DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 680

A GEOLOGIC RECONNAISSANCE FOR PHOSPHATE AND COAL IN SOUTHEASTERN IDAHO AND WESTERN WYOMING

BY

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

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A GEOLOGIC RECONNAISSANCE FOR PHOSPHATE AND COAL IN SOUTHWESTERN IDAHO AND WESTERN WYOMING.

By Alfred Reginald Schultz.

INTRODUCTION.

PURPOSE OF INVESTIGATION.

A reconnaissance examination of a part of southeastern Idaho and western Wyoming lying between meridians 110° 45′ and 112° and parallels 43° and 44°, comprising an area of approximately 2,000 square miles in the vicinity of Big Bend of South Fork of Snake River, was undertaken in 1912, for the purpose of collecting data for the elimination of lands from existing phosphate reserves if it was found that they contained no valuable deposits of phosphate. The writer spent three weeks in the region north of Snake River and north of the area examined in a reconnaissance by Schultz and Richards[1] in the autumn of 1911. As a result of this examination 141,287 acres of withdrawn phosphate land was restored to agricultural entry. The data collected during the examination indicate that only a part of the phosphate land in this region was included in the phosphate reserves created by the withdrawals of December, 1908, December, 1909, and July 2, 1910. The former boundary of the phosphate reserve in this region has therefore been so modified and extended as to include all the known phosphate areas. This has necessitated the withdrawal of 84,507 acres, leaving a net reduction in the outstanding Idaho phosphate withdrawals of 56,780 acres as a result of this preliminary examination. The withdrawn lands have been included in the phosphate reserve because it is known that they are underlain by phosphate deposits. It was found to be impossible during this short reconnaissance examination to trace the outcrops of the phosphate beds throughout the area, measure the thickness of the phosphate beds at short intervals, determine the amount of phosphoric acid they contain, measure the thickness of the overlying beds, and work out the structure in sufficient detail to determine in what tracts the phosphate beds occur near enough

[1] Schultz, A. R., and Richards, R. W., A geologic reconnaissance in southeastern Idaho: U. S. Geol. Survey Bull. 530, pp. 267-284, 1913.

to the surface to justify the classification of the tracts as phosphate land. As more detailed examinations of these lands are made, part of the area now withdrawn will no doubt be classified as non-

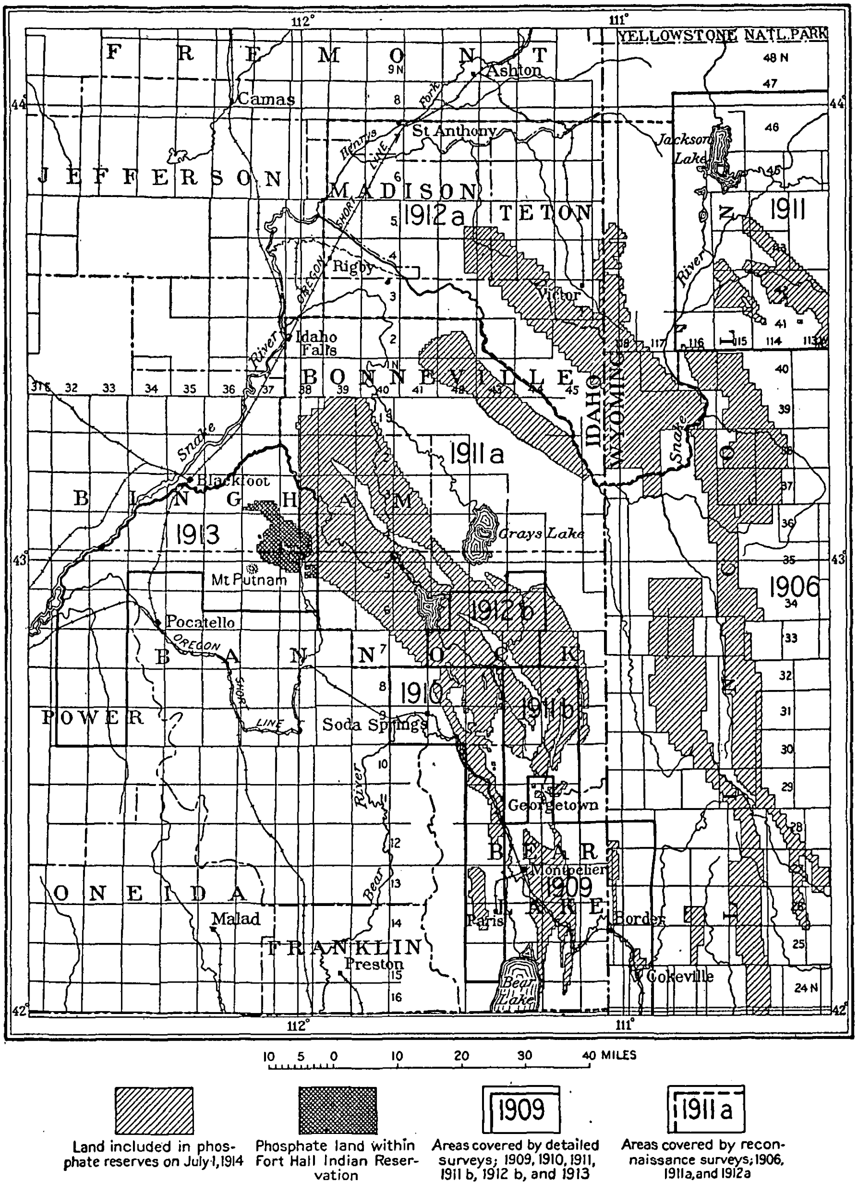


FIGURE 1.—Map showing areas examined by the United States Geological Survey and the extent of phosphate reserves in eastern Idaho and western Wyoming on July 1, 1914.

phosphate, and small outliers of phosphate rock may be found capping the ridges or included between fault blocks in areas not included in the outstanding phosphate reserves. Figure 1 shows the extent of the phosphate reserves on July 1, 1914, and the areas in the phosphate region in southeastern Idaho and western Wyoming examined by the Survey since 1909, when the first extensive mapping of the phosphate deposits in the Rocky Mountain region was undertaken.

EARLIER WORK.

The first geologic and topographic examination in the area considered in this report was made in 1872, when the Snake River division of the Hayden Survey traversed the country from Ogden, Utah, to Fort Hall, Idaho; thence went up Snake River and the valley of Henrys Fork to its head, where an examination of the lakes, geysers, and headwaters of the Fire Hole Basin and vicinity were made; thence crossed the divide to the headwaters of South Fork of Snake River and went down that stream by way of Jackson Lake and the canyon of the South Fork to its emergence on the great lava-covered plains a few miles north of Fort Hall, Idaho. The geologic report by Frank H. Bradley [1] and the accompanying maps set forth admirably the general features along the route of travel and give much information that is of value in interpreting the structure of the region.

The entire area covered in the present reconnaissance survey was mapped topographically by the Hayden Survey in 1877, and a considerable part of the area was examined geologically by Orestes St. John,[2] whose report includes a fund of accurate information and represents reconnaissance work of high standard. In accuracy and quantity the data given in the text are well in advance of the geologic maps which accompany them. To the errors in the maps and in the interpretation of the structure are due in part the mislocation of the phosphate reserves as originally constituted, and one of the main results of the present examination consists in corrections of the errors in these old maps and information on the localities not visited by St. John or members of his geologic party.

More recently part of the area was examined by members of the United States Geological Survey. In 1906 the writer [3] and party, while making a reconnaissance examination of the deposits of central Lincoln County, Wyo., examined a portion of the area east of the Absaroka fault and south of Snake River. In the summer of 1910 Eliot Blackwelder [4] and party traversed the region from Montpelier, Idaho, northeastward across the Preuss Mountains to Afton, Wyo., thence northward along the Salt River valley to Snake River, thence

[1] U. S. Geol. Survey Terr. Sixth Ann. Rept., pp. 189-271, 1873.

[2] U. S. Geol. and Geog. Survey Terr. Eleventh Ann. Rept., pp. 321-508, 1879.

[3] Schultz, A. R., Coal fields in a portion of central Uinta County, Wyo.: U. S. Geol. Survey Bull. 316, pp. 212-219, 1907; Geology and geography of a portion of Lincoln County, Wyo.: U. S. Geol. Survey Bull. 543, 1914.

