. In its broader features the topography resembled that of the present, for the erosion of many of the valleys and uplands was guided by structural features produced during late Mesozoic and early Tertiary upheavals. The mountainous topography permitted vigorous erosion and weathering, which continued with diminishing intensity until the country was reduced once more to comparatively low relief, though hills, perhaps even mountains, remained unreduced in localities which correspond essentially to the sites of the principal modern ranges. Such features as the Snake River Plain, related to later volcanism, had probably not yet taken form. Remnants of the post-Challis erosion surface are preserved as patches on upland summits in the region originally inundated by the Challis volcanics. Beyond that region, this erosion surface may merge with the old, or pre-Challis surface in those places where that surface had been little dissected. In other areas the valleys that had been cut in the old surface were widened and the interstream areas were subdued, but not obliterated. Thus in these areas the remnants of the post-Challis erosion surface, although modified by weathering and kindred processes, are still recognizable on benches and even-topped ridges at elevations below those summits that retain remnants of the pre-Challis surface.

The post-Challis subdued surface had already been cut into by rejuvenated erosion in many parts of Idaho before eruption of the Columbia River basalt began. In northern Idaho, this revived erosion is reported to have continued long enough to leave an extensive record in the form of upland flats well above the level of the present streams. Eruption of the Columbia River basalt brought about great changes in the stream patterns in western Idaho. The basalt covered the lowlands and in places spread up valleys into the mountains. Many of these valleys correspond in part with those of the present streams but most of them were broader and shallower. Differential movements that raised the mountainous region with respect to those covered by the lava again unbalanced the drainage and permitted renewed dissection. Part of the material removed from the rising uplands by the streams was redeposited in the lower areas, producing the sedimentary rocks now found associated with the Columbia River

basalt. The larger of these masses of sedimentary material in southwestern Idaho--the Payette formation--is formerly supposed to have been laid down in a great lake but it is now known that the rocks are too heterogeneous and formed at too great a range in elevation to have such an origin. Lakes and ponds, mostly rather short-lived, did exist but much of the sedimentary material is similar in character and mode of origin to that forming today in the larger valleys of the region. The character of the plant remains in the different sedimentary deposits is thought by most of those who have studied them to indicate that the climate of the region became progressively drier from early Tertiary to Recent times. This fact helps to explain why fine-grained uniformly-sized materials of probable lacustrine origin are more plentiful among the Tertiary sedimentary rocks than in the floors of most of the modern valleys. However, the difference in kind and quantity between the lacustrine parts of such formations as the Payette and Idaho and the modern lake beds in and near Jefferson County and other parts of eastern Idaho is not great.

During and after the eruption of the Columbia River basalt the earth's crust in and near Idaho was in a state of unstable equilibrium. Although no such upheavals took place as those that earlier had bent and fractured the marine deposits, there were shifts in level and warping and fracturing of the rocks. These movements influenced the progress of erosion and resulted in distinctive stream patterns. Fracturing took place along lines of weakness with northwesterly, northeasterly, and northerly trends closely akin to those along which in middle Tertiary time intrusive rocks were introduced. Surface streams, ever seeking paths of least resistance, followed such lines of weakness wherever they could. As a consequence many of the drainage channels in the State form a grid pattern. Some of the fractures that control this pattern are faults with observable displacements, but there was little displacement on the majority of the fractures that have guided the smaller streams. Many of the larger northwest-trending valleys in the east-central and southeastern parts of the State are controlled in general direction by folds and faults of ancient date, supplemented locally by more recent normal faults, approximately parallel to the old structures. In parts of western and northern Idaho faults that appear to be independent of the old structures break the Columbia River basalt. Faults of this latter kind have played a major part in the formation of some of the modern valleys--such as Long Valley in Valley County. It does not necessarily follow that all long, straight valleys and mountain fronts have such an origin. Consequently faults in western Idaho that are inferred to exist primarily on the basis of topographic form are mapped with dashed lines.

In southwestern Idaho some faults of northwesterly trend are known to have influenced the present topography. However, the pattern of northwesterly and northerly trends that is conspicuous on the geologic map is due to stripping of the thin cover of Snake River basalt from the silicic rocks below by erosion and is not the result of known faults. The pattern may result from control of drainage by regional lines of weakness similar to those farther north. To the

eastward, particularly in Cassia, Oneida, and Power Counties, the conspicuous mountain ranges are outlined by faults, mostly of northerly trend, the valleys between them having been dropped down relative to the ranges in late Tertiary time.

Warping has had a strong influence on the present topography of the State. The depression west of the Clearwater Mountains, which is floored by Columbia River basalt, and the Snake River Plain, floored by Snake River basalt, are the most conspicuous of the downwarped areas. Faulting played a subordinate part in forming both of these depressions, especially the Snake River Plain. Although the two great depressions were formed mainly during two separate geologic periods, they are similar in that both were flooded by lava during and after their downwarp, with resulting profound changes in the drainage lines.

Warping was not confined to the depressions. The mountainous area of central Idaho was uplifted during Tertiary and early Quaternary time somewhat unevenly and intermittently. As a result the upland area is tilted so that there is a general increase in the altitude of the peaks towards its southern and eastern borders. The irregularities of the uplift, locally complicated by faulting, have produced many changes and abnormalities in the drainage of the mountains. Streams whose vigor was increased by the warping have been extended in such fashion as to capture the headwater portions of less favored streams. Great valleys that may have been carved originally by individual streams now have drainage issuing from both ends, with low, in some instances scarcely perceptible, divides breaking the continuity of the old valleys. Among the many that might be cited, the Salmon River is an outstanding example of a stream that is composed of segments of several former streams with diverse trends. The great depression now drained by the Lemhi River and Birch Creek may once have been occupied by a single master stream, although it is not clear whether this stream flowed northwest or southeast.

Basins (in part structural), remnants of nearly level plains, and terraces along most of the streams testify to fluctuations in the erosion of the higher parts of Idaho that began in late Tertiary time. In much of Idaho north of the Snake River Plain, at least one erosion cycle persisted long enough to produce broad, graded lowlands whose remnants now lie high above the bottoms of the present valleys. In most localities two to four other steps in erosion were recorded in between the late Pliocene and the last and most widespread stage of Pleistocene glaciation. In southern Idaho, similarly, there were two, and in most places more, incomplete erosion cycles during this interval of more than a million years.

Most of the mountains of Idaho contained glaciers during the Pleistocene epoch and the last of the glaciers may have persisted until recently. Indeed, it would require very little change in the climate to convert some of the snow patches in the present mountains into small glaciers. The amount of ice and the number of recurrences of glaciation are thought to have decreased progressively from northern

to southern Idaho. In the narrow, northern part of the State lobes from the great ice sheets in adjacent parts of Canada pushed down the major valleys in at least three stages. Parts of these lobes attained thicknesses as great as a mile. They extended down to elevations of only 2,000 feet above sea level and, near the International Boundary, their upper surfaces reached such heights that most of the mountains were buried under ice. The glaciers brought down much debris and in places scoured the valleys so deep below present stream gradients that large lakes still remain. In some places where the ice did not itself occupy entire valleys, it dammed their outlets, producing temporary lakes. The largest of these lakes was glacial Lake Missoula in Montana. Melting of the ice dam at the outlet of this lake produced floods, which must have swept through northern Idaho into Washington.

In central Idaho there were at least two distinct stages of mountain glaciation although in many places the evidence of early stages has been obliterated by the effects of the numerous glaciers of the last stage. In most places the glaciers were confined to narrow mountain valleys, and did not descend much below a present altitude of 7,000 feet above sea level, but in northwestern Valley County and also in eastern Fremont County they have left deposits at altitudes close to 5,000 feet. South of latitude 43° the higher mountains show evidence of glaciation, but the glaciers were small and only one stage of glaciation has been recognized.

Much of the ruggedness of the topography of central Idaho was produced before the last of the clearly recorded glacial stages. In some places streams deepened their valleys more than a thousand feet in the interval between that stage and an earlier glacial stage; yet few streams have cut channels more than a hundred feet deep since the ice of the last of the Pleistocene glacial stages melted. Many of the picturesque details of the topography of the higher mountains and most of the high lakes now so attractive to fishermen and campers were produced by the ice of this stage. Small glaciers may have existed in the highest parts of the mountains in Recent time. Since the melting of the glaciers, the effects of frost, persistent snow fields, and landslides have united with those of running water to continue changing the landscape.

FIGURE 6 - DREDGES MINING COLUMBITE-TANTALITE, EUXENITE AND MONAZITE IN A CENTRAL IDAHO VALLEY FORMED PARTLY BY GLACIER DAMMING
---Courtesy, Porter Bros. Corp.

ECONOMIC GEOLOGY

INTRODUCTORY NOTE

The metallic and nonmetallic mineral resources for which Idaho is so well known are directly related to its geology. The soils on which the State's agricultural wealth is based are derived from the weathering of the rocks. The long series of geologic events described above have resulted in the present diversity of topography and of climate, which have fundamentally influenced stock-raising and farming. This same diversity has provided the foundation for the tourist trade. Thus all of the State's major industries are dependent on geology.

Figure 2, taken directly from a paper by Charles R. Hubbard (1955) shows the distribution of both metallic and nonmetallic resources in the State. An earlier paper (Ross, 1941) contains a map that shows the locations of the mining districts with their boundaries as nearly accurate as possible. At one time a mining district was, in a sense, a unit of local government and its boundaries were fixed with some care. These boundaries, however, were determined mainly by local usage. At present, the governmental aspect of a mining district has disappeared and in many instances the boundaries are decidedly indefinite.

METALLIC DEPOSITS

Historical note

Mining began in Idaho about 1852. During the following half century placer mining, largely by hand methods, yielded more than 5,000,000 ounces of gold. The richer and more accessible placers were exhausted during this period, but later revivals of placer mining through increased use of mechanical equipment have resulted in the production of over 2,500,000 ounces additional, and some deposits remain untouched. The revivals in placer mining served to attract attention also to gold lodes, particularly during the 1920's and 1930's. Several of the lodes were successfully exploited before war needs became so pressing as to cause a halt in precious metal mining. Economic conditions since the war have not permitted much expansion in gold mining.

