C N Savage

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Geology and Mineral Resources of Bonneville County

by

C. N. Savage

STATE OF IDAHO

Robert E. Smylie, *Governor*

IDAHO BUREAU OF MINES AND GEOLOGY

E. F. Cook, *Director*

Moscow, Idaho

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FOREWORD

This publication on Bonneville County is fifth in a series of County Reports designed for those persons interested in developing mineral resources, as well as professional geologists and others whose interests may lie more in geologic history than in commercial development.

Carl Savage gives us a comprehensive review of the geologic history of Bonneville County, describes the rocks and geologic structures and relates this information to the occurrence of mineral resources, their quality and economic potential.

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

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GEOLOGY AND MINERAL RESOURCES

OF

BONNEVILLE COUNTY

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C. N. Savage

ABSTRACT

Bonneville County includes 1,904 square miles of variable terrain features typified by the Snake River lava and alluvial plain, the narrow Swan-Grand Valley lowland, low to high rolling hills, and the Caribou and Snake River ranges. Principal drainage is by two branches of the Snake River and their tributaries.

Exposures of from 15,000 to 23,000 feet of folded, block-faulted, and overthrust Paleozoic, Mesozoic, and Cenozoic strata consist of older fossiliferous and nonfossiliferous marine and terrestrial limestone, dolomite, chert, shale, siltstone, sandstone, and conglomerate. More recent rock materials are clay, loess, silt, travertine, sand, and gravel.

Igneous rocks exposed are ash, pumice, tuff, basalt, andesite, trachyte, latite, rhyolite, monzonite, shonkinite, syenite, aplite, and granite.

The total value of the nonmetallic minerals--clay, sand, gravel, and pumice--produced in Bonneville County over a 9 year period ($7,989,000 - 1951-1959), exceeded all-time production of metallic minerals by about $5,400,000. Cinders, shale, basalt, sandstone, limestone, and tuff also have been produced as commodities.

Ample surface and subsurface water are present in this county.

Attempts to produce oil, gas, radioactive materials, and coal have all met with failure.

The total value of metallic minerals is reportedly $2,609,122, largely derived from gold, but including some silver and copper values.

Persons interested in future mineral production in this county should consider the vast limestone reserves. Further exploration for possible economic deposits of salt, gas, oil, copper, and vanadium should also be considered.

INTRODUCTION

HISTORICAL NOTES

Bonneville County is part of a region frequented by Indians, white trappers, and fur traders as early as the late 18th Century. The Snake River, principal drainage system was then variously designated: Mad, Shoshone, and Sagebrush River, or the Lewis Fork of Columbia River.

With the early history of the district are associated such names as Captain B. L. E. Bonneville (for whom the county was named), John Jacob Astor, Captain Nathaniel J. Wyeth, J. C. Fremont, Charles Preuss, and Robert Stuart. The life and activities of early times in this area are well described from two different points of view by Bancroft (1884 and 1890) and by Irving (1898).

Among the first maps showing the geographic features of this region are those prepared by Captain Bonneville's group in 1837, those by Fremont in 1843, and those by Preuss in 1850. One of the important historical features shown on these maps is the old emigrant route, the Oregon Trail, leading to the Pacific Northwest. It passed just south of Bonneville County. North of the Oregon Trail was the old Lander cut-off, a road that entered Star Valley in southeast Idaho and ran northwest to the south side of Grays Lake, and thence west along the Snake River Plain.

In 1865-66, the Oneida Road, Bridge, and Ferry Company built the first bridge across the Snake River on the Utah-Montana road at Eagle Rock, site of Idaho Falls. This bridge crossed Black Rock Canyon (Clark, 1941). Subsequently a 320-acre tract, including the bridge, became the townsite of Idaho Falls.

This region was explored and mapped by the Hayden Surveys; in 1877, as part of which work, A. C. Peal and Orestes St. John led geologic mapping parties into the area. Their subsequent excellent reports are still useful. These field parties were in the region shortly after the first gold discoveries were made on the flanks of Caribou Mountain in southwest Bonneville County.

In 1870, F. S. Babcock, F. McCoy, and Jesse "Carriboo" Fairchilds reportedly made the first placer gold discovery in Bonneville County near "Brainbridge" or "Carriboo" Mountain (Mount Pisgah), now called Caribou Mountain (Shupe, 1930, p. 19.)

The movement of Mormons from Utah north via Star, Grand, and Swan valleys played an important role in the early settlement of this region. These industrious first settlers, largely farming people, are credited with leading the first water off Willow Creek near Idaho Falls by means of an irrigation ditch.

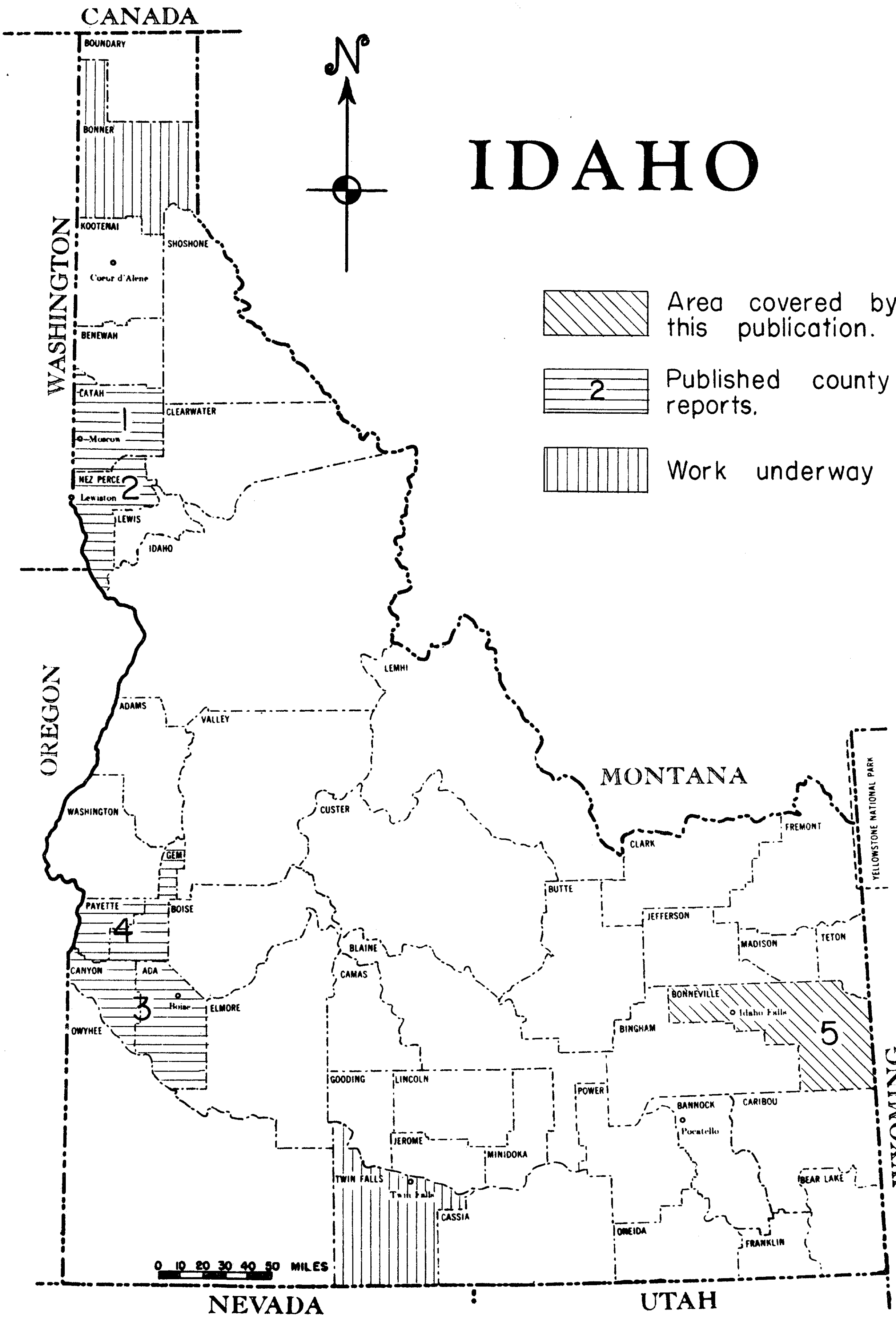


FIG. I – LOCATION MAP

PURPOSE OF INVESTIGATION

The principal motive for the preparation of this report is to encourage and facilitate the growth and expansion of the mineral industry in southeast Idaho. Over the last 10 years this area has experienced an increased demand for mineral commodities as well as an important industrial and population expansion. Several important mineral products are, or could be, obtained within the boundaries of Bonneville County.

Because this promising economic region is undoubtedly headed for further industrial expansion, it was deemed appropriate to conduct an investigation of its geology and mineral resources. This report is an effort to bring together under one cover a variety of scattered information obtained by a number of geologists who have worked in the region through the years.

It is sincerely hoped that the mining engineers, professional and amateur geologists, soils scientists, civil engineers, and many others will find this report an aid to a better understanding of Bonneville County geology and mineral resources.

Many sources of information, too numerous to mention in detail, were used to compile this report. Approximately four months of field investigations were carried out during the summers of 1959-60. Previous geologic field work by earlier investigators also provided additional information; all operating mineral-producing plants and claims were visited; and personal interviews about the area's geology and mineral production were conducted with public officials and private citizens.

PREVIOUS GEOLOGIC INVESTIGATIONS

Many geologic reports have been compiled that deal with portions of Bonneville County, but none describes the county as a whole (Fig. 2). A number of publications covering adjacent areas, including portions of Idaho, Utah, and Wyoming have some bearing on the geology of this county. A few unpublished reports or theses in both the above categories, also contain valuable data about southwest Idaho. The most important of these reports will be found on the accompanying list of references cited.

One of the earliest publications referring to southeast Idaho included geologic observations. This volume, an account of a trip taken in 1835 by Rev. Samuel Parker, was published in 1844.

The Hayden Surveys were first to produce quantitative data and maps; for example, F. H. Bradley (1873), geologist with the Snake River Division, made some major contributions in the field of general geology. In 1879, Orestes St. John, geologist for the Teton Division, prepared one of the first reports on the geology of part of Bonneville County. It included numerous sketches and cross sections, and was accompanied by detailed rock descriptions and measurements taken along traverse lines. The area referred to lies principally in the Caribou Range.

In 1898, Kirby contributed several pages of general geology to our knowledge of the gold deposits of Caribou Mountain. His report also appeared in an abstract (Lakes, 1898).

Other early reports on southeast Idaho include Gale and Richards' (1910) discussion of the phosphate deposits; Richards and Mansfield's (1912) description of the Bannock overthrust; Schultz and Richards' (1913) geologic reconnaissance in southeast Idaho; Schultz's (1918) reconnaissance report on phosphate and coal in southeast Idaho and west Wyoming; Mansfield's (1918) publication on the origin of western phosphates; and Conduit's (1920) and Kirkham's (1924) discussions of the geology and oil possibilities in Bingham, Bonneville, and Caribou counties. In 1927, Kirkham prepared an open file report on coal prospects on Willow and Fall creeks, Bonneville County.

In 1926, Piper and Kirkham prepared a report on ground water in the Idaho Falls area, while Stearns and others (1938) produced a comprehensive report on ground water resources of the Snake River Plain in southwestern Idaho. More recently, Taylor (1960) compiled an engineering report on the water supply and distribution system at Idaho Falls.

Mansfield was a most important contributor to published reports on southeast Idaho geology. Among his publications on geology, including stratigraphy, are: the Wasatch and Salt Lake Formations of Central Idaho (1920a); Triassic and Jurassic Formations in Southeastern Idaho and Neighboring Regions (1920b); Coal in Eastern Idaho (1920c); Igneous Geology of Southeastern Idaho (1921a); Types of Rocky Mountain Structure in Southeastern Idaho (1921b); Geography, Geology and Mineral Resources of Part of Southeastern Idaho (1927); and Geography, Geology, and Mineral Resources of the Ammon and Paradise Valley Quadrangles, Idaho (1952), a delayed publication covering field work accomplished in 1936.

Some special studies of the igneous rocks in Bonneville County have been completed; for example, in 1931 Anderson and Kirkham compiled a petrographic report on rocks from the Caribou Mountain area. Although this report included both field work and thin section studies, it emphasized the thin section work. In 1935, Mansfield and Ross published an article on the welded tuffs in southeast Idaho. In 1961, Hamilton wrote a thesis on the Caribou Mountain intrusives (unpublished).

In 1944, Gardner prepared a report on the phosphates of the Teton basin area. More recently, Cressman (1954), Swanson and others (1953), and McKelvey and others (1959) have written reports on the Phosphoria Formation in this region and its phosphate potential. In 1961, the U. S. Geological Survey had field parties mapping, among others, the Phosphoria Formation in the Snake River Range east of Swan Valley.

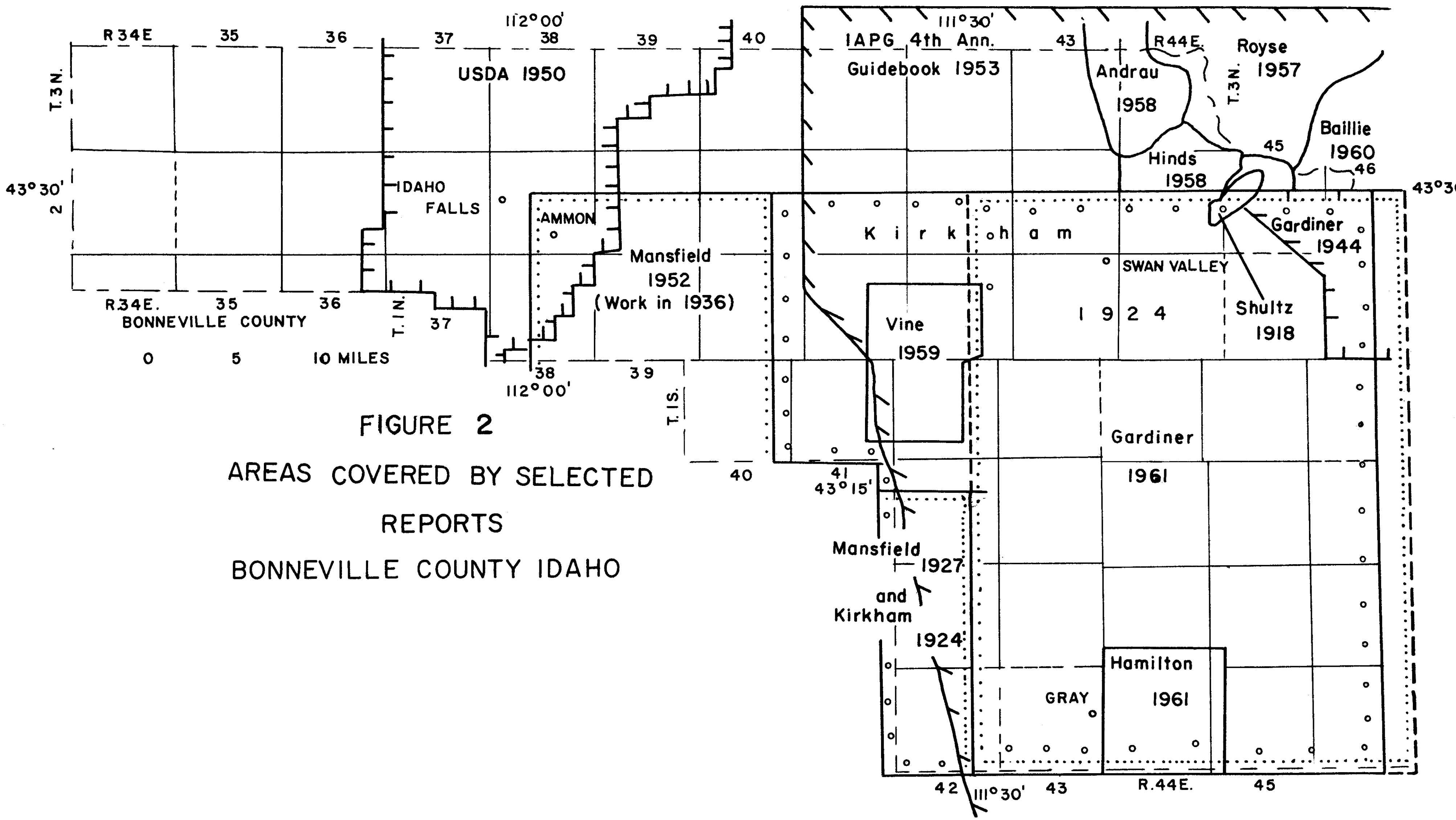


FIGURE 2

AREAS COVERED BY SELECTED REPORTS

BONNEVILLE COUNTY IDAHO

Several of the above reports treat briefly the geologic history, including geomorphology. Bayless (1950) described and interpreted post-Laramide geology, emphasizing geomorphology. A field conference guidebook, published by the Intermountain Association of Petroleum Geologists in 1953, covered a wide range of geologic subjects related to southeast Idaho.

One of the recent publications on this region is Vine's (1959) discussion of the geology and uranium deposits in carbonaceous rocks of the Fall Creek area, just west of Swan Valley; this report deals with an interesting part of the rock section in the Caribou Range.

A number of other publications concerning stratigraphy and structural problems have appeared from time to time: Mansfield and Roundy's (1916) Revision of the Beckwith and Bear River Formations of Southeastern Idaho; Moritz's (1953) Summary of the Cretaceous Stratigraphy of Southeastern Idaho and Western Wyoming; Kummel's (1954) Triassic Stratigraphy of Southeastern Idaho and Adjacent Areas; Imlay's (1952) Marine Origin of the Preuss Sandstone of Idaho, Wyoming, and Utah and Merritt's (1956) Upper Tertiary Sedimentary Rocks of the Alpine, Idaho-Wyoming Areas.

A number of graduate theses have been done in Bonneville County and nearby areas. They have proved useful to an interpretation of geologic history because they involved general and structural geology with emphasis on geologic mapping. Several are cited in this report and some have been used to compile the accompanying geologic map of Bonneville County. The individual researchers were as follows:

University of Michigan

Bayless (1947), Enyert (1947), McIntosh (1947) and Wyman and others (1949)

University of Wyoming

Espach (1957), Andrau (1958), Hinds (1958), Royse (1958), and Merritt (1958)

University of Idaho

Baillie (1960) and Hamilton (1961)

Wanless and others' (1955) detailed study of the stratigraphy of Paleozoic and Mesozoic rocks of the Gros Ventre, Teton, Hoback, and Snake River Ranges, is a very useful publication, although oriented toward Wyoming. The rock descriptions are excellent.

Finally, Louis Gardner (1961) of the U. S. Geological Survey, mapped the Irwin quadrangle several years ago; his work appeared only recently as an open-file report.

ACKNOWLEDGMENTS

The list of individuals who helped during the collection of data for this report is long; their assistance is gratefully acknowledged. Special mention should be made of the excellent services provided by two graduate students from the University of Idaho: Mr. William Baillie and Mr. James Hamilton, both of whom served ably during separate seasons as field assistants. Hamilton's (1961) work on Caribou Mountain has been used in the preparation of this report.

The indispensable contributions of earlier workers are acknowledged where used in the text. Their publications are cited at the conclusion of this report.

GENERAL GEOGRAPHY

PHYSICAL GEOGRAPHY

Drainage and terrain

Natural streams and lakes

The Snake River is the master stream in Bonneville County. From the point where it enters Palisades Reservoir on the southeast, it flows approximately 194 miles to a point six miles southwest of Idaho Falls, where it crosses the county boundary.

Just below the dam at Palisades, the elevation of the Snake is 5,200 feet; at Heise the river flows out of a steep sided valley at about 5,000 feet elevation. North of Idaho Falls is a series of falls, rapids, and man-made dams that interrupt the river flow in central Bonneville County. South of Idaho Falls, near the county line, the river flows at about 4,600 feet elevation. Thus the Snake drops about 600 feet or approximately three feet per mile through Bonneville County.

The most important secondary streams are in the east-central and the eastern part of the county where precipitation is highest; these streams are:

Jacknife Creek	Birch Creek	Fall Creek
McCoy Creek	Hell Creek	Pine Creek
Elk Creek	Palisades Creek	Willow Creek
Bear Creek	Rainy Creek	Grays Lake outlet

Western Bonneville County is a young lava desert that has no prominent stream valleys.

Two natural lakes occur in the eastern part of the area: Upper Palisades Lake and Lower Palisades Lake, with areas of approximately 0.25 and 0.06 square miles respectively. Grays Lake, frequently shown on maps as an open body of water, is essentially a low swampy plain with patches of water exposed (Fig. 5).

Terrain and natural geomorphic subdivisions

Bonneville County, 1,904 square miles in area, has a high range of relief and a variety of terrain features. The area may be subdivided as follows (Fig. 4):

Snake River lava and loess plain
Snake River alluvial plain
Willow Creek Hills
Caribou Range

Grays Lake lowland
Swan-Grand Valley lowland
Big Hole-Snake River ranges

The Snake River lavas and loess plain occupies over 14 percent of western Bonneville County or approximately 280 square miles. Of this area about one half (chiefly on the north) is covered with a variable thickness of loess; the rest is wasteland consisting of recent basalt flows (aa and pahoehoe) extensively rifted and fractured. Several low buttes, probably associated with former lava vents, produce relief varying from 200 to 700 feet. This western plain lies along the southeastern edge of a 50 mile wide portion of the Snake River Plain and has an over-all rolling appearance. General surface elevation is about 4,800 feet on the east, rising toward the west to 5,200 feet elevation.

The Snake River alluvial plain trends northeast across west-central Bonneville County, varying in width from 8 miles on the southwest to 12 miles on the northeast. This is a broad alluvial valley filled with intercalated clay, silt, sand, gravel, lava and pyroclastics. Low, terrace-like escarpments are identifiable adjacent to the river, while on the southeastern margin, bench-like surfaces rise from 4,700 to 6,000 feet elevation in the Willow Creek Hills.

South of Idaho Falls is a narrow belt of northeast trending sand dunes that lie along the edge of the alluvial plain. Some of these dunes rise 30 to 40 feet above the general surface of the plain (Fig. 6). The average elevation of the plain is 4,600 feet; relief varies from 20 to 40 feet.

The main alluvial plain extends northeast and becomes occupied by Henrys Fork (the "North Fork" of Snake River). The Snake River (the "South Fork" of Snake River) flows northwest from Heise, and is confluent with Henrys Fork near Menan Buttes in Madison County. The "South Fork" is forced to flow northwest at Heise by a broad, low fan whose axis trends northwest from Ririe. The surface of this fan slopes from 4,950 feet at Ririe on the east to 4,800 feet elevation at Ucon on the west. The difference in elevation is 150 feet in about 10 miles, which is a very uniform gradient of 15 feet per mile.

Willow Creek Hills lie in central Bonneville County, rising to the base of the Blackfoot Mountains (Bingham County) 14 miles south of Ammon. These hills are formed by irregularly dissected terrain drained by several perennial and intermittent streams. The highest elevations in this sector are 7,000 feet in the southeastern portion adjacent to the Caribou Range subdivision. Relief varies from 300 to 500 feet.

Drainage patterns and hills in this district are irregular. The hills are composed largely of silicic and mafic lavas partially mantled with loess. Locally on the east, resistant late Paleozoic shales, sandstones, and conglomerates form the highest hills. Grays Lake Outlet and Willow Creek tend to follow an irregular, yet prominent, topographic low that originates at Grays Lake lowland on the south.

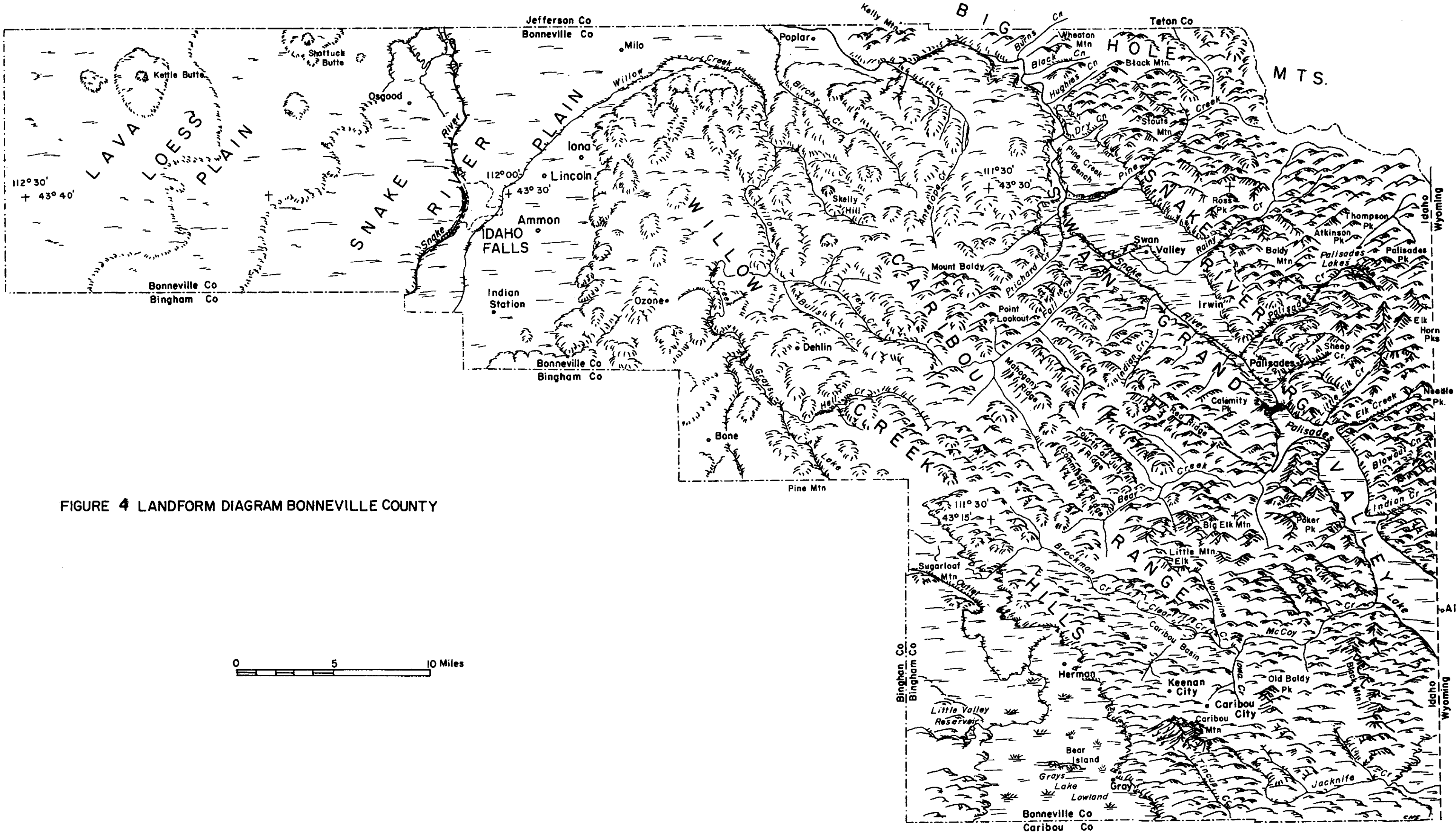


FIGURE 4 LANDFORM DIAGRAM BONNEVILLE COUNTY

Caribou Range rises to a maximum elevation of 9,805 feet at Caribou Mountain. The mountain is over 3,400 feet higher than Grays Lake lowland nearby. Several high peaks and ridges occur in the central and southern portions of this district, for example (Fig. 7):

Red Ridge, 8,947 feet elevation
Big Elk Mountain, 9,478 feet elevation
Poker Peak, 8,435 feet elevation
Old Baldy Peak, 8,330 feet elevation
Black Mountain, 8,905 feet elevation

Caribou Basin, northeast of Caribou Mountain, is an area of low relief about 12 square miles in extent. This basin is approximately 6,500 feet elevation or about 3,300 feet lower than Caribou Mountain.

The landforms in this district tend to be elongate in a northwesterly direction or parallel to the strike of the underlying folded and faulted Mesozoic and Paleozoic sedimentary strata. The drainage pattern is trellised and surface configuration is similar on a smaller scale to the Appalachian region in the eastern United States. Consequent, obsequent, resequent, and superposed streams have all been identified within the Caribou Range.

Relief varies from a maximum of over 3,300 feet (above Grays Lake lowland) to 1,000 and 1,500 feet along some of the stream valleys.

Grays Lake lowland is a flat swampy plain approximately 50 square miles in area of which 36 square miles are located in Bonneville County. It is located in the lowest part of a topographic depression that tends to parallel the northwest strike of underlying sedimentary rocks.

At one time, more of the area was flooded with water, but at present the site is a soft marshy area with a few patches of open water (Fig. 5). The general elevation of the surface is about 6,400 feet, but a small island rises 250 feet above this generally level surface.

Swan-Grand Valley lowland lies for the most part along the axis of the Snake River. This lowland in eastern Bonneville County is oriented northwest. Swan Valley lies at the northwest and is partly cut off from Grand Valley to the southeast by a conical hill of andesite: Calamity Point (Pyramid Butte). The valley is filled to an unknown depth with clay, silt, sand, and gravel. Palisades Dam extends across the southeast end of the valley at its narrowest point; Palisades Reservoir now floods most of Grand Valley lowland southeast of Calamity Point.

The walls of these lowlands tend to rise abruptly on each side, probably because of faults or fault-line scarps. Before Grand Valley was flooded, the valley floor sloped from about 5,600 feet elevation on the southeast to a little over 5,200 feet on the northwest. Pine Creek Bench, approximately 500 feet above the Snake River, is a lava plateau across the northwest end of Swan Valley.

The Snake River flows rapidly through Swan Valley at a gradient of about 20 feet per mile. The main river and tributaries have excellent trellised pattern; the river itself is a subsequent stream through this lowland sector.

The Big Hole-Snake River ranges lie northeast of the Snake River. Here are some of the highest peaks in the southeast part of Bonneville County. For example, Elkhorn Peaks attain a maximum elevation of 10,040 feet; Sheep Creek Peak, 9,940 feet, and Baldy Mountain, 9,830 feet. These mountains are more massive and less elongate than those in the Caribou Range. The nucleus of this mountainous region is normally thick, impure limestone and dolomite of Paleozoic age.

On the northwest the mountains are impressive: Stouts Mountain, 8,616 feet; Black Mountain, 8,805 feet; and Wheaton Mountain, 7,507 feet.

Pine Creek Valley, which forms a natural pass through the mountains, may be called the boundary between the Big Hole Range on the northwest and Snake River Range on the southeast. Relief along Pine Creek Pass varies from 1,200 to 2,900 feet.

From Burns Creek Canyon northwest of Swan Valley, to Indian Creek on the southeast, the major valleys tributary to Swan-Grand Valley Lowland are part of a general trellised drainage pattern. Dendritic drainage patterns are also present in this mountainous area.

Ancient valley and cirque glaciers, fault scarps, and landslides locally have produced precipitous cliffs in the Big Hole-Snake River ranges. The southwest marrin of the ranges along Swan-Grand Valley Lowland drop off sharply along a fault-line scarp.

Climate, flora, and fauna

Climatic conditions

Bonneville County climatic conditions are variable because of a wide range in physical setting. Western Bonneville County, including the vicinity of Idaho Falls, has a dry, semiarid continental climate. The eastern mountainous uplands are more humid but experience a high percentage of clear days. Daily temperature changes are great: the difference between mean maximum and mean minimum for winter months is about 20° F; for summer months, this variation is about 38° F., occasionally even greater.

In general, precipitation increases toward the east. Stearns and others (1938, p. 19) noted that prevailing westerly winds carry much of the water that is evaporated from the dry Snake River plains into the mountainous uplands on the east.