[4] Blackwelder, Eliot, A reconnaissance of the phosphate deposits in western Wyoming: U. S. Geol. Survey Bull. 470, pp. 452-481, 1911.

down the Snake River valley to Irwin, Idaho, and across the Snake River Range to Victor, Idaho, in the Teton Basin. Only cursory observations were made along the route from Montpelier to Victor, but on the west side of the Teton Range the party spent several days in more systematic geologic work. A similar study was made of the mountains south and east of Jackson Hole, including the canyon of Snake River in Wyoming. In the summer of 1912 Blackwelder again visited the region and made an examination of the rocks along the west side of the Teton Mountains from the Yellowstone National Park southward as far as Darby Creek, in the Teton Basin, but the results of this investigation have not yet been published. In the fall of the same year E. G. Woodruff examined some of the coal beds in the vicinity of Horseshoe and Packsaddle creeks, on the northeast slope of the Bighole Mountains west of Driggs, Idaho.[1]

GEOGRAPHY.

ITINERARY.

In making the reconnaissance examination of the withdrawn phosphate lands in the Snake River, Bighole, and Teton mountains the party moved by rapid stages from the railway at Rexburg, Idaho, southeastward across the lava-covered plains to Snake River; thence southeastward to the mouth of the Snake River canyon near the State boundary, a few miles east of the Salt River valley. Along the route of travel only cursory observations were made, but on Snake River above the mouth of the canyon several days were spent in more systematic geologic work, in examining sections and making traverses, which proved beyond question that the phosphate beds are present in the hills on each side of Snake River and have been eroded in the valleys, for they occur at no place along Snake River from the lower end of the canyon eastward to the Absaroka fault. Similar studies were made of the mountains at a number of places across the range from Snake River northwestward to Moody Creek, southeast of Rexburg. Several days were spent in a study of the geology of the mountains along Indian, Elk, Palisade, Rainy, and Pine creeks. The party then moved across the Snake River Range over the divide at the head of Pine Creek into Teton Basin, where cursory examinations were made along the east flank of the Bighole Mountains southwest of Victor, Idaho, and along the west flank of the Teton Mountains east of Victor, in the vicinity of Moose, Fox, and Darby creeks. From Victor the party moved northwestward along the east base of the Bighole Mountains to Horseshoe Creek, where a somewhat more detailed study of the Bighole Mountains was made. Owing to the heavy fall of snow at this time, which

[1] Woodruff, E. G., The Horseshoe Creek district of the Teton Basin coal field, Fremont County, Idaho U. S. Geol. Survey Bull. 541, pp. 379-388, 1914.

completely masked the geologic formations exposed in the mountains, the work was discontinued, and the party returned to Rexburg over the lava-covered plains by way of Canyon Creek and the village of Teton.

TOPOGRAPHY AND SETTLEMENT.

The entire area examined lies within the Snake River drainage basin. The drainage has a dominant northwesterly trend and is carried by Snake River, which in the eastern part of the area flows in a southerly direction and south of Jackson Hole goes between the Snake River and Salt River ranges in a deep canyon at nearly right angles to the trend of the mountains and thence flows northwest. The principal tributaries are Gros Ventre, Hoback, Greys, and Salt rivers and Henrys Fork. Teton River is the largest tributary of Henrys Fork and drains all of Teton Basin.

Two types of country are included in the area examined—lava plains or plateaus and the rugged mountain tracts which are made up for the most part of deformed sandstone and limestone and metamorphosed schists, granites, and gneisses of pre-Cambrian age. With the exception of the northwestern part of the area, north and west of the Bighole Mountains, Teton Basin, and part of Snake River valley, the entire area is one of ragged, well-forested mountains. On the east side of the area the ranges trend nearly due north; in the central and western portions they run northwest. The mountain ranges are generally separated by narrow valleys, but some of the intervening spaces are wide, flat-bottomed basins, such as Teton Basin and Swan Valley Basin in Idaho, and Jackson Hole, on Snake River, and Star Valley, on Salt River, in western Wyoming. These larger valleys, as well as the lava-covered plains in the northwestern part of the area, are now fairly well settled by ranchmen and dry farmers, but in the mountain districts there are few inhabitants and no settlements of importance. A considerable part of the area is included in the Palisade, Teton, and Caribou national forests, and is primarily used for cattle and sheep grazing during the summer and as a source of timber. The mountainous portion, especially in the vicinity of Jackson Hole, is a celebrated game country that has become noted for its elk and is visited annually by hundreds of hunters in search of big game. Trails and wagon roads are common throughout the area, and good hunting ground is readily accessible from all the settlements or larger valleys. The United States Forest Service in recent years has built excellent roads and trails in that portion included within the national forests.

The only railroad in this region is the Oregon Short Line, which crosses the northwestern part of the area at Rexburg and St. Anthony and has a spur line from Ashton to Victor, in the Teton Basin. The same company in the fall of 1912 completed a second survey of a railroad route from Idaho Falls, Idaho, to Jackson, Wyo., along Snake River. The approximate location of this alinement survey is shown on Plate I by a black line. It was reported in 1912 that construction work on this line was to begin in the near future. Rexburg, St. Anthony, and Driggs, Idaho, and Jackson, Wyo., are the main trading points, although there are numerous small villages and trading posts scattered throughout the area. Post offices are maintained at many places in this area.

GEOLOGY.

STRATIGRAPHY.

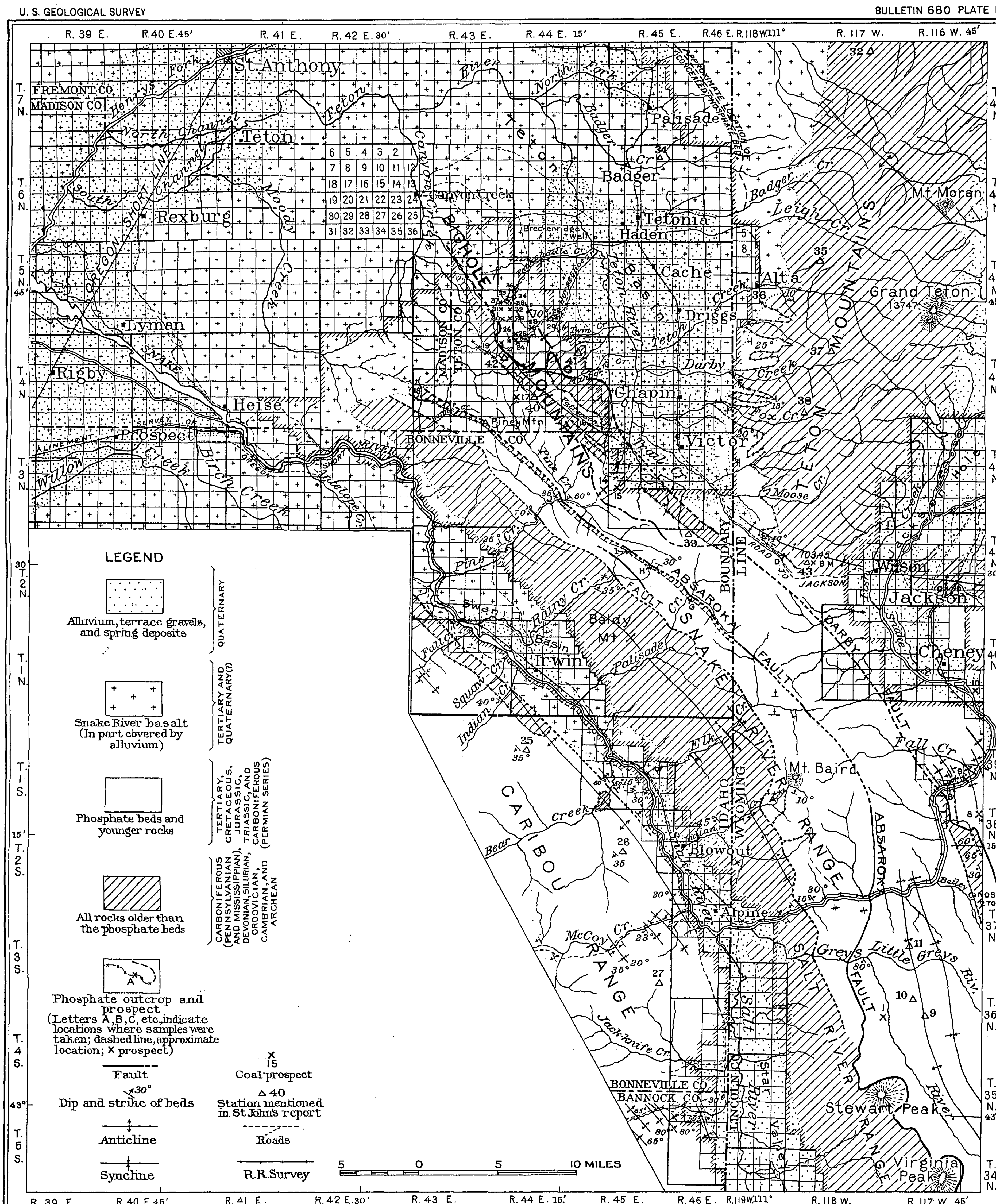
GENERAL SECTION.