In the early 1880's development of lead-silver lodes on a large scale began, and the continued production from these lodes has been the mainstay of the mining industry of Idaho. More than 6,650,000 short tons of lead, valued at over $885,000,000, have been produced through 1955. Idaho has yielded somewhat more than 650,000,000 ounces of silver, a small part of it from placers. The total production of zinc through 1955 is close to 1,800,000 tons. So much of this zinc has been obtained since 1935 as to make Idaho one of the leaders among the zinc-producing states. Discovery of ore bodies and the

vicissitudes of markets and of metallurgical practice have brought various other metals, such as copper, into prominence at different times. The special demands occasioned by World War II attracted attention to several metals formerly regarded as of slight commercial interest in Idaho. Among these metals, antimony, tungsten, and quicksilver attained substantial production early in the war effort. Prospecting initiated at that time has resulted in the discovery of numerous tungsten deposits and some of these are producing. The number of quicksilver mines is small but they are sufficient to give Idaho an important position in that field. Cadmium, chromium, cobalt, manganese, nickel, and tin are among other scarce metals of growing interest that are present in Idaho. Some of these have already been mined on a small scale. In recent years the search for uranium and other radio-active materials has been intensified. It has resulted in active placer mining for monazite and in some lode mining for thorium- and uranium-bearing minerals.

Distribution and character of the lodes

General statement

Mining districts are distributed throughout the mountainous parts of the State (Ross, 1941, p. 1). The Coeur d'Alene region in the southeastern corner of the narrow northern part of the State has maintained a commanding position in the industry since almost the beginning of mining in Idaho, but the south-central part of the State contains numerous and diverse mines, and some of those in other areas are famous. Most of the lodes were formed in two metallogenetic epochs; one thought to have been during the emplacement and cooling of the Idaho batholith, the other during an episode of marked igneous activity at some time during the Tertiary period. Most of the common varieties of lode deposits are represented but most of the more valuable deposits of the early epoch are somewhat ill-defined lodes in shear zones, mostly in siliceous sedimentary rocks. The deposits of middle Tertiary age include quartz veins, in many of which the valuable minerals are so fine-grained as to be inconspicuous, contact-metamorphic deposits, and other varieties.

Northern Idaho

Most of the successful mines in the extreme northern part of Idaho are in the Clark Fork district, and even these are relatively small. The principal mineralized area in the Clark Fork district is on the south side of the Hope fault where there are lead-silver replacement deposits containing galena, tetrahedrite, and lesser amounts of sphalerite, pyrite, arsenopyrite, and chalcopyrite in a gangue of siderite with some quartz and calcite. The district also contains copper veins with chalcopyrite in a gangue of quartz and siderite; and, north of the Hope fault, veins that consist largely of quartz and pyrrhotite with subordinate amounts of other sulfides. Boundary County and the western part of Bonner County contain a number of prospects but few mines. The principal metals mined are silver and lead, with some copper, molybdenum and other metals.

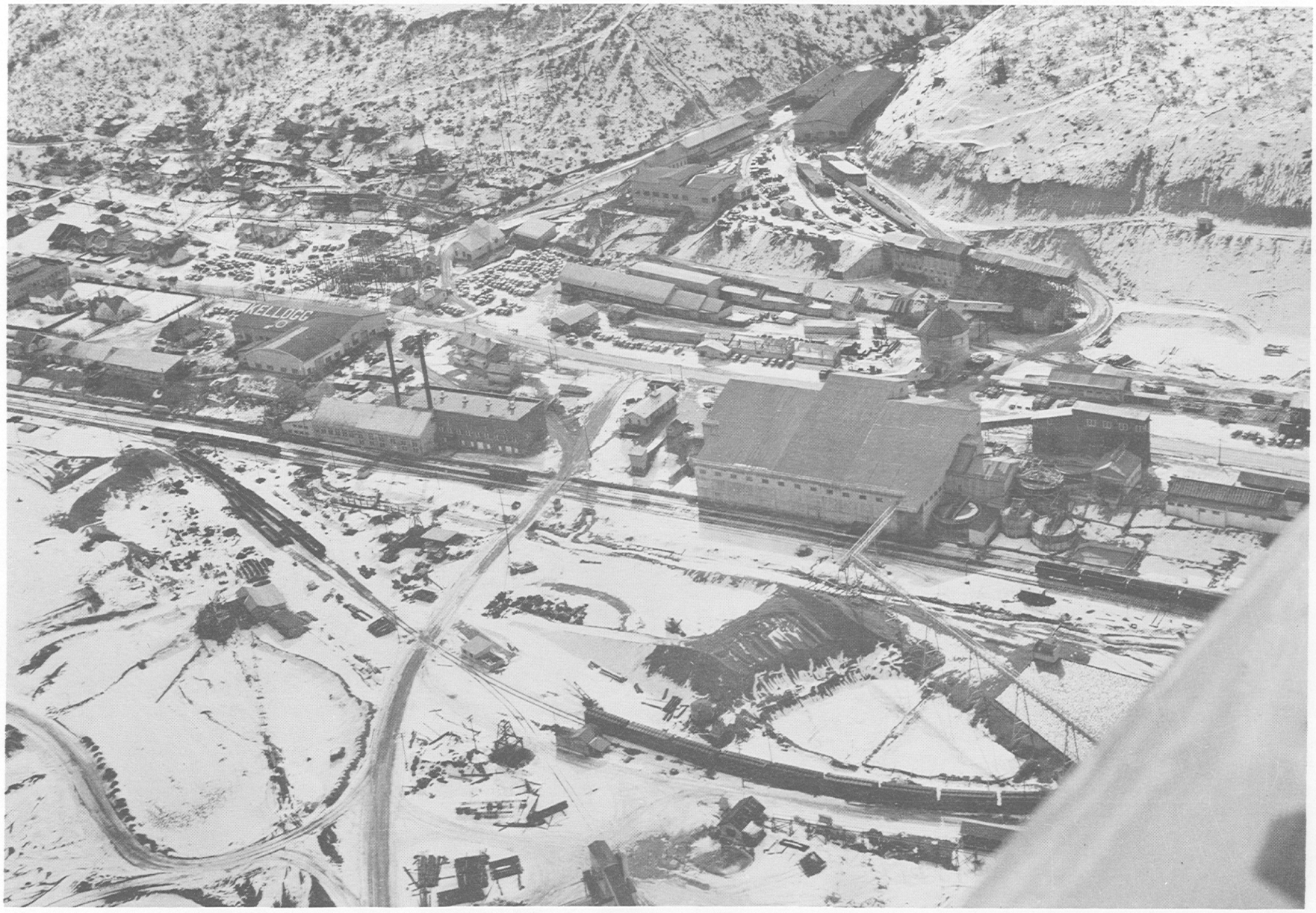

FIGURE 7 - THE BUNKER HILL MINE AND MILL, COEUR D'ALENE DISTRICT
---Courtesy, The Bunker Hill Co.

The Coeur d'Alene region, which includes ten mining districts in Shoshone County, has yielded roughly 80 per cent of the total value of metals produced in Idaho since mining began. Prospecting began in 1878 and exploitation of the great lead-silver lodes that have made the region famous was in full swing by 1889. The total value of metals produced in the region through 1955 exceeds $1,500,000,000. Most of the ore deposits are roughly tabular masses formed dominantly by replacement in shear zones in quartzite and locally in argillaceous and other rocks; in part the ore bodies are related to bleached zones which mark alterations in the country rock of the deposits. The lodes contain galena, sphalerite, siderite and quartz, with other less abundant minerals. Some contain enough copper in chalcopyrite and tetrahedrite to be a valuable by-product but the lode in the Snowstorm, the only highly productive copper mine in the region, is a zone of dissemination of minute particles of bornite, chalcocite, chalcopyrite, tetrahedrite, and their oxidation products through a particular stratum of Revett quartzite. The principal gold lodes in the region, now largely exhausted, are near Murray. They are fissure veins with quartz, pyrite, chalcopyrite, galena, sphalerite, and free gold, the sulfides being in relatively small amount. Some of the gold veins contain enough scheelite to constitute tungsten ore during periods of high prices. Antimony is another by-product of some mines.

The southern and western parts of Shoshone County contain deposits of lead, copper, gold and other metals, most of which have attained little production. The same is true of Kootenai County. In 1923 interest was aroused by the reported presence of platinum and related metals in Kootenai County, but investigation by the Idaho Bureau of Mines and Geology and cooperating organizations failed to substantiate the reports.

North central Idaho

The broad area that includes Benewah, Latah, Clearwater, Nez Perce, Lewis, and northern Idaho Counties contains few productive lode mines. Most of the lodes are of interest mainly for their gold and copper content, but there are a few lead-zinc deposits, and contact-metamorphic deposits which contain enough magnetite to be of possible future value are reported.

Southern Idaho County is best known for its placer production in the early days. Interest in the placers continues on a reduced scale, and there are also numerous lode mines, some of which have been profitable. Most of the lodes are worked for gold and copper and some contain enough tungsten to have attracted attention during World War II. Many of the lodes are rather small quartz veins but there are also large mineralized shear zones and silicified breccia zones.

South central Idaho

The Seven Devils region, which is mainly in Adams County and the northern part of Washington County, contains several mining districts, all somewhat inaccessible and not extensively developed. The principal metals sought are copper and gold, but deposits containing silver, lead, and other metals are known. The more productive lodes are contact-metamorphic deposits, mainly in limestone. A few of the deposits are in fracture zones in bodies of sparsely disseminated pyrite in hydrothermally altered rhyolite and andesite rocks of probable Permian age, others are disseminated deposits in monzonite that may be of pre-Triassic age, and there are quartz veins containing silver and gold, and replacement deposits of several kinds. Much of the ore so far mined in the Seven Devils region, unlike that of most areas of Idaho, is supergene.

Most of the mining districts in Valley County are still relatively inaccessible and have been active only on a small scale or for brief periods. The Yellow Pine district is an outstanding exception as it contains mines that during World War II were among the country's leading producers of tungsten and quicksilver. The district still has reserves of these metals and, in addition, substantial reserves of gold and antimony ores. Most of the tungsten, antimony and gold are found in large shear zones in the rock of the Idaho batholith, while the quicksilver deposits are mainly in silicified limestone that constitutes part of a block of sedimentary rock included in the batholith. The Thunder Mountain district farther east enjoyed a short-lived gold boom early in the present century and may still contain considerable gold in large but low-grade deposits in Tertiary volcanic rocks. The deposits in other parts of the county are varied. They include very large silicified shear zones in which minerals of gold, tungsten, and several other metals are sparsely disseminated; quartz veins that are locally rich in gold; contact-metamorphic deposits of copper, tungsten, and iron; lead-zinc ore shoots in a schistose xenolith in the Idaho batholith; and others.