Because this moisture frequently falls as precipitation when the water laden air masses are forced to rise, the water is thus recycled. The heaviest precipitation occurs around Grays Lake lowland and the Caribou Range. Annual distribution is also evenest in this region. Afternoon thundershowers during the summer are not uncommon in the mountains; however, this seasonal precipitation generally bypasses Swan Valley lowlands and the western lava plain.

Heavy dust storms are common in the western two thirds of Bonneville County during spring and summer months. Cultivation of the western and central loess-covered surfaces facilitates wind erosion.

In discussing weather conditions, Mogen and others (1950, p. 5) made the following statement about the area around Idaho Falls:

> The spring summer, and fall temperatures are ideal for livestock raising and dairying and where irrigation is possible, for crop growing. The ground remains open until sometime in mid or late November, enabling the farmers to complete their fall plowing. Severe winter temperatures, however, make it necessary to feed and shelter livestock during the cold months.

The following is a summary of selected data obtained from published records of the U. S. Department of Commerce, 1958:

Table 1. Climatic data

	Total mean annual:		Temperature (° F.)				
	Precipitation	Snowfall	Averages			Extremes	
	(inches)	(inches)	Ann.	Max.	Min.	High	Low
Gray	17.27	116.5	40.0	53.9	26.0	97	-39
Idaho Falls	9.13	35.9	44.6	57.6	31.5	104	-37
Irwin	15.78	58.2	42.7	56.7	28.7	102	-45
Palisades Dam	21.43	----	42.2	56.1	28.3	95	-28
Ririe	12.50	33.6	44.7	56.8	32.5	98	-23

Fauna and flora

Among the animals found in Bonneville County are black and brown bear, deer, and elk. Coyotes, porcupines, badgers, gophers, rabbits, and squirrels are the most abundant smaller animals. Birds, including game birds, are plentiful and migratory waterfowl are not uncommon.

Among the flora are sagebrush, juniper, rabbit-brush, buckbrush, greasewood, wild rye, bunch grass, cheat grass, and squirrel-tail (Stearns and others, 1939, p. 7-8).

Lombardy, silver, and Carolina poplars, largely introduced, grow well in most of the area where precipitation is heaviest. Douglas fir and lodgepole pine occur in moderately large stands at higher elevations in the eastern part of Bonneville County.

Soils

Soils, as well as the climate, are variable. Most of the formal study of soils has been in the Idaho Falls area. Mogen and others (1950, p. 19-21) describe these as upland soils, alluvial valley soils, and bottomland soils.

Upland soils are fine, silty, light-colored loams or loesses. Depth varies but most of the rolling upland areas have fairly thick covers of this fertile soil. They have good moisture-holding capacity and are dry-farmed or irrigated, although dry farming is not as profitable as it used to be.

Screen analyses of two samples of typical upland soil, collected in east-central Bonneville County are as follows:

Table 2. Screen analyses of upland soil

Size (mm)	Percentage distribution Sample S-9-59	Sample S-14-59	Classification
Over 0.295	1.7	1.6	Fine to medium sand
0.295-0.208	0.9	1.2	Fine to medium sand
0.208-0.147	1.1	1.8	Fine sand
0.147-0.104	1.8	1.8	Fine sand
0.104-0.074	4.0	2.4	Fine sand
0.074-0.043	18.3	12.3	Coarse silt to fine sand
0.043-0.015	62.7	70.2	Fine to coarse silt
Less than 0.015	9.1	8.7	Fine silt to clay
Total	99.6	100.0	

It will be noted that from 90 to 91 percent of these samples is fine sand, silt, and clay material that is easily transported by the wind. These fine soils are some of the most important in the area.

Soils of the valley floors are fine alluvium and consist largely of terrace and alluvial fan deposits blanketing coarser, waterlaid gravels. Sandy and silty, these brownish-gray to brown soils have moderate to good drainage and are usually productive. Generally these soils are located where it is necessary to irrigate.

Not widely distributed, alluvial bottom land soils occur along relatively narrow, stream bottoms. Where present, they are fertile and highly productive, if irrigated.

Mountain soils in eastern Bonneville County are thin, coarse, and stony. Talus slopes are common. Locally, coarse conglomeratic debris provides poor parent material for soil development.

CULTURAL AND ECONOMIC GEOGRAPHY

Accessibility of area

All-weather, paved highways into and through Bonneville County are U. S. Routes 26, 91, and 20. U. S. Route 26 follows the Snake River from Jackson, Wyoming, entering Bonneville County on the southeast at Alpine, Wyoming. This route skirts the Palisades Reservoir and passes through Swan Valley to Poplar, Rigby, and Idaho Falls. At Idaho Falls it is joined by U. S. Route 91 and both proceed south to Blackfoot. At Alpine, U. S. Route 89 runs south to Salt Lake City, Utah.

U. S. Route 91 is a north-south route through west-central Bonneville County, proceeding to Pocatello and connecting with other routes which parallel the south Snake River Plain.

From the west, U. S. Route 20 traverses the area occupied by a main portion of the U. S. Atomic Energy Reactor Testing Station, west of Idaho Falls, then crosses east into western Bonneville County. Route 20 extends northeast of Idaho Falls to St. Anthony, thence to West Yellowstone, Montana and Yellowstone National Park.

Local accessibility within the county boundaries varies; for example, areas adjacent to Idaho Falls and the Snake River alluvial plain are readily accessible by excellent roads. The northern half of Bonneville County west of Idaho Falls is also accessible by gravel and dirt roads, but the southern half is practically inaccessible because of irregular, fractured lava flows. The Willow Creek Hills area is also poorly accessible because dirt roads, once more widespread, have been destroyed by local washouts and cultivation practices.

Grays Lake lowland is fairly accessible by graveled roads, and Swan-Grand Valley lowland is readily accessible; however, most roads in the Caribou Range will barely accommodate four-wheel drive vehicles. The base of Caribou Mountain may be approached from McCoy Creek and from Grays Lake lowland, but the so-called roads are little better than trails.

Forest roads are commonly primitive, but they are in fairly good condition along Fall, Bear, and McCoy creeks. Normally these roads are open in summer months to most any kind of vehicle, although some roads may be very slick during heavy rains.

Except for a paved highway which traverses Pine Creek Pass (State Route 31), access to the Big Hole-Snake River ranges is very poor. A few roads extend short distances from Snake River Valley up the principal west trending valleys, but four-wheel drive vehicles are recommended for travel on most of these roads. A good pack trail follows Palisades Creek to Upper Palisades Lake.

Settlements and population

The 1960 U. S. Census revealed that Bonneville County, with a population of 46,646, is one of Idaho's main population centers. Over one half, approximately 28,165 people, live within the limits of the county seat, Idaho Falls. Most of the remaining population is distributed south and east of Idaho Falls in the towns of Ucon, Iona, Lincoln, and Ammon and in smaller towns like Swan Valley, Irwin, and Palisades. Attractive subdivisions are growing rapidly in the area south of Idaho Falls. A few people dwell on outlying ranches.

Transportation facilities

The Idaho Falls area is served by the Union Pacific Railroad, by several major motor freight carriers, and by several bus lines, including a government-operated fleet of buses running on regular schedule to the National Reactor Testing Station.

Western and West Coast airlines operate out of a good airport at Idaho Falls.

General water supply

Ground water supply is more than adequate for present public service and irrigation. Plans have been made for increased storage facilities, including the possible construction of a Federal Bureau of Reclamation dam at Burns Creek on the Snake River, and further development of water reserves on Willow Creek watershed. Water resources are discussed at length in a later section of this report.

Labor supply, electric power facilities, and natural gas

Labor market

According to a 1958 survey, made by the Idaho Falls Chamber of Commerce and the Idaho Employment Security Agency, Idaho Falls' labor market has available over 33,740 persons; estimated total employment at the time was 15,906. This survey catalogued the number of persons employed in various fields as follows:

Construction	1,753	Finance	493
Manufacturing	952	Services	4,562
Utilities	603	Government	1,394
Trade	3,687	Other	2,462

Power supply

Power and power reserves seem ample in this area. Power is supplied principally by the Utah Power and Light Company. In Idaho Falls there are also two municipal systems: hydro and diesel-electric. The main power system is interconnected with the Idaho and Montana Power companies.

At Idaho Falls the city plants are capable of producing a total of 9,550 kilowatt hours of electric power. This is supplemented by 116,000 kilowatt hours produced at Palisades Dam, which is operated by the U. S. Bureau of Reclamation, and has a capacity of 114,000 KVA from its four generating units.

Natural gas supply

Intermountain Gas Company supplies gas to the Idaho Falls area. Almost all of the larger industries use natural gas.

Industry, markets, and capital

Agriculture, the oldest industry in the region, is a $16 million business in Bonneville County. In 1959 it was reported that there were 1,538 farms in the county. Kohl, Moss and Smith (1958, p. 4) made the following estimates of the total annual valuation of various agricultural pursuits within the county:

Potatoes	$5,000,000	Winter wheat	$ 1,481,000	Misc. crops	$ 1,647,000	Dairy	$ 152,000
Spring wheat	2,016,000	Barley	560,000	Cattle & calves	2,282,000	Misc. livestock	449,000
Sugar beets	502,000	Hay	614,000	Sheep, lambs & wool	949,000		

Idaho Falls is a shipment center for large quantities of livestock and potatoes. Its stockyards are the largest in Idaho. Chief farm crops include potatoes, sugar beets, onions, seed peas, beans, wheat, rye, barley, alfalfa hay, red clover, and oats. A few fruits are produced, chiefly apples, plums, and cherries. It has been estimated that nearly 500,000 acres of farm land are available in this region if suitable irrigation methods are applied to the land. Currently about 155,000 acres of land are used for productive farming.

The cattle, sheep, and pig industries, including dairying, are estimated to yield close to $4.5 million annually. Local production of potato flour, powdered milk, and beet sugar is a major outgrowth of agriculture. The potato flour plant has produced as much as 2,500,000 pounds of flour annually, while the sugar beet factory at Lincoln has a capacity of 65,000,000 pounds annually.

According to the Idaho Falls Chamber of Commerce (1958), there are 46 manufacturing plants in the city. Leading plants include meat packing and processing, dairy products, potatoes and potato products, seed and grain processing, bakery goods, beet sugar and allied by-products, timber and millwork products, printing and publishing, concrete and brick products, and machinery and equipment products. The following are the 14 largest manufacturing or processing firms:

Upper Snake River Valley Dairymens' Assoc.	Idaho Falls Sheet Metal Works
Rogers Brothers Seed Co.	California Packing Company
Hart's Bakery	Old Faithful Beverage Company
Utah-Idaho Sugar Co.	American Potato Company
Post Register	Idaho Potato Starch Company
Clark Concrete Const. Corp.	Taylor Meat Company
Idaho Potato Growers, Inc.	Idaho Falls Brick and Tile Co.

Principal markets for livestock are the Middle West and Pacific Coast areas. Wool is shipped to eastern markets, while dairy products are shipped west to California; Idaho Russet potatoes are distributed all over the nation.

The National Reactor Testing Station, which occupies more than 894 square miles, is a vital element in the expanded economy of the county. Although located largely outside Bonneville County, the station plays a major role in Bonneville County economy. Total plant investment and facilities now under construction have a value close to $265 million (1960).

Bonneville County financial framework appears to be solid and as good as, if not better, than that of any other county in the state. According to a statement made by George L. Jensen (news release), county assessor, to the Post Register, Bonneville County valuation reached approximately $36,000,000 in 1959. For the same year, the city of Idaho Falls is on the rolls for a valuation of $14,063,020.

Retail sales and individual income estimates for 1958 and 1959 are given by the Editors and Publishers Market Guide for 1959 for Bonneville County, as follows:

	Retail sales	Individual incomes
1958	$55,200,000	$63,760,000
1959	55,450,000	66,090,000

In its three savings banks and three savings and loan associations, Idaho Falls has a total of about $22,998,000 in saving deposits, according to the Editors and Publishers Market Guide for 1959.

GENERAL GEOLOGY

SEDIMENTARY ROCKS

General section

Sedimentary rocks and rock materials in this region range in age from Cambrian to Tertiary; Precambrian metasediments, similar to those in the Grand Tetons to the northeast, probably form the basement rock. All geologic periods are represented except the Silurian. According to Stokes (1953, p. 14-18), the maximum thickness of the Paleozoic and Mesozoic geosynclinal facies is in excess of 67,000 feet; however, the geosynclinal axes where deposition was greatest were west and south of the present Snake River and Caribou ranges. Exposed sedimentary rocks in eastern Bonneville County vary from 15,000 to 23,000 feet in thickness. The following are approximate thicknesses (in feet) for each system represented:

Tertiary	800-1000
Upper Cretaceous	1020-5500
Lower Cretaceous	640-2200
Jurassic	1250-3350
Triassic	2000-7200
Permian	176-575
Pennsylvanian	200-2750
Mississippian	700-4100
Devonian	570-575
Ordovician	400-620
Cambrian	840-1180

As implied above, thickness of the sedimentary rocks in general increases toward the southwest; however, there are local variations in the thicknesses representing the different systems in Bonneville County (Fig. 9). For example, the Upper Cretaceous sediments appear to be thickest in the northeast, while Lower Cretaceous sediments are thickest toward the southwest. Jurassic rocks appear thickest to the southwest, while Triassic rocks seem to thicken in the central portions of both the Snake River and Caribou ranges.

The Permian Phosphoria Formation, though relatively thin over the whole area, does thicken some toward the southwest.

The remainder of the Paleozoic formations are too variable in thickness to indicate directional trends.

Cambrian System

Gros Ventre Formation

This formation is presumed to be a Middle Cambrian marine shale on the basis of its fossil trilobites. The strata consist of thin-bedded limestones and greenish-gray, brown, and red shales, with local calcareous flat-pebble conglomerates. The formation weathers easily, producing low relief and leaving few exposures except on steep-walled valleys. The Gros Ventre probably rests conformably on the Flathead Quartzite (Cambrian) as it does in adjacent areas.

The Gros Ventre Formation may be observed in the lower reaches of Palisades and Elk creeks in eastern Bonneville County.

Boysen ("Gallatin") Formation

This is an Upper Cambrian, marine, bluish to brownish-gray limestone, with yellow-brown and green, silty partings and thin beds or nodules of chert. Weathering produces the brownish-yellow appearance of local cliffs. It lies conformably on the Gros Ventre.

The Boysen occurs with the Gros Ventre along Palisades and Elk creeks.

Ordovician System

Bighorn (Fish Haven?) Dolomite

This formation is an Upper Ordovician (Richmondian Stage) marine, coarse to fine-textured, massive, cream to light-buff and light-blue-gray (locally darker gray) dolomite; a few lenses and masses of chert occur in the bedding planes. It weathers darker as well as chalk white, but mottled dark-gray patterns may show on a fresh, broken surface. Weathering produces characteristic, deeply pitted surfaces. It lies unconformably over Cambrian strata.

The Lehigh Dolomite Member, perhaps present in the upper part of the Bighorn, is a white, very fine-grained dolomite. Some doubt that it is Ordovician in age; perhaps it is Silurian and correlates with the Laketown Dolomite. It weathers nearly white and may include fossil fragments of crinoids, horn and honeycomb corals. When present, this member is near the middle of the Bighorn Dolomite.

The Bighorn Dolomite is not differentiated on the accompanying map, but may be recognized in several places along the southwestern side of the Snake River Range.

Figure 5. Grays Lake Lowland looking southwest toward the Blackfoot Mountains.

Figure 6. Large active sand dune south of Ammon, lee slope.

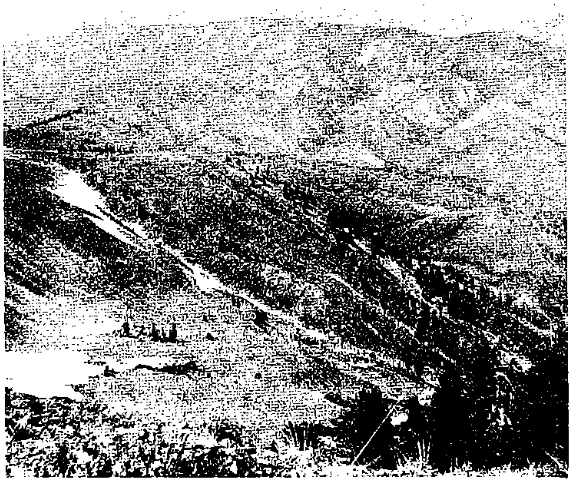


Figure 7. Red Ridge anticline from Big Elk Mountain, Caribou Range.

Figure 8. Steep surface of Blowout fault at northeast end of slide in Blowout Canyon, Snake River Range. Note large "horse", center right.

Silurian System

Rocks of Silurian age do not seem to occur in Bonneville County; however, according to Stokes (1953, p. 15), the Silurian is represented by the Laketown Dolomite (Niagaran series) in adjacent districts. This formation extends northwestward from the Bear Lake region and extends across the Snake River Plain.

Mansfield (1952, p. 18) said that the Laketown Dolomite probably could be reached in the Ammon area by deep drilling.

Devonian System

Darby Formation

This formation is an Upper Devonian (Chemung Stage) gray to brown and buff, marine dolomite and limestone, which includes some yellow, green, red, and brown shales, siltstone, and sandstone partings. Of varied lithologics, this formation tends to be dolomitic and limy in its lower beds and becomes more shaly and sandy in upper layers. In places, the formation may have a pebbly, quartzitic base. Potentially, it is a good oil reservoir, indeed, it smells like oil. The rock weathers easily into chalk-white to gray, cavernous masses. Probably the formation is the equivalent of the Threeforks Shale but could be slightly younger. Formerly, it has correlated with the Jefferson Limestone; however, Brooks and Andrichuk (1953), who noted the similarity of the clastic materials in the Threeforks Shale and Darby Formation, stated:

> The Darby typically shows shelf sequence made up predominantly of secondary dolomites with variable amounts of normal marine limestone. The sandstone has variable amounts of carbonate cement that passes laterally into sandy carbonates and pure carbonates.

Like the Bighorn Dolomite, the Darby is not differentiated on the geologic map, but may be found along the southwest edge of the Snake River Range.

Mississippian System

Madison Limestone

This marine formation is Lower Mississippian (Kinderhookian-Osagean series) in age. The rocks are dark bluish-gray to brown and red, thin to massive, bedded, prominent cliff-making limestones. These medium to coarse-grained rocks smell like oil when freshly broken. They contain beds of eliptical, nodular chert, and in places, shaly partings, although the Madison is a relatively pure limestone.

This formation is fossiliferous at several horizons. Schultz (1918, p. 21) reported the occurrence of many cup corals as well as the following fossil types:

Syringopora sp.	Spirifer centronatus
Loxonema sp.	Chonetes sp.
Productella sp.	Euomphalus sp.

The Madison lies unconformably above the Darby Formation and outcrops are common on the southwest flank of the Snake River Range and the northeast side of Caribou Range.

Brazer Limestone

This is an Upper Mississippian (Meramecian-Chesterian series), marine limestone that may resemble the Madison in general appearance. It is finer-grained: a fine to sublithographic gray to pinkish limestone; in places it contains breccia zones, dark nodular chert layers, and stringers of calcite and siderite. This rock commonly smells like oil when freshly broken. Much of it contains cup corals and other fauna, among them:

Syringopora	Martinia
Lithostrotion	Productus giganteus

The formation tends to be a ridge and cliff maker, and weathers to gray or almost white. It seems to be unconformable on the Madison Formation in most of this area.

Cherty and phosphatic beds about 80 feet thick have been reported to occur at the base of the Brazer by Mansfield (1952, p. 20).

Outcrops of the Brazer may be found in locations similar to those cited for the Madison Limestone.

Pennsylvanian System

Wells Formation

The Wells Formation of Pennsylvanian age is in some localities separable into three divisions of clastics, probably late Pennsylvanian in age: (1) lower massive limestones; (2) middle sandstones; and (3) upper calcareous fine sandstones and siliceous limestones (Mansfield, 1952, p. 21).

In general, the Wells consists of gray to yellow, cherty and sandy limestone and dolomite, and pale yellow to brown, white to gray calcareous sandstones and quartzites. It rests unconformably on the underlying Brazer Limestone. The upper and lower portions of the Wells tend to produce prominent cliffs or knobs which weather to white, gray, or reddish shades.

In the Snake River Range, some geologists (Wanless and others, 1955), divide the Wells into two units: The Amsden Shale, and the Tensleep Sandstone.

The lower unit, the Amsden is described as a thin-bedded pink to buff sandstone (Darwin Member), red to gray limestone and red shale. The limestone contains rounded nodules of gray, brown, orange, and black chert. Locally, there are breccia zones and brachiopod and bryozoan fossils. The latter include:

Spirifer occidentalis	*Marginifera* sp.
Spirifer rockymontanus	*Composita* sp.
Schizophoria sp.	

The upper unit, the Tensleep, is a fine-grained, white to grayish-yellow sandstone to quartizitic sandstone with beds of siliceous dolomite. Bluish-white chert bands occur in places. This rock produces white, weathered cliffs and talus slopes. Fossils include:

Squamularia sp.	*Productus* sp.

The Wells may be observed in outcrops along lower Fall Creek in the Caribou Range.

Permian System

Phosphoria Formation

The Permian is represented by yellowish to greenish-gray or black marine mudstone, shale, and sandstone, with local intercalations of impure limestone, dolomite, and chert. Some beds are pisolitic and oolitic, with bluish and whitish bands. In the past, carbonaceous horizons in the Phosphoria have been mistaken for coal-bearing strata.

The Rex Chert Member is a prominent and resistant horizon in some localities; it may stand out as low cliffs, ridges, and knobs. Where the entire formation is present, a typical section may be as follows (Wanless and others, 1955, p. 37):

Black chert (top)
Dark phosphatic shale with phosphorite beds
Fossiliferous sandstone
White chert
Geodiferous limestone and dolomite with chert bands
Lower phosphatic shale
Basal conglomerate

With the exception of the Rex Chert Member, the Phosphoria weathers and erodes easily, producing low relief or depressions. In places, weathered beds are black and produce gray granular soil.

These shales, limestones, and cherts were formerly included in the Park City Formation (type locality: Park City, Utah).

Although difficult to recognize, the contact between the Phosphoria and the Wells formations (Pennsylvanian) is unconformable in southeastern Idaho, according to Mansfield (1952, p. 22). However, he also thought that the upper part of the Wells might be Permian in age.

Shaly beds in the Phosphoria carry mud-loving types of brachiopods, while the limestones contain more varied forms. Locally, peculiar nodular and tubular concretions(?) are found in the Phosphoria. Girty (1910) described the fauna of the phosphate beds (then called part of the Park City Formation). He noted that Protozoa, Coelenterata, and Bryozoa are entirely absent from the phosphate beds. Some of the most common forms that do occur are:

Chonetes ostiolatus	Ambocoelia arcuata
Productus sp	Omphalotrochus ferrieri
Pugnax weeksi	O. conoideus
P. weeksi var. nobilis	Nucula montpelierensis
Gastrioceras simulator	Yoldia mcchesneyana
Lingulidiscina missouriensis	Grammysia(?) carbonaria

Although not unusually thick, the Phosphoria persists with nearly uniform character, over approximately 175,000 square miles. However, the economically valuable phosphate-bearing beds tend to vary in thickness and phosphate content. Schultz (1918, p. 23) thought that the entire series thinned toward the north.

The Phosphoria can be recognized in several places along Fall Creek.

Triassic System

Dinwoody Formation

This Lower Triassic formation is a light brown or olive-drab to tan marine shale, siltstone, and sandstone with some calcareous siltstone beds. Commonly it is platy, or thin-bedded and jointed. These beds interfinger with the Woodside and lie unconformably on the Phosphoria. Mansfield (1952, p. 29-30) noted that part of what has been called the Woodside Shale in the Ammon area is probably Dinwoody.

Fossils are found in this formation.

The Triassic is not subdivided on the accompanying geologic map: any such sub-division would have been impractical because of the small scale of the map. However, the various Triassic formations may generally be recognized along Fall Creek.

Woodside Shale

The Woodside Shale is light to russet-brown siltstone, reddish shale, and gray limestone of Lower Triassic age. Weathering of the red shale produces the characteristic red outcrops associated with the Triassic age in this region. Exposures are poor because the rock is nonresistant. The limestones tend to be fossiliferous. The formation probably lies unconformably above the Phosphoria Formation.

Thaynes Limestone

The Lower Triassic is represented in this area by the Thaynes Limestone which, in general, consists of dull gray, sandy limestone and some gray to brown calcareous sandstone, red and gray shaly sandstone and sandy limestone. The base is characterized by the so-called Meekoceras zone. Weathering tends to produce a light-brown to buff color. This formation has more clastic units on the east; limestone units increase toward the west. It lies conformably above the Woodside Shale.

In the formation investigators often recognize several units: a lower limestone and shale; a middle limestone and shale; and an upper calcareous siltstone, red shale, and limestone. Mansfield (1952, p. 30-33) recognizes in southeastern Idaho the three following formations as part of the Thaynes Group:

(1) Ross Fork Limestone (lower member), consists of gray and brown limestone with abundant Meekoceras, calcareous shales, and an upper dense calcareous gray to olive-green shale. These shales form cliffs in the locality. The Ross Fork contains fossils.

(2) The Fort Hall Formation consists of gray to yellow and reddish calcareous sandstones and limestones. Locally, it contains many fossils.

(3) The Portneuf Limestone is principally a massive, siliceous and cherty, gray to yellowish limestone containing some intercalated red sandstones and shales. It contains numerous fossils locally.

Ankareh Shale

The name Ankareh has been applied to Middle and Upper Triassic formations in this region. The Ankareh was described by Gardner (1944, p. 8) as "Shale, deep red, nonresistant and gray quartzite and red sandstone."

These units contribute red colors to the Triassic exposures as do the Lower Triassic formations mentioned earlier. Many believe that these rocks represent terrestrial deposits because of certain types of plant fossil they locally contain.

Mansfield (1952) has identified several units in the Ankareh and felt justified in setting up the following formation names for them (oldest to youngest):

(1) The Timothy Formation (p. 33-34) is a granular-textured, yellowish to grayish sandstone with red and green shaly partings. Weathering turns this formation pinkish or reddish. It rests unconformably on the underlying Portneuf. In Wyoming, this unit is correlated with the Lower Popo Agie.

(2) The Higham Grit (p. 34) is a "...coarse, white to pinkish, gritty or conglomeratic sandstone, which...in some places forms prominent topographic features - especially bold strike ridges...".

(3) The Deadman Limestone (p. 34-35), called the Upper Popo Agie in Wyoming, is variable in color and lithology. It may be white, pink, purple, gray, or green, but it is dense to granular and arkosic.

(4) The Wood Shale is primarily a bright red sandy shale and shaly sandstone.

Jurassic System

Nugget Sandstone

This formation is a massive pink to brick red, or gray sandstone and quartzite of Lower Jurassic age. Much whitish sandstone occurs at both top and bottom of this formation. In places the formation is cross bedded, ripple-marked, and banded. Probably the Nugget is terrestrial in origin.

Weathering produces blocks and slabs that form prominent talus slopes.

Presumably, the Nugget Sandstone rests unconformably on the underlying Triassic rocks (Kirkham, 1924, p. 20).

Outcrops of the Nugget may be easily recognized in the Caribou Range, for example, on Fall and Bear creeks.

Twin Creek Limestone

The Twin Creek Limestone of Middle and Upper Jurassic age, has a variety of lighologic characteristics and is also of marine origin. In general, it is a gray to dark blue, platy, soft to compact, fine-grained, splintery limestone (Fig. 10). Calcite veins and seams are common. Some yellow sandy limestone and calcareous sandstone may occur in spots near the top of the formation. It lies conformably on the Nugget Sandstone.

Weathering of this formation produces yellowish, greenish yellow, to grayish-brown rounded slopes.

The formation is fossiliferous in some horizons. Fauna include:

Pentacrinus asteriscus
Camptonectes pertenuistriatus
Trigonia americana
Astarte meeki
Thracia weedi
Gryphaea calceola
Ostrea sp.
Pholadomya sp.
Pleuromya sp.

The Twin Creek Limestone is well exposed along the old road that ascends the east flank of Big Elk Mountain, and also along Fall Creek.

Preuss Sandstone

Of uncertain origin, this formation is probably Upper Jurassic in age. Imlay (1952) noted that marine fossils have been found in the Preuss at other localities and concluded that it originated in saline lagoons. Variable in lithology, it consists of reddish to chocolate-colored and greenish-gray shale, shaly sandstone, and massive limestone. This formation is unconformable on the Twin Creek Limestone. It is usually poorly exposed because it is nonresistant. Originally it was included in the Beckwith Formation and is equivalent to part of the Sundance Formation lying to the east in Wyoming.

Exposures may be observed on Fall Creek.

Stump Sandstone

Also originating in the Upper Jurassic and included as a part of original Beckwith Formation, the Stump is a marine, blue-gray to brownish-green, calcareous shaly sandstone. It weathers to greenish-gray or yellowish-gray color. Locally, calcite seams are common. The greenish color common to this formation, is probably the effect of the mineral glauconite. It is also equivalent to the upper

Sundance Formation.

The Stump seems to rest conformably on the underlying Preuss, and yet the nature of the two formations suggests a somewhat different origin.

This formation includes minor limestone units containing Gryphaea nebraskensis, Pentacrinus asteriscus, Belemnites sp., Ostrea strigilecula white(?), "Rhynchonella", Camptonectes sp., Astarte sp., and Trigonia.

Outcrops of typical Stump may be observed in the section along Fall Creek.

Lower Cretaceous System

Gannett Group

These rocks are variable and appear to be composed of five separate, conformable formations although "...some are marine formations and others are of fresh water origin" (Kirkham, 1924, p. 23). In order from oldest to youngest, the units are called Ephraim Conglomerate, Peterson Limestone, Bechler conglomerate (shale), Draney Limestone, and Tygee Sandstone.

These formations are equivalent to the upper part of the original Beckwith Formation and also to the Cloverly Formation.

The Ephraim Conglomerate, of Lower Cretaceous age (perhaps Upper Jurassic, according to Mansfield, 1952, p. 39), may be partly of terrestrial origin, although it seems to be conformable with the underlying marine Stump Sandstone. This formation consists of red to purple, and yellowish conglomerate with minor amounts of purplish-red to maroon limestone, sandstone, and shale. The conglomerate contains large black chert pebbles, as well as pebbles of quartzite and limestone. The conglomerate facies is resistant, but the shale, sandstone, and limestone are softer and nonresistant to weathering.

The Peterson Limestone consists of thin bedded to massive, locally lithographic, fresh water dolomitic limestone. It is frequently veined with calcite. This formation is conformable with the Ephraim, weathers to a prominent grayish-white color, and forms low ridges and ledges. It contains some fresh water types of gastropods signifying its origin in a ponded environment.

The Bechler Conglomerate in this area tends to be composed of soft, reddish shales. The conglomerate facies described farther west at the type section, appears to be missing in Bonneville County. This formation weathers to reddish soil and forms rounded slopes and saddles between the more resistant limestones, Peterson below and Draney above.

The Draney Limestone resembles the Peterson Limestone in most respects. It is light-gray, fine-grained or lighographic, white-weathering, almost a dolomite locally. This formation is conformable on the underlying Bechler Conglomerate. It contains a few poorly preserved fresh water fauna.

The Tygee Sandstone resembles the younger Cretaceous sandstones (Wayan). In this area it tends to be a fine-grained brown to yellowish sandstone with shaly sandstone and carbonaceous shale layers. This formation is often completely missing, probably eroded away. Locally, it is separated from overlying Upper Cretaceous strata by a prominent unconformity.