The rocks of the region range in age from pre-Cambrian to Quaternary. The portion of the stratigraphic column from the pre-Cambrian basal complex to the Devonian appears to be only partly represented, as there are unconformities separating the Cambrian from the pre-Cambrian, the Ordovician from the Cambrian, the Silurian from the Ordovician, and the Devonian from the Silurian. The portion of the column above the Devonian appears to be more fully represented from the basal Carboniferous to the top of the Jurassic, where there is another pronounced unconformity. At or near the end of Cretaceous time there was an interval of erosion, which is indicated by a marked unconformity. Subsequent intervals of erosion resulted in unconformities in the Tertiary.

The main features of the section are set forth in the subjoined table.

Generalized section of sedimentary formations in southeastern Idaho and western Wyoming, in the area covered by this report.

System.	Series.	Group and formation.	Thickness.	Character of strata.	Remarks.
Quaternary.	Recent.		*Feet.* 0-250	Hill wash, talus, and landslide material.	Clay and soils derived largely from the weathering of underlying rocks. Good agricultural land.
			0-1,000	Valley fill, terraces, flood-plain deposits, small-stream bottom lands, and travertine.	
	Recent. / Pleistocene.		0-150	River terraces.	Gold placers worked along Snake River. Similar deposits of auriferous gravel occur both up and down Snake River beyond this area and on some of its tributaries.
	Pleistocene.		1-150	Boulders, gravel, and morainal material associated with hill wash.	No particular value.



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

MAP OF A PART OF SOUTHEASTERN IDAHO AND WESTERN WYOMING

SHOWING THE DISTRIBUTION OF PHOSPHATE AND COAL DEPOSITS

1918

Geology by Alfred R. Schultz
Surveyed in 1912

Generalized section of sedimentary formations in southeastern Idaho and western Wyoming, in the area covered by this report—Continued.

System.	Series.	Group and formation.	Thickness.	Character of strata.	Remarks.
Tertiary.	Pliocene (?)		*Feet.* (?)	Marls, marly limestones, and calcareous conglomerates.	No particular value.
		Unconformity			
	Eocene.	Wasatch group. Knight formation.	500±	Red and yellow sandy clays, shales sandstones, and concretionary limestones.	Occurs east of Snake River.
		Unconformity			
		Wasatch group. Almy formation.	1,000±	Red and yellowish-white conglomerates, sandstones, and sandy clays.	Occurs east of Snake River. Thickness not measured. Probable source of water supply.
Cretaceous or Tertiary.	(?)	Evanston formation (?).	(?)	In southwestern Wyoming, gray, yellow, and black carbonaceous shales and clays interbedded with sandstones containing some coal.	May be present along Snake River. Coal bearing in southwestern Wyoming.
		Unconformity			
Cretaceous.	Upper Cretaceous.	Adaville formation (?).	(?)	White, yellow, and brown carbonaceous shales and sandstones in southwestern Wyoming.	Not recognized in this field. May be present beneath lava cover. Coal bearing in southwestern Wyoming.
		Hilliard formation (?).	(?)	Gray and black sandy shales and sandstones in southwestern Wyoming. Weathers readily and affords a region of low relief.	Not recognized in this field. May be present beneath lava cover.
		Frontier formation.	3,000±	Gray, buff, and yellow shales and sandstones, with coal beds. The shales and sandstones are soft and sandy and do not form pronounced ridges. Rocks are of Benton age.	Coal-bearing throughout western Wyoming and in eastern Idaho.
		Aspen formation.	1,000–1,200	Gray and black shales, shaly sandstones, and beds of compact gray sandstone, containing fish scales of Benton age.	Oil bearing in southwestern Wyoming. Not measured north and west of Snake River.
		Bear River formation.	800±	Black shale, shaly sandstone, and shaly limestone with abundant invertebrate fossils.	Coal bearing in southwestern Wyoming and eastern Idaho. Coal beds are too thin and impure to be of value.
		Unconformity			

Generalized section of sedimentary formations in southeastern Idaho and western Wyoming, in the area covered by this report—Continued.

System.	Series.	Group and formation.	Thickness.	Character of strata.	Remarks.
Jurassic.		Beckwith formation.	*Feet.* 900-4,000	White, gray, yellow, brown, and reddish-yellow shales and sandstones, with some limestones, red or gray conglomerates, and quartzite, containing Jurassic fossils.	Present throughout western Wyoming and eastern Idaho. Not measured north of Snake River.
		Twin Creek limestone.	800-1,200	Chiefly black, gray, and bluish-gray shaly limestones, the whole containing numerous Jurassic fossils.	Present throughout western Wyoming and eastern Idaho. Entire section not measured north of Snake River.
		Nugget sandstone	500-1,000	Yellow, white, and red quarzitic sandstones.	Prominent ridge maker throughout region.
Triassic.	(?)	Ankareh shale.	200-500	Reddish-brown shale and shaly sandstone, with intercalated mottled limestone.	Has been prospected for copper in part of this region.
		Unconformity			
	Lower Triassic.	Thaynes limestone.	700-1,000	Yellow, gray, and blue cherty limestones, with some yellow sandstones. Bluish-gray limestones, very fossiliferous. Thin and thick bedded platy limestones.	Present throughout region.
		Woodside formation.	800-1,000	Red and pasty brown shaly sandstones and shales, intercalated with muddy limestone lentils.	Present throughout western Wyoming and eastern Idaho.
Carboniferous.	Permian.	Phosphoria formation.	75-400	Rex chert member and cherty limestones at top, over yellow to brown sandstones, brown to black shales, oolitic limestone, and phosphate rock.	Prospected for coal at many places in western Wyoming and eastern Idaho.
	Pennsylvanian	Wells formation.	300-1,000	Sandy limestones, calcareous sandstones, and variable quartzites. Includes the Weber quartzite and Tensleep sandstone as mapped in southern Idaho and western Wyoming.	This formation is present in western Wyoming and eastern Idaho, and has been mapped under various names whose limits are not the same. It probably includes both the Amsden and Morgan formations as mapped in some localities.

Generalized section of sedimentary formations in southeastern Idaho and western Wyoming, in the area covered by this report—Continued.

System.	Series.	Group and formation.	Thickness.	Character and strata.	Remarks.
Carboniferous.	Mississippian.	Brazer limestone.	*Feet.* 200-1,000	Gray to blue, thick-bedded limestones, some variegated reddish-gray shales, and calcareous sandstone.	Present throughout western Wyoming and eastern Idaho In some localities this series of beds has been mapped as parts of Amsden and Morgan formations.
		Madison limestone.	1,000	Dark gray to bluish limestones, thin-bedded in part but also massive.	Abundant marine fossils at many horizons.
Devonian.		Threeforks formation and Jefferson limestone.	350	Black, gray, and brown shales, dark limestones, and thin-bedded sandstones.	Upper 200 feet dark shale and thin-bedded limestone, probably represents the Threeforks formation. Lower 150 feet of massive crystalline limestone probably represents the Jefferson limestone.
		—Unconformity—			
Silurian.			50	Whitish-gray dolomite, thin bedded and brittle. Fragmentary fossils.	In places appears to be absent.
		—Unconformity—			
Ordovician.	Upper Ordovician.	Bighorn dolomite.	350	Gray to cream-colored dolomite with rough pitted surfaces.	Makes pronounced ridges and nearly perpendicular ledges.
		—Unconformity—			
Cambrian.	Upper Cambrian.	Gallatin limestone.	200	Gray oolitic and congomeratic limestones with some shale. Limestones not as massive as overlying bed. Contain few fossils.	
	Middle Cambrian.	Gros Ventre formation.	800	Gray, brown, red, and green shales and thin-bedded limestones.	Weather readily and usually form low relief.
		Flathead quartzite.	250	Buff or pinkish sandstone and quartzite with some conglomerate.	
		—Unconformity—			
Pre-Cambrian.				Schists, granites, gneisses, and igneous rocks cut by dikes of pegmatite and diabase. Some of the schistose and gneissic rock may have a sedimentary origin.	Prospected for copper, silver, lead, and gold.