Lemhi County, farther east, contains numerous mining districts with varied resources. A number of these districts contain deposits valuable mainly for gold and silver; most of these were of more importance in the early days than they have been recently. The total production of Lemhi County through 1955 may have exceeded $35,000,000. The Texas district, a small area that centers around Gilmore, is by far the most productive in Lemhi County, although placers in the general vicinity of Leesburg yielded richly from 1866 to 1880 and have had several revivals. The principal production in the Texas district was in 1902 through 1929. It came largely from lead and silver replacement deposits in fracture zones in dolomite of Paleozoic age. There are replacement deposits in limestone or dolomite containing lead and silver in other parts of the County and in neighboring parts of Clark and Butte Counties also. Deposits in shear zones in argillaceous and quartzitic rocks of the Belt series, valuable mainly for copper or gold, but locally with significant amounts of lead and silver, occur in several of the mining districts. Some

of the gold lodes along the border of the Idaho batholith are in schist, gneiss, and granitic rocks. The deposits of the Blue Wing district are in fracture and shear zones in strata of the Belt series. They comprise quartz bodies interlayered with quartzite and contain a complex assemblage of metallic minerals. The deposits have been known since 1881 but attained prominence during World War II, when their hubnerite content made the district one of the leading producers of tungsten in the United States. The deposits in the Blackbird district, Lemhi County, contain deposits of the precious metals, in part as selenides, in ill-defined zones of fracture and alteration in tuff and lava of Tertiary age.

Lemhi County contains deposits of cobalt ore, monazite, thorite, and other comparatively rare minerals of present commercial interest. Development of the cobalt deposits is being actively carried on and some of the other deposits are being explored. Production through 1955 has not been large.

The mining districts in Custer and Blaine Counties and adjacent parts of Butte, Camas, and Elmore Counties together constitute the most active and productive mining region in Idaho outside of the Coeur d'Alene region. The mines of Custer County produced more than $42,000,000 prior to World War II, and, in spite of war-time difficulties, some of the lead-silver and other mines have continued to grow. Blaine County and areas in other counties tributary to it produced well over $76,000,000 through 1955. The Triumph mine, with complex zinc-lead-silver ore that could not be treated by methods in use in the early boom years, later became an outstanding producer. The lodes of Custer and Blaine Counties and adjacent areas are varied, but the region is known principally for its shear zones in Paleozoic strata with ore shoots principally valuable for lead, silver, and zinc. Many of them also contain copper, gold, antimony, tungsten, arsenic and other metals. In some of the lodes many of the known ore shoots have been exhausted. Some of them ended against post-mineral faults, but this factor in the limitation of ore shoots in the region is of less importance than is popularly supposed. In many the ore is in shoots of only a few hundred feet of vertical range and arranged en echelon, but the vertical distance through which such shoots may be distributed is much greater than that yet tested by exploration. Some of the lodes in the region, especially in the Bayhorse district, are replacement bodies in Paleozoic limestone and dolomites mainly valuable for lead, silver, and zinc. Others are contact-metamorphic deposits, also mainly in Paleozoic calcareous rocks. Some that have recently been developed for tungsten are in the Hyndman formation (Precambrian?). The contact-metamorphic deposits have proved valuable, so far, principally for copper indeed, the Empire mine was formerly one of the principal copper producers in the State. Some contact-metamorphic lodes may be related to the Idaho batholith and kindred intrusive masses but others, including the Empire, are related to granitic rocks believed to be younger. The region also contains silicified shear zones, quartz lenses, and irregular quartz veins which contain various minerals but, so far, have proved valuable mainly for the production of gold

and silver on a small scale. Many of the quartzose lodes are in rock of the Idaho batholith. There are several areas, such as the Yankee Fork and Lava Creek districts, in which the lodes are in fractures in Tertiary volcanic rocks, or, where in older rocks, are clearly related to the lodes in the Tertiary strata. Most of the lodes thus known to be of Tertiary age have been explored in the past mainly for their silver and gold content, but some contain enough lead, zinc, tungsten, and other metals to be of economic interest.

Gem, Boise, Ada, and western Elmore Counties contain a number of small mining districts in most of which the principal production has been in the precious metals, although lead and other metals have been mined. Bismuth, molybdenum, and other metals are byproducts of possible economic value. This region contains some of the most famous placer districts in Idaho but, with a few outstanding exceptions such as the Gold Hill mine in the Boise Basin and those near Atlanta, Elmore County, the lode mines have been worked only on a small scale. The Gold Hill and other mines near Quartzburg have produced over $8,000,000 mainly in gold; and the Boise-Rochester mine, the principal one near Atlanta, has yeilded over $6,000,000, mainly in silver and gold. Bismuth is a byproduct of possible future importance in the Gold Hill and other mines. Most of the lodes in the region are in shear zones in rock of the Idaho batholith, but many are intimately and genetically associated with dikes of Tertiary age.

Southwestern Idaho

Southern Washington County contains gold lodes and placers, iron deposits, and deposits of fuller's earth, none of which has yet attained much production, but it also contains the Weiser quicksilver district with deposits in sandy beds of probable Miocene age. One of these deposits was among the leading quicksilver producers during World War II and has recently been reopened.

Owyhee County in the little-known southwest corner of the State has a number of mining districts. There has been little activity in any of them recently, but the Silver City region has produced over 1,000,000 ounces of gold and well over 20,000,000 ounces of silver. It is one of the few regions in the United States that contains enough tin to have aroused interest but so far the production of this metal has been negligible. The principal known tin resources are in the wood tin of placer deposits. The lodes of the South Mountain district contain lead, copper, silver, and zinc. One mine, the Galconda, maintained production throughout World War II. The principal previous activity in the district was in 1871 to 1875. The other districts in the county have had little production.

The lodes of the Silver City region are of Tertiary age and include masses of white quartz, lodes characterized by lamellar quartz, silicified shear zones, and cemented breccias. The principal host rocks are granodiorite and Tertiary lava. The diverse hypogene metallic minerals include argentite, ruby silver minerals,

naumannite (silver-lead-selenide), stibnite, tetrahedrite, and others. The principal lodes of the South Mountain district, on the contrary, are replacement deposits in metamorphosed calcareous rocks that form parts of inclusions in a granitic stock. They contain abundant galena and sphalerite and smaller amounts of other common sulfides in a gangue of quartz and calcite.

Southeastern Idaho

The rest of the State contains comparatively few and unimportant metallic lodes, none of which has received much development recently. Several deposits containing silver, gold, zinc, lead and quicksilver are known in southern Cassia and southwestern Oneida Counties, but their production record is not impressive. The deposits in Bannock, Bear Lake and Franklin Counties contain copper, gold and manganese but have never received much exploration. The little-known Mt. Pisgah district in Bonneville County has tabular quartz lodes in Mesozoic strata which have been shattered and re-cemented by calcite and pyrite. Gold is obtained from the pyrite that has been decomposed by oxidation.

Placers

Placer mining had its heyday during the last half of the nineteenth century. Although the use of dredges and similar equipment, which began in 1897, has resulted in substituting company operation in large measure for the activities of individuals and groups of individuals, the placer mines continued to outnumber the lode gold mines until World War II put a temporary stop to gold mining. Sand and gravel along most of the streams that drain areas where gold lodes are present will yield placer gold by panning, and this is also true of such master streams as the Boise and Snake Rivers. Along the Snake River, however, the gold is so finely divided and commonly so sparse as to hinder recovery. In most of the mountain country the flood plains of the present streams and bars not far above them were the first placer deposits exploited by the miners and have proved generally to be the richest. However, high level deposits of Pleistocene and Pliocene age that contain valuable amounts of gold are preserved in some of the broader stretches of the present valleys. These stretches are remnants of depressions formed in early erosion cycles, in part as a result of faulting and warping. The gold-bearing deposits in them include parts of moraines left by Pleistocene glaciers. In a few places sedimentary rocks of Miocene age are known to contain gold but they are of small importance. Locally the weathered bedrock of old erosion surfaces also contains a little gold.

The placers contain several constituents of possible value in addition to the gold and its accompanying silver. Attempts to recover monazite and other components of placers have been made from time to time. The recent revival of interest in recovery of monazite and other radioactive minerals has resulted in more activity than any of the previous attempts. Placer deposits in streams that drain areas of Tertiary rocks containing metallic lodes have long been known to

contain a little tin. The special need for this metal that resulted from World War II caused studies to be made of the tin-bearing placers of Owyhee and Lemhi Counties in the summer of 1942 but no commercial exploitation followed.

The broader relations of the lodes

Since Lindgren (1900a, p. 103) established the concept of two major periods of mineralization in Idaho there have been several changes in emphasis and viewpoint. In the early 1920's some geologists (Thomson, 1924, p. 533-540) thought that all of the lodes in the State were related to the Idaho batholith. Later, after intrusive rocks of Tertiary age were found to be abundant (Ross, 1928, p. 673-693), the importance of Tertiary ore deposits became more fully realized, (Ross, 1931, p. 169-185; 1933, p. 265-272). Now it is believed that most of the ore deposits in the State formed during two major stages of mineralization but some originated at other times.

Anderson (1942, p. 510-519; 1951, p. 592-607) has suggested that the ore deposits in Idaho belong to five groups, one of Precambrian, one of early Tertiary, another of middle Tertiary and two others of late Tertiary and Quaternary age. He thinks none of these groups is related to the Idaho batholith. The group of mineral deposits he regards as Precambrian has few representatives, mostly of small economic importance. As Anderson indicates, the age assignment of some of them is open to question.

The group Anderson thinks of as early Tertiary is essentially that commonly regarded as related to the Idaho batholith. He has postulated that batholith to be incapable of giving birth to ore deposits because it is a result of granitization of pre-existing rocks (Anderson, 1952, p. 55-60). In another paper (Anderson, 1951, p. 255-265) he states that rocks he regards as products of late stages in the production of the Idaho batholith formed late in the Laramide orogeny. He further states that the ore deposits of his early Tertiary group are closely associated with structures produced during the Laramide orogeny and with hypabyssal intrusive rocks of early Tertiary age that utilize these structures. Thus the difference in date of mineralization between that implied by Anderson's concept and that of those who think of the Idaho batholith as the source of the solutions is not great. The fact that some lodes cut the rock of the main batholith demonstrates that these lodes are appreciably younger than the intrusion of the magma but it by no means follows that they are without genetic relation to the batholith. Circulation of mineralizing solutions would be one of the latest events related to batholithic activity. The validity of the assumption that none of the lodes in and near the Idaho batholith is genetically related to it depends on satisfactory explanation of such things as the presence of uraninite, calculated by R. C. Wells to be of Late Cretaceous age, in association with gold in the Warren mining district (Reed, 1937, p. 8-25) well within the Idaho batholith, and the presence in and near the batholith of lodes without apparent ties

to rocks of Tertiary age; some of these lodes are associated with zones of igneous metamorphism that seem clearly related to the batholith. Further proof of the assumption would require more positive dating of the various outliers of the batholith with associated ore deposits than is now possible.