In the Snake River Canyon, Wanless and others (1955, p. 57) found light-gray limestone and reddish shale near the top of the Tygee. The beds also contained a number of poorly preserved pelecypods and gastropods.

There is some possibility that the Tygee may be part of the so-called Bear River Formation of Lower and Upper Cretaceous age.

The Gannett Group are relatively easy to recognize when several of the formations may be observed in one area. The middle portion of Fall Creek has excellent exposures of most of the group. The Tygee Sandstone is a little difficult to distinguish from younger Cretaceous sandstones. The best outcrops occur in the headwaters area of Fall Creek.

Lower(?) and Upper Cretaceous rock units

Wayan Formation

Strata representing minor portions of the Lower Cretaceous, but consisting principally of the Upper Cretaceous have been studied by several investigators. Although conclusions are varied, in this report the name Wayan Formation is given to rocks that elsewhere have been assigned to the Bear River Formation , Aspen Shale, and Frontier Formation. Moritz (1953, p. 72) noted that the discovery of the fossil plant *Tempskya minor* in both the Wayan Formation and the Aspen Shale suggests they are of similar age. He also indicated Reeside's oral opinion that "the age of the Wayan formation is that of the Bear River and Aspen together, with possibly a little Frontier."

Vine (1959, p. 262-263) noted an unconformity separating the underlying Bear River Formation and the younger Wayan Formation in the vicinity of Fall Creek Basin (Idaho).

In the Palisades Creek area, Gardner (1944, p. 6-7), described the Bear River Formation, Aspen Shale, and Frontier Formation as follows (with modifications):

The Bear River Formation is of terrestrial origin and consists of black nonresistant shale; gray to green, calcareous, cross-bedded sandstone and siltstone; and rusty brown quartzite. It is unconformable on the underlying Gannet Group. Locally this formation contains impure coaly layers. Fauna include:

Pyrgulifera humerosa	Unio sp.
Campeloma macrospira	Viviparus sp.
Corbula pyriformis	Goniobasis sp.
Corbicula durkeei	Pachymelania sp.

The Aspen Shale consists of black, pale gray or green siliceous shales, siltstones and sandstones; a few thin beds and lenses of limestone and calcareous shale; and green and gray "porcelanites" (light-colored fused, porcelaneous shales, ash(?) and clays). The formation weathers to long rounded hills of gray color. Fossiliferous locally, it includes the plant fossils Tempskya minor and Tempskya knowltoni, and represents stems and root bundles of two species of fern.

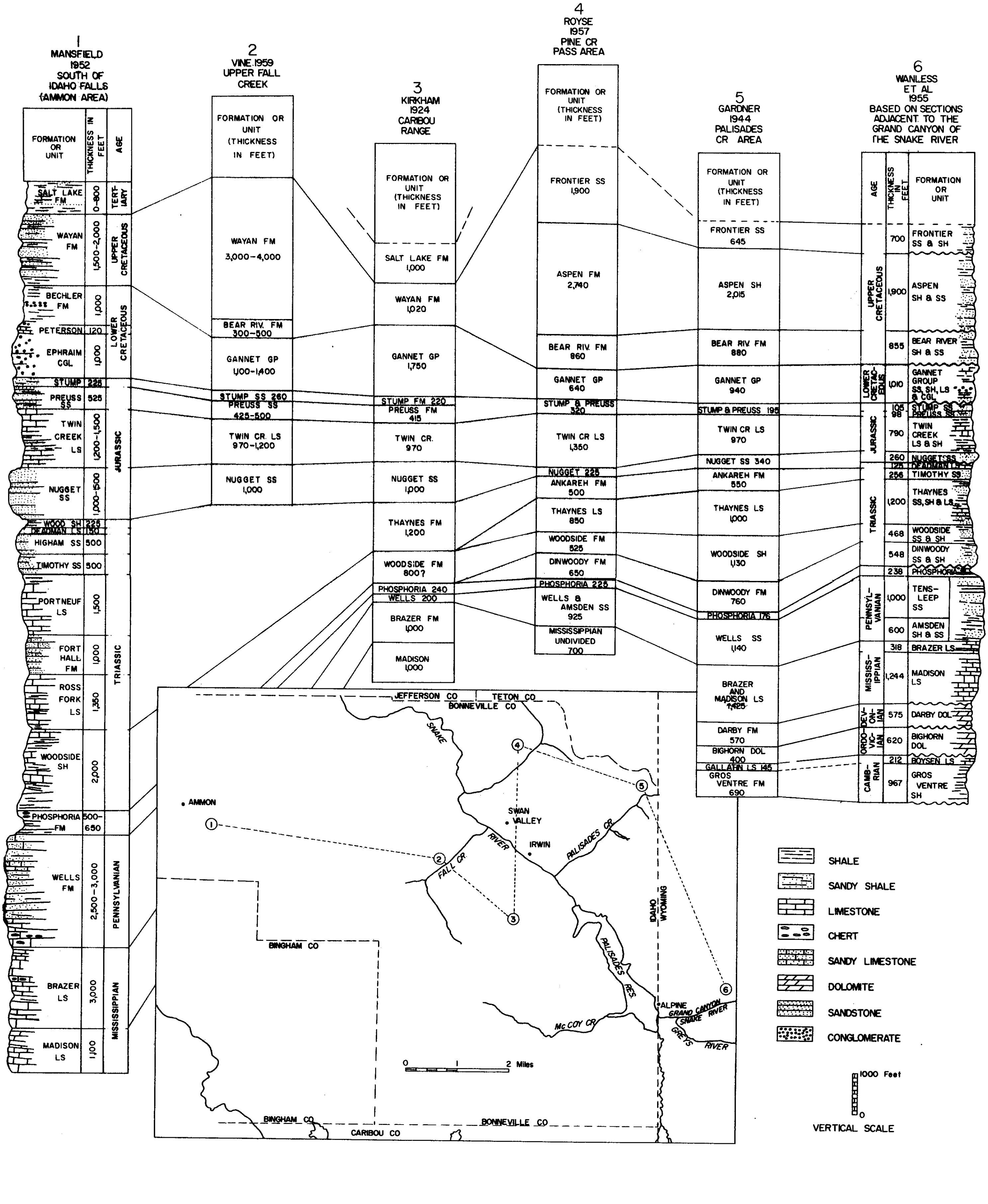
The Frontier Formation consists of greenish-gray to olive-brown calcareous shale and sandstone; and at least two whitish to gray rusty sandstone and conglomerate zones, one near the base. This formation lies conformably above the Aspen Shale. It is terrestrial in origin, and has some layers of coaly shale. Fauna of the formation include:

Ostrea glabra	Turritella sp.	Glauconia sp.
Cardium sp.	Barbatia sp.	Inoceramus erectus
Mactra sp.	Corbula sp.	I. labiatus
Anomia sp.	Gyrodes sp.	Modiola sp.
Inoceramus sp.	Pholadomya sp.	Neratina sp.
Goniobasis sp.	Avicula sp.	

Moritz (1953, p. 71) suggested that the Wayan in the McCoy Creek area could be divided as follows:

Unit	Wayan Formation (Youngest unit at the top of list) Description	Equivalent to southwest (Wyoming)
E	Gray shales, tan sandstones and porcelanites	Frontier Formation(?) and Aspen Shale
D	Red and variegated sandstones and mudstones	
C	Light-colored gray and tan sandstones and shales, numerous coal beds and brackish and freshwater limestones	Bear River Formation

FIGURE 9 COLUMNAR SECTIONS SNAKE RIVER AND CARIBOU RANGES, SOUTHEAST IDAHO.



B Red and variegated sandstones and mudstones.

A Black shales and tan sandstones

Moritz stated (p. 72):

> It is likely that some of the freshwater limestones exposed in this section may belong in the Wayan Formation, although it is possible that most of them may represent infolded limestone units of the Gannett group.

Hamilton (1961, p. 20-21) divided the Wayan Formation of the Caribou Mountain area into the following three members:

The Upper Wayan arenites consist of pale yellow to yellowish-gray, fine to medium-grained quartz arenites. These arenites are well-sorted, subangular grains cemented with silica. The principal mineral is quartz and minor constituents include magnetite, hematite, feldspar, mica, and clay. Within this unit, reddish-brown conglomerate, with subangular to subrounded fragments, occurs as lenses. Chert is the predominant pebble type.

The Middle Wayan clastic limestone is primarily a blue limestone with approximately 60 percent calcite and 35 percent clastic quartz. Minor constituents include labradorite, microcline, magnetite, biotite, muscovite, and chert fragments.

The Lower Wayan arenites consist of grayish olive-green to grayish-orange limy arenites, including conglomerate facies, gray and red siltstones, and red shales. The arenites predominate as normally fine to medium-grained, well-sorted, and subangular particles. The major minerals in the arenites are quartz and calcite (also the cementing agent); minor minerals include green mica, leucoxene, hematite, magnetite, zircon, sericite, muscovite, detrital phosphate, fragments of chert, and possibly fragments of felsic volcanic materials. Cross-bedding and oscillatory ripple markings suggest a terrestrial environment of deposition.

The conglomerate facies is composed of about 95 percent light to dark gray, poorly sorted, rounded to subangular chert pebbles in a matrix of quartz grains.

Because all these units appear to be in contact with rocks of Jurassic to Triassic age, Hamilton (p. 20-21) believes that the situation on Caribou Mountain represents "depositional onlap." He admits, however, that "faulting could also account for the contact pattern" although he has recognized no major faults in the area.

Tertiary System

General discussion

Several investigators have attempted to clarify Tertiary stratigraphy in southeast Idaho; however, most have succeeded only in proposing additional formation names (Fig. 11). The Tertiary rocks, largely formed from fluviatile and lacustrine sediments deposited in basins, were formerly more widespread. Repeated blockfaulting and erosion have reduced the area of the Tertiary rocks to remnants along the sides of deeper valleys, and smaller patches ranging up to 1000 feet above the lowest outcrops. This range in elevation is probably the result of intermittent faulting.

A large portion of the Salt Lake conglomerate, sandstone, siltstone and shale; and of the clay, tuff, and sand in Bonneville County, is now covered by fluviatile deposits, or in the case of the Palisades Reservoir area, by water and recent silt.

Wasatch Formation

One of the first geologists to subdivide Tertiary strata in southeast Idaho, Mansfield (1927, p. 108-112) recognized early Tertiary and late Tertiary beds: The Wasatch Formation and Salt Lake Formation, respectively (Fig. 11). He described the Wasatch Formation as a coarse red conglomerate containing pebbles and boulders that ranged up to 3 feet or more in diameter. The coarse fragments reportedly ranged from subangular to well-rounded shapes consisting chiefly of Paleozoic quartzites and limestones.

Salt Lake Formation

Mansfield (1927, p. 110) described the Salt Lake Formation in southeast Idaho as light-gray to buff conglomerates with a relatively soft, white, calcareous matrix. He found the pebbles to be local materials varying from angular to well-rounded forms. Some included boulders were 4 or 5 feet in diameter. He stated that, in addition to conglomerates, the Salt Lake included beds of white marls, calcareous clays, sandstones, grits, and in places many rhyolitic fragments.

According to Mansfield (1927, p. 111), the following fresh water fossils, which indicate a possible Eocene to Pliocene affinity, have been found in the Salt Lake Formation in southeastern Idaho.

- *Valvata* sp.
- *Pisidium saginatum*
- *Planorbis aequalis*(?) white
- *Lymnaea similis*(?) Meek
- Ostracodes

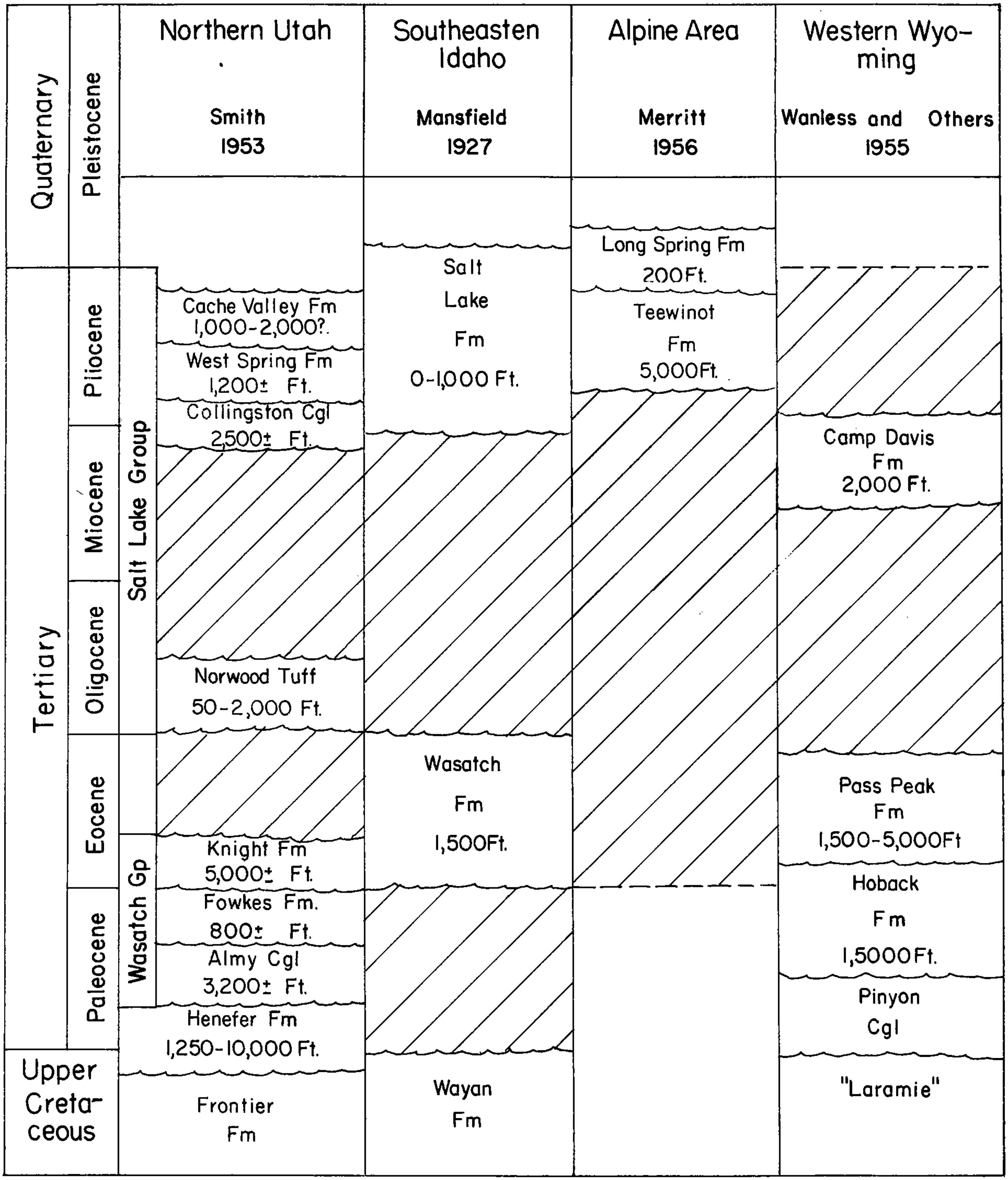


FIGURE 11 COMPARATIVE TERTIARY STRATIGRAPHY

Kirkham (1924, p. 42) affirmed that the Salt Lake Formation in Bonneville County and adjacent areas, was part of a series of igneous flows, pyroclastics, and conglomerate. These elements included a basal calcareous conglomerate of unknown thickness, two basalt flows, three trachyte flows and 100 feet of conglomerate with pink volcanic ash matrix and travertine.

More recent investigations

A few years ago, Smith (1953, p. 73-77), subdivided the Tertiary into the Henefer Formation, the Wasatch Group, the Norwood Tuff, and the Salt Lake Group.

(1) The Henefer Formation is red to gray shale, sandstone, and pebble to boulder conglomerate "...probably of latest Cretaceous and earliest Paleocene age..."

(2) The Wasatch Group consists of:

(a) Almy Conglomerate, which is a red cliff-making conglomerate, and yellow to reddish-yellow sandy clays, sandstone and shale of possible Paleocene or Eocene age(?);

(b) Fowkes Formation, which is light gray grit, sandstone, shale and ash, all of which originated largely as pyroclastics, but contain fossil fresh water shells and fish plates of Paleocene or Eocene age;

(c) Knight Formation is a series of variegated yellow and red conglomerates, sandstones, sandy clays and shales, whose animal remains (including Coryphodon) are probably Eocene in age;

(3) The Norwood Tuff unconformably overlies the Wasatch Group, and from which fluviatile deposits vertebrate remains have been recovered.

(4) The Salt Lake Group has been divided into:

(a) The basal Collingston Conglomerate, a cobble-boulder conglomerate with a matrix of white calcareous and tuffaceous material;

(b) West Spring Formation, a soft, gray tuff with occasional pebble conglomerate zones and thin stromatolitic limestone; and

(3) The Cache Valley Formation, a thin-bedded tuff, tuffaceous sandstone, and pebble conglomerate with a few limestone layers, which contain middle to late Pliocene fossils.

The foregoing subdivisions of the Wasatch and Salt Lake groups were not positively identified in the Bonneville County area. Time did not permit detailed mapping of separate units. Furthermore, because of rapid lateral changes, it is doubtful whether some of the above facies are present or recognizable for any great distances away from the type sections. It was deemed preferable to follow precedent and use the designation Salt Lake Formation for the upper Tertiary in Bonneville County. Although some of the Wasatch Group may be present, any representative is probably limited in extent. Possibly some of the conglomerates cropping out along the east side of Swan Valley, called Camp Davis Formation by Wanless and others (1955) and Teewinot by Merritt (1956), may be equivalent to part of the Wasatch to the south.

The Salt Lake Formation is exposed along the east side of Palisades Reservoir at several places. If the fairly widespread silicic volcanic rocks, including the tuffs and pumices, are considered part of the Salt Lake, then exposures of those members may be observed southeast of Ammon.

Quaternary System

Quaternary rocks in southeastern Idaho consist principally of clays, silts, sands, and gravels. No attempt has been made to divide and map these materials in detail. They may be subdivided generally into

Glacial drift(?) and older alluvium
Spring deposits of travertine or tufa
Sand dunes and loess
Recent alluvium and slope wash, and mass-wasted material

Wanless and others (1955, p. 76) pointed out that three stages of glaciation are recognized in the Jackson Hole area: The Buffalo, Bull Lake and Pinedale (Kansan, Iowan, and Mankato, respectively). In the Teton Pass area northeast of Bonneville County, Horberg (1938, p. 11) recognized the following:

Pinedale Drift - Fresh undissected moraines and outwash
Bull Lake Drift - Submaturely eroded moraines and outwash with loess cover; outwash commonly terraced
Buffalo Till - Remnants of till on mountain slopes, ridges and buttes; 400-1200 feet above present drainage systems.

Early glaciers spilled south during the Pleistocene from Yellowstone Park Plateau and Teton Range into the Teton Basin. The highest peaks of the Big Hole, Snake River, and Caribou ranges probably supported cirque glaciers too, but their former area and extent is not well known. Possibly an occasional short valley glacier was formed. If Buffalo or Bull Lake drift deposits are present in the southwest Bonneville County area, they must compose part of the Grand-Swan Valley fill, as outwash material, for example. Bayless (1947, p. 25) mentioned mapping terrace remnants of coarse stream deposits 10-20 feet thick which covered the "Camp Davis" (Lower Salt Lake?) Formation at an elevation of 6200 to 6400 feet. He thought these might be "...Bull Lake or early Wisconsin outwash."

More prominent are the erosional and depositional effects of a later, probably Pinedale glacial episode. Bayless (p. 25) described Pinedale moraines "...conspicuously developed 5 miles east of the range (Snake River) front in North and South Forks of Indian Creek." The dam of debris that forms Lower Palisades Lake may also be Pinedale moraine. Cirque-like areas heading the valleys on the eastern sides of higher peaks in the Snake River Range, on the eastern side of Caribou Mountain, may be related to the Pinedale glacial stage.

Walker (1954, p. 1318) described terraces of the Upper Snake River that are cut into valley train; they extend downstream on the Snake from Jackson Hole to the lava plains. One terrace of probable Pinedale age is said to extend from a point 4 miles south of Jackson Lake 90 miles downstream.

Older alluvium must be intimately associated with any glacial drift that may be present in the Grand-Swan Valley area and also any drift lying farther west in the Snake River Plain. This alluvium consists of stream and slope wash debris locally and includes some waterlaid ash and cinders.

Some of this older alluvium is intercalated with Pleistocene lava flows. Other valleys, the one occupied by Grays Lake Lowland, for example, also must contain older alluvial fill.

The large, low, fan-like deposit that marks the point where the Snake River leaves its canyon and enters the Snake River Plain downstream from Heise is probably composed of older alluvium.

Spring deposits of travertine or tufa were noticed in the region by members of the early Hayden Surveys. Many of these occurrences are too small to map and some have been covered by the flowage of Palisades Reservoir. The travertine is typically porous and tubular, somewhat massive, gray to white limestone. It is well-exposed along lower Hall Creek and at the falls on the creek's mouth on the Snake. Other similar deposits occur along spring lines located on or close to Snake River and Grand-Swan Valley fault zones.

Schultz (1918, p. 31-33) noted several of these deposits associated with warm springs at a number of places from Alpine to Heise. Specifically he found springs at: Alpine, near Blowout Canyon, on Fall Creek, in lower Conant Valley, and at Heise. Some of the deposits are from springs now extinct.

Interesting sand dunes occur south of Idaho Falls; for example, in secs. 24 and 25, T. 1 N., R. 37 E, and secs. 8, 9, 17, 18, and 19, T. 1 N., R. 38 E. Many of these dunes are active (Fig. 6). The sand is gray to tan and contains appreciable amounts of minerals derived from igneous rocks.

Loess deposits are widespread in the area. The cultivated uplands have soil that is largely windblown silt. Two representative samples of this upland loess were collected about 4 to 5 miles northwest of Swan Valley. Analysis (Table 2) showed they contain 63 to 70 percent fine to coarse silt (0.043 to 0.015 mm in size); about 9 percent of both samples is clay to fine silt; only 1 to 2 percent was as coarse as medium sized sand (0.295 mm).

Clay, silt, sand, and gravel sediments of Recent age lie along the narrow floodplains of streams tributary to the Snake in eastern Bonneville County. Where such valleys open up along Swan Valley, the Recent sediments spread out like an apron.

Talus slopes are fairly common in Caribou, Snake River, and Big Hole ranges, while at least one prominent landslide has modified Blowout Canyon east of the Snake River.

IGNEOUS ROCKS

General discussion

There are both intrusive and extrusive igneous rocks in Bonneville County. These rocks have assumed various forms, identified by previous investigators as ash beds, welded tuffs, flows, cones, dikes, plugs, sills, laccoliths, and stocks. Although the igneous rocks are variable, Mansfield (1921a p. 251) referred them to only three general groups: olivine basalt, hornblende andesite porphyry, and rhyolite. In addition to these rocks, there are also the unique and interesting intrusive rocks that occur at Caribou Mountain. They include andesite and latite porphyry, and monzonite, shonkinite, syenite, aplite, and granite.

Tertiary extrusive rocks occur widely distributed over southeastern Idaho They consist of a complex of salic and femic volcanics, composed of both pyroclastics and flows that seem to be intimately associated with the sedimentary Salt Lake Formation. Considerable geologic investigation remains to be done, and widely diversified opinions must be reconciled before these rocks can be satisfactorily classified and catalogued.

Among the major problems related to the igneous rocks of southeast Idaho are the questions of their origin, sequence, and age. Earlier volcanic rocks seem to comprise both silicic and mafic types of material, but the most recent eruptive rocks appear to be largely mafic in composition.

Cretaceous volcanic rocks

Materials of rhyolitic or latitic composition occur in the ash, clay, bentonite, and porcelanite beds of the Upper Cretaceous (Wayan Formation). These constitute evidence of some of the earliest known igneous activity in this region.

Older Tertiary igneous rocks

The oldest igneous rocks of Tertiary age seem to be hornblende syenite, andesite, and locally, latite and basalt. Their actual or even relative ages are difficult to assign. According to Mansfield (1921a, p. 252-253), at Sugarloaf Mountain and in adjoining areas, gray hornblende, trachyte and andesite porphyries occur as sills or dikes with "...large phenocrysts of andesine and pale green, zoned hornblende." Rocks petrographically similar to those of the Sugarloaf area are found at Caribou Mountain and Tincup Creek, southeast of Caribou Mountain. Aligned on a northwest strike, these rocks may be part of a great dike system that follows some kind of major fault zone. The sedimentary strata in the region strike nearly parallel to the trend of some of the intrusive rocks, which has suggested a sill-like origin for a few of the intrusive rocks.

Igneous rocks at Caribou Mountain intrude Upper Cretaceous and Jurassic sedimentary rocks and contain limestone xenoliths composed of limestones from these periods. Judging from the amount of erosion necessary to expose the igneous intrusions, one must infer the latter be no younger than the lower Tertiary.

Anderson and Kirkham (1931, p. 65-66) called attention to numerous andesite and latite porphyries that occur on the west and east slopes of Caribou Mountain. The rocks are light to medium gray in color with dark phenocrysts of augite, hornblende, and biotite and commonly contain pyrite in cubes, pyritohedrons, and grains. According to Anderson and Kirkham, these are sills composed of rock varieties ranging from augite-andesite porphyry through hornblende-andesite porphyry, augite latite, and augite-hornblende-biotite andesite and latite porphyry. Some of the rocks apparently contain sufficient orthoclase bo bring them into the class of a trachyte porphyry.

Hamilton called a hornblende syenite the oldest igneous rock type in the Caribou Mountain area. It seemed to be an intrusive rock with trachyte borders which occurred as small sills and dikes of hornblende trachyte or hornblende-trachyte porphyry. The hornblende syenite was described as medium to fine grained, greenish-gray, containing potassium feldspar, plagioclase, and hornblende as principal minerals. Biotite, magnetite, quartz, and chlorite occur as accessories. Carbonate replacement after hornblende seemed to be a common occurrence.

Later Tertiary rocks

Dark basalt-like rocks occur in the district about Palisades Dam in eastern Bonneville County. It is not known whether they are early or late Tertiary in age. Dupree (1947, p. 21) reported that C. P. Berkey identified these rocks as andesite lying on the borderline between a basalt and an andesite. They are gray to bluish black, fine-grained, locally porphyritic, and a little vesicular. Their composition is essentially plagioclase, augite, olivine, and magnetite.

Reportedly, the Salt Lake Formation is intruded by the andesite at Palisades Dam (Dupree, 1947, p. 24). This intrusion would seem to make the andesite younger than the Caribou and Sugarloaf andesites and trachytes. According to Dupree, the intruded sedimentary rocks where exposed during dam construction, were fused and had flowed, while particles of fused sand were enclosed in the andesite. This evidence suggests that the andesite at Calamity Point near the west end of Palisades Dam, as well as similar andesites east and southeast of the east end of the dam, is upper Tertiary in age.

Hamilton (1961, p. 29-32) stated that the Palisades Dam andesite or basalt (depending upon one's system of identification) does not appear to be related petrographically to any of the igneous rocks in the Caribou Mountain area. He also felt that the porphyritic basalt (called andesite by some) at Castle Rock and the olivine basalt or basaltic andesite near the headwaters of Brockman Creek, were petrographically similar to the previously mentioned intrusive rocks near Palisades Dam.

Kirkham (1924, p. 39) described the material at Castle Rock as a volcanic plug composed of an andesite with a "...black, fine-grained groundmass with huge glassy plagioclase phenocrysts..." Near the mouth of Fall Creek Valley is a rock type that megascopically resembles the Palisades andesite.

Hamilton (1961, p. 24-29) described an andesite of "intermediate" age, that includes an occasional gabbroic facies, presumably intruding older hornblende syenite (previously discussed), but not observed in this relation. He described the andesite as medium to fine-grained bluish-gray. Principal minerals contained are potassium feldspar, plagioclase, clinopyroxene, biotite, and calcite. Accessory minerals are magnetite, quartz, and apatite.

Mansfield (1952, p. 48-49) found andesitic breccia and tuff south of Ammon (approximately 8 square miles in area in T. 3 S, R.38 E). Remnants of the Salt Lake Formation lie above the breccia and tuff. The breccia fragments include basalt and rock similar to the Caribou Mountain hornblende-andesite porphyry. Mansfield considered it possible that the breccia zone might constitute some sort of volcanic vent. This conjecture is important because it may be a clue to the source of widespread deposits of silicic volcanic tuff.

Figure 10. Typical splintery character of upper Twin Creek Limestone. East flank of Big Elk Mountain.

Figure 12. Black glassy welded tuff capping angular, pebbly, gravel, and water-laid pyroclastics including pumice.

Figure 13. Salt Lake Formation(?). Pumiceous beds underlying tuff.

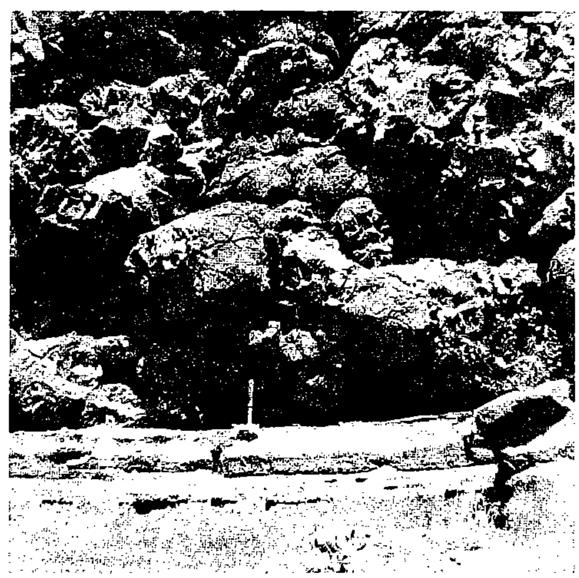


Figure 14. Pillow lavas lying on lake(?) sediments, Conant Valley near mouth of Garden Creek (northwest of Swan Valley).

Youngest Tertiary rocks of the Caribou Mountain area

General discussion

A unique group of intrusive sills and dikes, and possibly a stock, that occur in the Caribou Mountain district, include rocks that appear to be the youngest (Tertiary) intrusive rocks in the area. The accompanying geologic map (Figure 3) shows these as undifferentiated intrusive rocks because of their complex nature and method of occurrence, and because of the small scale of the base map.

Sill-like intrusive bodies range from a fraction of an inch to 500 or more feet in thickness. Individual sills commonly average 15 feet in width, but they have a great range in length, from a few feet up to four or more miles long, for example. The top of Caribou Mountain is composed of a stock-like body that seems to vary from 500 to 900 feet in width and is probably 2 or more miles in length.

Anderson and Kirkham (1931, p. 54-65) were the first to describe thin sections of these Caribou Mountain rocks, recording the resemblance of the rocks to potassium, lime, magnesia, and iron-rich types that occur in the Highwood Mountains of Montana. Hamilton (1961, p. 24-29) also described the rock types, but in somewhat less detail.

Hamilton's youngest intrusions were represented by two syenites: a leucosyenite and a darker syenite both of which were found to cut the older andesite mentioned previously. The darker syenite is medium to coarse-grained with principal mineral constituents of potassium feldspar, clinopyroxene, augite, aegirine-augite, and biotite. Accessory minerals are magnetite, muscovite, sphene, apatite, perthite, and zircon.

According to Hamilton, the second syenite is lighter (leucosyenite), medium to fine-grained, and pale red in color. Principal minerals in this rock are potassium feldspar, plagioclase, clinopyroxene, and amphibole. The accessory minerals are magnetite, quartz, perthite, sphene, and biotite.