PRE-CAMBRIAN TO CARBONIFEROUS (PENNSYLVANIAN SERIES, INCLUSIVE).

GENERAL FEATURES.

In the extreme northeastern part of the area shown on the accompanying map lie the Teton Mountains. This range trends nearly north along the Idaho-Wyoming State line, lying chiefly in western Wyoming. It consists of a gentle westward-dipping monocline, crossed in the north by a low anticline that trends northwest and in the south by a low anticline that trends nearly due west and in its westward extension swings toward the northwest, nearly parallel to the Bighole Mountains. The strata in several places are broken by normal faults parallel to the monocline. Along the crest of the Teton monocline and also along the axis of the northern transverse anticline the pre-Cambrian granite, gneiss, and schistose rocks are exposed. Against these older rocks on the southwest flank of the range rests a comprehensive sequence of Paleozoic strata, ranging in age from Cambrian to Carboniferous. The same rocks reappear on the northeast side of the transverse anticline. All the beds along this range, from pre-Cambrian to Carboniferous, were mapped and studied and detailed sections were measured by Eliot Blackwelder in 1912, while making a study of the Grand Teton quadrangle, but no report has yet been published.

In the course of this reconnaissance examination it has been found advisable for the small-scale map to group all the beds older than the Phosphoria formation, including the pre-Cambrian, Cambrian, Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian, into one map unit, and the Phosphoria formation and the pre-Quaternary beds younger than that formation, which range in age from Permian (late Carboniferous) to Tertiary, inclusive, into another map unit.

In the greater part of the region examined the area occupied by outcrops of the Permian, Triassic, and Jurassic formations practically represents the lands that were regarded in the field as containing phosphate deposits in large enough quantities and near enough to the surface to be eventually suitable for economic development. Some of the beds overlying the phosphate deposits tend to become thinner toward the north, in eastern Idaho and western Wyoming, and in this part of the region the area that contains phosphate deposits within workable depth susceptible of economic development is probably represented by the outcrop of the beds from the Phosphoria formation up to the Beckwith formation, including the Twin Creek limestone and a considerable portion of the Beckwith.

The general distribution of the rocks older than the Phosphoria formation is shown on the accompanying map by one pattern, without any attempt to indicate the distribution of the several formations, and the distribution of the Phosphoria formation and younger pre-Quaternary beds is shown by the absence of a geologic pattern. Detailed examinations are needed to work out the distribution and thickness of the Phosphoria formation, which contains the phosphate beds, and the Frontier and Bear River formations, which contain the coal beds. The Quaternary deposits, exclusive of the glacial material, which is not mapped, are shown by a different pattern on the map.

PRE-CAMBRIAN ROCKS.

The oldest rocks that underlie the Paleozoic sedimentary series in this region consist of pre-Cambrian crystalline gneisses, granite, and schists of various kinds. This basal complex is composed largely of igneous rock, although some of the schistose and gneissic rocks may have had a sedimentary origin. The gneisses are in part coarsely crystalline, and the entire series shows the effect of metamorphism by pressure and is in places intricately folded and traversed by dikes of pegmatite and diabase. The age of this complex has heretofore been regarded as Archean, but the reasons for this assignment are not entirely satisfactory. Rocks of Algonkian age are represented in many parts of the Rocky Mountain province and may in part be represented in the intensely mashed and metamorphosed components of this basal complex. For the present, therefore, or until much more detailed work has been done, it seems advisable not to separate the rocks composing this basal complex, but to refer the entire series as a unit to the pre-Cambrian. Exposures of these older rocks occur in the northeastern part of the area here described and form the central and eastern parts of the Teton Mountains. More detailed studies will no doubt determine the age of these rocks and definitely assign them either to the Algonkian or Archean or to both.

CAMBRIAN SYSTEM.

Upon the basement complex of the Teton and associated ranges was deposited unconformably in Paleozoic time a great thickness of sandstone, limestone, and shale. These strata include the Cambrian, the lowest known sedimentary beds exposed, Ordovician, Silurian, Devonian, and Carboniferous. The basal beds of the Paleozoic sedimentary series were formed from the detrital material derived from the disintegration of the schist and gneiss that formed the old continental land mass. Some of the members of these sediments consist of soft, poorly cemented, imperfectly stratified material, composed of coarse vein quartz, feldspar, fine conglomerate, and fragments of the underlying crystalline rocks.

FLATHEAD QUARTZITE.

In the Teton region and elsewhere in Wyoming the Flathead quartzite is the lowest of the Cambrian formations and consists essentially of pale-brown to reddish sandstone and quartzite. varying considerably in character both horizontally and vertically. In places the beds are streaked and spotted with a dark-maroon color, due to the presence of ferric oxide. In many places the beds are firmly cemented and constitute a typical quartzite, which forms pronounced ridges and gives rise to reddish-tinged outcrops that are very conspicuous and readily distinguished from the overlying beds. Near the top of the formation the sandstones become more or less argillaceous and are interbedded with gray or greenish shales that, as a rule, are less well exposed than the underlying massive sandstone or quartzite. The Flathead quartzite in this area is approximately 250 feet thick and is of Middle Cambrian age. Exposures of similar beds have been observed by the writer in western Wyoming, in the Teton, Gros Ventre, and Wind River mountains, in the Hailey anticline, in Sweetwater Valley, in the Green Mountains, and in the Rawlins dome, and in northern Utah on the north flank of the Uinta Mountains.

GROS VENTRE FORMATION.

Conformably overlying the Flathead quartzite and grading down into the green-brown shales at the top of that formation is the Gros Ventre formation. This formation is approximately 800 feet thick and comprises green and brown clay shales, gray calcareous shales, thin beds of gray limestone, and flat-pebble limestone conglomerate. Good exposures of these beds are rare, because the soft shale erodes readily and the beds are generally concealed by soil and vegetation. However, excellent exposures may be observed in some of the deeper valleys or steep slopes where erosion is actively going on at the present time. The name Gros Ventre formation as here used was first proposed by Blackwelder, in 1912, in connection with the preparation of a report, not yet published, on the stratigraphy of the Wind River Mountains, in Wyoming. The name was chosen by Blackwelder from exposures of the beds in the eastern part of the Gros Ventre Range, at the head of Gros Ventre River. The same formation was traced by him into the Teton Mountains, which lie in the eastern part of the area treated in this report. The formation as described by Blackwelder has been identified by the writer in the Teton, Gros Ventre, and Wind River mountains of Wyoming, and he has observed beds of similar lithology and stratigraphic position in the Green Mountains, in Sweetwater Valley, in the Hailey anticline southeast of Lander, Wyo., and in northern Utah, on the north flank of the Uinta Mountains. In all these localities the beds overlie a red quartzite formation. The Gros Ventre formation is believed to be of Middle Cambrian age.

GALLATIN LIMESTONE.

Conformably overlying the Gros Ventre formation is the Gallatin limestone, of Upper Cambrian age. This formation consists of limestone, shale, and sandstone, the limestone greatly predominating. The lower part of the formation is composed of finely crystalline limestone of dark yellowish-gray color, clouded with brown, so that it has on weathering a brownish-yellow appearance. Overlying this limestone are thin beds of gray calcareous sandstone, shale, and limestone which consist more and more of relatively thin-bedded limestone near the top of the formation. The uppermost beds contain little or no shale and are more or less siliceous. As a whole the formation, which is approximately 200 feet thick, is primarily one of limestone in which the rocks are more or less siliceous and contain thin beds or nodules of chert.

Outcrops of deposits of similar lithology and stratigraphic position have been observed by the writer at many places in Wyoming—in the Teton, Gros Ventre, Wind River, and Green mountains, in Sweetwater Valley, in the Hailey anticline southeast of Lander, and in Labarge Ridge, 40 miles northeast of Kemmerer—and also extend northward into Idaho and Montana and eastward into the Big Horn Mountains.

ORDOVICIAN SYSTEM.

BIGHORN DOLOMITE.

Unconformably overlying the Cambrian sediments is the Bighorn dolomite, of Ordovician age. Exposures of this formation are seen in the Teton Mountains and at several places in the Snake River Range and in the Bighole Mountains in eastern Idaho. The distribution of the formation was not determined, and only a preliminary examination was made. The formation consists chiefly of massive dolomite of a cream to light-buff color, somewhat darker when weathered, but on freshly broken surfaces appearing mottled with dark-gray cloudy patterns. In places the beds contain a little chert in irregular horizontal lenses and masses. This siliceous material on weathering forms on the surface a ragged network, which is characteristic of the formation. In part this deeply pitted surface may be due to the difference in porosity of the rock and the manner in which some of the particles are cemented. In this area the formation is approximately 350 feet thick, but apparently it thins toward the southeast.