There is general agreement that many of the lodes in south central Idaho are genetically related to intrusions of about the age of the Challis volcanics. This group of deposits is commonly considered of middle Tertiary age but, if future work shows that the Challis volcanics are older than they are now thought to be, the deposits would be of early rather than middle Tertiary age. Some lodes, notably in the Silver City region, cut volcanic rocks that may well be younger than part or all of the Challis volcanics. Others, such as the quicksilver deposits near Weiser, may be even younger. Many of the lodes in south central Idaho regarded as of about the same age as the Challis volcanics, those in the Silver City area and also those near Jarbidge, Nevada (Schrader, 1923), contain selenides, which suggests that they belong to the same or closely allied periods of mineralization. Igneous activity occurred at rather closely spaced intervals throughout the Tertiary and early Quaternary periods. Perhaps deposition of mineral deposits was similarly spaced. It would be difficult to assign close age limits to some of the deposits, such as those of the Mount Pisgah district in Bonneville County.

The above discussion covers all but the Precambrian(?) lodes in Idaho. It is probable that certain lodes in Boundary County are of that age (Kiilsgaard, 1949) and lodes near Pocatello and near Salmon have been tentatively assigned a Precambrian age. In the Coeur d'-Alene region uraninite, regarded as 750 million years old (Kerr and Kulp, 1952, p. 86-87), has been found in certain veins but there is disagreement as to the age relations of the uraninite and the silver ore minerals (Thurlow and Wright, 1950, p. 395-404; Robinson, 1950, p. 818-819). Although the uraninite is doubtless of Precambrian age, many geologists familiar with the region continue to regard the ore deposits as of Mesozoic age.

In summary, mineralization has occurred in Idaho at intervals from Proterozoic to Recent times. Throughout most of the State most of the valuable deposits fall into two age groups. The larger group still seems best regarded as related to the Idaho batholith and more or less closely related outliers and hence of Mesozoic age, although arguments for regarding the group as of early Tertiary age have been offered. The second age group has genetic relationships to intrusions associated with the Challis volcanics, although certain of the lodes that have been regarded as belonging to this group may be somewhat older and younger than the Challis volcanics. Many of the lodes within the Idaho batholith belong to the second group and, thus, are without genetic relation to their granitic wall rocks.

In general, the lodes are governed in origin and distribution, first, by the parent intrusive masses and, second, by structural disturbances, themselves related in one way or another to the intru-

sions, which have furnished suitable paths for the localization of the metalliferous solutions. The physical and chemical character of the different country rocks also have influenced mineralization.

Most of the lodes regarded as of Mesozoic age are clustered, more or less closely, around outlying stocks, rather than in the Idaho batholith itself. Those more closely associated with the main batholith are either in sedimentary rocks close to its border or, less commonly, within the granitic rock on the sides, rather than near the eroded top, of the exposed mass. These include deposits containing scheelite, chalcopyrite, and magnetite in parts of the sedimentary roof rocks that have suffered much igneous metamorphism. Many of the gold lodes are in or near the outer parts of the main Idaho batholith, but none of those now classed as Mesozoic was formed far within the original confines of the granitic mass. None of the principal lead, copper, or zinc deposits is closely associated areally with the main batholith. Distribution of this kind is in keeping with modern concepts that mineralization tends to be concentrated around projecting parts of the intrusive mass and around the smaller stocks rather than great batholiths (Loughlin, 1941, p. 667-689). Mineralization is, however, one of the last phases of igneous activity and commonly takes place only after at least the outer parts of the main intrusion have cooled and cracked enough to form openings in which ore deposition can take place.

The Belt series is made up of several remarkably thick and uniform aggregates of beds which, although locally much faulted, have been in general only moderately folded. The resultant more uniform chemical and structural conditions controlling the mineralizing solutions in the Coeur d'Alene region may account in part for the fact that the ore shoots there are so much larger and extend uninterruptedly to so much greater depths than in otherwise similar lodes in the more deformed and variable Paleozoic strata farther south.

It has long been known that some of the copper deposits are in and genetically related to widespread but inconspicuous zones of igneous metamorphism in the Belt series. Studies that began in the late 1920's (Shenon and McConnel, 1939, p. 8-9) show that some of the silver-lead lodes of the Coeur d'Alene region are in somewhat similar zones. The preparation thus made for the later mineralizing solutions may have been another factor in promoting the formation of large ore shoots.

Most of the lodes that have been regarded commonly as Middle Tertiary are in extensive zones of uplift and fracture that furnished channels for intrusions and, somewhat later, for the mineralizing solutions. The principal zone of this kind cuts diagonally across the southern part of the Idaho batholith, but less extensive zones are widely distributed throughout the State. Wherever the Challis volcanics are present, the ore deposits extend upward into them. With minor exceptions, the lodes in the Challis volcanics and in the rhyolitic strata have proved valuable only for silver and gold

although lead, tungsten, antimony, and other metals, probably including tin, may increase the production of nonprecious metals from lodes within the volcanic rocks in the future. Most of the Tertiary lodes that have yielded significant quantities of metals other than gold and silver are in pre-Tertiary rocks, and so many are within or near the borders of the Idaho batholith as to lend support to the suggestion, based on mineral relationships, that some of them may be composite. The quartz veins may have formed late in the Mesozoic era but some minerals are believed to have been added during Tertiary mineralization.

The post-Challis rocks that cover large areas in Idaho are so nearly devoid of metallic lodes as to be of no interest to those in search of most metals. The only exception of consequence at present is quicksilver deposits of opalitic character. The productive lodes of this kind are in rocks that are but little younger than the Challis volcanics, but similar deposits in northern Nevada are in part in rocks of supposed Pliocene age.

As the lodes in Idaho are diversified, yet for the most part related to only two distinct periods of mineralization, they would be expected to show evidence of zonal relations, such as are found in some mining districts (Emmons, 1924, p. 969-997; Spurr, 1923, p. 253-291). Zoning, however, has been recognized only to a very limited extent. Conclusive evidence of changes in the character of the ore with depth, other than those related to surficial oxidation, has not yet been found. In some of the Tertiary lodes the proportion of original silver and gold minerals to those of lead may decrease with depth. Regional zoning is shown, to a limited extent, by the fact that most of the gold lodes of Mesozoic age are in or close to the Idaho batholith, but most base-metal lodes are in sedimentary rocks at various distances from subsidiary granitic masses and at considerable distances from the main batholith. Local zoning with respect to the subsidiary granitic masses is recognizable in a few localities. For example, one of these masses in southern Blaine County has lodes relatively high in zinc in a poorly defined zone close to it, whereas the lead lodes are farther away.

NONMETALLIC RESOURCES

Industrial minerals

Although Idaho contains a large variety of nonmetallic minerals of economic interest, few have as yet attained much production, and exploration of most of the deposits has been too scanty to furnish an adequate basis for estimating their value. All are handicapped by transportation difficulties and most of them by lack of markets. With increases in industrial activity in the western United States these disadvantages will tend to disappear.

Asbestos, of the variety known as anthophyllite, has been mined intermittently on a small scale since 1909 near Kamiah, Idaho County. It seems to be an alteration product of an igneous rock called dunite,

thought to be older than the Idaho batholith (Anderson, 1930, p. 43-51). Asbestos, of this and other varieties and generally in small amounts, has been reported from several other localities. Tremolite schist in Valley County and other localities, although entirely undeveloped, has possibilities for use as commercial talc. Garnet is produced in Benewah County, making Idaho one of the principal sources of this material.

There are large barite veins near Hailey, Blaine County, and barite is a constituent of the gangue in various lodes in several localities in Idaho. So far there has been little attempt to mine barite in Idaho, although small amounts have been utilized for drilling mud.

Clays of several kinds occur in the State. Bentonitic material is reported but has been only slightly exploited. Brick clays are common and have been utilized on a small scale in several localities. Clay of both transported and residual character, derived from alteration of granitic and other rocks, is fairly plentiful in Latah County and neighboring regions. It is reported to be suitable for refractories and pottery, and some quarrying has been done. Latah County has yielded some mica. The pegmatite dikes of north-central Idaho contain some feldspar of the sort used in porcelain manufacture. If greater use is made of the clays of the region, a local market for the feldspar may be created. The pegmatites locally contain beryl and mica. There has been some production of both from localities in Idaho in past years and mica continues to be quarried at intervals. Columbium-bearing rutile has been recognized in recent years near Shoup, Lemhi County.

Diatomaceous earth is present in Tertiary rocks in several localities in southwestern Idaho. Small amounts have been used recently in the local sugar refining industry. Pumice is quarried in Blaine and Bonneville Counties. Fluorspar is a gangue mineral in several different kinds of lodes in Idaho and small amounts were mined at a few places during and after World War II. The total production has been small but enough deposits are known so that sufficient demand should meet with adequate response.

Numerous gem stones, including diamonds, sapphires, topaz, garnets, and zircon have been reported. The correctness of the reported identification of some of the rarer stones is in doubt and most of the other gem stones are deficient either in quality or quantity, so that the production has been trivial. Opal and some of the other gem stones may eventually be of some value. Some of the jasper and travertine locally present in Tertiary strata is attractive when polished and has possible value for ornamental purposes.

There are beds of gypsum in the Wells formation in Bear Lake County and in the Payette formation in Washington County, and small amounts elsewhere. Some is being quarried in Washington County. Nitrates are known in several localities, mostly in caves, but none of the deposits has been proved valuable. Several other mineral

products such as salt and sulfur in saline springs have been investigated by those interested in possible commercial development, but the known deposits are neither large enough nor of high enough quality to compete with more advantageously situated deposits in other regions.

The phosphate beds of southeastern Idaho, mainly in the Phosphoria formation, constitute the outstanding nonmetallic mineral resource of the State. Commercial development has long been in progress and has been expanded recently. The reserve of high-grade phosphate rock in the State in 1945 was approximately 5,000,000,000 long tons. Interest in the Phosphoria formation was increased during World War II because of the vanadium content of certain beds in it. The tonnage of vanadium-bearing rocks is large, but the tenor is low. In 1942 and later several Federal agencies cooperated in intensive exploration of these rocks in Idaho (Swanson, McKelvey, and Sheldon, 1953) and, to a larger extent, in nearby Wyoming, in part because they have been found to contain radioactive material.