According to Anderson and Kirkham the younger intrusives on Caribou Mountain may be subdivided into the following rock types.

Monzonite

Monzonite sills and dikes are present on the east side of Caribou Mountain. The rock is dark gray, fine-grained, and equigranular to slightly porphyritic. Principal minerals contained are orthoclase, andesine, diopside, and biotite; apatite and magnetite occur as accessories.

Shonkinite

Shonkinite occurs on both the east and west side of the mountain as dikes and sills, and as part of the summit stock. This rock is dark gray, massive and granitoid, and ranges from medium-fine to coarse grained. Dark greenish diopside crystals, dark-brown biotite, and olivine are recognizable megascopically. The olivine is reddish and pitted.

Thin section study reveals the presence of diopside, olivine, biotite, and orthoclase, and accessory plagioclase, magnetite, and apatite. Magnetite is abundant in these rocks, as well as in other rocks of this district.

Syenite

Syenite is one of the most common of the intrusive rocks that occur in the form of dikes and sills, as well as in the stock at the top of the mountain. This rock, which notably lacks plagioclase, is divisible into aegirite-augite syenite and diopside syenite.

The aegirite-augite syenite is grayish to dark gray, and fine-grained. Tabular orthoclase gives the rock a trachytoid appearance. The principal minerals in this rock are diopside, aegirite-augite, biotite, orthoclase, and a little plagioclase. Accessory minerals are apatite and magnetite.

The diopside syenite is a pinkish gray, medium-grained rock with crystals of dull greenish diopside and plates of biotite. This rock also has pronounced trachytoid texture because of tabloid orthoclase. Minerals included are diopside, biotite, and orthoclase with abundant magnetite and less abundant apatite.

A nordmarkite variety of syenite is the most abundant. It is pinkish, equigranular to slightly porphyritic, and contains only traces of diopside and biotite. Orthoclase is the primary mineral.

Granite

A few of the Caribou Mountain intrusives are composed of orthoclase, quartz, and amphibole, much like the nordmarkite mentioned above, for example. Magnetite and zircon occur as accessory minerals. The rock might be called granite.

Aplite

Small dikes of light pinkish-gray aplite cut the monzonites and syenites.

Quartz monzonite porphyry

Several sill-like bodies on both the west and east sides of Caribou Mountain are composed of reddish to pinkish stained or banded, medium-grained quartz monzo-

Figure 20. State owned cinder pit at Shattuck Butte west of Idaho Falls.

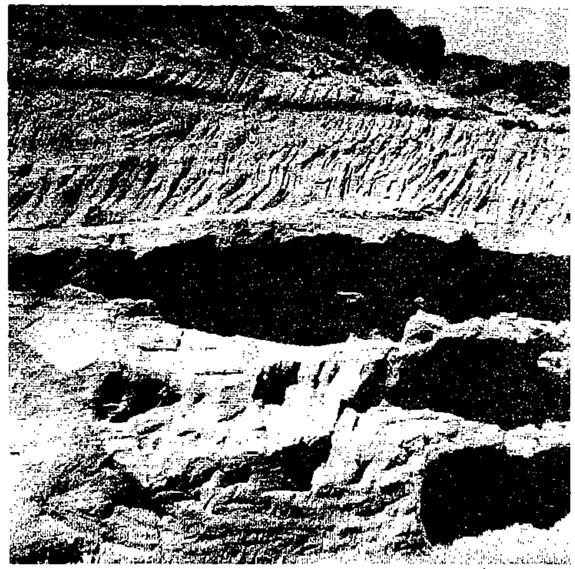


Figure 21. Waterlaid pumice beds capped by welded tuff south of Ammon. Beds are 60-80 feet thick.

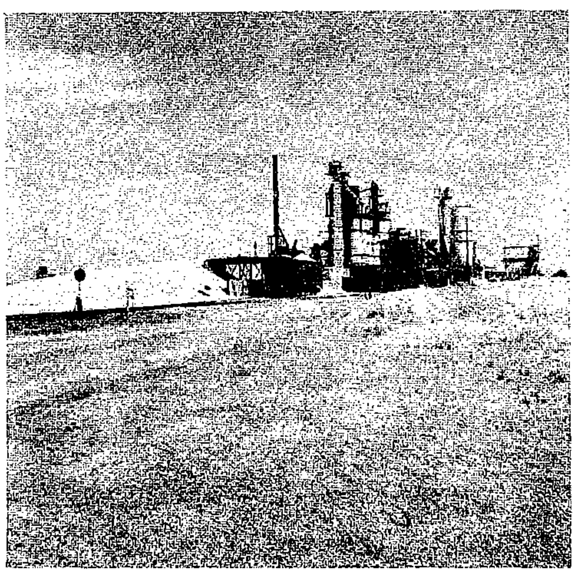


Figure 22. Pumice preparation plant, Pumice Inc., Ammon, Idaho.

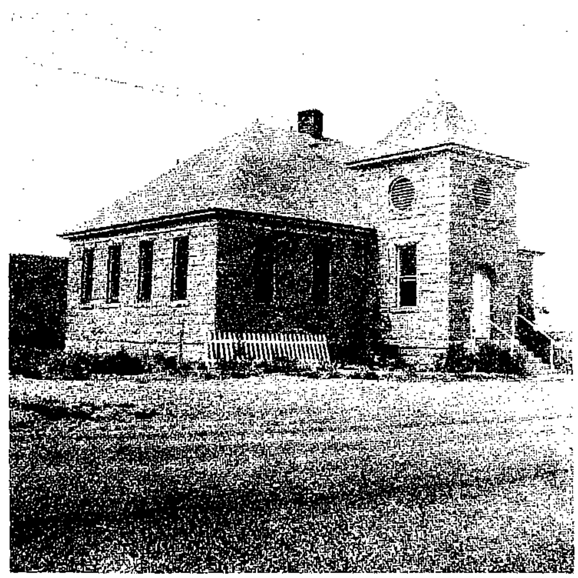


Figure 23. School built of rhyolitic tuff in 1910. Located on Rt. 26 east of Ririe.

nite with local porphyritic texture. The rock is composed of oligoclase, orthoclase, and quartz, and also a little magnetite.

Granite porphyry

Several sills and dikes are composed of granite porphyry similar to the granite described above except for porphyritic character. The rock is light pinkish gray.

Tertiary extrusive rocks

Early basalts

There are basalt flows in southeastern Idaho that seem to have occurred early in the upper Tertiary. For convenience, one might designate these flows as Early Snake River Basalt. Their original extent is uncertain and they seem to be largely covered. Principal evidence of their existence is the basaltic pebbles that are found in the early Salt Lake conglomerate facies. Large boulders presumably of similar basalt may be found in places in the younger welded tuffs (also Salt Lake in age(?).

Possibly some of the areas designated "older basalt" on the accompanying geologic map, may include some of the earlier mafic rocks.

Later silicic volcanic rocks

Rhyolitic and trachytic welded tuffs are widespread in southeastern Idaho. They vary from hard glassy rock (Fig. 12) through dense compact to soft chalky material; some are devitrified or poorly welded (Fig. 13) grading into ash and nonwelded tuff, for example. Glassy varieties are brown to black in color, while stony types vary from whitish gray to buff, and from reddish to pinkish and lavender colors. The tuffs are rudely bedded with layers varying from a fraction of an inch up to about 10 inches in thickness. Locally, they show some waterlaid characteristics. Wyman and Newcomb (1949, p. 44-46) called attention to fragments of foreign rock material in these tuffs: unaltered rounded pebbles of sandstone, altered limestone pellets, and fragments of granite and quartzite.

The welded tuffs contain well-developed spherulites and lithophysae in some sections. The spherulites suggest retention of gases during the cooling phase. Frequently, in most of the welded tuff, phenocrysts are present, which vary in number from a few up to 25 percent of the rock. Oligoclase is one of the most common minerals where crystallization has occurred, but some quartz, orthoclase, augite, and albite are present. Ross's(in Mansfield 1952, p. 52) description of thin sections of the silicic rocks near Ammon is listed in Table 5. Sorenson (1961, p. 57-62) also described thin sections of similar rock types collected in the Big Hole Mountains just north of Bonneville County.

Some of Kirkham's (1924, p. 42-43) so-called trachytes mapped in Fall and Hell Creek areas, have been included with the general silicic volcanic rocks in the Caribou Range by later investigators. In a general section, he described a 35-foot-thick, dark gray trachyte near the "base of the Salt Lake Formation." Higher up in this section he recorded a 35-foot pink trachytic tuff and agglomerate, and still higher reported layers of red and gray trachyte. In the same general area -upper Fall Creek-, Vine (1959, p. 264) mapped silicic volcanic rocks.

Vine pointed out that silicic volcanic remnants capping hills at different altitudes, suggested deposition on a surface with at least 1,000 feet of relief. Actually, the total relief of the general surface on which the silicic volcanic rocks were deposited in this region was probably closer to 3,000 feet or more, although it must be remembered that post depositional faulting has increased the apparent range in altitudes between various outcrops.

The silicic tuffs were once much more widely distributed. Some geologists think they were nearly continuous over more than 3,000 square miles, excluding similar rocks that occur in Montana and Yellowstone Park. Their thickness is not definitely known, but sections over 100 feet thick have been measured.

Sorensen (1961, p. 14) stated that Tertiary volcanic rocks (Pliocene welded tuffs) in the Thousand Springs Valley area (Big Hole Mountains) were more than 750 feet thick.

Few records of measured sections of Tertiary volcanic rocks are available for comparison and tabulation; however, Mansfield (1952, p. 52) described general sections in the Ammon area that suggest the composite section developed below (not visible at any one place). If the situation is correctly interpreted, possibly there may be at least four separate falls of pyroclastic material represented in the Bonneville area:

4) Upper, brick red, pink, drab, or black welded tuff,
   1 to 5 feet thick

   Unconformity(?)

3) Rhyolitic tuff, highly vesicular, 10 feet thick
   Stony rhyolitic tuff, non-vesicular and spherulitic,
   1.5 feet thick
   Black, glassy, perlitic tuff, 3 feet thick

2) Black baked volcanic ash, 1 foot thick
   Cross-bedded, whitish, grayish, yellowish streaked
   volcanic ash with lumps of grayish-white pumice,
   4 feet thick
   Vesicular welded tuff, 4 feet thick

1) Sandy ash, a few inches thick
Stony non-vesicular devitrified welded tuff, thickness unknown.

Sorensen (1961, p. 62) reported finding "evidence of thin fossil soils..." within the welded tuffs.

Latest basaltic rocks

The many salic and femic rocks in Bonneville County were erupted intermittently over a long period of time. However, two late basaltic lava and pyroclastic facies seem to be recognizable. For convenience, these two facies have been designated as Intermediate and Late Snake River Volcanics.

Much of the olivine basalt that rims Willow Creek Canyon and other canyons in the Ammon area as well as the basalt that composes Pine Creek Bench near Swan Valley, belongs to the Intermediate Snake River group of volcanic rocks. However, some of the basalt in these areas may be older, Early Snake River Basalt, for example. Considerable time may be required in any attempt to map these separate volcanic rocks accurately.

Late Snake River Basalt and associated pyroclastic rocks are extensively exposed in the lava desert west of Idaho Falls. Locally red cinders, bombs, and scoria identify probable vents. Fresh appearing, these rocks are probably Pleistocene to Recent in age. Locally waterlaid sands and gravels are intercalated with these late volcanic flows, while pillow lavas occur in some outcrops (Fig. 14). Some of the youngest volcanic flows in western Bonneville County may be correlated with those at Craters of the Moon National Park 65 to 70 miles west of Idaho Falls. Stearns and others (1938, p. 100) estimated that the Craters of the Moon flows erupted as recently as within the last 250 to 1000 years. Lava flows just southwest of Idaho Falls appear about as fresh and may be as recent as some of the flows at the Craters of the Moon.

Origin and relative ages of Tertiary igneous rocks

Attributing the origin of the igneous rock types in southwest Idaho to magmatic differentiation, Mansfield (1926, p. 260-266) said:

> The simplest view...is that these rocks were formed from an original magma of intermediate composition, from which first came the hornblende andesite porphyry, and then by continued differentiation the series of rhyolites and basalts.

Mansfield also noted that Lindgren had attributed the basalt flows to a deep-seated magmatic source, that is, to a deeper source than that of the silicic materials.

The similarity of the rock sequences in this area, particularly in the Caribou Mountain district, to those of the Highwood Mountains in Montana (Pirsson, 1905) was noted by Anderson and Kirkham in 1931 (p. 51). In the Highwood district, Larsen (1940) recognized four groups of volcanic rocks:

(1) quartz latites rich in quartz, oligoclase, and hornblende;
(2) a monzonite and syenite stock;
(3) an intrusion of ultrabasic rock; and
(4) basic potassic rocks and their associates.

The rocks of the Caribou Mountain area may be hypabyssal representatives of some of the surface extrusive rocks elsewhere in Bonneville County.

No cones have been recognized in Bonneville County, but this type of landform exists in adjacent areas. For example, Big Southern Butte about 48 miles west of Idaho Falls rises nearly 2,500 feet above the Snake River Plain. About 5 miles in diameter, this old volcanic vent is composed of basaltic and rhyolitic flows similar to the Tertiary extrusives of Bonneville County. The main material at Big Southern Butte is light-colored porphyritic rhyolite and glassy or pumiceous debris of explosive origin. Locally, beds of coarse white ash and agglomerate, huge blocks of white pumice, and obsidian bombs are common. It is not difficult to imagine this vent and others, now partially or wholly buried beneath the Snake River Plain, as the sources of much of the pyroclastic and flow rocks of the region.

At Big Southern Butte, porphyritic basalt containing feldspar and olivine phenocrysts also occur with the silicic rock. Stearns and others (1938, p. 36) noted an aphanitic vesicular basalt that flowed out over the rhyolite and hence is younger than the rhyolite. This vesicular basalt is presumed to be approximately the same age as some of the Snake River basalts.

About 34 miles west of Idaho Falls are East and Middle Buttes. They are composed of layers of trachyte, pumice, obsidian, and basalt. These buttes represent additional vents that poured forth pyroclastics and flows in Tertiary time.

According to Stearns and others (p. 33-34), the Challis Volcanics (well known to the northwest) are part silicic, part mafic flows and pyroclastics; thus they may be older representatives of the silicic volcanic flows that border the Snake River Plain. They pointed out that the Challis and similar volcanic rocks parallel a belt of volcanism that extends from the Yellowstone Plateau along the approximate axis of the Snake Plain to southwestern Idaho. These silicic volcanic rocks include rocks variously referred to as Mount Bennett Rhyolite, Owyhee Rhyolite, Tertiary late lava, Tertiary silicic rocks, and so forth.

The principal basis for correlating the younger Challis with older silicic volcanic rocks in the Snake Plain area is that the Challis Volcanics have been mapped to the edge of the Plain and traced into the Tertiary silicic layers. In other words, the late Challis units may be the same age as the early late Tertiary rocks (including the Salt Lake Formation) in Bonneville County.

Mansfield (1952, p. 59) stated that the welded rhyolitic tuff near Ammon might be as young as Pleistocene. His decision was based upon plant fossils found in rhyolitic ash near Willow Creek (NE 1/4 NE 1/4 sec. 16, T 1 S, R 40 E). The fossils may be considered unreliable evidence, however, because they were admittedly poorly preserved and their identification was not positive.

Kirkham (1924, p. 43) stated that the oldest of the late Tertiary rocks in southeast Idaho were andesites, trachytes, rhyolites, and basaltic rocks, all of which, he implied, were intercalated with the upper Salt Lake beds of Pliocene age. However, if one accepts Mansfield's conclusions, all the late Tertiary extrusive rocks lie above the Salt Lake Formation. On the other hand, some of the younger andesites, like those previously described at Castle Rock and near the Palisades Dam, may be in part extrusive and intercalated with the Salt Lake beds as well as intruding into them; consequently, it seems reasonable to raise the top of the Salt Lake Formation to include the early basalts, andesites, and silicic volcanics as Kirkham did.

South of Yellowstone Park, Love (1956, p. 91) found Pliocene welded tuffs and rhyolite flows that he regarded as similar in age to the Yellowstone Tuff (Boyd, 1961) on the north. These welded tuffs may be the same age as those in southeastern Idaho.

Mansfield's early studies led him to conclude that both normal rhyolite flows and welded tuffs were present in southeast Idaho. He thought they may have originated from northeast-and northwest-striking fissures. Later, however, Mansfield quoted Ross on the welded tuffs (Mansfield, 1952, p. 51):

> The ground mass is glass or devitrified glass, and no normally crystallized rhyolites were observed...the rhyolitic materials show pyroclastic structures and no normal flow rocks were observed.

Boyd's work in the Yellowstone Park area has shed much light on the subject of welded tuffs. He noted (1961, p. 387) that experiments proved rhyolite glass will weld at approximately 600° C (1112° F); also that the temperatures of tuffs after deposition are determined by pressure, time, and water content of the glass. He was convinced that the welded tuffs in the Yellowstone area were the product of fissure eruptions (p. 417), and stated that the turbulent pyroclastic flows, probably moving at about 10 miles per hour, may have spread over tens of miles.

Fissure eruptions similar to those Boyd describes in Yellowstone Park, may have taken place across southern Idaho to southwest Idaho in an arc roughly parallel to the Snake River Plain. At some localities pyroclastic material was erupted;

at others, mafic and silicic flows were extruded. In the latest stage, deep-seated basaltic flows spread over the Plain.

STRUCTURAL GEOLOGY

General structural framework

Bonneville County, located at the western edge of the Central Rockies, the eastern margin of the Snake River Plain, and the northern border of the Basin and Range province, exhibits structural characteristics of all of these areas. On the east, a general northwest structural trend may be seen (Fig. 3). The trend of mountain ridges and principal valleys emphasizes the northwest strike of the strata, thrust faults (Fig. 15), and the axes of folds (Fig. 16). This eastern area is an intricate tectonic framework of open to tightly compressed and overturned folds of Paleozoic and Mesozoic sedimentary rocks, broken by normal faults and imbricate thrusts.

The work of Horberg and Fryxell (1942) in the Teton Range to the northeast, leads to the assumption that 15 to 20 thousand feet or more of disrupted strata in southeast Idaho rest upon a basement complex of Precambrian metasedimentary rocks intruded by small quantities of granite and pegmatite.

The western part of this county is underlain by nearly horizontal flows of lava, intercalated beds of pyroclastics, and sand and gravel. Paleozoic and Mesozoic sedimentary rocks lie deep beneath the down-warped or down-faulted Snake River Plain; they are known to reappear northwest of the lava beds that form the surface of the plain.

Principal folds

Folded strata are best exposed in the Caribou Range anticlinorium (Fig. 16). Similar folded rocks occur in the Big Hole and Snake River ranges on the northeast, but there folded structures are less distinct because of complex thrusting and normal faulting. On the extreme northeast, a kind of synclinorium has developed in rocks of Wayan age, and a similar complex structure strikes northwest across Caribou Basin and the Caribou Range.

Hamilton (1961, p. 33-36) explained the pattern of his geologic map of Caribou Mountain as the expression of a major anticlinal fold with several culminations and depressions along its axis. The fold axis strikes north and must plunge in that direction, according to the map. It is composed of Wayan and Gannett Group rocks. Hamilton states:

> The Wayan sedimentary rocks are along a culmination of the anticline axis near Caribou Summit and the Gannett Group and older rocks are along depressions to the southwest and possibly to the

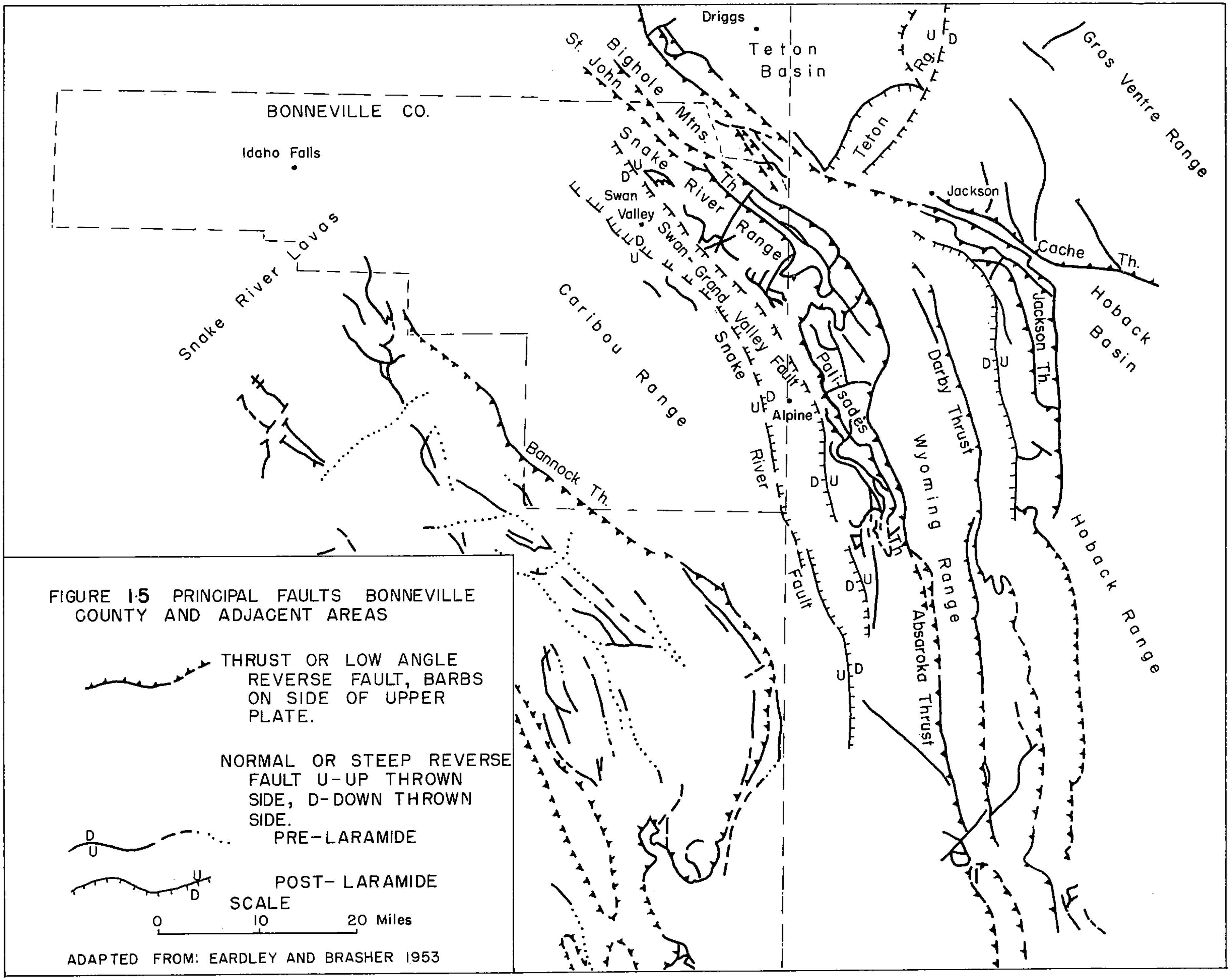


FIGURE 1·5 PRINCIPAL FAULTS BONNEVILLE COUNTY AND ADJACENT AREAS

THRUST OR LOW ANGLE REVERSE FAULT, BARBS ON SIDE OF UPPER PLATE.

NORMAL OR STEEP REVERSE FAULT U-UP THROWN SIDE, D-DOWN THROWN SIDE.

PRE-LARAMIDE

POST- LARAMIDE

SCALE

0 10 20 Miles

ADAPTED FROM: EARDLEY AND BRASHER 1953

northwest. The culmination could be the result of forceful emplacement of the igneous rocks which might be part of a much larger body.

Thick, Early Paleozoic limestones along the southwest front of the Big Hole and Snake River ranges show broad, open folds. Locally transverse folds tend to modify the major northwest-trending axes of the synclines and anticlines in this region.

Folds vary in their complexity, but most of them are asymmetrical. Some overturning has occurred in places, generally toward the northeast. However, notable exceptions may be found on the southwest side of Caribou Range where some of the folds are overturned toward the southwest. Kirkham (1924, p. 31-32) called attention to an upright fan fold that he mapped in a ridge trending northwest across T 1 S, R 43 E.

Principal faults

Southeast Idaho has long been known as part of an area noted for thrust faulting that occurred after the folding of Paleozoic and Mesozoic strata (Fig. 15). Richards and Mansfield (1912) first applied the name Bannock overthrust to a series of thrust faults along which a slice of the earth's crust over 200 miles long had been thrust northeastward about 35 to 40 miles. In 1952, Mansfield commented (p. 64):

> One of the remarkable characteristics of the Bannock overthrust is the fact that its thrust plane is systematically warped or gently folded so that the trace of the fault plane is notably sinuous in places... Elsewhere the overlying block is cut through by erosion, thus exposing the rocks of the underlying block.

Northeast of the Bannock thrust are several others, among them, the Palisades complex, St. Johns, Absaroka, and Darby thrusts. All trend north or northwest, and in general are thrust belts instead of well-defined single thrust planes. The faults seem to have been slightly modified by later folding and normal faulting. Armstrong and Cressman (1957, p. 1697) reinterpreted the southeastern Idaho faulting as "an imbricated thrust zone possibly several tens of miles wide extending at least from southwestern Montana to northeastern Utah." It was proposed that the area of thrusting be called the "Southeastern Idaho thrust zone." They concluded that the sinuous character of the fault traces was the result of curvature of the original breaks, and they were convinced that the breaks should not be tied together as one continuous fault or thrust sheet.

McIntosh (1947, p. 15-17) described the complex faults in the Palisades area as representing three imbricate thrust sheets: the Blowout, Needle Peak, and Ferry Peak thrusts. Occurring near the head of Blowout Canyon (Fig. 8), these three thrusts were thought to be related to the larger St. John fault or major thrust that is exposed still farther east.

The St. John thrust forms a sheet broken by the imbricate Palisades complex. It seems possible that the St. John thrust and the Palisades complex are only western extensions or branches of the main Absaroka thrust zone. The Absaroka fault is noticeable topographically for it tends to follow the approximate crest or divide of the Snake River and Big Hole ranges.

Some of the latest faults in Bonneville County are late Tertiary normal faults. Because the normal faults are widely scattered, many probably remain unmapped; however Grand-Swan Valley lowland, the main representative of block faulting, is topographically prominent. Its prominence suggests a northward extension of Basin and Range structure.

Truncated spurs along the west side of Palisades Reservoir make it easy to pick out the trace of the Snake River fault. In general, the dip of this fault is towards the east but it varies from almost vertical to about 35°. Grand Valley fault on the east is not as easy to recognize; on this fault, displaced strata and brecciated zones occur close to the place where Palisades Creek Valley opens out into the valley of the Snake. Warm and cold springs, mineralized and nonmineralized, as well as breccia zones mark the line of both principal normal faults that bound the Swan-Grand Valley graben.

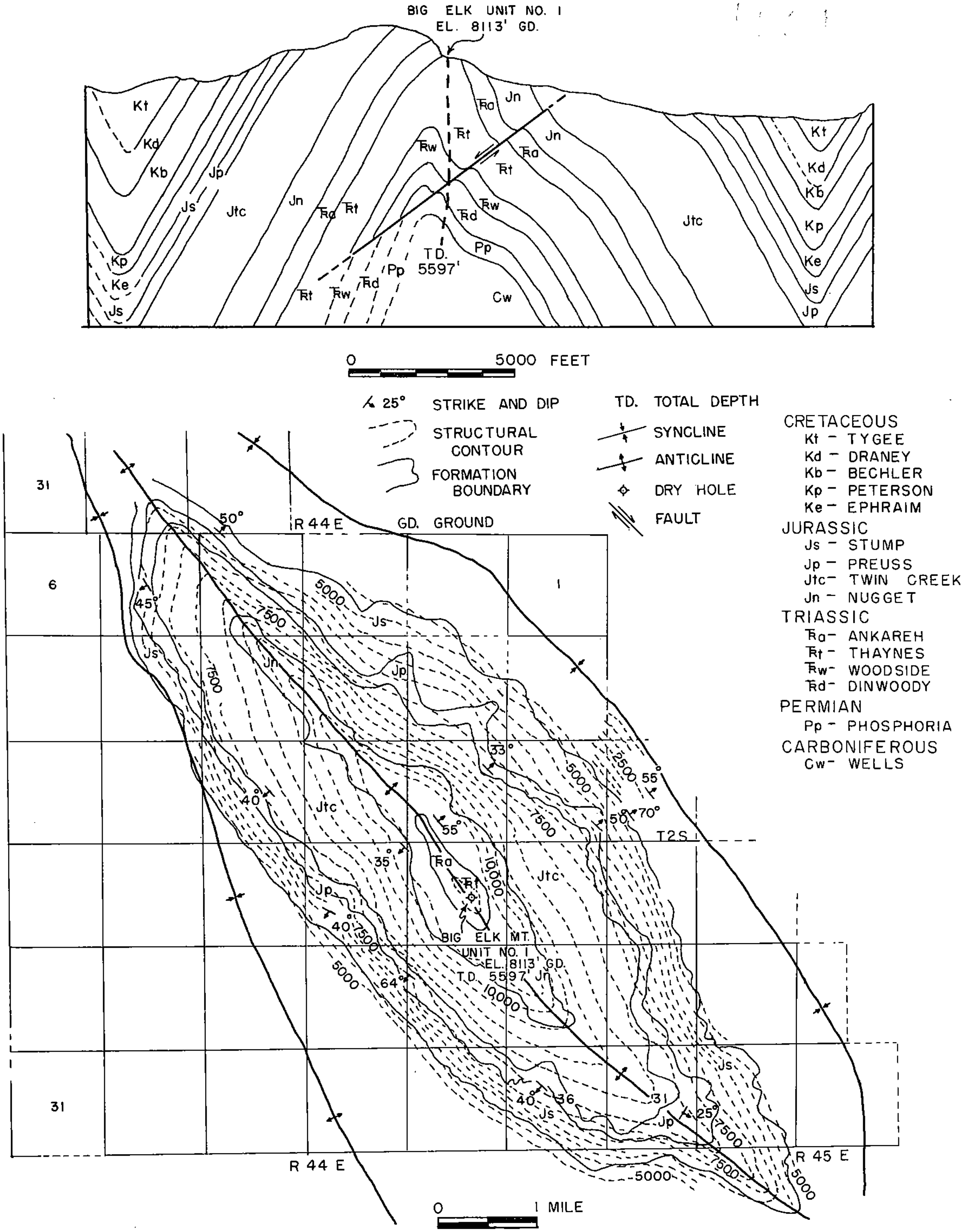
Bradley (1873, p. 269) described the spring lines long ago. He stated that they produced recognizable "...calcareous, sulphurous, and saline deposits.... At some points, the odors of sulphurous acid and of sulphureted hydrogen were quite noticeable.... The highest temperature observed was 144°."

Several of the springs described by Bradley are now submerged by Palisades Lake: springs still flow from the Snake River fault zone farther north near the mouth of Fall Creek.

Hamilton (1961, p. 35-36) failed to find evidence of any major faulting in the Caribou Mountain area. Contrariwise, Gardner (1961) recognized complex faulting in the district. It might be concluded that certain anomalous patterns and rock types, dips, and strikes suggest the necessity of some faulting; however, many of the areas vital to such an interpretation are covered by overburden or talus slopes.

Igneous bodies

Kirkham (1924, p. 34) pointed out the presence of various forms of igneous bodies in southeast Idaho. He listed "exhumed plugs, dikes, laccoliths, and sills, as well as crater cones, flows and ash beds". To this might be added the stock-like body at Caribou Mountain (Fig. 17). Kirkham described Sugarloaf Mountain as an eroded laccolith or thickened sill. Sills, dikes, and a stock may be found at Caribou Mountain, while flows are of widespread occurrence over most of the western two-thirds of Bonneville County. Kirkham (p. 39) called Castle Rock a plug,



NOTE: STRUCTURAL CONTOURS ON TOP OF TWIN CR. FORMATION, INTERVAL 5000 FEET.