Exposures of the Bighorn dolomite have been observed by the writer in the Snake River and Bighole mountains in Idaho and in the Teton, Salt River, Gros Ventre, Wind River, and Green mountains and in the Hailey dome southeast of Lander, in Wyoming.

SILURIAN SYSTEM.

Unconformably overlying the Bighorn dolomite along the west flank of the Teton Mountains is a thin-bedded dense, brittle white slabby dolomite which is both distinctive and persistent. The individual beds range in thickness from 1 to 12 inches and show remarkable wavy stratification lines. On weathering some of this dolomite becomes as smooth as porcelain and shows on the surface numerous shallow depressions in rectangular pattern. Eliot Blackwelder, who has recently studied the Paleozoic formations along the west flank of the Teton Mountains and determined their areal distribution, informs the writer that on Leigh Creek, on the west slope of the Teton Range, where he studied detailed sections of these beds, they aggregate about 50 feet in thickness, and are limited both above and below by unconformities. He has observed similar conditions at several places in the Wind River Mountains.

DEVONIAN SYSTEM.

THREEFORKS FORMATION AND JEFFERSON LIMESTONE.

Above the thin-bedded white dolomite of Silurian age and below the massive cliff-making ledges of the early Carboniferous (Mississippian) Madison limestone occurs a much less resistant group of black, green-gray, and brown shales interbedded with dark fetid sandstones and limestones, which in the Teton Mountains are approximately 350 feet thick. No measurement of their thickness was made in the Bighole Mountains, but it is believed that in this general region they range in thickness from 350 to 400 feet. The lower 100 to 150 feet of beds are barren of fossils and consist of relatively massive crystalline limestone, darker than the overlying rocks. The upper part of the series contains more shale and thin-bedded limestone, which as a rule are much lighter in color and in which fossils are frequently found, but the fossils are not conclusive enough to determine whether the beds belong to the Upper, Middle or Lower Devonian. The lithologic character of these beds, however, and their position in the stratigraphic section indicate that they closely resemble the Jefferson and Threeforks formations of the Yellowstone National Park.[1] Although the beds in this area have not been separated into two formations, it is highly probable that the lower dark crystalline limestone or shale that gives the strong fetid odor represents the Jefferson limestone and the overlying 200 feet of strata represents the Threeforks formation of the Park region.

Exposures of similar rocks were observed by the writer in 1906, while making a study of the coal beds in the vicinity of Labarge

[1] U. S. Geol. Survey Geol. Atlas, Yellowstone National Park folio (No. 30), 1896; Geology of the Yellowstone National Park: U. S. Geol. Survey Mon. 32, pt. 2, 1899.

Ridge, in T. 26 N., R. 113 W. sixth principal meridian, Wyo., about 40 miles northeast of Kemmerer. In 1907 E. M. Kindle measured a section across the beds near the south end of Labarge Ridge and found that the Devonian in this locality is at least 1,080 feet thick. Regarding these beds, Kindle makes the following statement:[1]

> In this section the gray and black limestone is preceded by beds holding a Cambrian fauna and followed by a limestone holding the usual Madison limestone fauna. The 80-foot shale formation at the top of the magnesian limestone appears to occupy the position of the Threeforks shale, but it is barren of fossils. Composition, texture, manner of weathering, and relationship to the other parts of the section all indicate the magnesian limestone to be the same as the Jefferson limestone of the Montana sections.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

MADISON LIMESTONE (LOWER MISSISSIPPIAN).

The basal Carboniferous rocks are dark bluish-gray, relatively thin-bedded cliff-making limestones, in places consisting of massive gray-blue limestones with numerous beds of dolomite and a few thin beds of shale. The entire series is approximately 1,000 feet thick. The fauna collected from these marine beds at many horizons include many cup corals, *Syringopora, Loxonema, Productella, Spirifer centronatus, Chonetes, Euomphalus,* etc., and according to G. H. Girty corresponds to the fauna of the basal portion of the "Wasatch limestone," of the Wasatch Mountains of Utah, as described by earlier writers.

BRAZER LIMESTONE (UPPER MISSISSIPPIAN).

Above the Madison limestone, apparently in conformable succession, occurs a series of massive light to dark gray limestones, weathering white to light gray, which represent the Brazer limestone of northern Utah and southeastern Idaho. The total series of beds at the south end of the area examined in this reconnaissance survey are approximately 1,000 feet thick, but in the northeastern part, in the Teton Mountains, they are only about 200 feet thick. Locally there is near the top a zone of dark shale about 15 feet thick. In places also the beds contain chert nodules in concentric and irregular forms and streaks of chert. The limestones are here and there specked with siderite and seamed with calcite or aragonite and at some horizons are abundantly fossiliferous. The fauna includes large cup corals with many fine septa, *Syringopora, Lithostrotion, Martinia,* and *Productus giganteus*.

[1] U. S. Geol. Survey Bull. 543, p. 37, 1914.

PENNSYLVANIAN SERIES.

WELLS FORMATION.

The Brazer limestone is succeeded by a series of sandy limestones, calcareous sandstones, and quartzites of somewhat variable character, which represent the Wells formation of southeastern Idaho. At the type locality in Wells Canyon, in T. 10 S., R. 45 E., the formation consists of three portions having a total thickness of about 2,400 feet. Toward the north the thickness greatly decreases and a change in the lithology can be observed. The total series of beds at the south end of the area examined in the reconnaissance survey is approximately 1,000 feet thick; at the north end of the area they are only about 300 feet thick.

In the type locality[1] the upper and lower portions of the Wells formation are predominantly calcareous. The middle is mainly sandy. The upper limestone, 75 feet thick, consists of dense gray siliceous limestone or calcareous sandstone which weathers into white massive beds that are topographically conspicuous as cliff makers. Bluish-white chert occurs in bands 2 inches to 1 foot thick and locally in ovoid nodules. Toward the base the chert becomes more nodular and darker. Silicified fragments of brachiopods project in little crescents from the weathered surface of the limestone. The most abundant fossils are *Squamularia* and a large *Productus*. The middle portion comprises 1,700 to 1,800 feet of calcareous sandstone and quartzite, with a few thin beds of limestone, weathering white, red, or yellow and forming smooth slopes with few projecting ledges. No fossils have been found in this member. The lower portion is from 100 to 800 feet thick. The rocks are cherty limestones and interbedded sandstones and form prominent cliffs. They weather gray or reddish. The base of the formation is marked by a *Schizophoria* zone, containing also *Marginifera, Composita, Spirifer rockymontanus*, Bryozoa, etc.

LATE CARBONIFEROUS (PERMIAN SERIES) TO RECENT.

FORMATIONS INCLUDED.

For convenience in mapping and because of lack of information in many parts of the area all the beds overlying the Wells formation and underlying the Quaternary deposits in this area have been grouped together. These rocks, which correspond to the Laramie and in part to the Jura-Trias of the Hayden Survey reports on this area, comprise the Phosphoria formation (Permian), the Woodside formation, Thaynes limestone, and Ankareh shale (all Triassic), the Nugget sandstone, Twin Creek limestone, and Beckwith formation

[1] Richards, R. W., and Mansfield, G. R., The Bannock overthrust: Jour. Geology, vol. 20, pp. 681-709, 1912.

(all Jurassic), the Bear River and Aspen formations and the overlying coal-bearing sandstones and shales of the Frontier formation (all Upper Cretaceous), and the unconformably overlying undifferentiated Tertiary deposits. As most of these formations occur at a considerable distance stratigraphically above the phosphate horizon very little study was made of their distribution.

CARBONIFEROUS SYSTEM.

PERMIAN SERIES.

PHOSPHORIA FORMATION.

The Phosphoria formation, of Permian age, overlies the Wells formation conformably, so far as observed in the course of this and earlier examinations. Its stratigraphic relation to the overlying and underlying formations in the Snake River Range is shown in the traverse sections along Pine, Rainy, and Indian creeks (figs. 2, 3, and 5). The Phosphoria formation carries the economically valuable deposits of phosphate of this and the surrounding region, and in this area the entire formation ranges in thickness from 75 to 400 feet.