Fuels

Idaho is deficient in mineral fuels. Deposits of coal, lignite, gas, and oil are known, but production so far has been small. The coaly material in Paleozoic strata near Ketchum, Blaine County, is now so metamorphosed as to burn with difficulty even in those samples in which the ash content is not excessively high. It is more adaptable for use as impure graphite than as a fuel. Subbituminous coal has been mined on a small scale from Cretaceous rocks in southeastern Idaho. The lignitic coal that is found in the Tertiary strata in numerous places is generally of such inferior quality as to be of no value except for local use in localities where its accessibility offsets the advantages of better coals that have to be shipped in from distant points. The deposit at Salmon, Lemhi County, was for some years the principal source of fuel for that city.

The strata of Mesozoic age that are not highly metamorphosed in southeastern Idaho, especially the Cretaceous rocks, locally contain gas and oil, but the quantities so far found are so small as to be discouraging. The Tertiary strata in the Snake River Plain and tributary valleys have been tested with negative results. These beds are of continental origin and quite different from those in which most of the principal commercial deposits in the world of oil or gas occur. Very little oil has been found in them and most of the gas found in drilling is methane, presumably derived from the decay of vegetable remains.

Building materials and similar products

Idaho contains many rocks suitable for use as road metal and in rubble masonry. For such uses accessibility is generally the prime consideration, but it is well to bear in mind that some rocks are much more suitable than others for particular purposes. Knowledge of the local geology allows the user to discriminate so as to improve

FIGURE 8 - OPEN-PIT PHOSPHATE OPERATIONS AT GAY MINE OF J. R. SIMPLOT COMPANY, NEAR POCATELLO

---Courtesy, J. R. Simplot Co.

High and rugged mountains make up somewhat less than half of the area of the State. Here the rainfall is comparatively large, but there are extreme ranges in temperature, short growing seasons, and only scattered small areas suitable for cultivation of crops. Although forests are widespread over large areas it is only in a few localities, mainly in the northern part of the State, that lumbering is a major industry. Modern methods of rapid road building and use of large trucks for lumbering are increasing the number of areas in which the industry can be undertaken profitably. Grazing is the principal agricultural pursuit in most of the mountainous areas. Many of the sheep and cattle that range over the mountains during the grazing season are brought long distances from ranches and winter quarters in less rugged country. Extension of the road system in the mountains, which is aided by new road-making equipment and by improved utilization of local materials derived from the rocks, is increasing the area accessible to sheep and cattle. This is in part a by-product of lumbering and mining.

The parts of the State occupied by intermontane valleys, dissected plateau areas, and foothills are together almost equivalent in area to the high mountains. In spite of short growing seasons and other disadvantageous factors, these areas in 1950 contributed 16 per cent in value of the State's dairy products and their harvested crops were about equally valuable. They contained more than 20 per cent by value of the livestock in the State. The figures just given and similar ones below are estimates based on production data for the counties concerned (Hurley, 1952).

War-time demands for man-power, both in industry and in the armed services, had made serious inroads on the population of much of the upland country, as is reflected in the fact that in 1939 they had contributed nearly 30 per cent of the dairy products, a similar proportion of harvested crops, and contained over 35 per cent by value of the livestock in the State. However, this condition had begun to be relieved before hostilities stopped. In some of the more favorably situated valleys improvement has continued.

In many of the intermontane valleys precipitation is ordinarily sufficient for the growth and maturity of frost-resistant crops. Dry farming and stock raising predominate, supplemented by irrigation where practicable and necessary. In some of the valleys and tillable hilly ground, grains and other forage crops are extensively grown, but cash crops, such as potatoes, yield rich returns under suitable conditions. Dairying is practiced in many places, notably in the wide, glaciated valleys of northernmost Idaho. The soils differ in many details, but in many of the valleys they contain enough material derived from lava to be fertile. In some valleys, such as that of the Pahsimeroi River, excessive proportions of coarse gravel and boulders in the alluvium are serious disadvantages, hindering tillage and causing high seepage losses, both in irrigation ditches and in the channels of natural streams. Ground water from wells is utilized in most intermontane valleys only to a limited extent.

The dissected plateau drained principally by the lower reaches of the Clearwater River contains prosperous farming country in which much wheat and other grains are grown. Fruits and numerous other crops are grown in suitable localities and dairy farms are also plentiful. Most of the plateau is underlain by Columbia River basalt and this valuable source material has contributed largely to most of the soils. Many of the soils are of eolian origin but some are residual, and alluvial material is abundant in places (Agee, Graves, and Mickelwaite, 1917, p. 5-13; Agee and Peterson, 1920, p. 5-17; Lewis and Denecke, 1923, p. 1-14; Paulson and Platt, 1930, p. 1-9). In contrast, the drier and less thoroughly dissected plateau in and near Owyhee County is used principally for grazing. The area of this plateau exceeds that of the country just described and both basaltic rock soils and eolian soils are plentiful, but climatic and physiographic conditions limit cultivation to a few areas near the major streams. The basalt throughout the country is so young that residual soils are scanty. Also in most areas it is thin and is underlain by rhyolitic rocks which constitute a less favorable soil source.

The Snake River Plain, which comprises about 20 per cent of the State, contains some of the most intensively cultivated and valuable land in Idaho. The 23 small counties that comprise the Snake River Plain and the adjacent parts of tributary valleys are credited by the 1950 Census with over 60 per cent in value of the State's livestock and in 1949 yielded over 75 per cent of the dairy products and 70 per cent of the harvested crops. Precipitation throughout the Plain is insufficient much of the time for dry farming, but irrigation has now been so developed that the more favorably situated and fertile areas are being cultivated rather intensively. Most of the water is obtained by means of dams across the Snake River and across some of its tributaries near the borders of the Plain. In most of the mountainous and hilly parts of the State geologic conditions are such that feasible damsites and locations for canals and tunnels for transfer of irrigation water from one drainage basin to another are plentiful. Consequently, if and when economic conditions warrant the necessary expenditures, greatly expanded use of water for power and irrigation in the Snake River Plain and other areas can be attained. Increasing attention is being given to development of ground water and in some sections this has become a major source of water and has materially expanded the area that can be used for agriculture.

Much of the eastern and central parts of the Snake River Plain is underlain by lava so recent that the soil cover is inadequate for farming and, in many areas, inadequate even for the growth of enough native grasses to afford good grazing. There are, however, wide areas with soils suitable for many kinds of crops. Most of these soils are made from a wide variety of materials brought in from the surrounding regions through the agency of winds and streams and, hence, are broadly similar to one another irrespective of marked differences in the character of the rocks on which they lie (U. S. Dept. Agriculture, 1939, p. 1090-1100, and map; Young, Baldwin, Kern,

and McDole, 1928; Baldwin and Young, 1925, p. 1367-1394; Paulson and Thompson, 1931; Young, Trail, and Young, 1933; Paulson, Nelson, and Paulson, 1943). Almost everywhere, except in those sections of its western part where Tertiary sedimentary rocks predominate, the Snake River Plain is underlain by great thicknesses of permeable basaltic rocks. The surface water available for irrigation is supplemented by the ground water in the great natural reservoirs provided by the permeable Snake River basalt. Ground-water reservoirs in the Snake River Plain, and the alluvium of valleys in other parts of the State, take in large amounts of water that would otherwise run to waste in the spring, and yield it to the streams later in the season when it is needed for irrigation and the generation of power. They also supply water to wells for domestic, stock and industrial uses, and to some extent for irrigation, especially where the geologic structure favors artesian flow. The widespread permeable material beneath the soils of the Snake River Plain also aids irrigation by providing drainage that hinders the accumulation of alkalies in the soils under cultivation.

Much of the material in the soils throughout the Snake River Plain is of wind-blown origin. In the upper (eastern) portion of the Plain some of the soil contains also much material of alluvial and lacustrine origin. In restricted areas in this portion of the Plain the soil is so permeable that irrigation is effected by raising the water table by leakage from canals outside of the cultivated area instead of by the usual methods of bringing water onto the land in surface ditches. In this part of the Plain potatoes, sugar beets and seed alfalfa are extensively grown.

In the central parts of the Plain (west of American Falls) the soils are largely eolian and on the whole are neither as deep nor as permeable as in the areas farther northeast. There potatoes, beans, and sugar beets are outstanding crops. Still farther west, between Boise and the Oregon boundary, dairy and fruit ranches are numerous. There the bedrock consists largely of lake beds and other sedimentary rocks of Tertiary age, but the soils are largely transported. In nearly all of the cultivated parts of the Snake River Plain, forage crops are grown on a large scale, principally for winter feed for stock that migrates to the mountains for grazing during the summer.

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GLOSSARY OF GEOLOGIC TERMS

(Compiled by D. A. Holmes)

Alluvial fan - a gently sloping conical stream deposit with its apex at the mouth of a narrow valley, built by a stream emerging from a steep narrow valley onto a broader plain or valley.

Alluvium - sediment deposited by flowing water, including the sediments laid down in river beds, flood plains, lakes, alluvial fans, and estuaries.

Apophysis - small dikes and stringers extending from a mass of intrusive igneous rock into the surrounding wall rock.

Arenaceous - containing sand or having a sandy texture.

Argillaceous - clayey, or containing clay.

Batholith - a large mass of granitic rock, covering more than 40 square miles.

Bentonitic - containing chemically altered volcanic ash, or bentonite.

Calcic - containing, or pertaining to, calcium; said especially of those feldspars of which calcium is an important constituent, or of the igneous rocks containing such minerals.

Carbonaceous - containing carbon, commonly of organic origin.

Clastic - a descriptive term applied to rocks formed from fragments of other rocks.

Conformable - When beds or strata lie upon one another in unbroken and parallel order, and this arrangement shows that no disturbance or denudation has taken place at the locality while their deposition was going on, they are said to be conformable.

Consolidated - compressed or cemented from a loose aggregate of mineral grains or organic remains to "solid" rock; firm and coherent.

Contact metamorphic deposits - mineral deposits formed at or near the contact of an igneous mass, and presumably caused by the heat and/or addition of substances from the igneous mass.

Correlate - to determine the equivalence in geologic age and stratigraphic position of two formations or other stratigraphic units in separated areas.

Cross-bedding - stratification inclined to the true bedding, and caused by swift local currents, deltas, or swirling wind gusts. Especially characteristic of sandstones, both eolian and aqueous.

Deformed - folded, faulted, or changed from the original form or volume in any manner by crustal movements

Diatomaceous - composed mainly of the siliceous remains of diatoms, microscopic algae which secrete siliceous shells.

Dike - a tabular body of igneous or igneous-appearing rock which cuts across the bedding or other layered structure of the country rock.

Equivalent - corresponding in geologic age or stratigraphic position; a rock unit of the same geologic age or stratigraphic position.