ADAPTED, WITH SOME CHANGES, FROM: NEIGHBOR, 1953 (SUN OIL COMPANY).

FIGURE 16 . BIG ELK MOUNTAIN ANTICLINE

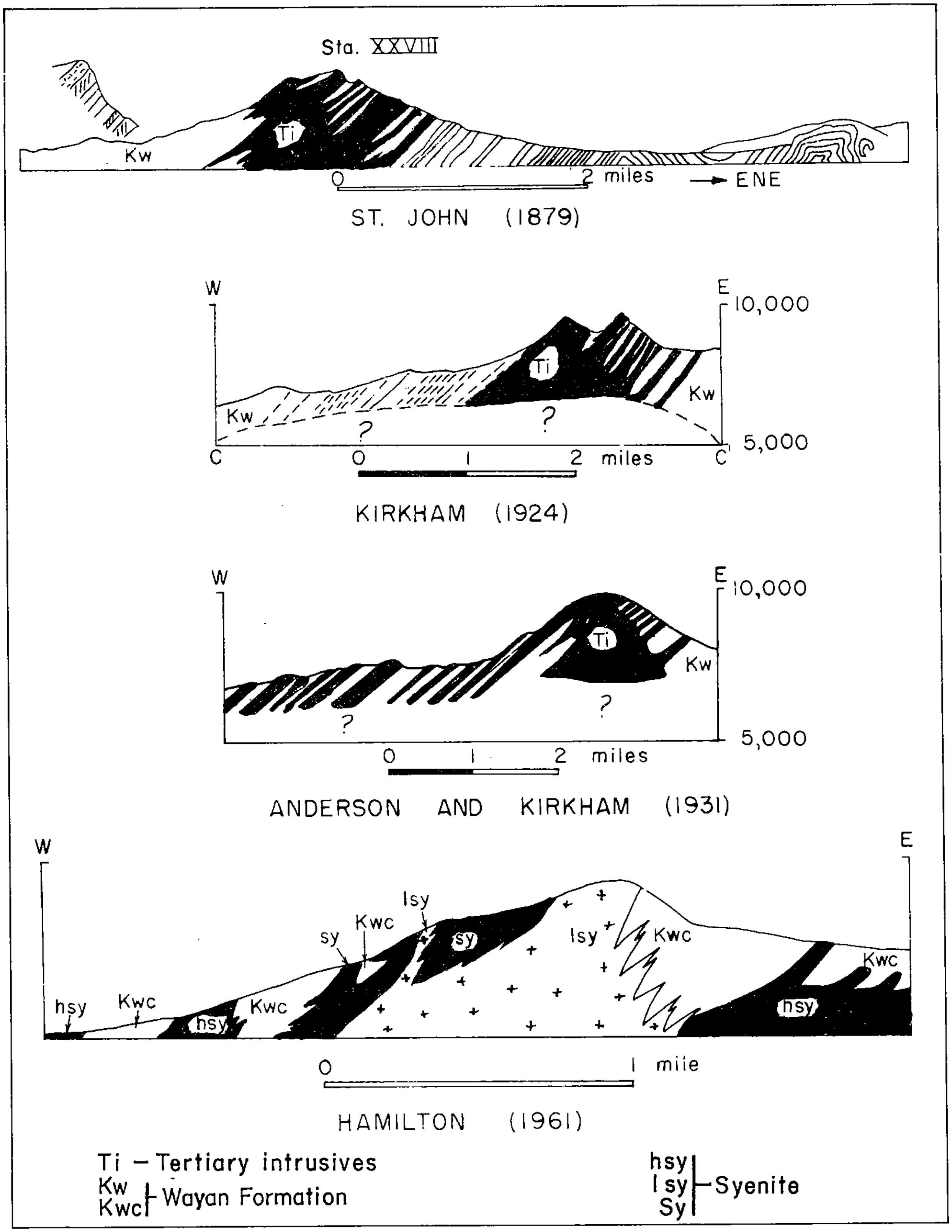


FIGURE 17 STRUCTURE SECTIONS CARIBOU MOUNTAIN BASED UPON SEVERAL INTERPRETATIONS OF INTRUSIVES

while he recognized several so-called "vents" in the general area of Bonneville County.

Lakes (1898, p. 56) was convinced that Caribou Mountain intrusive bodies were like "...those cases of laccolitic structure so often noted in this western region".

Anderson and Kirkham (1931, p. 53) stated "...that the large body at the summit of Caribou Mountain is a stock or wedge-shaped dike".

I concur with Hamilton's (1961, p. 38-39) conclusion:

> Large-scale mapping reveals that most of the igneous rocks regardless of age or type cut across the structure of the sedimentary rocks...

GENERAL GEOLOGIC HISTORY

Pre-Paleozoic events

Previous geologic work in the region northeast of Bonneville County leads to the assumption that the Precambrian surface upon which Paleozoic sedimentary rocks were deposited in Bonneville County was one of slight relief (Wanless and others, 1955, p. 7-9); Horberg and Fryxell (1942, p. 387) assigned these early Precambrian metasedimentary rocks to the Archaeozoic era. They have considered certain exposures of quartzite and quartzitic conglomerate in the same general area to be younger (perhaps Proterozoic(?))

Paleozoic and Mesozoic history

Bonneville County is near the margin of a former Paleozoic geosyncline where sediments were transitional towards shelf-zone types (Fig. 18). Swanson and others (1952, p. 12) pointed out that the Cordilleran miogeosyncline accumulated 20,000 to 40,000 feet of sediments on the shelf area. Mansfield (1952, p. 74) said the total thickness of these sediments was 46,000 feet in southeastern Idaho.

Late Mesozoic shallowing seas and continental environments produced noticeable changes in sedimentary facies, for example, a trend from finer marine sediments to coarser continental types. Folding of the sedimentary rocks in the eastern part of the geosyncline into Appalachian-type structures, during the Laramide orogeny, has narrowed the original breadth of this part of the geosynclinal area by an estimated two-thirds. Thrust faulting later decreased the breadth again, perhaps by as much as 50 to 75 miles.

Wanless and others (1955, p. 19) decided that the petroliferous Darby Formation possesses characteristics suggesting deposition in a basin, partly barred or enclosed in Devonian time. The basin, which has been called the Nevada-Idaho Basin, lay west of the so-called Cambridge Arch (Fig. 18). Early Paleozoic climate is believed to have been moderate and humid because no evaporites have been found in the record.

Again in the Mississippian period, the Madison and Brazer basins lay across southeast Idaho with a shelf area to the east and an orogenic region to the southwest (Fig. 18). The Mississippian record, preserved by fossiliferous limestones, indicates the dominance of a marine environment.

During the Pennsylvanian period, the Montana-Wyoming areas were undergoing increased uplift with only a narrow shelf zone on the west bordering the basin that stretched north and south across Idaho and Utah. The record is one of deposition of fine to medium clastics in southeast Idaho.

Permian time again brought seas that were probably more widespread than formerly supposed. Correlatives with the well known Phosphoria Formation have been mapped in Arizona and southern Utah. Mansfield (1952, p. 27) said:

> The peculiar conditions leading to the deposition of beds of phosphate and of massive chert though actually extensive, were much more restricted than the area covered by the Phosphoria Sea itself.

While mudstone, chert, and phosphorite were accumulating in the Phosphoria Formation in southeast Montana, east Idaho, and northeast Utah, farther east limestone, dolomite, and sandstone were accumulating.

Mansfield (1952, p. 75) noted that the transition from Paleozoic to Mesozoic times in southeastern Idaho was characterized by marked contrasts in faunal types. A principal reason was the fluctuation between marine and non-marine depositional environments. Toward the close of the Permian, the surface may have been low and monotonous which provided easy access for early Mesozoic seas. However, uplift that arched much of Montana and central Idaho, resulted in shallow-water shelf conditions and possibly some local terrestrial environments in eastern Idaho, although, even in late Jurassic time, the Preuss Sandstone appears to be largely marine in origin (Imlay, 1952, p. 1737-39).

By early Cretaceous time an orogenic belt was beginning to develop north and south across much of central Idaho, and a parallel basin formed in eastern Idaho (Fig. 18).

The Ephraim Conglomerate at the base of the Gannett Group has been said to be either Late Jurassic or early Lower Cretaceous. Probably it is evidence of the

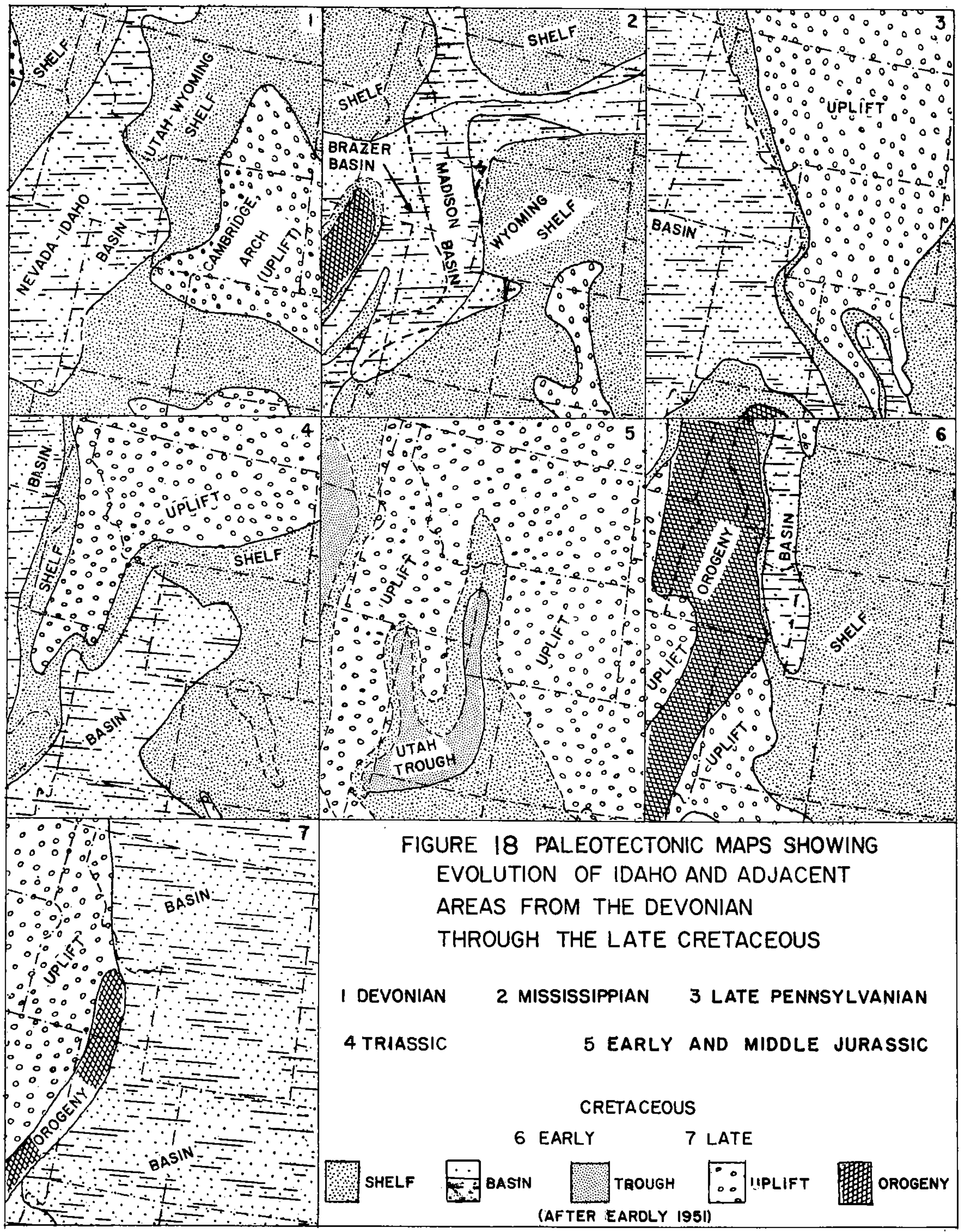


FIGURE 18 PALEOTECTONIC MAPS SHOWING EVOLUTION OF IDAHO AND ADJACENT AREAS FROM THE DEVONIAN THROUGH THE LATE CRETACEOUS

1 DEVONIAN 2 MISSISSIPPIAN 3 LATE PENNSYLVANIAN

4 TRIASSIC 5 EARLY AND MIDDLE JURASSIC

CRETACEOUS

6 EARLY 7 LATE

Nevadan orogeny. In any event, it represents uplift and erosion between the Jurassic and Cretaceous periods. However, if this coarse clastic was the result of the Nevadan Revolution, the disturbance was slight in southeast Idaho for no major folding of earlier sediments has been observed.

Fresh water (lacustrine(?)) limestones, the Peterson and Draney limestones of the upper Gannett Group, indicate a phase of terrestrial deposition before the succession of Late Cretaceous muds, silts, and sandstones were deposited.

The Wayan Formation, containing carbonaceous materials and intercalated muds, silts, and sands represents a terrestrial environment possibly consisting of a strip of low swampy land just west of a marine embayment.

Cenozoic history

The close of the Mesozoic era and start of the Cenozoic was marked by the Laramide Revolution. This event probably started, in southeastern Idaho, with uplift on the west and eventually folding of the Paleozoic and Mesozoic sedimentary rocks. These rocks were compressed by forces pushing them toward the east and northeast; thrust faulting occurred after the major folding took place, possibly in the early Tertiary, or Paleocene epoch. If folding subsequent to the faulting deformed these thrusts, as presumed by many investigators, then it probably occurred about Eocene, as a late Laramide orogeny.

Tertiary and Quaternary geologic events in this area were principally uplift, erosion, and repeated volcanism. Later climatic changes strongly influenced the local erosional processes. Mansfield (1952, p. 77) recognized about four erosional cycles in southeast Idaho. These cycles were not identified in Bonneville County, but they are no doubt represented. Attention was also called to block (graben and horst) faulting that probably occurred in Miocene or early Pliocene time. This faulting produced uplifted surfaces and escarpments as well as linear valleys (grabens like Grand-Swan Valley) that rapidly filled with coarse clastics, including pyroclastics and fanglomerates. These clastics constitute the Eocene Wasatch Formation, and the Miocene(?)-Pliocene Salt Lake (Camp Davis) Formation. Similar mid-Tertiary block faulting also produced the Teton and Hoback blocks. As erosion and volcanism proceeded on through late Miocene and Pliocene, conditions developed that permitted deposition of the upper Salt Lake sediments until, as Mansfield said (1952, p. 77), they "...blanketed many valleys and lower hills and even reached altitudes now as high as 7,000 feet."

In the late Pliocene and Pleistocene(?) silicic volcanic rocks including welded tuffs from fissure vents and perhaps central cones, were deposited extensively over the entire area. Post-depositional faulting was partly responsible for the difference in elevation of remnants of the Salt Lake Formation and silicic volcanic flows as well as the displacement of late basalt flows now found at various altitudes.

Some portions of mid-Tertiary fault valleys were exposed by late erosion. Locally, the upper Salt Lake beds were deposited in ponded water that accumulated in exhumed Tertiary valleys because of damming by volcanic materials. For example, Grand, Swan, and Conant valleys show evidence of an early ponded condition. This evidence is in the form of finely laminated ash and sand beds, and pillow lavas (Conant Valley, Fig. 14).

In western Bonneville County, successive volcanic eruptions of pyroclastics and lava flows nearly kept pace with the down-faulting and down-warping movements along the Snake River Plain, thus the valley was kept filled. It is possible that drainage locally dammed by volcanic debris, produced ponded conditions along the Snake Plain.

The total effects of Pleistocene climatic changes on this area are not yet fully known; however, it may be pointed out that small cirque-like areas and higher valleys possibly shaped by ice erosion mark the flanks of Caribou Mountain and in the Snake River Range to the east.

Some of the terrace-like sand and gravel deposits along the Snake, and the large low fan built out onto the Snake Plain west of Heise, are probably related to meltwater deposition: the deposits were built as glacial temperatures were modified by warming trends.

Extensive sand and sand dune deposits south and southwest of Ammon were probably the result of temperatures also somewhat higher than present ones, as well as of an increase in the strength of westerly winds (Fig. 6). Certainly the thick upland loess deposits are the result of drier, less moist postglacial climatic environments.

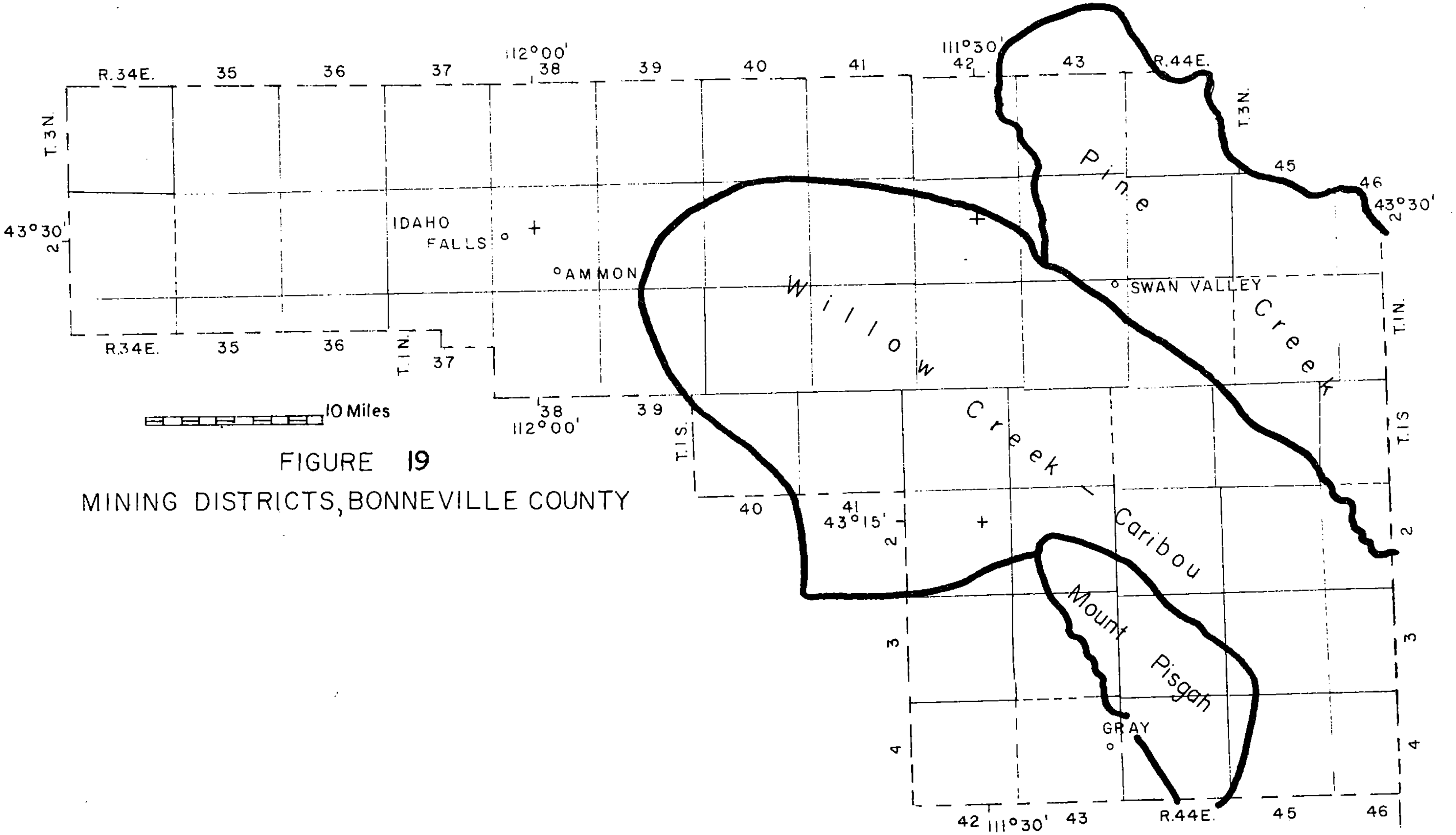


FIGURE 19

MINING DISTRICTS, BONNEVILLE COUNTY

ECONOMIC GEOLOGY

INTRODUCTION

In the past, valuable mineral commodities have been produced from the wide variety of rock types and rock materials that occur within the boundaries of Bonneville County (Tables 3 and 4). It seems safe to predict that in the future, the exploitation rate of some of these natural mineral resources will increase.

Among the mineral commodities that have been successfully developed, both within and outside Bonneville County's mining districts (Fig. 19) are:

Gravel, sand, cinders, pumice, shale, and clay
basalt, sandstone, quartzitic sandstone, limestone,
and tuff

Water resources

Gold, silver, and copper

Attempts--for the most part less successful--have been made to develop the following minerals and related materials in Bonneville County:

Phosphate rock
Radioactive minerals
Coal, oil, and gas

The earliest recoveries of placer gold were reportedly profitable, but the value of nonmetallic minerals produced in Bonneville County to date, greatly exceeds that of metallic minerals. Bancroft (1890, p. 533) stated that the Caribou district yielded about $2,500,000 in gold values during the 10 years following the first strike in 1870. Production figures for the period 1880-1914 are vague, or concealed in figures for a larger designated area: Bingham County (including Bonneville County). Later figures, somewhat questionable, are recorded by the U. S. Bureau of Mines (1904-1914 and 1915-1959): they record total value of gold and silver for Bonneville County over the period 1904 to 1959 as $59,243. They record the total value of stone, sand and gravel, pumice, and clay produced during the 9-year period, 1951-1959, as $7,989,000. In other words, the value of the nonmetallic minerals produced over a recent 9-year period exceeds by more than 134 times, the value of metals produced over a 45-year period.

Adding Bancroft's $2,500,000 figure for the early production of gold and the totals in Table 3, that is: $49,298 as the value of early Bingham-Bonneville County gold production; $59,243 as the value of gold and silver produced more recently in Bonneville County; and the reported $581 total value of copper production in the area, one arrives at a figure of $2,609,122 as the total recorded value of all metal-

TABLE 3 GOLD AND SILVER PRODUCTION IN BONNEVILLE COUNTY AREA 1904-1959

From: U. S. Bureau of Mines Mineral Resources of the United States 1904 to 1931, and U. S. Bureau of Mines Minerals Yearbooks 1932-1959

Bingham County including Bonneville County area 1904-1914

Year	Gold	Silver	Total	Copper
1904	$ 9881	$	$ 9881	$
1905	5705	2	5707	
1906	5409		5409	
1907	7713		7713	
1908	6148	23	6171	263
1909	3559	8	3567	
1910	1343	1	1344	
1911	2860	3	2863	
1912	1495	4	1499	
1913	1203	2	1205	
1914	3937	2	3939	
	$49,253	$45	$49,298	$263

Bonneville County 1915-1959

	Gold	Silver	Total	Copper
1915	4532	20	4552	$144
1916	5268	4	5272	
1917	2183	12	2195	162
1918	2239	3	2242	
1919	2333	3	2336	
1920	346	1	347	
1921	2294	4	2298	
1922	97		97	
1923	817	2	819	
1924	300		300	
1925	381		381	
1926	800	1	801	
1927	404		404	
1928	492	1	493	
1929	201		201	
1930	240		240	

TABLE 3 GOLD AND SILVER PRODUCTION IN BONNEVILLE COUNTY AREA CON'TD

Year	Gold	Silver	Total	Copper
1931	384		384	
1932	1294		1294	
1933	1200		1200	
1934	1242		1242	
1935	1814		1814	
1936	4956	7	4963	
1937	5040	3	5043	
1938	4340		4340	
1939	3220		3220	
1940	2695		2695	
1941	2730	5	2735	12
1942	1155		1155	
1943				
1944				
1945	1225		1225	
1946	1645		1645	
1947				
1948				
1949	980		980	
1950				
1951				
1952	385		385	
1953				
1954	630		630	
1955	315		315	
1956				
1957				
1958				
1959				
	$58,177	$66	$59,243	$318

TABLE 4 STONE, SAND AND GRAVEL, PUMICE AND CLAY PRODUCTION IN BONNEVILLE COUNTY

From: U. S. Bureau of Mines Minerals Yearbooks, 1951-1959

1951	248,000
1952	1,488,000
1953	2,000,000
1954	489,000
1955	673,000
1956	738,000
1957	1,084,000
1958	735,000
1959	534,000
	Total $7,989,000

lic minerals produced in Bonneville County and adjacent areas. The recent 9-year value of total nonmetallic minerals production in Bonneville County is still three times greater than this 89-year total value of metal production.

It is reported that over $717,986,744 worth of gold and silver have been produced in Idaho since 1860 (Teske and others, 1961, p. 67-69). Based on this figure, Bonneville County yielded somewhere around 0.36 percent of the total gold and silver produced in Idaho.

Records of mining claims locations in Bonneville County are preserved in five large volumes at the county courthouse in Idaho Falls. Placer records extend back to 1894; quartz lode records extend to 1895. The location of claims and affidavits of work performed are not always clearly presented in the records. Some affidavits of work indicate from $100 up to $3,000 worth of recent work on the claims involved; however, these claims often fail to show any visible evidence of recent activities.

In 1959, assessment work was recorded for claims as follows: the Iowa Group of placers on Iowa Creek; the Lucky Strike Group, Pisgah District (location believed to be recorded incorrectly); the Ken and Janet Group; and the Billie Borah, located on an island in the Snake River near Idaho Falls.

Also in 1959, work was reported on the following pumice claims located southeas of Ammon: Whiterock, Albino, Grass, Ridge, Hill, Wilson, Fish, and End. Fall Creek Uranium Corp. Inc. also reported assessment work on the God Send to Health mine located on upper Fall Creek.

In 1960, assessment work was reported for the following claims:

Lucky Strike Group
God Send to Health
Golden Jack
Whiterock and Albino
James Nos. 1 to 8
Rossana Nos. 1 to 40
Lottie Nos. 1 to 4
Billie Borah
Janet, Ken, Sage, and
  Hard Luck Groups
Iowa Nos. 1 to 5

The following is a summary of activities relative to major mineral commodities in Bonneville County over the 8-year period 1952-1960 (U. S. Bureau of Mines Yearbooks, 1952 to 1960):

Clark Concrete Co., Idaho Falls Brick and Tile Co., Gemstone Insulation Products Co., Pumice Inc., and Idaho Falls Pumice Co. were all producing pumice and pumice products during the early part of this period; later, only Idaho Falls Pumice Co. and Pumice Inc. were active. Bonneville County was the largest producer of pumice in the Pacific Northwest during much of this period. By 1953, this area was producing 83,000 tons of crude and prepared pumice valued at $150,000.

Local clays were being used by Idaho Falls Brick and Tile Co. in the fabrication of brick products.

By 1954, although quantities of sand and gravel were still being used in connection with the construction of Palisades Dam, such use began to taper off. Production in 1954 was valued at $233,700.

In 1955, nonmetallic minerals output was valued at $673,000 in the county. Some activity in gold placering occurred at the Stapleman placers in the Caribou (Mt. Pisgah) district. However, only a few ounces of gold were produced.

Sand and gravel and pumice production were high again in 1956 and 1957, and though 1958, 1959, and 1960 production of these commodities fell off sharply, they were still the leading mineral commodities in the county.

NONMETALLIC MINERALS

Natural aggregate and similar products

Sand and gravel

Sand and gravel are generally plentiful in Bonneville County. The largest supplies occur in the Snake River alluvial plain and in Swan-Grand Valley lowland. Pit locations are indicated on Figure 3.

The gravels of the Snake River Plain are imbricated in a way which shows deposition by a stream flowing in a generally southwesterly direction. One water well on the plain was drilled in over 170 feet of intercalated clay, silt, sand and gravel before encountering lava rock. Many wells encountered gravel intercalated with basalt to even greater depths. Generally the total thickness of exploitable gravel varies from 4 to 14 feet.

Gravels of the Snake River Plain contain subrounded to rounded pebbles and cobbles that are well supplied with quartzitic sandstones. Rock types found in these gravels include:

quartzite	sandstone
granite (rare)	conglomerate (rare)
limestone	basalt
siltstone	scoria

In southwestern Bonneville County, gravel is being exploited from the floodplain of Eagle Creek east of Grays Lake Marsh. This material is reasonably clean but needs screening. It has been crushed for use as road ballast by the county.

In the vicinity of McCoy Creek east of Caribou Basin, and at the placer ground adjacent to old Caribou City site, abundant cobble gravels are available.

Much of the gravel present in the Swan-Grand Valley area consists of fanglomeratic and conglomeratic material, probably from the Salt Lake Formation but reworked by thorough slope wash and stream action. Excellent gravel has been exploited from the floodplain of the Snake River below the Palisades Dam. During the construction of the dam large quantities of earthfill were removed from the slopes northeast of the dam site. This material consists of dirty, angular to subangular pebbles and cobbles, and finer colluvium and slopewash debris. Probably it was derived from the outcrops of fanglomerate to the east. Rock types occurring in this material are largely limestone, sandstone, and quartzite.

While the general quality of the sand and gravel in Bonneville County is reasonably good, classification and generally washing is advisable in order to produce a premium product. Such a product free from clay, silt, and caliche may sell for $2.50 per cubic yard.

In recent years the following firms were among the leading producers of sand and gravel in this county.

Falls Concrete Co.
Clark Concrete Construction Corp.
Ready-to-Pour Concrete Co.
Guderjohn Sand and Gravel Co.
Picket and Nelson Construction Co.
Wandamere Inc.
Builders Supply Co.

Cinders

Cinders are available at several localities in west central Bonneville County. Several such locations are shown on the accompanying geologic map (Fig. 3). These pyroclastics are located near a former volcanic vent in most instances, but water-laid cinder deposits are present near Conant Valley and also east of Poplar in the eastern part of the county.

The Conant Valley cinder deposit has been exploited for road ballast. A large pit at this site exposes 75 to 100 feet of brown to gray-black cinders and pyroclastic fragments. The fragments include pink rhyolitic tuff, scoria, and an occasional rounded pebble of sedimentary rock. This deposit is moderately to poorly cemented and surmounted by black to gray compacted tuff and a basalt flow. The latter exhibits pillow structure (Fig. 14), suggesting that the pyroclastics accumulated in a ponded environment. The ponded water may have formed a shore line at approximately 5,500 feet elevation because thin cobbly gravel layers occur at about this elevation along the slopes above the lava flow.

Five to 6 miles west of Poplar on the north side of the Snake River near Table Rock, large quantities of waterlaid pyroclastics are exposed. Because they are highly indurated, their commercial value is greatly limited. The exposed section includes gray to brown ash, silt, and fragments of scoria and obsidian.

Shattuck Butte, northwest of Idaho Falls, is composed of large quantities of pyroclastics and scoriaceous basalt flows. The cinders are composed of very brittle and crumbly fragments including many elongate, striated tubular particles. Silt, fine ash, and loess are mixed with the cinders, while volcanic bombs litter the top as well as the slopes of the vent. Two large pits are located on the flanks of the structure (Fig. 20). In one of the pits, the cinders are filled with ropy, scoriaceous lava and red and black blocks of basalt.

<u>Pumice and pumicite</u>

About 3 miles southeast of Ammon is a belt of pumice and finer pumicite deposits that crop out in places over an area nearly 10 miles long and two miles wide (Fig. 21). Five to 6 miles south of Poplar, pumice outcrops occur along Call Dugway on the side of Meadow Creek Valley. Pumice outcrops are reportedly widespread over this area near Ammon. A few water wells on the Snake River Plain southeast of Ammon have pierced pumice at from 40 to 60 feet below the surface. These pumice and pumicite deposits have contributed a major portion of the value of nonmetallic mineral commodities in Bonneville County.