In the Preuss Range of Idaho, southwest of the area covered by this reconnaissance, the formation has been examined in detail and found to consist of two parts. The upper part is mainly chert and cherty limestone, and has been called the Rex chert member. This member ranges from a maximum thickness of about 450 feet to a feather-edge but usually is from 50 to 200 feet thick. The basal portion of the formation consists of 75 to 630 feet of alternating brownish shales, brownish sandstone, compact fetid limestones, usually lenticular, with one, two, or three zones bearing high-grade oolitic phosphate rock which contains 70 per cent or more of tricalcium phosphate and occurs in beds from 1 to 7 feet thick.

Within the area examined the natural exposures are for the most part not good enough to afford detailed sections. In all the districts where the outcrop is indicated on the map the formation was noted as composed of ledge-making cherts at the top (Rex chert member) and softer rocks—shales and sandstones, with phosphate rock—at the base. The upper portion locally, as on Pritchard Creek south of Snake River, near the north end of the Caribou Mountains, includes a thin bed of high-grade rock phosphate. At a few localities, as on Snake River and at the south end of the Blackfoot Range, a thin bed of phosphate was found overlying the Rex chert, but in no place is this bed known to be of commercial value. It is thought that careful measurements may show that the upper chert portion of the formation (Rex chert member) occupies a relatively greater part of the entire section in this area than it does farther south, but that the entire series thins toward the north. The areal distribution of this formation, so far as known, is practically represented by the line indicating phosphate outcrop on Plate I. Most of the area shown on the map without a geologic pattern is underlain by phosphate deposits, but more detailed work is required before the depth and attitude of the beds in that area can be determined.

TRIASSIC SYSTEM.

Triassic rocks, including the Woodside, Thaynes, and Ankareh formations, occur throughout western Wyoming and eastern Idaho. Exposures of these rocks have been examined in western Wyoming along the Meridian and Absaroka ranges, on Thompson Plateau, and in the Sublette, Salt River, and Wyoming mountains. In eastern Idaho they have been studied in the Bear River, Preuss, Blackfoot, Caribou, Snake River, and Bighole mountains. In all of this area these beds were for the most part mapped by the Hayden Survey as Jura-Trias but also in part as Carboniferous.

WOODSIDE FORMATION.

The Woodside formation conformably overlies the Permian Phosphoria formation and is composed mainly of russet-brown to olive-green calcareous shales, intercalated with muddy limestone lentils in which fossil shells are so closely matted that their specific characters are often barely discernible. The formation in this area is from 800 to 1,000 feet thick. Toward the top the limestones become a prominent feature of the formation, and throughout much of eastern Idaho the distinction between these and the overlying Thaynes limestone depends mainly upon the recognition of a cephalopod zone containing *Meekoceras* at the base of the Thaynes.

THAYNES LIMESTONE.

The Thaynes limestone, which apparently lies conformably upon the Woodside formation, includes both thick-bedded and thin-bedded, platy limestone and has a total thickness of 700 to 1,000 feet. The rock has a bluish-gray color on fresh fracture but weathers to light brown or buff and generally to an uneven sandy surface. The geologists of the Hayden Survey noted the *Meekoceras* zone at several places in the southeastern part of Idaho, in the Preuss and Blackfoot mountains, and mapped it in the Salt River Range and in the Wyoming Range as far north as Virginia Peak. This zone was not observed north of Snake River, but very probably detailed work will prove that it occurs in the Snake River and Bighole mountains.

ANKAREH SHALE.

A red series ranging in thickness from 200 to 500 feet and composed of red shale and intercalated mottled sandstone unconformably overlies the Thaynes limestone and is known as the Ankareh shale. This formation and the two immediately underlying formations were originally described by Boutwell from observations in the Park City mining district, Utah. The similarity of the beds in the Idaho-Wyoming section to those around Park City has led to the use of the same formation names in this region. Red shales which are representative of the Ankareh shale were noted in the canyons of Pritchard and Fall creeks in the Caribou Mountains, in the Salt River and Wyoming ranges south of Snake River, and along the east side of the Snake River Range, the west side of the Bighole Mountains, and the southwest side of the Teton Mountains north of Snake River.

JURASSIC SYSTEM.

NUGGET SANDSTONE.

The Nugget sandstone overlies the Ankareh shale conformably and consists of massive red sandstone with white conglomeratic sandstone in places at the base and top of the formation. Locally the sandstone is silicified to a quartzite. Owing to its massive and resistant character the Nugget sandstone forms high ridges with broad rounded slopes. The formation thins toward the north, and in the north end of the Caribou Range south of Snake River is approximately 1,000 feet thick. The thickness of the Nugget sandstone was not measured north of Snake River in either the Bighole or the Snake River mountains, but the formation was recognized throughout the area examined in 1911 and 1912 along Fall Creek and Pritchard Creek, in the Caribou Range, and at several places in the Snake River, Bighole, Teton, Wyoming, and Salt River ranges. The formation thins toward the north, and its thickness is believed to range from 1,000 feet near the south end of the area to approximately 500 feet at the north end.

No fossils were found in the formation in this area, but Jurassic fossils were obtained by Gale from corresponding beds in northwestern Colorado, and the formation is therefore now classified as Jurassic.

TWIN CREEK LIMESTONE.

The Twin Creek limestone overlies the Nugget sandstone, and, so far as observed in the course of this examination, is conformable to it. The beds consist principally of grayish-white shaly limestones and are readily recognized wherever they are exposed. The Twin Creek becomes thinner toward the north and is approximately 1,200 feet thick on Fall Creek, in the northern part of the Caribou Range, and

800 feet at the north end of the area examined. The beds in this formation are exposed in this area on Bailey Creek and Little Greys River in Wyoming and in the Snake River and Bighole mountains in Idaho. On Rainy Creek in the Snake River Range, 450 feet of beds were measured below the Beckwith-Twin Creek contact without seeing the base of the formation. In some areas in Idaho and Wyoming these beds were for the most part mapped by the geologists of the Hayden Survey as a portion of their Laramie. They have been traced by the writer from the southwest corner of Wyoming northward to Snake River and have been examined at many places in eastern Idaho south of Snake River, but were noted north of Snake River in this examination only on Rainy Creek and at several places between the Darby and Absaroka faults, and on the northeast flank of the Bighole mountains in the vicinity of Horseshoe Creek. Their occurrence at these localities clearly indicates that the Twin Creek limestone is exposed at a number of places in the Snake River and Bighole mountains. The fauna includes *Pentacrinus asteriscus, Camptonectes pertenuistriatus, Trigonia americana, Astarte meeki, Thracia weedi, Gryphaea calceola, Ostrea, Pholadomya*, and *Pleuromya.*

BECKWITH FORMATION.

The Beckwith formation overlies the Twin Creek limestone and is extensively exposed in the northeastern part of the Bighole Mountains and in the area east of the main crest of the Snake River Range, or between the Darby and Absaroka faults. The exposures of these beds and their relations to one another are indicated in the sections along Pine and Rainy creeks (figs. 2 and 3, pp. 42, 43). Beds of Beckwith age have been examined and mapped by the writer in the Salt River, Snake River, and Wyoming mountains in western Wyoming and in the Snake River, Preuss, Caribou, and Blackfoot mountains in eastern Idaho. In all these localities the beds were mapped by the geologists of the Hayden Survey as part of their Laramie formation. The Beckwith formation consists of reddish or chocolate-colored sandstone and shale, associated with whitish to grayish limestone and red conglomerates, and in this general region ranges in thickness from 900 to 4,000 feet. The upper member consists of calcareous sandstone, red conglomerate, and massive gray limestone. In 1906 the writer collected fossils from these beds on Hoback River, on Meridian Ridge, and at numerous other localities in the Hoback Range in western Wyoming.[1]

[1] Schultz, A. R., Geology and geography of a portion of Lincoln County, Wyo.: U. S. Geol. Survey Bull. 543, pp. 53-54, 1914. Mansfield, G. R., and Roundy, P. V., Revision of the Beckwith and Bear River formations of southeastern Idaho: U. S. Geol. Survey Prof. Paper 98, pp. 75-84, 1916.

CRETACEOUS SYSTEM.

UPPER CRETACEOUS SERIES.

BEAR RIVER FORMATION.

Overlying the Beckwith formation occurs a series of beds whose thickness in this area was not determined but is believed to be approximately 800 feet. They consist of gray limestones, calcareous sandstones, dark-colored shales, thin and impure coal beds, brownish and gray sandstone, and light calcareous deposits. The beds are very widely distributed south of Snake River, north of the old Lander trail, and east of Willow Creek, lying for the most part on the west flank of the Caribou Range or between that range and Willow Creek. Beds of the same type and of the same age occur in Wyoming between the Salt River and Wyoming mountains, forming part of the crest of the Greys Ridge anticline. Good exposures were observed along Snake River east of the Salt River and Snake River ranges and also east of the Wyoming Mountains near the mouth of Hoback River. Similar beds were noted at many places along the strike of the beds north of Snake River, in the area between the Darby and Absaroka faults. The formation is coal bearing in many places, but the coal beds are too thin and impure to be of commercial value, although they may serve locally as a source of coal for domestic use.