Erosion cycle - the sequence of landforms in successive and definite stages resulting as erosional processes work upon the surface of the earth; or, the time involved in the reduction of a land area to a surface of low relief.

Erosion remnant - an exposure of rock surrounded by older rocks, and resulting from removal by erosion of the younger rock from most of the area; an outlier.

Exposure - an outcropping of rock at the earth's surface; same as outcrop.

Fault - a break or fracture in the earth's crust along which there has been movement or displacement parallel to the plane of the break.

Feldspathic - containing feldspar as a principal constituent.

Flood plain - a strip of relatively smooth land bordering a stream, built of sediment carried by the stream and dropped in the slack water beyond the influence of the swiftest current.

Folding - warping and bending of rock strata.

Formation - the ordinary unit of geologic mapping consisting of a large and persistent stratum of some one kind of rock, or of closely related strata.

Fracturing - cracking or breaking of rocks due to folding or faulting.

Gangue - the nonmetalliferous or nonvaluable metalliferous minerals in an ore.

Geomorphology - the study of the configuration and development of the surface of the earth.

Gneissic - a banded and streaked texture in coarse-grained igneous or metamorphic rocks.

Granitic - a texture of coarse-grained igneous rocks in which most of the mineral grains have well-defined boundaries and are of uniform size; or, rocks resembling granite in composition and texture.

Granitization - the process by which solid rocks are converted to rocks of granitic character without passing through a magmatic state.

Granitoid - a textural term to describe those igneous rocks which are composed entirely of recognizable minerals of approximately the same grain size.

Groundmass - the fine-grained or glassy matrix of a porphyry.

Group - a sequence of successive formations related by rock type or position with reference to unconformities.

Hill wash - the material accumulating from the erosion of hillsides by water not confined to definite channels, usually following cloudbursts or other flash flood conditions.

Hornblendic - containing hornblende as a principal constituent.

Horizon - a definite position in the stratigraphic column; a surface separating two beds.

Hydrothermal - pertaining to hot water, or the mineral deposits formed by deposition from hot watery solutions.

Hypabyssal - igneous rocks which solidified at moderate depths; applied to minor igneous bodies such as dikes and sills, and to the rocks which compose them.

Hypogene - a term applied to mineral deposits formed from ascending vapors or solutions.

Igneous rock - a rock formed by solidification from a molten state, or believed to have been so formed.

Inclusion - any foreign material (gas, glass or mineral) enclosed within a mineral grain; also connotes fragments of country rock enclosed in an igneous rock while the igneous rock was in a molten state.

Interbedded - occurring between beds, or lying in a bed parallel to beds of different material; interstratified.

Intercalated - a term generally applied to a body of one kind of material interlaminated with another.

Intergrowth - the interlocking of crystals due to their crystallizing at the same time and in contact with one another.

Intraformational - formed or existing within a geologic formation.

Intrusion - the thrusting or penetrating of molten rock into or between other rock masses; the intruded mass.

Intrusive - an adjective applied to those rocks which solidified from a molten state underground.

Laccolith - a mushroom-shaped intrusive body which archs or bows the overlying rocks upward.

Laramide orogeny - the period of crustal unrest and mountain-building near the close of the Mesozoic era.

Lava - igneous rock that was poured out on the earth's surface and there solidified.

Lithologic - of or pertaining to the description or study of the composition and texture of rocks.

Lit-par-lit - French for leaf-by-leaf; a banded structure caused by the intimate penetration of granitic rock between the foliae or leaf-like sheets of a foliated rock such as schist.

Lobe - a marginal projection from the body of a continental ice sheet.

Lode - a mineral deposit that fills a fissure in the country rock; a vein.

Loess - a homogeneous, nonstratified, unindurated deposit consisting mainly of silt, deposited primarily by wind.

Magma - molten rock beneath the surface of the earth.

Metalliferous solutions - hydrothermal solutions which carry metals in suspension or in solution.

Metallogenetic epochs - definite periods in the earth's history when widespread mineral deposition resulted from and was related in time and place to crustal or igneous activity.

Metamorphic rock - rocks whose original mineral composition and/or texture have been markedly changed by heat, temperature, and/or pressure.

Miarolitic - pertaining to, or containing small irregular cavities into which small crystals of rock-forming minerals project.

Micaceous - containing mica.

Mineralization - deposition or formation of mineral deposits.

Ore shoot - a more or less vertical zone or chimney of rich vein material.

Orogeny - the process of forming mountains, particularly by folding and faulting.

Outlier - an area of younger rock completely surrounded by older rock; commonly an erosion remnant of a younger formation which covered the area.

Peneplain - a land surface worn down by erosion to a nearly flat or broadly undulating plain.

Period - the fundamental unit of geologic time measurement, based on widely accepted stratigraphic subdivisions.
Petrography - the systematic classification and description of rocks.
Phenocryst - the larger crystals in a porphyry; usually of near perfect shape and embedded in a finer-grained matrix or groundmass.
Porphyry - an igneous rock in which relatively large, conspicuous crystals (phenocrysts) are set in a finer-grained or glassy groundmass.
Porphyritic - a textural term designating the presence of isolated crystals in a matrix or groundmass of finer material.
Pseudophenocryst - metamorphic rocks commonly contain conspicuous crystals distributed in a groundmass of smaller mineral grains and closely resembling the phenocrysts of igneous rocks. These large crystals, however, were formed subsequent to the original rock, and are conveniently referred to as pseudophenocrysts, or porphyroblasts.
Replacement deposits - mineral deposits formed by practically simultaneous solution and deposition within the rock, by which minerals of new or partly differing composition are substituted for older minerals; opposed to fissure-filling deposits.
Schistose - a foliated or "leaf-like" structure resulting from recrystallization of mineral grains under stress; resembling schist.
Sedimentary rock - rock formed by accumulation in water and cementation of fragments of rocks, minerals, and organisms, or as precipitates from sea water and other surface solutions.
Series - a time-stratigraphic unit ranked next below a system; the rocks deposited during an epoch.
Shear zone - a fault zone in which shearing has occurred on a large scale, so that the rock is crushed or brecciated.
Silicic - containing an abundance of silica.
Silicified - converted into or replaced by silica.
Sill - a tabular body of igneous or igneous-appearing rock lying between sedimentary strata.
Stock - a body of igneous or igneous-appearing rock that covers less than 40 square miles, and has steep contacts; or, a cupola rising above the general level of a batholith roof.
Strata - sedimentary beds or layers.
Stratigraphic - of or pertaining to the formation, composition, sequence, and correlation of rocks.
Supergene - applied to mineral deposits consisting of alteration products of earlier mineral deposits, and resulting from weathering or from enrichment by descending waters.
System - a time-rock unit including all the rocks deposited during a period, as the Silurian system.
Tuffaceous - containing volcanic fragments, generally smaller than 4 mm.
Unconformity - a buried erosion surface.
Unconsolidated - uncemented; in a loose aggregate form.
Volcanic - pertaining to volcano or fissure eruptions.
Volcanic neck - the filled-up vent or pipe of a dead volcano.
Xenolith - a fragment of other rock inclosed in an igneous rock; an inclusion.

MINERALS MENTIONED IN THIS PUBLICATION

A mineral is a naturally occurring substance with a characteristic internal structure, and with a chemical composition and physical properties that are either fixed or vary within a definite range.

Anthophyllite - iron magnesium silicate, $(Mg,Fe)SiO_3$.
Argentite - silver sulphide, Ag_2S.
Arsenopyrite - sulpharsenide of iron, FeAsS; frequently associated with gold.
Barite - barium sulfate, $BaSO_4$.
Bornite - sulfide of copper and iron, Cu_5FeS_4; peacock copper ore.
Calcite - calcium carbonate, $CaCO_3$; hexagonal, rhombohedral.
Chalcocite - copper sulfide, Cu_2S; important secondary copper ore.
Chalcopyrite - sulfide of copper and iron, $CuFeS_2$.
Feldspar - a group of rock forming minerals which are silicates of Al, K, Na, Ca.
Fluorspar - calcium fluoride, CaF_2; fluorite.
Galena - lead sulfide, PbS; principal ore of lead.
Garnet - a mineral group, formula $A_3B_2(SiO_4)_3$ where A = Ca, Mg, or Fe, and B = Al, Fe, or Cr.
Gypsum - hydrous calcium sulfate, $CaSO_4 \cdot 2H_2O$.
Hornblende - complex amphibole, $(CaNa)_3(Mg,Fe,Al,Ti)_5(Si,Al)_8O_{22}(OH,F)_2$.
Hubnerite - tungstate of iron and manganese $(Fe,Mn)WO_4$.
Magnetite - magnetic iron oxide, Fe_3O_4.
Microcline - sodium aluminum silicate, $KAlSi_3O_8$; a feldspar mineral.
Monazite - phosphate of the cerium metals $(Ce,La,Di)PO_4$; principal ore of rare earths and thorium.
Naumannite - selenide of silver and lead, $(Ag_2Pb)Se$.
Phosphate rock - a sedimentary rock containing calcium phosphate.
Plagioclase - a feldspar mineral group series from $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$.
Potassium feldspar - commonly orthoclase, $KAlSi_3O_8$.
Pyrite - iron sulfide, FeS_2; frequently associated with gold and copper.
Pyrrhotite - iron sulfide, $Fe_{n-1}S_n$; magnetic pyrites.
Quartz - silicon dioxide, SiO_2.
Rutile - titanium oxide, TiO_2.
"Ruby silver minerals" - proustite, Ag_3AsS_3; pyrargyrite Ag_3SbS_3.
Scheelite - calcium tungstate, $CaWO_4$; frequently contains molybdenum.
Siderite - iron carbonate, $FeCO_3$; often associated with metallic ores.
"Silicates" - minerals classified as salts of hypothetical silicic acids.
Sphalerite - zinc sulfide, ZnS; principal ore of zinc.
Stibnite - antimony sulfide, Sb_2S_3; principal ore of antimony.
Tetrahedrite - sulfide of copper, antimony and arsenic, $Cu_3(Sb,As)S_3$.
Thorite - thorium silicate, $ThSiO_4$.
Tremolite - calcium magnesium silicate, $Ca_2Mg_5(OH)_2(Si_4O_{11})_2$.
Uraninite - essentially uranium oxide UO_2; pitchblende.

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ROCKS MENTIONED IN THIS PUBLICATION

Rocks are aggregates of minerals. Three great classes are recognized. The sedimentary rocks have been formed at the surface of the earth, either by the accumulation and cementation of fragments of rocks, minerals and organisms, or as precipitates from sea water and other surface solutions. The igneous rocks have formed from molten material that solidified on cooling. The metamorphic rocks have been formed by the transformation, in the solid state of pre-existing rocks beneath the earth's surface through the agencies of heat, pressure, and chemically active fluids.