The pumice beds exposed southeast of Ammon are at least 60-80 feet thick where they have been developed commercially. They frequently include silty and ashy layers. Generally the pumice is capped by 4-5 feet or more of silty ash, and scoriaceous rhyolite and tuff. Some of the lower reddish or pink beds rest on a basalt surface. Locally, the beds strike N. 54° and dip about 12° NW. Some of the pumice layers were deposited as fan-like structures near the mouths of early streams that flowed northwest from the hills into either a ponded environment, or out onto the flat Snake River Plain; some may be lenticular wind-blown accumulations; and other deposits seem to have accumulated as stream valley fill.

In places, the pumice is fairly coarse and may contain fragments of obsidian. The coarser pumice ranges from 1-1.5 inches up to 2-3 inches in diameter. Finer-grained, water-laid pumice generally occurs only at lower elevations. In some exposures the pumice grades upward into white, gray, or black welded tuff (Call Dugway at Meadow Creek). Small displacements or faults, and channel fills occur locally in some pumice sections. In one pit, 15-18 feet of brown to buff water-laid silts occur between the pumice and a lava-tuff caprock. The pumice in general is probably part of the Salt Lake Formation, although there may be some pumice that is younger.

A percentage analysis of Bonneville County pumice was supplied by the Pittsburgh Testing Laboratory in 1952 as follows:

SiO_2	72.5	Al_2O_3	23.0
Fe_2O_3	0.1	MgO	0.05
CaO	1.6		

In the last few years, two or three companies have been producing from 90 to 95 thousand short tons of pumice annually in Bonneville County (see photo on cover). The product retails for from $1.50 to $2.50 per ton. Special bagged traction granules may sell for $1.00 for 35 lbs. U. S. Prices are summarized in general by Williams and Burgin (1960, p. 6) as follows:

Domestic U.S.	1957	1958
Average short tons crude	$1.68 per ton	$1.92 per ton
Average prepared pumice	2.97 per ton	3.06 per ton

The pumice industry has been responsible for adding close to $160,000 per year to the nonmetallic mineral industry of the county.

Much of the market is local, but bulk pumice shipments have been made in 50-60 ton carloads to such states as Montana, Utah, Wyoming, Nebraska, North Dakota, Minnesota and Kansas. In recent years pumice production in other states (including Montana) has sharply reduced the volume of the state markets for Idaho pumice.

At the present time the major producers in Bonneville County are:

Idaho Falls Pumice Co., Idaho Falls
Pumice Inc., Ammon

Processing of the pumice product includes crushing, screening, and grading by mechanical equipment designed for this job. Pumice Inc. has a plant located at Ammon (Fig. 21) while Idaho Falls Pumice Co. has one at Indian Siding several miles southwest of Ammon.

Pumice in Idaho has been used for:

- Block aggregate
- Concrete aggregate
- Stucco aggregate
- Mortar aggregate
- Plaster aggregate
- Insulation granules
- Roofing granules
- Traction granules
- Acoustical granules
- Soil conditioner

Among the major uses for pumice is the fabrication of building blocks (8" x 8" x 16"), that can be colored in various shades; the split-block types have been given the trade name: Gemstone.

Because of its slight pozzolanic action, this pumice product makes a good lightweight aggregate for use in cement. Still greater use probably could be realized if architects would study the many possibilities. Savings could be made in many aspects of design. Concrete made with pumice is reportedly better insulated and fireproofed, and is rodent, termite, and weather resistant.

In mortar the pumice tends to prevent crumbling or slough. About one-half more pumice is used in place of ordinary sand.

As an insulation material pumice is rated between rock wool and granulated cork. It has been used as follows:

- Block or tile core fill
- Under concrete floor slabs
- For jacket insulation around water heaters, furnaces, stoves, refrigerators, etc.
- In concrete as aggregate
- In pipe trench fill
- For wall and ceiling fill
- As roofing granules

Pumice reportedly promotes plant growth, not as a fertilizer but as a soil conditioner. It supposedly allows easier utilization of organic and inorganic material, while it makes heavy and clayey soils more friable.

Other uses for pumice and pumicite are discussed by Williams and Burgin (1960), in a rather complete analysis of its origin, classification, uses, prices, and compositions.

Crushed stone aggregate and ballast

Basalt, sandstone, and limestone occur widely distributed in Bonneville County, and they are readily available for crushed stone aggregate or ballast. In the western part of the county basalt is plentiful, but is little used for crushed rock. In the eastern area the Madison and Brazer limestones, the Wells Formation, and the Nugget Sandstone are all available for crushed stone. The Nugget commonly has talus slopes that could supply large quantities of quartzitic sandstone by gravity feed for crushing operations.

There is a quarry northwest of Dehlin on a tributary to Willow Creek in south central Bonneville County that is in the Nugget Sandstone. Farther east, just northwest of Palisades Dam is another rock quarry in the Nugget Sandstone.

Near the mouth of McCoy Creek is a quarry in shale. This rock has apparently been used locally for a low grade of ballast on the McCoy Creek road.

Dimension stone

Sedimentary and igneous rocks both have been quarried sporadically in this county. Small quarries are numerous east of Ammon. Sometimes referred to as "sandstone," a rhyolitic tuff probably has been used as frequently as any rock type in this area for building purposes. Buildings of tuff may be found in a number of places including Idaho Falls, and Ammon (Fig. 23). An old house and school house are built of this gray tuff near Poplar on State Rt. 26. The school house has been standing since 1910, yet 50 years of weathering have had little visible effect on the rock.

Quarries in the tuff were examined south of Poplar (Fig. 24). The rock is a buff to gray to blue-gray, pink to lavender compact, nonwelded tuff. Generally workable faces in the quarries are from 15 to 20 feet thick. The rock shows only slight tendency to be layered; more often it is massive to slabby. Lack of uniform parting and cleavage surfaces would make it difficult to split out into good blocks, but on the other hand it could be cut quite well with a rock saw.

Loughlin (1914, p. 1379) calls attention to the fact that this tuff tends to harden on prolonged exposure, while it also tends to resist disintegration under the climate of southeastern Idaho. It should be made clear that tuffs that are poorly consolidated in the first place do crumble and are easily subject to abrasive wear. Blocks of such material also will suffer transverse breaks even under a light load.

Loughlin (p. 1379) said:

> These rocks do not give as high results as granite and marble upon testing, but are easily worked...both of the flow rocks (true rhyolites, and andesites) and the tuff are quite adequate for all demands that have been made upon them.

Basalt has been used as a building stone in a number of places in Idaho Falls. Loughlin (1914, p. 1379) mentions the use of basalt as a building stone in the Zion Cooperative Mercantile Institution building at Idaho Falls. Some of the blocks are 6 feet in length. Although it gives a somewhat somber effect to the building, it wears well even as door sills subject to loaded truck traffic.

The Nugget Sandstone has been used as a dimension stone in other areas (Mansfield, 1927, p. 336-337). Tests on this rock were very satisfactory showing that it is more durable than many well-known building stones of the east.

Limestone and travertine are available in some quantity and they are of reasonably good quality for building stone. These types of rock, however, have never been used much locally.

Dimension stone production and use is unpredictable and depends upon fashion, changing architectural styles, and cost of construction. In all probability relatively small quantities of premium stone will be used in the future, principally for facing and trim stone. There should be a small demand for colored varieties of easily workable tuff for decorative stone. An enterprising supplier might stimulate such a demand. Travertine deposits near the mouth of Fall Creek, and in other localities might bear investigation as to their possible use as a decorative stone. In the past this type of rock has been used to produce some rather beautiful architectural effects.

Clay and clay products

Alluvial clay of a quality suitable for making bricks occurs in the vicinity of Ammon and Bone. Clay also occurs intercalated with the lava flows making up the Snake River Plain. Some clay for brick making is imported from Jefferson County (source near Roberts) and from Bingham County. A total of 9 to 10 thousand short tons of clay is used annually.

Local clay appears to be somewhat inferior and not too plentiful, but with care it is used to make a satisfactory brick. Some of the local clay has phosphatic nodules that have to be removed from the raw material.

It is possible that some of the clay shales that occur in the Wayan Formation might be suitable for brick making. This kind of material is successfully and extensively used by brick makers in the eastern United States.

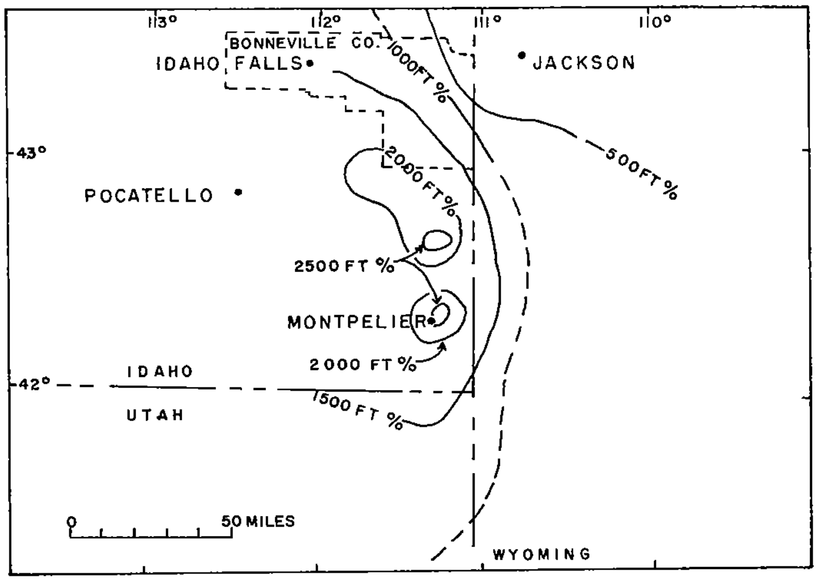
At present Idaho Falls Brick and Tile Co. operates the only brick making plant in Bonneville County. An extruded wire-cut type of brick is produced in red, pink, and buff colors. Local clay produces light pinkish brick.

Mr. Herman Pullman, operator of the Idaho Falls Brick and Tile Co., stated (personal communication) that the capacity of the plant is about 4 million bricks per year based upon a 4 month production year. The retail price of the brick varies from $52 to $62 per thousand. Tile is not produced locally. Principal competition is from Utah brick companies who ship brick into the area.

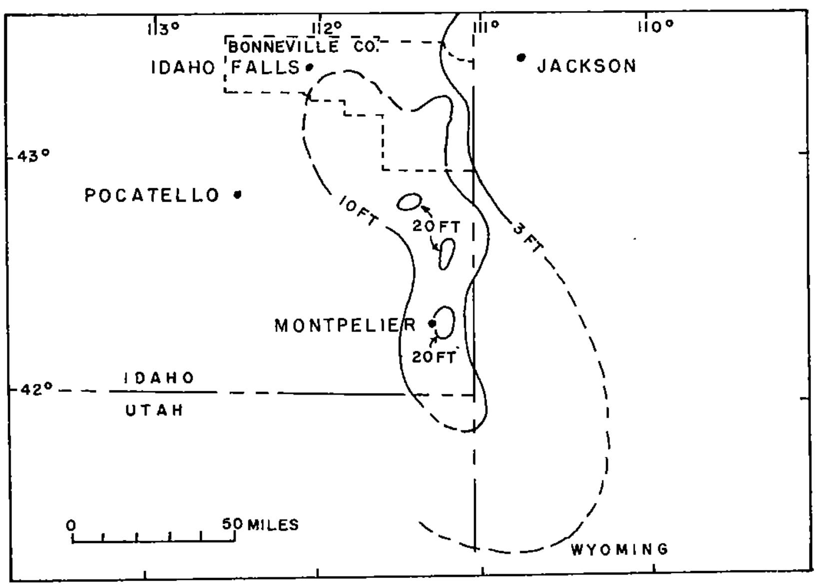
Phosphate rock

Phosphate rock, probably of low potential value occurs in the Phosphoria Formation in Bonneville County. Phosphate-bearing beds are characterized by pelletal or oolitic textures, dark color, and petroliferous odor when freshly broken. Often the carbonaceous appearance of the beds leads to the staking of claims under the false impression that the strata contain coal. In places, the phosphate rock may take on a bluish-white coating or bloom.

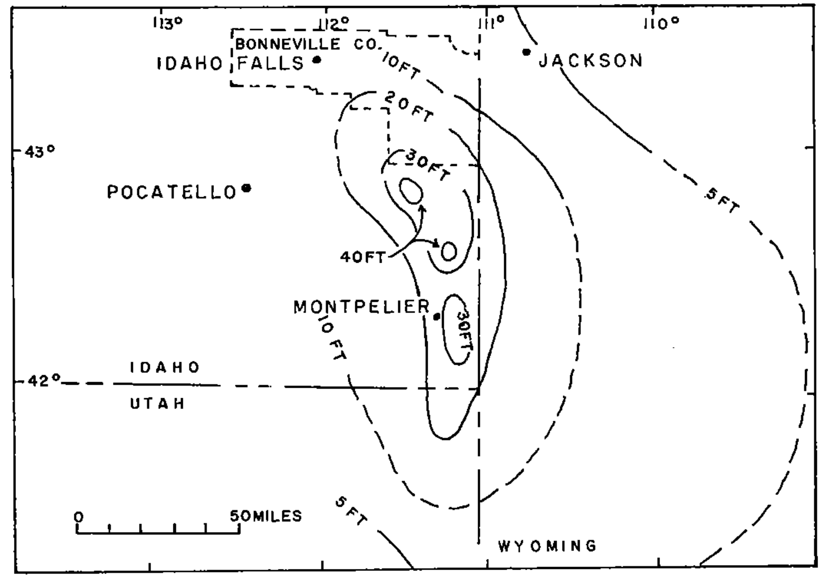
Sears (1955, p. 1680) described the Phosphoria in this general region as about 190 feet thick with a lower, 55-foot thick, phosphatic-shale member and about 135 feet thickness of Rex Chert above a disconformity. He stated that a 1.5 to 10.5-foot thick, high-grade, phosphate-rock zone lies at the top of the shale member, and



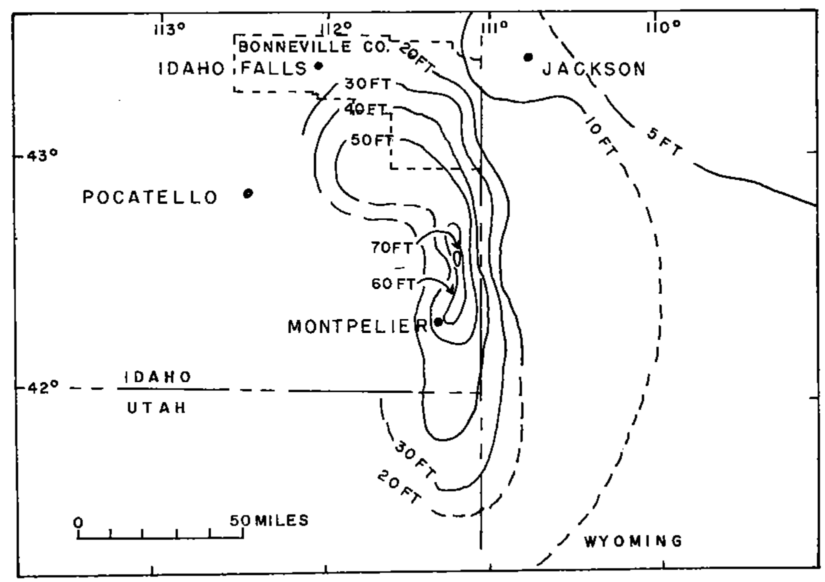
A. TOTAL PHOSPHATE IN PHOSPHATIC PORTIONS (FEET TIMES % P_2O_5)



B. TOTAL THICKNESS OF ROCKS CONTAINING MORE THAN 31 % P_2O_4



C. TOTAL THICKNESS OF ROCKS CONTAINING MORE THAN 25% P_2O_5



D. TOTAL THICKNESS OF ROCKS CONTAINING MORE THAN 18 % P_2O_4

FIGURE 24 THICKNESS AND P_2O_5 CONTENT IN THE PHOSPHORIA AND PARK CITY FORMATIONS IN SOUTHEAST IDAHO (ADAPTED FROM SWANSON ET AL, 1953: U.S.G.S. CIRC. 297) he recognized four main rock types in the formation: a finely oolitic rock, a coarsely oolitic section with a white matrix, a fish scale and bone fragment zone, and a blocky, finely detrital series of beds.

In southeast Idaho, phosphate rock is generally a fluorapatite; for example, $9CaO.3\ P_2O_5 \cdot CaF_2$ (Mansfield, 1952, p. 77). In the fertilizer trade, $Ca_3(PO_4)_2$ is called "bone phosphate of lime" (B.P.L.), and percent of B.P.L. is calculated by multiplying percent P_2O_5 by 2.18.

Among the impurities occurring in Idaho phosphate rock, Mansfield (1952, p. 78) mentioned vanadium, iron, and alumina. Vanadium, previously reported from beds near Driggs in percentages ranging from 0.5 to 2.0, appears to be present in highest quantities in coaly or carbonaceous or graphitic(?) layers. Gardner (1944, p. 19) stated that "15 samples of phosphate rock from the Snake River Range showed 0.03 to 0.41 percent V_2O_3" (0.04-0.50 V_2O_5). He demonstrated that vanadium content seemed to depend upon organic matter present, not phosphate content. W. W. Rubey (1943) estimated that "millions of tons of rock that contains 0.75 percent or more of V_2O_5..." may be present in Idaho, Wyoming, and Utah in the Phosphoria Formation.

As for the iron and alumina, most phosphate rock contains less than the 3 to 4 percent limit. According to Mansfield, (1952, p. 78) the phosphate rock in the Ammon region contains iron and alumina ranging from 1.30 to 5.34 percent. Gardner (1944, p. 19) said experience in the region shows that "at least 90 percent of the rock that contains more than 61 percent of B.P.L. is free of objectionable amounts of these impurities."

Schultz and Richards (1913, p. 267-281) described the geologic section in the Caribou Range. Their measurements convinced them that the "...upper cherty portion of the (Phosphoria) formation occupies a relatively greater part of the entire section than it does to the south" (p. 273).

Schultz (1918, p. 23) mentioned that the upper portion of the Phosphoria locally includes a thin bed of high-grade rock phosphate in the Caribou Range, and cites its occurrence on Pritchard Creek. This location was recently opened up by bulldozing, and seems to be located on a fault zone. Similar, but somewhat disturbed, beds occur on Fall Creek in a carbonaceous zone opposite Little Current Hollow, located about 3.5 to 4 miles up the creek from Snake River. There is an old mine drift at this site with about 262 feet of completed tunnels. Some trenching has been done in the phosphate beds about 0.5 to 1 mile north of the mine entrance.

Swanson and others (1953, p. 11) stated that during their investigation "...several valuable deposits (of phosphate rock) were discovered...most noteworthy of which is ... a 12-foot bed of 33 percent P_2O_5 rock in the Caribou Range...:" This deposit is located on Bear Creek about 3 to 4 miles south of Palisades Dam. The phosphate beds are on a complicated structure, and are nearly vertical.

Smart and others (1954) measured this Bear Creek exposure and another on Fall Creek (previously noted).

Based upon their studies, Swanson and others (1953) produced a series of maps indicating thickness and P_2O_5 content of the Phosphoria in southeastern Idaho. These maps are reproduced in Figure 25. It should be emphasized that they are constructed from relatively little data in the region of Bonneville County.

Beds of Phosphoria crop out in the Snake River Range. Schultz (1918, p. 41-44) and Gardner (1944, p. 20-29) located phosphate rock exposures in several places: most exposures were in disturbed zones, but one section near the top of a ridge southeast of Upper Palisades Lake seemed undisturbed. It contained 29.2 feet of phosphatic shale averaging 23.26 percent P_2O_5, or 50.71 percent B.P.L. On Pine Creek, Schultz found in a broken and distorted zone, a sample of phosphate that yielded 27.51 percent P_2O_5, or 60.1 B.P.L. The Phosphoria Formation here was reportedly 375 to 400-feet thick with at least one 4-foot section of phosphate rock. On Rainy Creek, he found the Phosphoria to be 375 feet thick with a 3.5-foot thick phosphate bed that yielded 31.69 percent P_2O_5, or 69.4 percent B.P.L. The North Fork of Rainy Creek also yielded a sample of phosphate rock that was analyzed as 17.08 percent P_2O_5, or 37.4 percent B.P.L. This site had been claimed as a potential coal deposit because of the presence of carbonaceous material in the shaly beds. Again, on Palisades Creek, both Schultz and Gardner found similar phosphatic deposits in carbonaceous layers. Phosphatic rock from this location showed 12.69 percent P_2O_5, or 27.8 percent B.P.L. on analysis.

The Geological Survey recently started a program of remapping areas underlain by the Phosphoria in the Snake River Range. This work eventually should reveal any commercial phosphate deposits that may exist in the area.

At the present time, no major high grade, commercial sources of phosphate are known to exist in Bonneville County. Late in the summer of 1961, however, a report was received stating that Wells Cargo Company were seriously considering the possibility of phosphate production in the Fall Creek area.

In his report, Gardner (1944, p. 33-34) made the following summary statement:

> Overthrusts have ruined much of the phosphate rock in the northern part of the Snake River Range by destroying the continuity of high-grade beds and by mixing worthless material with the phosphate rock. The weak phosphatic beds were favored zones along which the overthrust blocks could easily move. At some places the beds were eliminated or smeared to mere streaks, and elsewhere they were piled in disorderly heaps as much as five times thicker than normal

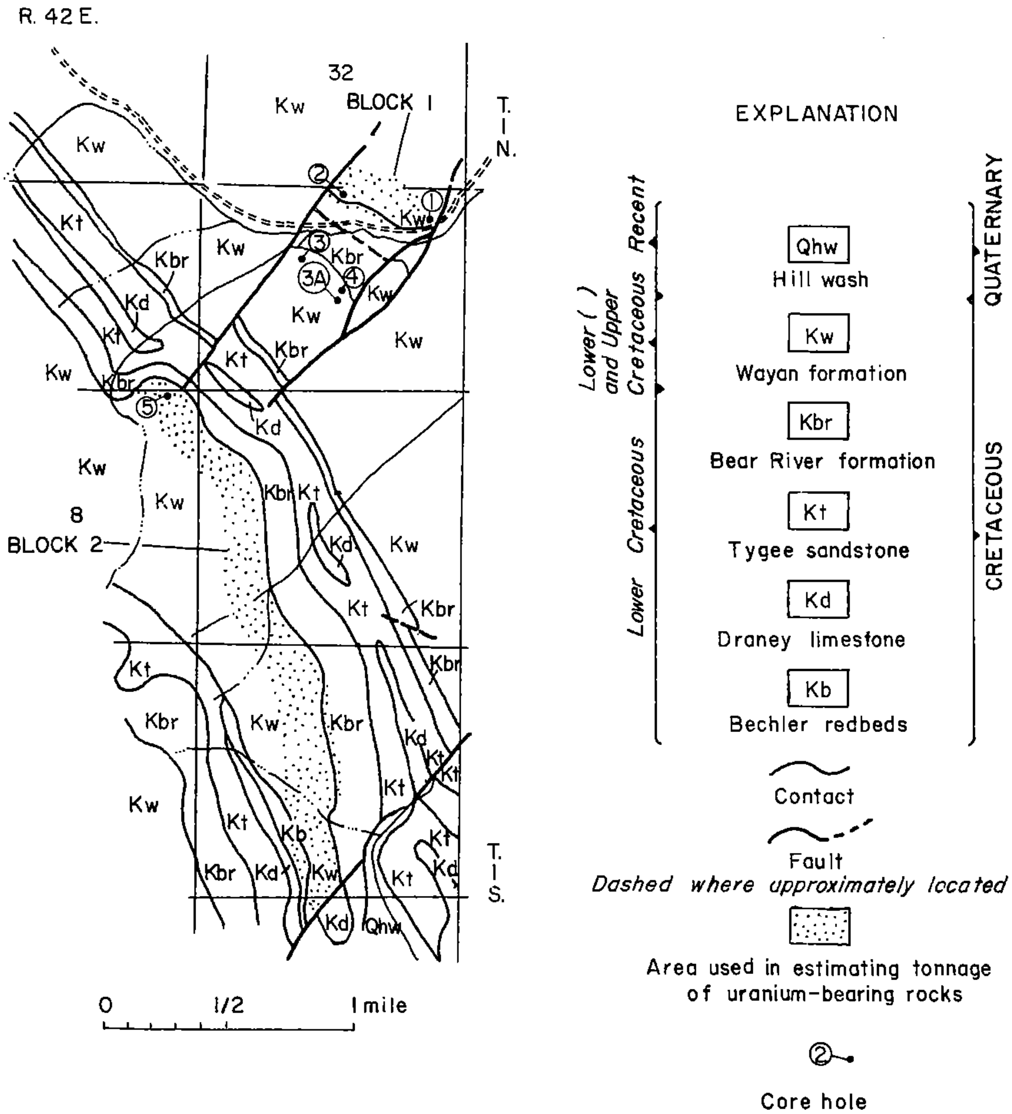


FIGURE **26** Sketch map of part of Fall Creek area, Bonneville County, Idaho, showing location of core holes and areas underlain by uranium-bearing rock. (After Vine 1959)

> ....it is therefore impossible to predict the underground extent, thickness, or composition of the phosphate beds that have been affected by the overthrust.

Similar reasoning and conclusions might well be made in respect to phosphate production prospects in most of the Caribou Range.

Mineral fuels

Coal

The lower Wayan (Bear River) Formation locally contains carbonaceous shaly materials resembling lignite. Higher up in the formation (Frontier) a slightly better grade of coal occurs to the northeast in Teton County. The coal fields of western Wyoming were developed in these younger strata.

Schultz and Richards (1913, p. 281) were among the first to publish notes on Bonneville County coal prospects. They noted occurrences on Fall Creek, Willow Creek, and Grays Lake Outlet. In all three instances their location data are probably in error. It was reported "that a Mr. Brinson was installing machinery at the so-called Brinson prospect and expected to mine coal during the winter of 1911-12."

In 1918, Schultz (p. 64-76) reviewed some of the coal prospects in southeast Idaho. He verified the fact that most of the coaly material is Cretaceous in age, and that the deposits tend to range from a few inches to 4 or 5 feet in thickness. He concluded that the coal is not of economic importance because of its low grade and small quantity.

Schultz's coal sites included the Croley mine near Grays Lake Outlet (he located the deposit about 4 miles northwest of the site later designated Croley's mine). Fall Creek basin mine (J. Smith mine), and the Miller (Brinson) mine. Schultz's original location of the Fall Creek basin mine is incorrect.

Mansfield, in 1920 published the results of a survey of coal occurrences in eastern Idaho. His comments on the economic value of the coal were generally unfavorable. He found that the "coal...is hardly more than carbonaceous shale in which the carbon is locally abundant enough to burn. The moisture and ash are high and the heating value is low..." Mansfield (1920c, p. 132-134) described four principal coal sites west of the Snake River in Bonneville County: the Cloward, Brinson, Croley, and Fall Creek locations.

The Cloward mine, opened in 1916, consisted of a tunnel 100 feet long in earthy carbonaceous shale lenses. The coaly material occurred in nine layers ranging from one-sixteenth of an inch to 1.5 feet in thickness. The value of this deposit is negligible even for local use.

The Brinson (Miller) mine was reportedly opened by the Canyon Coal Mining Co. in 1900. About $8,500 was spent for machinery, for sinking a 40-foot shaft, and for opening a 115-foot long tunnel. Two coaly layers were developed that were 6 inches and 11 inches thick, respectively.

A third, vertical, gypsum-bearing, coaly, shale bed 7.5 feet thick was considered to be the principal "coal" source. The coaly material ended against a conglomerate bed, probably because of faulting. Mansfield considered this bed a very poor prospect. Bell (1903, p. 36-39) gave an analysis of this coal as follows:

Fixed carbon	45.20 %
Volatile carbon	32.10 %
Moisture	1.40 %
Ash	21.30 %
Sulphur	trace

The Croley mine represents only one of several prospects in the Wayan Formation along the valley of Grays Lake Outlet. When examined by Mansfield (p. 134), the workings consisted of two caved tunnels. According to various reports, the thickness of the coaly material was between 8 and 18 inches. Again this material appears to have been only a low-grade, lignitic shale.

East of the Snake River, a coal prospect on upper Rainy Creek (Fig. 3), was described by Mansfield (p. 136). The coaly beds occurred in layers about 7 feet thick. Two caved adits were reported.

In 1927, Kirkham (p. 13-15) described the Cloward coaly deposits on Willow and Fall Creeks, placing the strata in the Wayan on the basis of their contained fossils. He also concluded that Brinson's mine was in beds of the same age.

Kirkham described the Joseph Smith mine on Fall Creek, but his location seems erroneous. This mine is now called the God Send to Health, which is actually located just west of the Fall Creek Ranger Station (Fig. 3). Again Kirkham dated the coaly beds as Wayan on the basis of fossil content.

Vine and Moore in 1952 and Vine in 1959, prepared rather detailed reports on the God Send to Health mine, which they referred to as "Fall Creek coal prospect." The original Smith (Gold Send to Health) mine was developed in 1922 in carbonaceous rocks located on a tightly folded and faulted anticline. The folding and faulting destroyed any original value that this coal may have had.

Smith dug a drift extending 98 to 100 feet down the dip of the coaly beds (at an angle of 33°). A limestone forms the headwall. Much shearing and slippage is apparent in the coaly layers, while clay and shale fragments are squeezed into them. The coal is too sparse and low grade to be of commercial value, although one early investigator called this the "best" coal deposit in the area.

The report that this mine has curative powers because of radioactive nature of the carbonaceous materials, (hence its name), was not verified.

Gas and oil

Schultz (1918) was one of the first to mention the possibility of the occurrence of natural gas and oil in southeast Idaho, while Kirkham (1922, 1924, 1925a, 1925b, and 1935) prepared several somewhat detailed reports on the subject. Kirkham was convinced that this part of Idaho, compared to other parts of the state, offered the best promise for development of petroleum.

Among the reasons for early optimism was the presence in nearby states of commercial oil and gas wells drilled in lithologically similar strata of the same geologic ages and with similar structures. Seventy miles to the southeast, gas and oil wells were developed in the Green River Basin of Wyoming. Somewhat farther away, strata believed to be correlative with those of southeast Idaho, have produced gas and oil in the Big Horn Basin (100 miles to the northeast), and the Wind River Basin (120 miles to the east). In Montana, oil and gas-producing strata in the Sweetgrass Arch may also be generally correlated with the formations of southeast Idaho, although in this instance, they are about 300 miles farther north. Table 5 lists the potential oil-bearing formations in southeast Idaho and their equivalent oil and gas-producing formations in Montana, Wyoming, and Utah.

Table 5

Potential oil and gas-bearing formations in Bonneville County and their producing equivalents in adjoining states

Idaho	Montana	Wyoming	Utah
Wayan	Kootenai-Fuson-Lakota	Cloverly-Dakota	-----
Gannett-Stump	-------------	Morrison	-----
Preuss-Twin Ck-Nugget	Sundance-Ellis	Sundance-Ellis	Vermilion Cliff
Thaynes-Woodside	Chugwater	Chugwater	Vermilion Cliff
Phosphoria	--------	Embar	Goodrich
Wells	Tensleep-Quadrant	Tensleep-Quadrant	Goodrich
Brazer	Madison	Madison	-------

There are many feet of limestones, dolomites, shales, siltstones, and sandstones of marine and brackish water origin underlying southeast Idaho. These rocks are lithologically and structurally compatible to the accumulation of natural gas and oil. In Bonneville County, many of the Paleozoic limestones have a fetid oil-like smell when freshly broken, although no oil seeps are known in the area.