The beds of the Bear River formation throughout most of the field have the same dip and strike as the underlying formations and may therefore readily pass as a conformable series. It is known, however, by the absence of the Lower Cretaceous, that an unconformity of considerable magnitude exists between the Bear River formation and the underlying Beckwith formation.

The fauna collected from the Bear River formation in the vicinity of Snake River includes *Pyrgulifera humerosa*, *Campeloma macrospira*, *Corbula pyriformis*, *Corbicula durkeei*, *Unio*, *Viviparus*, and *Goniobasis*. In the fall of 1912 E. G. Woodruff collected a small lot of Cretaceous fossils on Pine Creek in sec. 19, T. 3 N., R. 45 E., in the Bighole Mountains, about 5 miles southwest of Victor, Idaho. Among these T. W. Stanton identified *Corbula pyriformis*, *Corbicula durkeei*, *Pyrgulifera humerosa*, and *Pachymelania* sp. In 1911 the writer made a hurried examination of similar beds in the Fall Creek basin, along the west flank of the Caribou Mountains, Idaho, at a locality 2 miles northeast of Herman post office, northeast of Grays Lake. About a quarter of a mile east of the east quarter corner of sec. 25, T. 3 S., R. 43 E., a few fragmentary fossils were collected from beds lithologically resembling the Bear River formation of western Wyoming. A similar fossil bed was seen where Fall Creek enters the canyon. It is more than likely that St. John and Peale, of the Hayden Survey, mapped these beds, together with a part of the Beckwith and Twin Creek formations, as Laramie on the basis of similar fresh-water fossils. T. W. Stanton, who examined the fossils collected in T. 3 S., R. 43 E., reports on them as follows:

I have examined the small lot of fresh-water fossils which you recently handed me from a locality northeast of Grays Lake, on the west slope of the Caribou Range, about 2 miles east of Herman, Idaho. It has not been found practicable to develop the fossils by etching or otherwise, and the preservation of the specimens on weathered surfaces is not satisfactory. Fragments of *Unio* and casts of *Viviparus* or *Campeloma* are recognized, and *Goniobasis* and possibly other genera of fresh-water gastropods may be represented. In my opinion this fauna is Cretaceous, but on account of the absence of definitely characteristic forms I am unable to determine whether it belongs to the Bear River formation. Similar imperfect fossils have been collected in Montana in rocks that are provisionally referred to the Kootenai formation. Additional good collections and accurate stratigraphic data concerning the rocks that were mapped as Laramie by St. John in this general region are greatly desired.

ASPEN FORMATION.

The Aspen formation is composed of black shale, dark-drab to gray sandy shale, and gray sandstone. In places the sandy shale weathers into small splintery fragments and the harder sandstone layers produce long rounded hills of peculiar gray color. Outcrops of these beds were observed along the Wyoming Range in the area between the Absaroka and Darby faults and on the northeast flank of the Bighole Mountains in the vicinity of Horseshoe and Packsaddle creeks. No carefully measured section of these beds was made in any of these localities, but the total thickness approximates 1,000 feet. Beds in this formation yield oil in southwestern Wyoming, and throughout the area examined in a previous survey contain abundant fish scales, but only a few good collections of fossils were obtained from the beds.

FRONTIER FORMATION.

Conformably overlying the Aspen formation occurs a series of sandstone, clay, shale, and shaly sandstone beds with which are associated beds of carbonaceous shale and of coal, the entire series approximately 3,000 feet thick, which constitute the Frontier formation. The sandstone is grayish white and yellow and occurs both in thick massive beds and in thin shaly beds. The coal beds are not continuously exposed for any great distance, nor are the associated strata sufficiently characteristic to render correlation certain, but it is known that this formation is coal bearing throughout the region extending from southern Wyoming northward to the north end of the Bighole Mountains, southeast of St. Anthony, Idaho. Coal beds and other strata belonging to the Frontier formation were observed in the Wyoming Range at the mouth of Hoback River south of Jackson, Wyo.; in the Greys River area, in western Wyoming south of Snake River; in the Snake River and Bighole mountains north of

Snake River; in the area between the Absaroka and Darby faults; and on the northeast side of the Bighole Mountains in the vicinity of Horseshoe and Packsaddle creeks, where the beds are exposed on both sides of the overturned fold or faulted anticline. The fauna of the Frontier formation consists of *Ostrea glabra, Cardium, Mactra, Anomia, Inoceramus, Goniobasis, Turritella, Barbatia, Corbula, Gyrodes, Pholadomya, Avicula, Ostrea,* and *Glauconia.*

On Packsaddle Creek in the SW. ¼ sec. 24, T. 5 N., R. 43 E., occurs an outcrop of soft gray sandstone which dips 50° S. 55° W. and which has been quarried for the purpose of building a dam at the reservoir in secs. 18 and 19, T. 5 N., R. 44 E. In this sandstone the writer found fragments and several complete casts of *Inoceramus labiatus, Inoceramus erectus,* and other associated fossils of the Frontier formation which indicate that these beds and their associated coals are of Colorado age.

Woodruff in the fall of 1912, while examining the coals in this vicinity, collected a small lot of Cretaceous fossils in the NW. ¼ sec. 6, T. 4 N., R. 44 E., and at the Brown Bear mine, in the SE. ¼ sec. 25, T. 5 N., R. 43 E., of which T. W. Stanton identified the following:

NW. ¼ sec. 6, T. 4 N., R. 44 E.:
- Modiola sp.
- Cardium sp.
- Corbicula? sp.
- Corbula undifera Meek.
- Neratina.

SE. ¼ sec. 25, T. 5 N., R. 43 E.:
- Cardium sp.
- Lucina? sp.
- Corbula sp.
- Undetermined material.
- Shells.

These fossils suggest the Mesaverde formation of the Rock Springs field, but they are not distinctive enough to warrant positive identification of the horizon. There are some similar forms also in the Adaville formation in western Wyoming.

HILLIARD AND ADAVILLE FORMATIONS (?).

The beds immediately overlying the Frontier formation in southwestern Wyoming constitute the Hilliard formation, which consists of dark-colored sandy shale, clay, and shaly sandstone, chiefly of Colorado age but in part of Montana age. The entire series is soft and weathers readily, forming marked depressions in which comparatively few exposures are seen. In southwestern Wyoming the Hilliard formation is overlain by the coal-bearing Adaville formation, also of Montana age. Beds belonging to the Hilliard and Adaville formations were not observed in this area in the course of the reconnaissance examination. This portion of the Upper Cretaceous series may, however, be present in some parts of the Snake River or Bighole mountains, but the examinations thus far made indicate that all the Cretaceous beds exposed at the surface are older than the

Adaville and Hilliard formations. Until the area is studied in detail it will not be possible to state definitely whether or not beds belonging to these formations occur in surface exposures in the Snake River and Bighole mountains or whether they are present in any part of the field beneath the lava-covered plains of the Teton Basin.

CRETACEOUS OR TERTIARY SYSTEM.

EVANSTON FORMATION (?).

The deposition of the Adaville formation in southwestern Wyoming was succeeded by a long period of folding, faulting, and erosion, after which was laid down a series of gray, yellow, and black carbonaceous shales, clay, and white and yellow sandstone, which make up the Evanston formation. It is not positively known whether or not this formation,[1] which carries coal in the Hoback River basin and in the vicinity of Evanston, Wyo., is present in the area covered by this report. Beds resembling the Evanston formation, however, occur on the east side of Snake River south of Jackson, Wyo., where coal-bearing beds lie apparently conformably below the Almy formation.

TERTIARY SYSTEM.

EOCENE SERIES (WASATCH GROUP).

ALMY FORMATION.

The Almy formation, which may be equivalent to the Pinyon conglomerate of the Yellowstone Park region, is well exposed between Snake and Hoback rivers in Tps. 39 and 40 N., R. 116 W., Wyoming, where, in beautiful weathered exposures, conglomerate representing this formation may be traced from Hoback River northwestward to Snake River. The beds here strike N. 32° W. and dip about 25° NE. At no other place in the area examined were these deposits observed. The conglomerate is overlain by later Tertiary deposits.

KNIGHT FORMATION.