Agglomerate - pyroclastic rock containing angular fragments.
Andesite - large group of medium acid igneous rocks.
Aplite - dike rock, light in color, having a characteristic fine grained granitic texture.
Argillite - metamorphic intermediate between shale and slate.
Basalt - extrusive igneous rock, primarily calcic plagioclase, pyroxene and $\pm$ olivine.
Chert - cryptocrystalline varieties of silica.
Coal - compact and earthy organic rock with less than 40% inorganic components.
Conglomerate - rounded water worn fragments cemented together by another material.
Dacite - extrusive aphanitic porphyritic igneous rock composed of plagioclase, quartz, pyroxene, and hornblende with minor biotite and sanidine.
Diabase - an igneous rock of basaltic composition consisting essentially of labradorite and pyroxene.
Diorite - a plutonic rock composed essentially of sodic plagioclase and hornblende, biotite or pyroxene.
Dolomite - a rock approximating $CaMg(CO_3)_2$ in composition.
Dunite - a rock consisting almost entirely of olivine with accessory pyroxene.
Gabbro - a plutonic rock consisting of calcic plagioclase, pyroxene and olivine.
Gneiss - a coarse-grained rock in which bands of mafic schistose minerals alternate with the granular minerals.
Granite - a plutonic rock consisting essentially of alkalic feldspar and quartz.
Granophyre - a quartz porphyry or fine grained porphyritic granite characterized by a micrographic groundmass.
Hornfels - a fine grained non schistose rock resulting from contact metamorphism.
Lamprophyre - a group name applied to dark dike rocks in which dark minerals occur as phenocrysts and in the groundmass, but light minerals only in the groundmass.
Latite - extrusive volcanic composed of both orthoclase and plagioclase with hornblende, biotite and olivine in varying amounts.
Lignite - low grade, brownish black coal.
Limestone - a bedded sedimentary deposit consisting chiefly of $CaCO_3$.
Marble - metamorphic rock composed chiefly of calcite and/or dolomite.

Micropegmatite - rock composed essentially of intergrowths of potash feldspar and quartz, distinguishable only under the microscope. (See pegmatite below).

Microperthite - very fine grained intergrowth of potasic and sodic feldspars.

Monzonite - a granular plutonic rock containing approximately equal amounts of plagioclase and orthoclase. Hornblende, diopside and biotite are usually present.

Mud stone - an indurated clay rock which is not fissile.

Pegmatite - igneous rocks of coarse grain found usually as dikes associated with a large mass of plutonic rock of smaller grain size.

Phyllite - an argillaceous metamorphic rock intermediate between slate and schist. Mica content gives the rock a characteristic silky sheen.

Pumice - an excessively cellular glassy lava usually of rhyolitic composition.

Quartz diorite - plutonic rock composed mainly of sodic plagioclase, hornblende, and quartz.

Quartzite - a granulose metamorphic rock consisting almost entirely of quartz.

Quartz latite - extrusive volcanic consisting of essentially orthoclase, plagioclase and quartz with hornblende, olivine and biotite in varying amounts.

Quartz Monzonite - aphanitic porphyritic equivalent of quartz latite.

Rhyolite - extrusive igneous rock composed essentially of orthoclase, quartz, and biotite.

Sandstone - a cemented or compacted detrital sediment composed predominately of quartz grains.

Schist - a medium grained metamorphic rock with sub-parallel orientation of the micaceous materials which dominate its composition.

Shale - a laminated sediment in which the constituent particles are predominately clay grade.

Silicic volcanics - igneous flow rocks high in quartz content.

Slate - a fine grained metamorphic rock possessing a well developed slaty cleavage.

Soda granite - granite especially rich in soda or whose soda exceeds the potash.

Sub-bituminous coal - soft coal having 8300 to 13000 B. T. U.'s per pound.

Tuff - a rock formed of compacted volcanic fragments usually more than 4 mm. in diameter.

Welded tuff - a tuff indurated by the action of heat, retained by the particles and the enveloping hot gases.

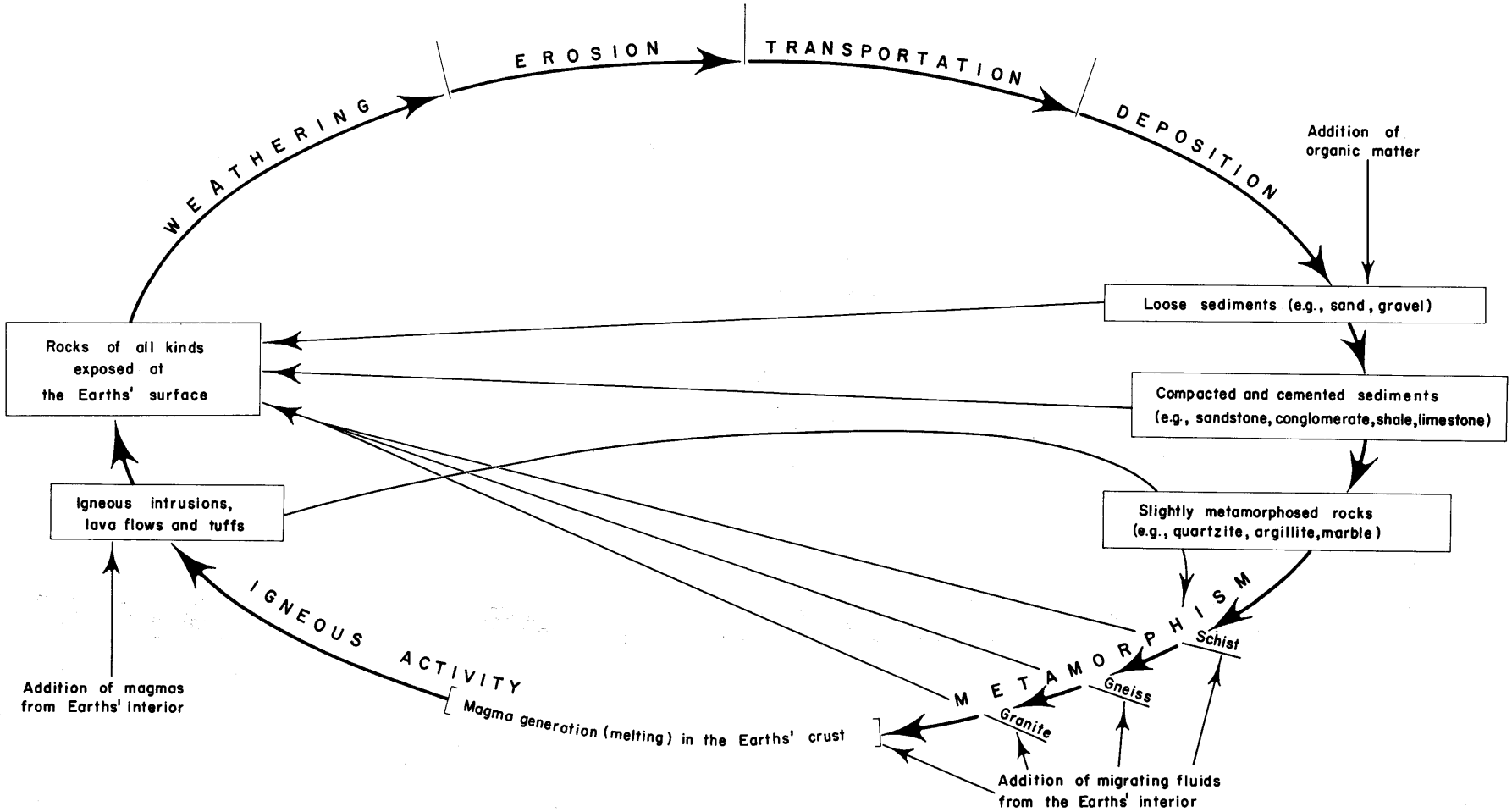

FIG. 9. THE CYCLE OF ROCK CHANGE
(Modified from Holmes, *Principles of Physical Geology*, p. 66.)

ERA	PERIOD	LIFE	IDAHO FORMATIONS
CENOZOIC	Quaternary (1M)	Man and the ice age	Snake River basalt Hagerman lakebeds — Idaho fm. Salt Lake fm.
	Tertiary (75M)	Age of mammals	Columbia River basalt — Latah fm. Payette fm. — Carmen fm. Challis volcanics — Kamiah volcanics Wasatch fm.
MESOZOIC	Cretaceous	Flowering plants	Wayan fm. — Idaho batholith Tygee sandstone Draney limestone Bechler conglomerate Peterson limestone Ephraim conglomerate } Gannett group
	Jurassic	Age of reptiles-dinosaurs	Stump sandstone Preuss sandstone Twin Creek limestone — Nugget sandstone
	Triassic (200M)	Conifers	Wood shale Deadman limestone Higham grit Thaynes limestone Dinwoody fm. Seven Devils volcanics — Casto volcanics
PALEOZOIC	Permian	Early reptiles	Phosphoria fm.
	Pennsylvanian	Tree ferns	Wood River fm. Wells fm.
	Mississippian	Amphibians	Brazer limestone Madison limestone Milligen fm.
	Devonian	Fishes	Milligen fm. Grandview dolomite Three Forks fm. Jefferson fm.
	Silurian	Land plants	Laketown dolomite — Trail Creek fm.
	Ordovician	Shelled animals	Saturday Mountain fm. Kinnikinic quartzite — Phi Kappa fm. Ramshorn slate Fish Haven dolomite Swan Peak fm. Garden City limestone
	Cambrian (550M)	Crustaceans Early invertebrates	Bayhorse dolomite Garden Creek phyllite St. Charles limestone Nounan limestone Bloomington fm. Blacksmith fm. Ute limestone Langston limestone Brigham quartzite
PRECAMBRIAN (2000-3000M)		Algae Dawn of life	Bannock volcanics Blackrock limestone — Pocatello fm. Swauger quartzite — Lemhi quartzite East Fork fm. Hyndman fm. Hoodoo quartzite Yellowjacket fm. Orofino series Belt series

age in millions of years

FIGURE 10

V.J.E.