These strata have excellent porosity in some horizons because of the presence of porous sandstones, cavernous limestones, and their faulted and jointed zones. It should be noted, however, that some of the local sandstones which are orthoquartzites, have a very low porosity.

Also favorable to migration and accumulation of oil are the numerous unconformities and folded strata that include permeable and impermeable layers. Although some of these folds may be rather small locally to produce major collecting reservoirs, the anticlinal and synclinal structures are related, for the most part, to topographic features and easy to locate by topographic expression. In other words, there is a marked tendency for anticlinal structures to underlie topographic highs, while synclinal structures occur under valleys or basins.

Unfortunately neither of the two deep wells that have been drilled in Bonneville County have produced gas or oil. This may be because of the amount of post-depositional folding, faulting, erosion, and igneous intrusion. Heald (1922) discounted this idea: he said that ..."such evidence as is available does not indicate that alteration has progressed so far as to seriously injure the chances for the persistence of oil." His statement that "...Idaho contains enormous areas where there is no proof that oil is absent" may be pertinent. It does seem illogical to abandon a potential oil-producing area after drilling only two dry holes, particularly when it has such a good lithologic and structural setting.

Furthermore, it should be noted that both dry holes were in anticlinal structures, and seem to have been abandoned before reaching the base of all the potential oil-bearing strata. For example, the Darby Formation of Devonian age seems to have good possibilities judged by surface exposures. Wanless and others (1955, p. 19) spoke of the Darby's oil and gas-bearing potential, stating that because of its cavernous porosity it should be "...an excellent reservoir rock for oil and gas." The formation contains many highly permeable zones alternating with dense impermeable black to gray limestones.

Because the degree of cementation of the Nugget, the Wells, and other sandstone formations varies, there might be good reservoir conditions at one location and very poor conditions at another site.

Oil shale is known to be present in Bonneville County, Conduit (1920, p. 15 and 31) stated that samples of the Phosphoria yielded traces of oil; for example, several samples of this formation taken along Palisades Creek each yielded oil at the rate of 3 gallons per ton.

It would not be wise to exclude this area completely as a potential gas or oil-producing district until oil traps other than anticlinal structures have been investigated; until test wells have satisfactorily penetrated the entire column of potential oil-bearing strata; and until the younger Wayan (Bear River, Aspen, and Frontier) Formation has been definitely eliminated as a potential producer.

The locations of the two known drilled wells are shown on Figure 3. These holes are designated Bonneville No. 1 and Bonneville No. 2 in the Idaho Bureau of Mines and Geology file of gas and oil well logs.

Well No. 1 was drilled on the J. C. Sorenson property just south of Birch Creek. The best available information locates the well by section only, that is, in sec. 33, T 3 N, R 41 E. Drilling was done by the California Oil Company, who called the well Meadow Creek-Sorenson No. 1. Reportedly, the drilling was started at 5,849 feet elevation and was stopped at 2,075 feet, or at a depth of 3,774 feet below the surface. Drilling started in 1928, completed in 1930, and the hole was abandoned. An unconfirmed report stated that asphaltic material was discovered during the drilling operation. Following is a brief interpretation of the log based on rock description only:

Table 6

Condensed log of Bonneville County oil and gas Well No. 1

Formation	From (feet)	To (feet)	Thickness (feet)
Lava boulders	0	20	20
Nugget	20	250	230
Ankareh	250	815	565
Thaynes	815	1,980	1,165
Woodside	1,980	2,438	458
Dinwoody	2,438	3,425	987
Phosphoria	3,425	3,662	237
Wells	3,662	3,774	112
		Total	3,774

Well No. 2 was drilled within the boundaries of Caribou National Forest, just east of the top of Big Elk Mountain (Fig. 28). The well was located (Neighbor, 1953, p. 88)

> ...2,600 feet north of the South Line, and 1,880 feet west of the East Line of sec. 23, t 2 S, R 44 E, at an elevation of 8,113 feet.

This well was designated the Sun-Sinclair No. 1. Drilling started August 24, 1949, at 8,113 feet elevation (as noted above), and was stopped at 2,516 feet elevation, or at a depth of 5,597 feet below the surface on October 5, 1950. The well was abandoned as a dry hole. Following is a summary of the formations penetrated:

Table 7

Condensed log of Bonneville County oil and gas Well No. 2

Formation	From (feet)	To (feet)	Thickness (feet)
Ankareh	0	460	460
Thaynes	460	3,112	2,652(?)
Woodside	3,112	3,853	741
Dinwoody	3,853	4,507	654
Phosphoria	4,507	4,878	371
Wells	4,878	5,597	719
		Total	5,597

Neighbor (1953, p. 88) pointed out that in drilling the well on Big Elk anticline, circulation was frequently lost; for example, at intervals between 51 and 496 feet, cement plugs and other material had to be used to regain circulation. Between 2,716 and 3,110 feet, loss of circulation was so bad the section was drilled dry. Circulation was regained below 3,110 feet, but lost again at 5,020 and 5,440. At the 5,440 foot level, circulation was never regained and the hole was drilled dry to a depth of 5,597 feet. Porous and vuggy dolomite and sandstone were probably responsible for this loss of circulation in the lower part of the hole. The Wells Formation is probably more porous at depth at this site than surface exposures at other localities would suggest.

Water resources

Natural availability

Natural availability of water in Bonneville County is good, although an average annual precipitation of 15 inches (ranging areally from about 8 to 21 inches) produces a local semiarid climate. Ample supply of water in this area can be attributed to good surface supplies brought in by the South Fork of Snake River and Henrys Fork (North Fork of the Snake), and to good subsurface water storage conditions. South Fork watershed above Palisades reservoir is about 5,110 square miles, and the annual discharge from this area averages about 4,172,000 acre-feet (U. S. Bureau of Reclamation). Stearns and others (1938, p. 202) report an average of 1,335,000 acre-feet of runoff from Henrys Fork (at a point near Rexburg). Willow Creek, southeast of Idaho Falls, contributes a fairly large annual runoff to irrigation ditches and to the Snake River system. The Snake is both effluent and influent along its course through the area.

A naturally good ground water storage condition obtains over much of the area, but the depth to ground water level varies from near zero, close to the Snake River on the north, to as much as 1,000 feet deep on the west. The water table in central and western Bonneville County slopes south and southwest. The Snake River

Plain is composed of broken lava and intercalated sediments, along with old alluvium filled channels. Water storage conditions are good. The loess plains, or gravel and loess plains, located in the east central part of the county are also quite permeable. Conglomerate and gravel valley fill in the Swan-Grand Valley area produces good ground water storage conditions. In the Grays Lake area, ground water lies close to the surface much of the year. In the mountainous portions of Bonneville County the presence of some perennial surface water streams suggest a moderate amount of subsurface water. While not heavily endowed with surface and subsurface water, the mountain slopes have sufficient water to maintain stands of conifer growth in many places.

General developed water supply

Except for large quantities of water diverted from surface sources for irrigation, water supplies are drawn principally from wells.* Piper and Kirkham (1926, p. 7) commented:

> West of Snake River water is usually encountered at the average depth of 175 feet and rises in the bore hole to the dry crevices but no higher.... A good many of the shallower wells go dry each year between March and June, but the deeper wells deliver 14 to 20 gallons per minute.

The same report (p. 8) describes shallow, dug and drilled wells which occur in fan deposits of sand and gravel east of Idaho Falls. These wells reportedly have not been pumped to capacity, but seem to have good year-round potential. The same yield may be expected of wells in the Swan-Grand Valley lowland.

In 1960, a new plan to develop a 135,000 acre-foot multipurpose storage reservoir on Willow Creek east of Idaho Falls, was discussed by a group of officials representing the U. S. Bureau of Reclamation and the U. S. Army Engineers. This plan, if put into effect, would increase developed surface water supplies in the area by an appreciable amount, probably a desirable goal.

Idaho Falls municipal water supply

Water supply at Idaho Falls is obtained from eight deep wells distributed around the city. The system has only one storage area: a 500,000 gallon capacity storage tank; therefore much of the supply is pumped directly into the main distribution system. Chlorination is the only treatment applied to raw water. The general consumption of water is metered, but only large commercial and industrial users are individually metered. The system is capable of supplying over 34 million gallons of water per day (mgd).

During 1959, the Idaho Falls municipal water system yielded 4.43 billion gallons of water (Taylor, 1960, p. 1-4), with a daily peak demand of 24.4 mgd.

*Appendix I - Bonneville County water well logs.

This peak demand in warmer summer months is about 217 times the average daily demand during cooler winter months. Average daily demand for 1959 was about 12.2 mgd based upon the total consumption figure for 1959, or about 370 gallons per person per day (gpd) for the city. Although this per capita figure is about three times the amount used by many municipalities at Idaho Falls it reflects the use of municipal water for some irrigation in addition to domestic and commercial use (including water for air conditioning).

The water is good except for an objectionable degree of hardness: About 260 parts per million (calcium carbonate). Also there is some threat of surface pollution because of the nature of the aquifer, broken and fissured lava with highly permeable contact zones between flows. Danger of pollution is highest during the irrigation season. Elimination of the practice of using drainage wells for excess irrigation water and sewage disposal in this area would help defeat the ground water pollution problem. Locally, sand may produce a problem in some wells, but this situation can generally be remedied.

The eight water wells at Idaho Falls penetrate alternate layers of basalt and intercalated sediments. Separate basalt flows extend to a depth of about 450 feet (Taylor, 1960, p. 17). This basalt rests upon about 900 feet of clay, silt, sand and gravel with an occasional intercalated basalt layer. Below these sedimentary layers is another basalt mass 500 or more feet thick.

According to Taylor (p, 17), the main water-bearing zones in the vicinity of Idaho Falls range in depth from 150 to 400 feet. Water comes principally from fractured layers of lava at contacts between separate flows. The primary sources of water in these layers is from surface stream seepage and from artificial drain wells extending into the lava layers. Taylor suggests that rock layers below 400 feet will not yield sufficient water to warrant drilling much below this depth.

In the future, additional water supplies may be obtained from Willow Creek, southeast and east of Idaho Falls; the Snake River; or by development of additional underground water. Taylor (1960, p. 24) considers the latter more feasible because it would involve less expense. Records indicate that annual fluctuations in the local water table do occur, but over the last 30 years the mean depth to the water table has remained the same. This fact indicates a very reliable and large supply of ground water in the district, even for future development of additional wells.

Ucon water supply

At Ucon, northeast of Idaho Falls, water supply is derived from wells sunk in silty and gravelly materials. A total of 100,000 gpd is the average summer consumption. No chlorine or chemicals are added to the municipal supply.

Iona water supply

Water supply at Iona, east of Idaho Falls, is obtained from two wells drilled in basaltic rock to a depth of about 198 feet. Water is pumped into the main lines and two

2,500 gallon tanks connected with the main system. An older well is tied into the system as a standby well. Services are to be expanded with additional wells and equipment. Total usage is unknown since the system has not been metered.

Irrigation

Large quantities of surface and subsurface water are used for irrigation in this area. The Great Feeder Canal at Poplar is reportedly one of the world's largest irrigation ditches. Irrigation started with the first ditch taken out of Willow Creek in 1866 (Clark, 1941, p. 55); however, major irrigation started about 1890 with the old Eagle Rock and Willow Creek Canal, now a part of the progressive system. Some 31 water service areas are supplied by irrigation companies and cooperatives in this general region of the Snake River.

Natural Lakes and Palisades Reservoir

Two small natural lakes occur along Palisades Creek in eastern Bonneville County. Both of these water bodies have value principally as recreational facilities.

The most important reservoir in Bonneville County is Palisades Reservoir. Built by the U. S. Interior Department Bureau of Reclamation, the following are salient statistics pertaining to this development:

Dam	Reservoir
Height, 260 ft.	Capacity 1,140,000 cu. ft.
Crest 2,200 ft.	Area 16,100 acres
Thickness 2,650 ft.	Length 20 miles
Volume 13,800,000 cu. yds.	Depth 221 ft.

The earth-fill dam was designed as a multipurpose project, both to store water for irrigation and flood control, and to produce power.

The need for water stored behind Palisades Dam was apparent during the summer of 1960. The heavy demand for irrigation water, which greatly reduced the supply stored in the reservoir as shown by Figure 27 suggests the need for even greater future storage facilities on this portion of Snake River.

Miscellaneous mineral materials of potential value

Perlite

Perlite is known to occur in small quantities in association with flow rocks south of Ammon. In fact, this material may be more widespread, but its expanding qualities as well as quantity available is still unknown. It is a potential source of expanded aggregate, provided it has the necessary physical characteristics.

Limestone and travertine

Lime-bearing rocks are abundant and widely distributed in the eastern half of Bonneville County. True limestones are found in the following formations:

Gros Ventre	Wells	Brazer
Darby	Thaynes	Boysen ("Gallatin")
Twin Creek	Madison	

The Boysen ("Gallatin"), Madison, and Brazer are composed almost entirely of limestone. Magnesium-rich limestones are found in the Big Horn Dolomite, the Peterson and Draney limestones.

According to the U. S. Bureau of Mines (U. S. Bur. Mines Staff, 1960, p. 463), calcination of limestone for the manufacture of quicklime and hydrated lime is still one of the more important industries in the United States because these materials are of great value in the chemical as well as other industries. Smaller quantities of lime are used in construction and agricultural fields. In agriculture, lime is used for conditioning or neutralizing soil. Lime for these purposes is generally ground or pulverized, uncalcined limestone. It should be noted that more than 5 percent SiO_2 in a limestone makes it unsuitable for lime production.

Some of the Bonneville County limestones are of suitable quality for a variety of commercial uses (Table 8); in fact, a lime kiln reportedly once operated in one of the canyons southeast of Pine Creek a few miles northeast of Swan Valley.

Part of the local limestone may be classified as "high-calcium" rock because it carries 95 to 97 percent $CaCO_3$. On the other hand, some of the so-called "limestones" are closer to the composition of a dolomite, for example, the Draney and Peterson limestones. These two formations contain 13.8 and 20.2 percent $MgCO_3$ respectively. This "adulteration" would exclude them from use in the cement industry, while their relatively high SiO_2 content would also exclude them from use in the lime industry.

Other uses for limestone include use in the construction field as crushed stone ballast and in concrete; as flux for smelters and for open-hearth and blast furnaces; and for use in glass, sugar, and paper-making industries. Magnesium limestone (dolomitic limestone) may be superior for use in some of the chemical industries.

Bonneville County limestone is suitable for use in the sugar industry. Not only has it been used for this purpose in the past, but a comparison of analyses of local rock and rock from the stock pile at the U and I Sugar Company at Lincoln (east of Idaho Falls), indicates similar rock composition (Table 8, D1 and 2, and E). The U and I Sugar Company uses 18,000 tons of this type of limestone per year. Their present supply is obtained from a quarry on Fox Creek near Teton Valley in Wyoming, and is hauled to the plant by railroad cars.

Local limestone also seems suitable for use in the cement industry. Several high-calcium limestones would need modifications--for example, shale additives; however, adequate supplies of shale are located in the same general area as the limestones.

A thorough check of the limestones in Bonneville County might reveal "natural cement" rock, that is, limestone with a composition close to that of finished cement (Table 9). Mansfield (1927, p. 332) indicated that the Twin Creek Formation in the Georgetown area south of Bonneville County has a natural cement rock composition locally (Table 10).

Table 8 Limestone analyses

Specimen		Percentage			
		SiO_2	Al_2O_3 & Fe_2O_3	$CaCO_3$	$MgCO_3$
A.	Lehigh, Pa. district				
	"Cement rock" (av. of 4 specs)	12.54	4.92	77.27	4.46
	Limestone (av. of 2 specs)	2.50	1.30	93.62	2.53
B.	Utah				
	"Cement rock"	21.2	8.00	62.08	3.80
	Limestone	6.8	3.00	89.8	0.76
C.	California				
	"Cement rock"	20.6	13.46	63.04	1.54
	Limestone	7.12	3.52	87.70	0.84
D.	Bonneville Co. Ida.				
	(1) Limestone approx. 4 mi. up Palisades Cr.	1.7	0.4	97.3	1.2

Table 8 Limestone analyses (continued)

Specimen	SiO_2	Al_2O_3 & Fe_2O_3	Percentage $CaCO_3$	Percentage $MgCO_3$
D.. Bonneville Co. Ida.				
(2) Madison Limestone near Pine Cr. Bridge, Rt. 31	1.7	1.5	95.0	1.5
(3) Draney Limestone Jensen Pass	10.1	0.8	76.8	13.8
(4) Peterson Limestone NW of mouth of McCoy Cr.	14.5	1.6	64.0	20.2
E. Wyoming U and I Sugar Co. stock pile at Lincoln	2.1	0.5	95.9	0.8

Table 9

Analyses of Portland cement mixtures
(Mansfield, 1927, p. 334)

	(1)	(2)	(3)	
Silica (SiO_2)	12.85	12.92	13.52	14.94
Alumina (Al_2O_3)	4.92	4.83	6.56	2.66
Iron oxide (Fe_2O_3)	1.21	1.77	---	1.10
Lime carbonate ($CaCo_3$)	76.36	75.53	75.13	75.59
Magnesium Carbonate ($MgCO_3$)	2.13	4.34	4.32	4.64

Table 10

Analyses of Twin Creek Limestone from Georgetown Canyon
(Mansfield, 1927, p. 332)

	M-169a	M-169b
Silica	15.06	10.41
Alumina	2.03	3.57
Iron oxide (total)	0.68	1.41
Magnesia	0.55	1.69
Lime	44.76	44.39
Carbon dioxide	35.89	37.01
Loss on ignition less CO_2	0.60	1.00
	99.57	99.48

Fairly large travertine deposits near the mouth of Fall Creek west of Swan Valley have a high lime content and might be worth investigation as a source of high grade lime. The travertine analysis is as follows (figures are percentages):

Specimen	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	Insol. Residue
Fall Creek	0.0	0.0	0.0	99.8	0.0	0.2

It should also be noted here that the extensive tuff and pumicite deposits in Bonneville County might be used to produce an excellent pozzolanic cement. Analyses cited by Mielenz and others (1951, p. 320) for pozzolanic quality pumicites from Kansas and California follow (figures are percentages):

Specimen	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	Ignition loss
Ellis, Kansas	71.44	13.08	1.80	0.27	2.22	3.32
Friant, Calif.	73.98	13.70	1.22	0.45	1.97	3.59

Because laboratory tests show that some rhyolitic tuffs and pumicites make excellent pozzolanic cements, the possibility of greater use of tuffs, pumicites, and limestones from this county should be investigated by interested parties. Mielenz and others (1951, p. 312) reported an increase in the use of pozzolans in concrete construction.

Silica rock

Several of the formations in Bonneville County are rich in SiO_2. Locally the silica rock is badly stained with iron oxide, but in some instances the rock is very white. Although actual silica content is not known it must be high in both the Wells (Tensleep) Formation and the Nugget Sandstone.

Silica-rich tuff is widespread over this area, but its possible use as a source of silica was not investigated; locally it seems to have the qualities of a good natural abrasive product.

Bentonite

Bentonite, or decomposed volcanic ash, was discovered along the southwest bank of the Snake River in an exposure of the Salt Lake Formation about 2 miles west of Swan Valley. Only a few inches thick, the bentonitic layers are not present in commercial quantities at this site, but bentonite has been reported occurring at the base of the Salt Lake Formation at other locations outside this county. Its quality is not known.

Traces of bentonitic clay have also been reported in the Wayan Formation, but none were observed during this field study.

Salt

About 14 miles south of the southern Bonneville County line is an old salt works (on Stump Creek west of Auburn, Wyoming). This area abounds with salt springs, and layers of rock salt have been exposed locally. Breger (1910, p. 562-567) indicated that the salt was originally derived from the "Beckwith" Formation (a member of which is now called the Preuss). Breger presumed that salt was disseminated in small quantities in the sandstone, conglomerate, and shale that compose this formation. He proposed that the salt was concentrated on alkali flats during pre-Pleistocene time, shortly after deposition of Oligocene(?) conglomerates.

If these salt deposits are related to physical circumstances that were local to the Stump Creek area, then one would not necessarily expect to find similar salt deposits in southern Bonneville County. However, if the rock salt beds originated earlier in connection with the deposition of the basal "Beckwith" or Preuss Sandstone, then there might be a good chance that salt-bearing beds would also be present 14 miles to the north in Bonneville County.

Imlay (1952, p. 1738) said:

> The lower part of the Preuss sandstone, locally along the Idaho-Wyoming border contains salt beds that in one boring aggregate 96 feet throughout a thickness of 456 feet and include a single bed of salt 29 feet thick.

Breger, (1910, p. 558) reported that the quality of the salt obtained from the Stump Creek locality was superior and cited the following analysis:

Sodium chloride (NaCl)	98.900
Calcium sulphate ($CaSO_4$)	0.817
Potassium chloride (KCl)	0.261
Magnesium chloride ($MgCl_2$)	0.022
	100.000

Wallace-Wyoming Oil Co., in 1922, reported drilling operations in the Tygee Creek area near Stump Creek (Mansfield, 1927, p. 340); Boyer (1926) had also mentioned drilling near this site. The well logs recorded by these two reports, presumably the same well, are different; however, there was some question as to the actual location of the well and two locations were given as follows:

NW 1/4 SW 1/4 sec. 3, T 8 S., R 46 E.
SW 1/4 SW 1/4 sec. 34, T. 7 S., R 46 E.

The important point is that both well logs showed good thicknesses of rock salt. Boyer's account indicated that at least 114 feet of salt were intercalated with the rocks of the Preuss Sandstone, and probably even greater quantities of salt are present, because over 415 feet of the hole showed interbedded shale and salt. The hole probably reached a depth of 2,448 feet.

Mansfield's log indicated a total depth of only 694 feet, with salt bearing strata intercalated through about 456 feet of the hole. Six beds of actual salt ranging in thickness from 6 to 29 feet were penetrated. Anhydrite and gypsum were also present. As Mansfield pointed out, (p. 340) the salt layers and the enclosing beds of Preuss seem to have been contemporaneous in deposition.

The two well locations noted above may indicate that two different wells were actually drilled, but such a conclusion was not verified.

While no salt springs and seeps were observed in southern Bonneville County and no record was found of subsurface salt layers like those a few miles to the south, the information presented above does suggest the possibility that salt may be associated with the Preuss Sandstone in southern Bonneville County. Mansfield believed the salt beds farther south were not of great breadth and that they also might be cut off by faulting. This belief remains to be proved conclusively. In the meantime, interested groups could test-drill several sites underlain by Preuss beds to test the possibility that salt might occur in Bonneville County.

METALLIC MINERALS

Snake River alluvial gold deposits

The earliest production of gold in this region was from sand and gravel terraces along the Snake River. This production was flour gold probably derived from widely disseminated deposits in the Teton, Gros Ventre, and Caribou mountains, then carried downstream to the master drainage system. The gold occurs as both "free flakes" and "coated forms", and has a high degree of fineness (quality). Much of it is small enough to pass through a 150-mesh (0.104 mm) screen.

An area that has been worked in recent years, about 7.5 to 8 miles upstream from Heise along the south bank of Snake River, is representative of the Snake River placers. This deposit, called the Roy Coles property, encompasses about 160 acres and reportedly yields around $5 worth of gold per cubic yard. Similar lean placers generally yield less--for example, around 25 cents to $1 per cubic yard of placered gravel. Pay streaks are very irregular and gold values per cubic yard of gravel fluctuate widely within any one placer.

Flour gold has also been recovered from sediments on an island in the Snake River near Idaho Falls and no doubt from other gravelly deposits along the Snake River in Bonneville County.

Placers at Caribou Mountain and in adjacent areas

Early placering

Historians agree that placer gold was discovered in the Caribou Mountain district in 1870. Credit for the initial discovery is given to Jesse Fairchilds, F. McCoy, and F. S. Babcock; however, some reports indicate that a George Chapin, Negro cook at the Stump Creek salt works, may have been the original discoverer (Clark, 1941, p. 90). Nicknamed "Carriboo" because of his previous experiences in parts of British Columbia, Fairchilds probably inspired the name Caribou for the mountain. Originally the mountain had been called Mount Pisgah, then Mount Bainbridge.

The main gold "rush" occurred through the 80's and 90's when seasoned miners appeared, and it is estimated that the total gold output from early placering may have amounted to as much as 50 million dollars (Clark, 1941, p. 90-94).

Shupe (1930, p. 19-20) more realistically contends that the placers yielded $250,000 per year for several years, and reported that the miners washed about one ounce of gold per day from their individual placers. By 1887, when hydraulic operations had started at Iowa Bar, gold recovered reportedly amounted to from $50 to $250 per placer per day. Water shortage always has been one of the greatest handicaps to hydraulic mining in this district. One may depend only upon about 3 months of melting snow to supply sluicing and hydraulicking water.

Schultz and Richards (1911, p. 282) described small-scale placering or sluicing along McCoy Creek. The miners worked sand and gravel from benches and terraces. Burlap tables were used with sluice boxes. It was reported that gold-bearing gravels were richest in Bilk and Iowa gulches; the gravels extended 5 miles along this drainage system downstream to McCoy Creek. Barnes (Ketchem), City, and Tin Cup creeks were also known as placer areas. Possibly the headwaters of Eagle Creek were placered too, but this presumption has not been verified.

From the early 1900's to the present, placer claims have changed hands frequently and new claims have been staked on many tributaries of the Snake River. Small quantities of gold, usually amounting to only a few ounces are recovered from some of these streams almost every year.

Origin of the placers

Most of the streams draining the flanks of Caribou Mountain have been placered for gold. In general the auriferous deposits seem to be thicker and more widespread on the northwest and northeast flanks of the mountain, because ice and snow have caused minor cirquation, including frost-and ice-wedging of gold-bearing bedrock and thereby provided an abundance of shattered rock debris for transportation downstream, particularly by later floods of meltwater. Therefore, much of this placer material may be drift of glaciofluviatile origin. It is mixed with colluvium and slopewash (Fig. 28).

In general the gravels are angular to subangular with only a few pebbles approaching rounded shapes. Rocks are intrusive and extrusive igneous types, such as granite, diorite, syenite, andesite, trachyte, gabbro, diabase, and basalt; and also sedimentary rock types including red shales (Triassic), conglomerates (Ephraim and Wayan(?)), limestones (Jurassic), and sandstones (several ages represented). In other words, the rocks contained in the alluvium and colluvium closely reflect the nature of the local bedrock. It should be added that secondary iron oxide pebbles, cobbles, and even small boulders are remarkably common in the placers.

Caribou City

One of the important placer areas in the Caribou City district is at the head of Bilk Gulch. The placer ground consists of large bouldery gravels. The gravel contains abundant dark-gray, alkali-rich, igneous rocks like those found on Caribou Mountain, which suggests the source of the gold. Resembling glaciofluviatile sediments, the Bilk Gulch placer deposits rest on nearly vertical beds of the Wayan Formation.

A similar placer occurs at the head of Iowa Creek; between the two areas is the so-called "Iowa Bar" of earlier placering fame (Fig. 28). In this area--essentially the former site of Caribou City--some placering still goes on during the spring, principally by hydraulic and sluice box methods. About 30 feet of placer gravel overlies the bedrock. The area of the deposit is unknown but probably it is not great.

McCoy Creek

Placering on McCoy Creek has spanned many years, starting shortly after 1870 and continuing spasmodically up to the present time. In 1960, the so-called McCoy Creek Mutual Mining Association held about 22 claims downstream along McCoy Creek. These included the Sage, Janet, Ken, and Hard Luck groups. The Sage Group, according to Jack Van Noy of Idaho Falls (oral communication), runs about $6 in gold per cubic yard of gravel, a little too high a yield for this type of deposit. Panning tests were not successful in verifying such a recovery. The gravel is bouldery and contains subangular to rounded fragments; pockets of clayey silt surround the boulders in many places. Thereabouts gravel plastered thinly onto the bedrock walls of the main valley, resembles poorly sorted glacial drift that has been transported a short distance by meltwater.

Farther downstream near the junction of Iowa and McCoy creeks, the fluviatile materials are finer and include abundant silt and rock flour. The placers that have been worked here seem to be low, terrace-like forms of gravel. Panning tests yielded 5 to 8 colors per pan. At one time, a small dredge boat attempted to operate on lower McCoy Creek. Whether or not much gold was recovered is debatable. Samples along the upper valley walls in these portions of the stream, and along the valley floor showed no colors.

Tincup Creek

Placers have been operated in Tincup Creek about 4 miles southeast of Caribou Mountain. The gold yield was probably very small. Field pan sampling produced no colors.

City Creek

Approximately 3 miles northwest of Caribou Mountain some early placering was done on City Creek. The deposits are small and again gold yield must have been small also.

Barnes Creek

North of Caribou Mountain, large placering operations were conducted near the original site of Keenan City on upper Barnes Creek. Claims are still placered at irregular intervals in this area. The present claims are reportedly called the Lucky Strike Group.

Outlook for placering

Probably most of the better placer areas have been worked; however, gold can still be recovered in very small quantities in McCoy Creek. Better values are still present at the head of Bilk and Iowa creeks, particularly where relatively undisturbed placer ground still remains. It is doubtful, however, that any sizable placer mining operation could again be conducted profitably in this region.

Lode minerals at Caribou Mountain

General discussion

Unsafe or caved mine openings, overburden or talus, and lack of time prohibited a detailed investigation of the Caribou Mountain mineral deposits; however, gold, silver, copper, and iron in minor amounts from a commercial standpoint are known to occur in the district. Very small quantities, in most cases, probably noncommercial amounts, of the following metals are also known to be present:

Boron	Nickel	Chromium	Sodium
Cobalt	Strontium	Lead	Titanium
Gallium	Tin	Magnesium	Aluminum
Molybdenum	Vanadium	Manganese	
Silicon	Calcium	Potassium	

Shafts, adits, and prospect pits are scattered along the flanks of the mountain; many are in most unusual locations--for example, in talus slopes. These features evidence periodic visits of prospector and miner.

Figure 24. Quarry in gray to lavender rhyolite tuff. Northeast bank of Willow Creek west of Call Dugway.

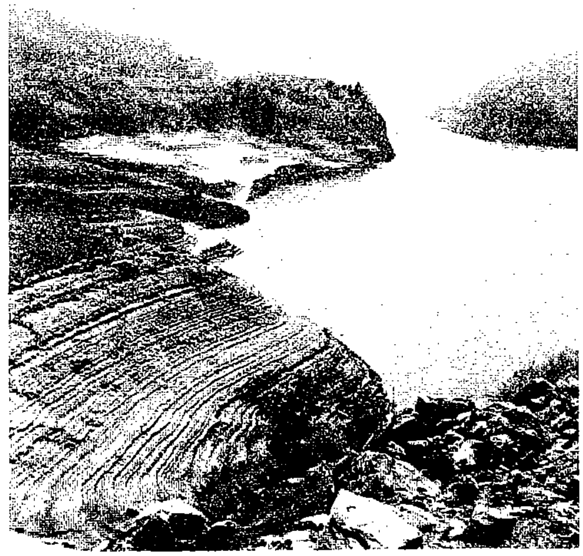


Figure 27. View showing greatly reduced water storage in Palisades Reservoir during the summer of 1960.

Figure 28. Small remnant of once larger deposits of placer gravel at Caribou City. This gravel may be of glacio-fluvial origin.