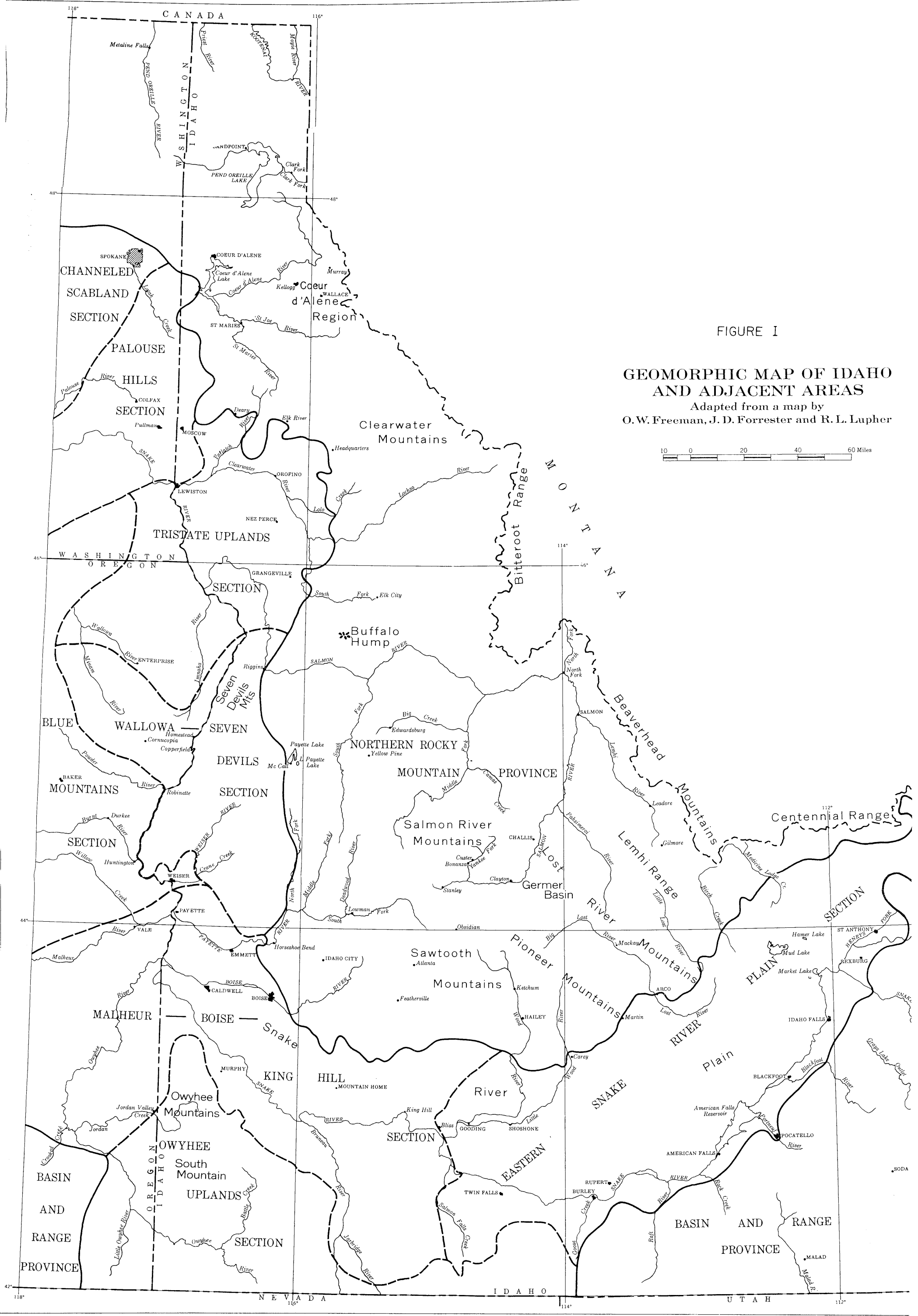

FIGURE I

GEOMORPHIC MAP OF IDAHO AND ADJACENT AREAS

Adapted from a map by
O. W. Freeman, J. D. Forrester and R. L. Lupher

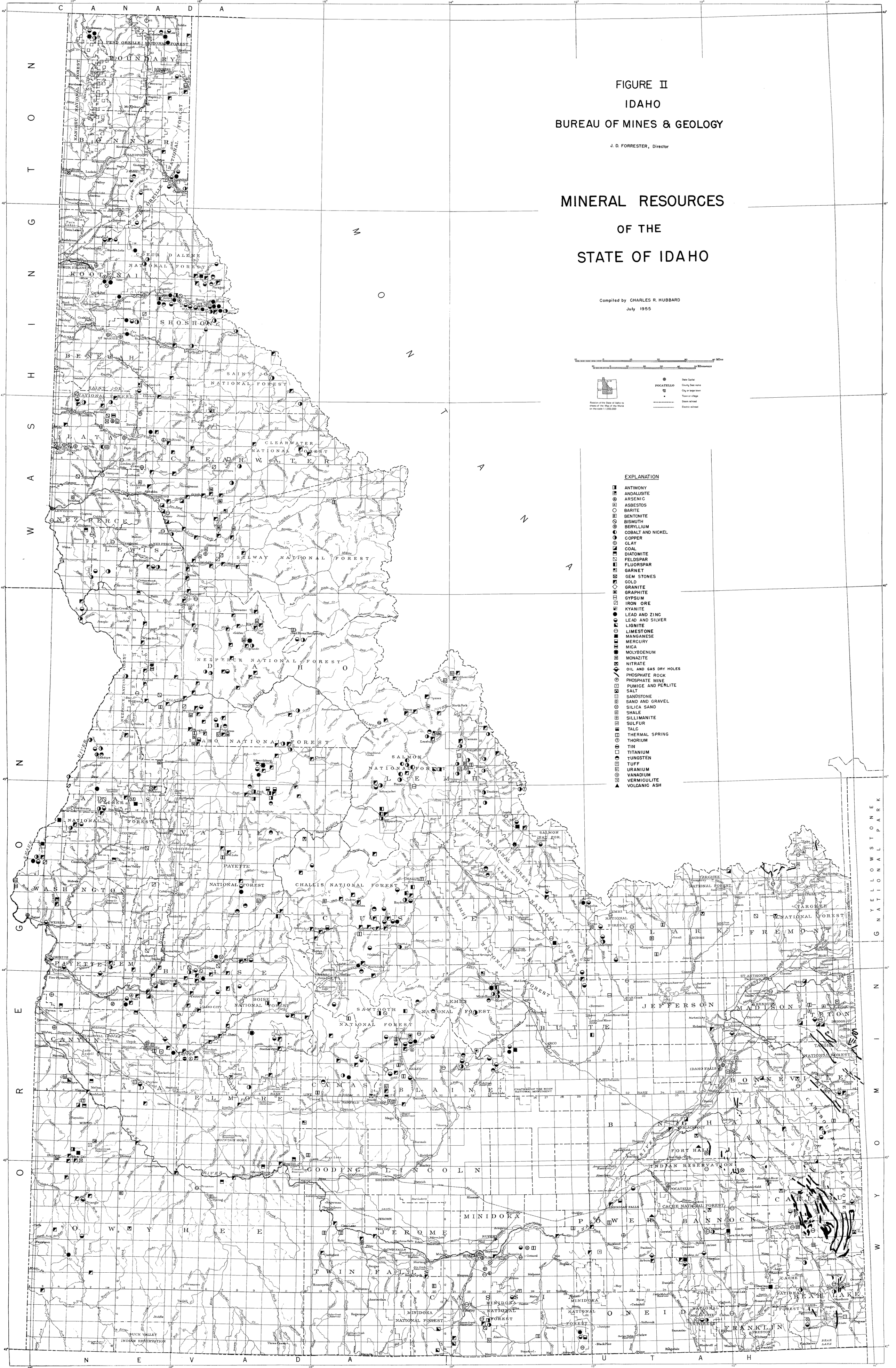
FIGURE II
IDAHO
BUREAU OF MINES & GEOLOGY
J. D. FORRESTER, Director
MINERAL RESOURCES
OF THE
STATE OF IDAHO
Compiled by CHARLES R. HUBBARD
July 1955
EXPLANATION
ANTIMONY
ANDALUSITE
ARSENIC
ASBESTOS
BARITE
BENTONITE
BISMUTH
BERYLLIUM
COBALT AND NICKEL
COPPER
CLAY
COAL
DIATOMITE
FELDSPAR
FLUORSPAR
GARNET
GEM STONES
GOLD
GRANITE
GRAPHITE
GYPSUM
IRON ORE
KYANITE
LEAD AND ZINC
LEAD AND SILVER
LIGNITE
LIMESTONE
MANGANESE
MERCURY
MICA
MOLYBDENUM
MONAZITE
NITRATE
OIL AND GAS DRY HOLES
PHOSPHATE ROCK
PHOSPHATE MINE
PUMICE AND PERLITE
SALT
SANDSTONE
SAND AND GRAVEL
SILICA SAND
SHALE
SILLIMANITE
SULFUR
TALC
THERMAL SPRING
THORIUM
TIN
TITANIUM
TUNGSTEN
TUFF
URANIUM
VANADIUM
VERMICULITE
VOLCANIC ASH
State Capital
POCATELLO County Seat name
City or large town
Town or village
Steam railroad
Electric railroad
Miles
Kilometers
Relation of the State of Idaho to sheets of the Map of the World on the scale 1:1,000,000
CANADA
MONTANA
WYOMING
NEVADA
UTAH
WASHINGTON
OREGON
YELLOWSTONE NATIONAL PARK
PEND OREILLE NATIONAL FOREST
BOUNDARY
BONNER
KOOTENAI
COEUR D'ALENE NATIONAL FOREST
SHOSHONE
BENEWAH
SAINT JOE NATIONAL FOREST
LATAH
CLEARWATER NATIONAL FOREST
NEZ PERCE
LEWIS
SELWAY NATIONAL FOREST
NEZ PERCE NATIONAL FOREST
IDAHO NATIONAL FOREST
SALMON NATIONAL FOREST
LEMHI
ADAMS
WEISER NATIONAL FOREST
VALLEY
PAYETTE NATIONAL FOREST
CHALLIS NATIONAL FOREST
CUSTER
BOISE
BOISE NATIONAL FOREST
SAWTOOTH NATIONAL FOREST
ELMORE
CAMAS
BLAINE
BUTTE
BINGHAM
CANYON
GEM
OWYHEE
GOODING
LINCOLN
MINIDOKA
JEROME
TWIN FALLS
CASSIA
POWER
BANNOCK
CACHE NATIONAL FOREST
FORT HALL INDIAN RESERVATION
DUCK VALLEY INDIAN RESERVATION
ONEIDA
FRANKLIN
BEAR LAKE
CARIBOU
BONNEVILLE
JEFFERSON
MADISON
TETON
FREMONT
CLARK
LEMHI
TARGHEE NATIONAL FOREST
CRATERS OF THE MOON NATIONAL MONUMENT