History of exploration and exploitation

Onderdonk (1884, p. 174) reported that lode gold was discovered by Daniel Griffiths and J. Thompson in 1874. They located the Oneida Mine, first quartz claim on Mt. Caribou. In 1877, John Robinson discovered a porphyry belt about one-half mile wide extending across the northern slope of the mountain; in places, the rocks yielded gold. The Robinson and Austin mines were developed here at the head of the well-known placers on Bilk and Iowa gulches.

In 1879, at the time of St. John's visit (p. 405), two men--Griffin (Griffiths(?)) and Noelans--were opening a lode gold prospect on a nearly vertical vein, reportedly in a mass of "rotten ferruginous quartz" that occurred in a "...tough trachytic mass". The mine was located about a mile southeast of the peak of Caribou Mountain; later it became known as the Griffin (Griffiths(?)) mine.

In earlier years, other lode mines and prospects were established on another porphyry belt located on the southern slope of Caribou Mountain: these mines included the Northern Light, Virginia, Orphan Boy, and Paymaster, among others. The lode ore was said to carry free gold varying from $10 to $1,200 per ton (Bancroft, 1890, p. 533). At this time, other well-known mines in the district were the Peterson, Nabob, Mountain Chief, Nealson, Oneida, South, Northern Light Extension, N. S. Davenport, and Silver Star. By 1881, three stamp mills were reported in operation (Clark, 1941, p. 132-133).

Bell (1903, p. 36-39) mentioned that the Robinson mine had been equipped with a 40 stamp mill that subsequently burned down. At this time the Robinson was said to be producing an average of $5 per ton in free gold. This vein was stated to be 20 feet wide with ore in contact veins. Bell also reported that the so-called Holden Group were located on a vein of ore, ranging from 8 to 19 feet wide, that carried high values of copper which assayed from 10 to 50 percent. This same vein supposedly carried gold and silver values of from $10 to $20 per ton of ore.

In 1908, Bell reported (p. 216-217) that Corona Consolidated Mines had taken over the Robinson Mine. In the same year, good copper values were reported from the Monte Cristo (now the Copper Queen(?) located on the west side of Caribou Mountain).

In 1923, Campbell (p. 58) stated that the Idaho Gold Mining Company's 10 stamp mill and amalgamation plant, located on the Robinson Group, were idle. Later reports stated, however, that the Robinson mine tunnel was driven to 1200 feet.

In 1944, Campbell (p. 233) noted that the "Mount Pisgah" (Mount Caribou) district was visited by a Charles H. Wetzel, "eminent mining engineer, graduate of Princeton, and first mayor of Butte." Campbell quoted Wetzel as having said:

> Anyone who will drive a tunnel through Pisgah at the lowest possible level, say around 6,000 feet, will develop the greatest copper deposit in the United States--far superior to Butte.

This is a pretty strong statement considering Butte is called "the richest hill on earth."

In the same report, Campbell recorded that one of the old mine dumps on Caribou Mountain (probably the Monte Cristo, now the Copper Queen(?)) was leveled and 12 carloads of copper ore were handpicked from the dump (1941).

St. John (1879, p. 405) called attention to reports of an iron deposit at Caribou Mountain; he said:

> ...a vein of magnetic iron ore has been discovered in the hornblendic trachyte mass which forms the bulk of the western side of the mountain. This vein...is said to be 20 feet wide and extends in a northwest and southeast direction...

In the summer of 1960, Hamilton (oral communication) spent some time searching unsuccessfully for this iron ore deposit. However, it may be well to record that several placer deposits in this area yield considerable secondary iron (mentioned earlier).

Total figures for lode ore production in the Caribou Mountain area are apparently unavailable, but it seems safe to state that the value of recovered placer gold must greatly exceed the total value of past exploited lode metals.

<u>Geology of the lode deposits</u>

Based upon limited field observations, gold, silver, and copper in the Caribou mineralized areas are epigenetic, showing characteristics of both hydrothermal and contact metasomatic processes. Far too few mineralized rock samples were available for study; however, mineralization seems to include ore types representative of small cavity fillings, implacements in shear zones, and some replacement ores. In one rather fresh-appearing prospect pit, orbicular structures were found that show alteration halos. These mineralized "knotty" and vuggy zones contain iron and copper sulphides, and calcite. Some may contain gold, but this was not verified. The iron present is specularite and limonite. In some places, copper "bloom" is very common on the surfaces of more massive rock float. The contained sulphides include pyrite, chalcopyrite and bornite.

Ross (1941, p. 26) commented on the nature of the Caribou Mountain lode deposits:

> The principal lodes are large tabular masses of quartz (whether veins or quartzite beds is not clear), which have been shattered and had calcite and auriferous pyrite deposited in them. In the material so far mined, the pyrite is oxidized and the gold is free.

Lakes (1898, p. 56) also described the lodes. He considered the possibility that the principal intrusion on Caribou Mountain may have been a laccolith, and that the event was accompanied by mineralization. Some of his "quartzite" beds were examined during this current investigation, and it seems that some of them are metamorphosed carbonate rocks rich in silica; possibly they are uplifted or upfaulted blocks of the Gannett Group--for example, remnants of either the Draney or Peterson "limestones" (described earlier) or both. Because these rocks are dolomitic and siliceous, baking by contact might produce a quartzite-like appearance. Some of the specimens collected along igneous-sedimentary rock contact zones effervesce slightly in dilute hydrochloric acid which indicates the presence of $CaCO_3$. Contact metasomatism is indicated by iron oxide pseudomorphs after garnet, plus the occurrence of some epidote.

In his discussion Lakes proposed a hydrothermal origin for the ore deposits; he said:

> ...the corroding and dissolving action of alkaline waters... honey-combed the quartzite mass with vugs and covites.... At some later period...they now deposited carbonate of lime.... Gold-bearing pyrite was also deposited with the calcite.

He also visualized late liberation of free gold in the oxidized gold-bearing pyritic zones as the result of ground water processes by which he accounted for the placer deposits in the vicinity.

Because the group of highly alkaline rocks in the Caribou Mountain area are a somewhat unusual group of intrusives, mineralizing processes would differ from those associated with silica-rich or iron-magnesium-rich intrusives. Mineralization, as far as is known, seems to be related to areas near andesitic and trachytic contacts with carbonate rocks, and to shear zones in these rock types. There may be other relations that were not observed.

Structural features already described, suggest that local igneous rocks were forcibly intruded into carbonate and silicate-rich sedimentary rocks of both Lower and Upper Cretaceous ages. During the intrusion of the igneous rocks as stocks, dikes, and sill-like masses, both contact metasomatic and hydrothermal mineral deposits were emplaced. The true volume and extent of this mineralization is yet unknown, but mineralization appears to be limited in volume. However, iron oxide and copper bloom are widespread. Possibly mining up to the present has been principally in the outer fringe of the affected area.

Unfortunately, as previously pointed out, too little information exists upon which to make sound judgments, chiefly because of the lack of good rock exposures and samples of ore. About the only possibility of improving this situation would be to conduct some program of systematic core drilling. Until more information becomes available, any discussion of ore genesis, or volume of potential gold, silver, or copper ore must be largely speculation.

Outlook

Much of the development work in the regional lode deposits appears to have been in oxidized epithermal deposits, as implied earlier. Several of the mineralized zones in the vicinity of the Robinson mine are associated with small gossan-like masses. For these reasons, it seems conceivable that deeper exploration might be successful, even though such exploration is often proposed as a panacea for "sick" mines. Wetzel's statement (cited earlier) that Caribou Mountain holds copper deposits richer than those at Butte, Montana, need not be taken too seriously in view of our present knowledge; however, there may be merit in the implication that deeper investigation might be rewarding. Quite possibly erosion has exposed only the upper portion of a well-mineralized area. Should this be true, any future serious lode development program should undoubtedly be preceded by properly supervised, core-drilling, exploratory work.

Furthermore, only the carbonate rocks and shear zones have been seriously considered as host rocks. The widely occurring conglomerates should also be carefully investigated for possible mineralization.

In order to learn more about what minerals might be present for potential development at Caribou Mountain, a few ore samples were selected for semiquantitative spectrographic analyses, and for assays. The results are summarized in the following tables (Table 11 and 12). The ranges of percentages under each heading should be carefully noted. Also it should be emphasized that the mere presence of an element in the "less than 0.01" percent column (spectrographic analyses) could mean very little. Generally, minerals containing the elements there listed are not present in commercial quantities.

Table 11 Semiquantitative spectrographic analyses of samples from Caribou Mountain area (in percentages)

(By R. E. Cassell, Washington Testing Laboratories, Inc., Spokane)

Sample S-149-150-60 — Robinson mine dump area

Less than 0.01	0.01 to 1	1 to 5	5 to 30
Boron	Copper	Aluminum	Calcium
Cobalt	Chromium	Potassium	Iron

Table 11 (Continued)

Gallium	Lead	Silicon
Molybdenum	Magnesium	
Nickel	Manganese	
Silver	Sodium	
Strontium	Titanium	
Tin		
Vanadium		

Sample S-245-60 Copper Queen mine dump area

Less than 0.01	0.01 to 1	1 to 5	5 to 30
Boron	Chromium	Aluminum	Calcium
Cobalt	Columbium	Silicon	Copper
Gallium	Lead		Iron
Molybdenum	Magnesium		
Nickel	Manganese		
Tin	Potassium		
Vanadium	Sodium		
	Titanium		

Table 12 Sample assays Caribou Mountain area
(By M. H. Alief, Idaho Bureau of Mines and Geology)

Sample location	Gold (Oz./ton)	Silver (Oz./ton)	Copper (Percent)
Copper Queen mine dump Sample No. 6	0.16	0.30	5.3
Robinson mine dump Sample No. 7	trace	trace	7.3
Robinson mine dump Sample No. 8	trace	trace	---

Radioactive materials

Carbonaceous rocks in the Phosphoria and the Wayan (Bear River Member) formations have accumulated some radioactivity because they have absorbed uranium compounds In the Phosphoria, the amount of radioactivity is generally unmeasurable with ordinary portable hand devices. However, some coal seams near the base of the Wayan may activate a portable scintillometer up to about 0.885 over background count.

In the Fall Creek area, Vine and Moore (1952, p. 6) conducted investigations in an old coal prospect. They collected 48 samples in what is now called the God Send to Health mine (mentioned earlier). Uranium enrichment was found to be greatest near the top of the coaly layers, diminishing downward. One sample with relatively high uranium content was found in a lense of dense, black, brittle coal in a gouge zone. This sample showed 0.053 percent uranium in the coal, and 0.31 percent uranium in the ash. Average uranium content proved to be about 0.045 percent in the upper 1-foot of coal, and 0.082 percent in the ash. This uranium-bearing coal bed seems to extend for at least 0.5 miles northwest of the old mine, perhaps farther. About 0.5 miles northwest of the adit, fragments of radioactive carbonaceous limestone were collected.

Vine (1959, p. 275-278) proposed that the radioactivity originated through weathering and leaching of slightly radioactive silicic volcanic rocks, or rhyolitic tuffs that occur in the area. Analysis showed that they contained 0.002 to 0.004 percent equivalent uranium, but less than 0.0012 percent uranium. These rocks were probably more widespread in distribution at one time.

As the silicic volcanic roads weathered, meteoric waters seem to have transferred uranyl ions to depths where they were absorbed by carbonaceous material and limy rock. No uranium minerals have been identified as such.

The structural setting of this area is one of closely spaced, parallel folds that are locally disrupted by faulting. A fault has elevated the lower Wayan or Bear River in the vicinity of the old coal mine.

Six exploratory core holes were drilled near the site, providing information upon which Vine (1959, p. 281-282) based his conclusions that "...there are about 6.5 million tons of rock containing 0.02 percent uranium underlying about 400 acres of the Fall Creek area (Fig. 26).

As the result of a small-scale uranium boom in the eastern part of Bonneville County several years ago, two mining corporations were formed. McDowell (1956, p. 90) mentioned these two groups: The E. A. Rex Mining Corporation holding 44 unpatented claims in Clark and Bonneville Counties reportedly in phosphate and uranium ground; and Fall Creek Uranium Corporation, Inc. with two claims near Swan Valley. Very little development work was done by either company, and the interest in uranium slowly subsided.

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APPENDIX I

BONNEVILLE COUNTY WATER WELL LOGS
(Compiled from Driller's logs)

No.	Location and Depth to Water Table	Thickness (feet)	Rock or materials
(1)	N 1/2 N 1/2 sec. 28, T 3 N, R 38 E	7	Overburden(?)
		8	Cemented gravel, boulders
		3	Gray lava
	Water table 120 feet deep	72	Brown lava
		17	Red lava
		33	Gray lava
		10	Sand
		5	Broken lava
		10	Solid rock, porous (?)
	Total	165	
(2)	S 1/2 NE 1/4 sec. 12 T 3 N, R 39 E	5	Clay
		10	Boulders
		6	Gravel
	Water table 15 feet deep	79	Gravel and clay
		4	Gravel
		5	Gravel and clay
		3	Yellow clay
		8	Gravel and clay
		10	Gravel, sand and clay
		1	Lava [boulder(?)]
		37	Gravel, sand and clay
		3	Clay
		1	Sandstone [float(?)]
		10	Clay
		28	Lava
	Total	210	
(3)	NE 1/4 SE 1/4 sec. 36, T. 2 N, R 37 E	37.5	Gravel
		12.0	Gravel(?)
		30.5	Lava
	Water table 150 feet deep	17.0	Sand
		48.0	Creviced and broken lava
		25.0	Broken lava
		13.0	Green lava
		18.0	Sand, cinders and clay
	Total	201.0	

*NOTE: Well numbers correspond to circled locations on Figure 3 - Geologic map of Bonneville County.

(4)	NW 1/4 NW 1/4 sec. 1, T 1 N, R 37 E	15	Gravel
		5	Boulders
		7	Gravel and boulders
	Water table 87 feet deep	43	Lava
		17	Red clay
		3	Loose lava and sand
		25	Lava
		10	Cinders and loose rock
		10	Lava(?)
		5	Cinders
	Total	140	
(5)	SE 1/4 sec. 3, T 2 N, R 38 E	7	Well pit
		20	Gravel
		58	Lava
	Water table 110 feet deep	10	Red lava
		13	Black lava and loose rock
		15	Gravel
		8	Lava
		29	Porous brown lava
		3	Large void
	Total	163	
(6)	NW 1/4 NW 1/4 sec. 32, T 2 N, R 38 E	6	Well pit
		59	Loose and cemented gravel
		15	Hard gray lava
	Water table 126 feet deep	13	Hard brown lava
		12	Hard green lava
		14	Loose brown lava
		6	Solid brown lava
		5	Gray lava
		2	Clay and sand(?)
		8	Gray lava
		6	Green lava
		17	Gray lava
	Total	163	
(7)	NE 1/4(?) SE 1/4, sec. 34, T 2 N, R 38 E	5	Soil
		41	Gravel and boulders
		14	Gray lava
	Water table 52 feet deep	48	Dark brown lava
	Total	108	
(8)	SE 1/4 SE 1/4, sec. 13, T 3 N, R 38 E	5	Well pit
		35	Cobble gravel
	Water table 98 feet deep	60	Gravel
		48	Gravel and sand
	Total	148	

(9)	NE 1/4 NE 1/4, sec. 16, T 3 N, R 39 E	7	Well pit
		9	Soil
		107	Cemented and loose gravel
	Water table 115 feet deep	4	Gravel and sand
		11	Fine gravel
		3	Shale and gravel
		2	Shale and sand
		2	Shale and clay
		2	Hard brown rock
		22	Shale and clay
		49	Gray lava, some porous
		10	Brown lava, some porous
	Total	228	

(10)	NW 1/4 SE 1/4, sec. 35, T 3 N, R 38 E	7	Pit
		13	Gravel and clay
		31	Gravel and cemented gravel
	Water table 110 feet deep	9	Black lava
		10	Gray lava
		20	Green lava
		16	Gray lava
		19	Gravel, sand and clay
		40	Gravel and sand
		18	Black lava and sand
		10	Broken lava with clay
		22	Lava
		5	Green lava
		7	Clay
	Total	227	

(11)	NE 1/4 NE 1/4 sec. 31, T 2 N, R 38 E	7	Pit
		50	Gravel
		41	Lava, mostly broken
	Water table 130 feet deep	19	Hard green lava
		7	Hard brown lava
		28	Hard green lava
		5	Sand and cinders
		6	Lava
		12	Sand and cinders
	Total	175	

(12)	Sec. 1, T 1 N, R 43 E	5	Overburden(?)
		10	Gravel and boulders
	Water table 5 feet deep	25	Porous lava
	Total	40	

(13)	SW 1/4 NE 1/4 sec. 12 T 1 N, R 43 E	5	Record missing
		25	
	Water table 7 feet deep	30	
	Total	60	
(14)	NE 1/4 sec. 39, T 2 N, R 38 E	55	Gravel
		25	Fine gravel and sand
	Water table 58 feet deep	3	Coarse gravel and/or lava
	Total	83	
(15	NE 1/4 SE 1/4 sec. 17, T 1 N, R 44 E	20	Cobble gravel
		32	Gravel
	Water table 20 feet deep		
	Total	52	
(16)	NW 1/4 sec. 1, T 3 N, R 39 E	80	Boulders and cobble gravel
		35	Gravel
		13	Fine sand
	Water table not recorded	32	Gravel
	Total	160	
(17)	NW Cor sec. 2, T 3 N, R 37 E	47	Soil
		33	Lava
		10	Red lava
	Water table 235 feet deep	10	Lava
		130	(Record missing)
		20	Gray lava
		6	Loose rock
		9	Red and gray cinders
		2	Lava(?)
	Total	267	
(18)	SE 1/4 SE 1/4 sec. 4, T 3 N, R 39 E	7	Well pit
		100	Cobble gravel
		38	Gravel and sand
	Water table 108 feet deep	11	Gravel
	Total	156	
(19)	N 1/2 SW 1/4 sec. 4, T 1 N, R 37 E	8	Pit
		17	Cemented gravel
		72	Gray lava
	Water table 100 feet deep	32	Brown lava
		1	Gray lava
	Total	130	

(20)	NE 1/4 SE 1/4 sec. 15, T 2 N, R 38 E	6	Pit
		52	Gravel
		17	Lava
	Water table 68 feet deep	36	Gravel and sand
		28	Broken lava
		2	Lava
	Total	141	
(21)	SE 1/4 SW 1/4 sec. 5, T 2 N, R 38 E	8	Pit
		7	Gravel
	Water table 169 feet deep	35	Gray lava
	Many openings	35	Brown lava
		14	Cinders and clay
		66	Brown lava
		15	Reddish brown lava
		5	Gray lava
		12	Green lava
	Total	197	
(22)	NW 1/4 SW 1/4 sec. 24, T 2 N, R 38 E	4	Pit
		6	Soil and broken lava
		15	Brown lava
	Water table 38 feet deep	45	Gray lava
	Large openings near base	1	Black cinders
	Total	71	
(23)	E 1/2 SE 1/4 sec. 16, T 1 N, R 38 E	7	Pit
		3	Clay
		7	Gravel and clay
	Water table 64 feet deep	45	Gravel and silt
		3	Gravel
		25	Fine gravel and sand
	Total	90	
(24)	SE 1/4 SE 1/4 sec. 10, T 2 N, R 38 E	7	Pit
		55	Gravel
		13	Gray lava
	Water table 116 feet deep	16	Clay
		4	Broken lava and clay
		20	Gray lava
		5	Brown lava
		5	Green lava(?)
		20	Gray lava
		10	Brown lava
		1	Cinders
	Total	156	

(25)	NE 1/4 SE 1/4 sec. 8, T 3 N, R 38 E	1	Top soil
		29	Black lava
		4	Red lava
	Water table 160 feet deep	26	Broken lava
		17	Black lava
		4	Hard brown lava
		8	Clay
		15	Red lava
		15	Hard brown lava
		11	Hard green lava
		10	Broken red lava
		33	Broken lava
		20	Red lava
		12	Broken lava
		2	Green lava(?)
	Total	207	
(26)	E 1/2 NW 1/4 sec. 6, T 2 N, R 39 E	6	Pit
		4	Clay
		5	Broken lava
	Water table 90 feet deep	38	Lava
		2	Cinders
		25	Broken lava
		17	Hard lava
		49	Broken lava
	Total	146	
(27)	sec. 30, T 3 N, R 39 E	4	Top soil
		23	Cemented gravel
	Water table 155 feet deep	12	Gravel and sand
		14	Cemented gravel
		10	Gravel
		44	Cemented gravel
		9	Gravel
		10	Cemented gravel
		6	Gravel and sand
		8	Cemented gravel
		8	Fine gravel
		12	Cemented gravel
		5	Gray lava
	Total	165	

(28)	NE 1/4 SE 1/4 sec. 8, T 2 N, R 38 E	2	Soil
		1	Gravel
		57	Lava
	Water table 155 feet deep	5	Clay
		75	Lava solid and broken
		5	Red lava
		10	Green lava
		15	Lava solid and porous
		5	Gray lava
		13	Green lava
		17	Lava some openings
		201	Green lava
		3	Void
	Total	409	
(29)	NW 1/4 SE 1/4 sec. 19, T 1 N, R 38 E	7	Pit
		31	Gravel
		27	Gravel and silt
	Water table 60 feet deep	47	Fine gravel and sand
		25	Gravel and sand
		4	Coarse gravel
	Total	141	
(30)	NW 1/4 sec. 6, T 1 N, R 38 E	7	Pit
		2	Sand and boulders
		30	Gravel
	Water table 131 feet deep	15	Lava
		10	Brown lava
		11	Lava
		17	Clay
		7	Lava
		45	Soft and broken lava
		5	Lava
		30	Lava and sand
		15	Lava
		8	Broken lava
	Total	202	
(31)	N 1/2 N 1/2 sec. 19, T 2 N, R 39 E	4	Top soil
		76	Cobble gravel
		11	Gravel
	Water table 86 feet deep	15	Lava
	Total	106	
(32)	N 1/2 NW 1/4 sec. 27, T 1 N, R 38 E	6	Pit
		64	Cobble gravel and sand
	Water table 65 feet deep	35	Gravel and sand
	Total	105	

(33)	NE 1/4 NW 1/4 sec. 11, T 3 N, R 39 E	8	Pit
		37	Gravel
		5	Boulders
	Water table 70 feet deep	13	Boulders and silt
		22	Cemented gravel
		46	
	Total	131	
(34)	SE 1/4 SE 1/4 sec. 17, T 3 N, R 38 E	10	Gravel
		12	Boulders and gravel
		13	Gray lava
	Water table 107 feet deep	20	Brown lava
		5	Blue lava
		36	Gray lava
		13	Red lava
		18	Gray lava
		3	Sand
		7	Gray lava and sand
		15	Lava
	Total	152	
(35)	E 1/2 SW 1/4 sec. 4, T 1 N, R 38 E	28	Gravel
		18	Brown clay
		59	Lava, some openings
	Water table 77 feet deep	5	Hard green lava
		10	Hard blue lava
		13	Lava
		8	Cinders
	Total	141	
(36)	NE 1/4 NW 1/4 sec. 30, T 1 N, R 38 W	5	Top soil
		13	Soil and gravel
		67	Gravel
	Water table 105 feet deep	5	Gravel and clay
		13	Gravel
		7	Fine sand
		7	Gravel and sand
	Total	117	
(37)	NE 1/4 NE 1/4 sec. 20, T 1 N, R 44 E	6	Top soil
		8	Coarse gravel
		36	Fine gravel
	Water table 15 feet deep	14	Coarse sand
		5	Gravel and sand
	Total	69	

(38)	NW 1/4 SE 1/4 sec. 18, T 2 N, R 37 E	4	Top soil
		41	Red lava
		20	Gray lava
	Water table 205 feet deep	2	Lava and clay
		3	Clay
		15	Lava
		5	Clay
		90	Lava, openings locally
		10	Soft red lava
		15	Gray lava
		15	Green lava
		15	Cinders
		25	Porous lava
		2	Lava
	Total	262	
(39)	S 1/2 NW 1/4 NW 1/4 sec. 4, T 3 N, R 37 E	3	Loose top soil
		46	Hard pan
		38	Hard gray lava, some broken
	Water table 265 feet deep	7	Cinders
		92	Hard gray lava
		29	Hard brown lava
		15	Gray lava
		85	Brown lava
		15	Clay and loose rock
		60	Brown lava
		3	Cinders
		42	Hard brown lava
		20	Green lava
	Total	455	
(40)	SE 1/4 SW 1/4 sec. 5, T 3 N, R 37 E	2	Top soil
		31	Brown hard pan
	Water table 309 feet deep	34	Gray lava
		6	Red cinders
		5	Gray lava
		16	Cinders, 2 thin layers lava
		10	Broken lava cinders
		50	Lava some crevices
		94	Br. and gray lava, alternating
		3	Cinders and clay
		65	Br. and gray lava, alternating
		16	Gray lava
		8	Brown clay and cinders
		50	Brown clay
		4	Broken gray lava
		43	Gray lava
		15	Porous red lava
		18	Brown and gray lava
	Total	470	

(41)	SE 1/4 NE 1/4 sec. 15, T 3 N, R 37 E	59	Clay and top soil
		25	Gray lava
		26	Reddish brown lava
	Water table 210 feet deep	50	Gray lava
		50	Black lava
		11	Clay
		19	Red lava
		9	Black lava
		3	Clay
	Total	252	
(42)	SE 1/4 SE 1/4 sec. 3, T 3 N, R 40 E	18	Clay
		27	Gray gip [rhyolite tuff(?)]
		5	Pink gip [rhyolite tuff(?)]
	Water table 107 feet deep	19	Brown clay
		27	Gravel
		6	Boulders
		48	Gravel and silt
		46	Broken lava and sand
		29	Lava
		19	Clay
		30	Lava
		6	Broken lava, silt and cinders
		40	Lava
		10	Clay
	Total	330	
(43)	SW 1/4 NE 1/4 sec. 4, T 3 N, R 40 E	23	Clay
		22	Broken chalk rock [rhyolite tuff(?)]
		25	Sandstone [rhyolite tuff(?)]
	Water table 105 feet deep	15	Gravel and clay
		8	Gumbo clay
		7	Gravel, clay and broken lava
		6	Red lava
		9	Brown lava
		22	Lava
		11	Cinders, some clay and silt
		27	Lava
		8	Clay
	Total	183	
(44)	SE 1/4 NW 1/4 sec. 5, T 3 N, R 40 E	3	Clay
		22	Gravel and silt
		22	Gravel
	Water table 40 feet deep	3	Chalk rock [rhyolite tuff]
		5	Sandstone [rhyolite tuff(?)]
		48	Lava and sand
		7	Cinders
	Total	110	

(45)	SW 1/4 SE 1/4 sec. 5, T 3 N, R 40 E	7	Top soil
		20	Chalk rock [rhyolite tuff(?)]
		22	Sandstone [rhyolite tuff(?)]
	Water table 47 feet deep	9	Clay
		30	Lava
		15	Clay
		17	Broken lava
		5	Broken lava and cinders
		13	Cinders
		15	Lava
		7	Cinders
	Total	160	
(46)	NE 1/4 SW 1/4 sec. 6, T 3 N, R 41 E	20	Top soil
		58	Gravel
		15	Gravel and boulders
	Water table 70 feet deep	47	Gravel and sand
		5	Clay
		8	Lava
		2	Cinders
		24	Lava
		11	Brown shale(?)
		5	Lava
		12	Cinders
		8	Conglomerate
		2	Lava
		1	Clay
		15	Cinders
	Total	233	
(47)	SE 1/4 NW 1/4 sec. 31, T 2 N, R 43 E	35	Loose boulders, rock and dirt
		3	Red clay
		51	Gravel
	Water table 49 feet deep	5	Yellow clay
		2	Boulder(?)
		69	Cemented gravel
		20	Brown sandstone [rhyolite tuff(?)]
		83	Granite(?)
	Total	268	

(48)	NE 1/4 SW 1/4 sec. 30, T 2 N, R 43 E	10	Clay
		10	Gravel and clay
		8	Gravel and sand
	Water table 12 feet deep	4	Coarse gravel
		3	Gravel and silt
		13	Gravel and clay
	Total	48	
(49)	S 1/2 SW 1/4 sec. 12, T 3 S, R 42 E	44	Loose rock and clay
		32	Hard blue basalt
		5	Loose rock
	Water table 4 feet deep	94	Blue basalt
		5	Basalt and cinder
		2	Blue basalt
		13	Red clay, some gravel
		5	Red clay
		15	Sand and sandstone
	Total	215	


IDAHO BUREAU OF MINES AND GEOLOGY
E.F. Cook, Director
Geologic Map
BONNEVILLE COUNTY
Compiled by C.N. Savage
1961
2 1 0 2 4 6 Miles
Sedimentary Rocks
Quaternary
Qas Alluvium and slopewash Clay, silt, sand and gravel
Qcl Cultivated area Loess, underlain by basalt
Qls Landslide debris
Qts Travertine and sinter
Tertiary
Tsl Salt Lake Group Alluvium and pyroclastics and intercalated flows and conglomerate
Cretaceous
Kw Wayan Formation (Includes Frontier, Aspen and Bear Valley Formations) Graywacke, sandstone, and shale
Kt Tygee Sandstone Brown to yellowish sandstone with shaly sandstone layers
Kg Gannett Group (East of Snake River, includes Draney, Bechler, Peterson, and Ephraim; Ephraim excluded west of the Snake River) Sandstone, limestone and conglomerate
Cretaceous-Jurassic
KJesp Ephraim Conglomerate, Stump & Preuss Sandstones (West of Snake River) Conglomerate, sandstone and calcareous, shaly sandstone
Jurassic
Jsp Stump and Preuss Sandstones Sandstone and calcareous sandstone
Jtc Twin Creek Limestone Limestone and shaly limestone
Jn Nugget Sandstone Pink to reddish gray sandstone and quartzite
Triassic
Ru "Ankareh" & Woodside Shale, Thaynes Limestone, & Dinwoody Formation (undifferentiated) Limestone and shale
Paleozoic
Palu Paleozoic undifferentiated
Permian
Pp Phosphoria Formation Phosphate rock, including shale, oolitic sandstone and siltstone
Pennsylvanian-Mississippian
Cu Pennsylvanian-Mississippian (undifferentiated)
Cw Wells Formation Quartzitic sandstone, sandstone, and limestone
Ordovician-Devonian
ODu Ordovician-Devonian (undifferentiated) Dolomite and limestone
Cambrian
Cbg Boysen and Gros Ventre Formations (Undifferentiated)
Igneous Rocks
Quaternary
Qrb Recent basalt and local pyroclastics
Qvrb Vesicular recent basalt
Quaternary-Tertiary
QTb Older basalt
Tertiary
(Relative age relationship difficult to determine)
Teu Extrusive rocks (undiff.)
Tiu Intrusive rocks (undiff.)
Tsv Silicic volcanics
Ta Andesitic rocks
Symbols
Contact, dashed where approximately located
Fault, dashed where approximately located
Probable fault
Normal fault, hachures on down side
High angle fault, up and down sides shown
Thrust or reverse fault barbs on side of upper plate
Anticline axis
Syncline axis
Overturned anticline
Line of geologic cross section
Strike and dip of beds
Horizontal beds
Vertical beds
Strike and dip of overturned beds
Mine or metal prospect
Tuff quarry
Sand and gravel pit
Pumice pit
Cinder pit
Coal prospect
Water well
Oil and gas dry hole
Rock quarry
Gold placer
JEFFERSON CO.
MADISON CO.
TETON CO.
BINGHAM CO.
CARIBOU CO.
IDAHO
WYOMING
IDAHO FALLS
Iona
Lincoln
Ammon
Ucon
Osgood
Ririe
Poplar
Heise
Irwin
Palisades
Swan Valley
Grays Lake
Snake River
Palisades Reservoir
Base map from USGS and AMS 1:250,000 map, Series 1958
Section A–A'