Beds belonging to the Knight formation were identified southeast of Cheney post office, on the east side of Snake River, overlying the Almy formation. They consist of red and yellow sandy clays, shales, sandstones, and concretionary limestones and extend eastward south of the Gros Ventre Mountains, connecting with the beds observed north and east of the Hoback River basin.

[1] Veatch, A. C., U. S. Geol. Survey Prof. Paper 56, pp. 76-87, 1907. Schultz, A. R., U. S. Geol. Survey Bull. 543, pp. 68-71, 1914.

PLIOCENE (?) SERIES.

At Snake River in T. 1 S., R. 45 E., about 3 miles southeast of the mouth of Bear Creek, is a small area of calcareous conglomerates and inferior lithographic limestone which were provisionally mapped as Carboniferous by St. John, but which appear in the light of recent detailed study in Idaho farther to the south to be Tertiary lake beds, probably of Pliocene age. This correlation is made purely on lithologic and structural grounds. Similar conglomerates were observed along the west flank of the Snake River Range at several places along Snake River between Alpine and Irwin, and on Indian and Elk creeks.

QUATERNARY SYSTEM.

GLACIAL DEPOSITS.

Glacial deposits consisting of old eroded drift were observed on the slopes of the Teton, Bighole, and Snake River mountains, and fresh moraines were seen in some of the mountain valleys. In some of the smaller valleys near the summits of the higher peaks remnants of the receding mountain glaciers were seen, which earlier in the summer had extended much farther down the valley. In one place north of the canyon of the Snake one of these small valley glaciers had extended during the previous year nearly to the mouth of the valley, where it joins Snake River, and the moraine left by the melting ice could be distinctly seen through the entire distance, approximately half a mile.

SPRING DEPOSITS.

In certain parts of the area described in this report, notably along Snake River and Fall Creek, occur deposits of travertine and numerous hot springs, many of which are depositing tufa at the present time. These hot springs may represent the southwestern extension of conditions similar to those that gave rise to the numerous renowned hot springs in the region of the Yellowstone National Park. F. H. Bradley,[1] of the Hayden Survey, visited some of these springs in 1872 and gave an excellent account of the springs and their deposits. Regarding the hot springs of Snake River, which occur along the Darby fault in T. 39 N., R. 116 W., Wyoming, he makes the following statement:

> A small cluster of these [Warm Springs] escape among the gravel on the edge of the river in the south side, emitting an abundance of sulphureted hydrogen. Though somewhat mixed with the river water, they gave a temperature of 117°. About a hundred yards below this a group of calcareous springs has built up a dam of tuff so as to flood several acres about the vents, which are now inaccessible. The general flow from the pool gave a temperature of 94°.

[1] U. S. Geol. Survey Terr. Sixth Ann. Rept., p. 269, 1873.

The writer visited this locality in 1906 and found the condition of the springs much the same as in 1872, at the time of Bradley's visit. He observed, however, other hot springs not described by Bradley. Some of these lie on the gravel bench on the south side of Snake River. Over one of the larger of these springs a bathhouse has been erected. A number of other springs occur in this locality on the gravel terrace near Counts's ranch.

On the lower part of Snake River both spring deposits and hot springs were observed at several places from Alpine to Heise, Idaho. All the springs at Alpine, Blowout, and Heise, on Fall Creek, and in the lower Conant Valley, Idaho, occur along the fault line between the Caribou Range and the Snake River valley. It is very probable that similar deposits will be found at other localities in the mountains along this fault line as soon as a more detailed examination of this region is made. At Heise, on Snake River, in the SE. ¼ sec. 25, T. 4 N., R. 40 E., is the most northwestern hot spring observed in the course of the reconnaissance examination along this fault line. This spring is mentioned by Bradley,[1] who says:

> Some 3 or 4 miles below the mouth of this last canyon [lower Snake River canyon] a small hot spring, 4 or 5 feet across, stands on the north bank of the river about 20 feet above the bottom. This was not visited by any of our party but was reported by our guide to be too hot for one to hold his hand in it for more than half a minute. White-spring deposits were seen from a distance at several points on the north bank, but there is believed to be no flow at these points at the present time.

About 18 miles southeast of this locality, at the lower end of Conant Valley, in T. 2 N., R. 43 E., occurs another hot-spring deposit on the south side of Snake River. Of these deposits Bradley says:

> At the base of the mountain on the southwest side of the valley, just above the head of this lower canyon [lower Snake River canyon], calcareous deposits from now extinct springs form a heavy mass reaching about 100 feet up the mountain side.

In sec. 29, T. 1 N., R. 43 E., on Fall Creek, immediately west of the fault along the east side of the Caribou Range, where the crest of the anticline in the Paleozoic beds crosses the creek, occur numerous warm springs. Some of these are on the south side of the creek and several in the bottom of the stream. The largest one, which supplies a stream that fills an 8-inch pipe, comes in on the north side of the creek right at the water's edge. The water from most of these springs is luke warm and carries hydrogen sulphide. Considerable sulphur is deposited around the springs and in the stream. The stones and ground are coated with greenish-yellow algae. Travertine and other spring deposits are built up around the springs, the rims and domes of which are several feet in height.

[1] Bradley, F. H., op. cit., p. 271.

The largest spring deposits and the hottest water observed along the fault between the Snake River valley and the Caribou Mountains occurs on Snake River southwest of Blowout, in secs. 13 and 24, T. 2 S., R. 45 E., and in the southwest quarter of T. 2 S., R. 46 E. One of these springs on the east bank of Snake River is now utilized for a bathhouse. Regarding this group of springs Bradley,[1] who visited them in 1872, makes the following excellent statement:

> Here also is located a cluster of warm springs, making calcareous, sulphurous, and saline deposits. The largest spring, the Washtub, has built up a flaring table, 1 foot high, of an oval form, measuring about 4½ by 7½ feet, upon a mound consisting of calcareous mud, scarcely solidified, of from 5 to 7 feet above the creek bottom in which it stands. The central table has contracted so as to crack across diagonally, and the flow now escapes at its western base, depositing a fine mud tinged in the full pools with a faint sulphur-yellow, but pure white in the dry ones. These pools cover the mound in descending steps of great beauty. The present flow is southward, though it has been on all sides in succession. The deposit on the surface of the mound is still very soft and showed at the time of our visit (Oct. 6) the tracks of a small bear, who had recently investigated the wonders of the mound, even setting his foot on the central table. One mound, no longer active, is 5 feet high, with a circular base of about 5 feet diameter and an oval summit of about 1 foot by 6 inches. Many small springs escape along the bank for a hundred yards or more. The deposits vary greatly in color. At some points the odors of sulphurous acid and of sulphureted hydrogen were quite noticeable. The older deposits have built up a bank 10 feet high along the base of the terrace, and the beavers have taken possession and have dammed up on it the waters of the cold springs which flow from the second terrace at short intervals along this plain. On the opposite shore two considerable springs have built up their deposits against the foot of the mountain, one of which appears to be nearly dead. The highest temperature observed here was 144°. The Washtub gave 142°, and others 142°, 140°, 90°, 88°, etc

Similar springs occur on the bottom lands along the west side of Snake River and drain into the sloughs and low depressions on the gravel terrace bench.

ALLUVIUM AND TERRACE GRAVELS.

Along all the large streams in this region occur considerable deposits of washed soil and gravels of Quaternary age. Some of the gravels along Snake River and its tributaries are washed for gold. For the most part the alluvial bottoms are small and are confined to narrow strips along the streams or are cut out entirely where the stream has intrenched itself in the lava bed. The largest of the alluvial bottoms occur along the Salt River valley and around Jackson, Wyo., along Snake River above the canyon, and in places along Snake River below the canyon. In addition to the alluvial bottoms along the larger streams, gravel, sand, and silt deposits form large alluvial fans in the Teton Basin and Snake River valley and occupy narrow strips in the bottoms of the mountain valleys.

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[1] Bradley, F. H., op. cit., p. 269.

IGNEOUS ROCKS.

SNAKE RIVER BASALT.

Nearly all the northwestern part of the area is covered by igneous rocks, which consist largely of a series of lava flows whose relation to one another has not been accurately determined. There appear, however, to be two fairly distinct types of rock, which belong to the series of successive lava flows grouped by Russell under the term Snake River lava. The older lavas are rhyolites that cover extensive areas; the later basalt is less widespread in its distribution and is the most recent extrusive flow that occurs along the lower depressions. The greater part of the igneous rock is dense and in cliffs shows the development of irregular columnar jointing, but minor scoriaceous and cellular facies are found, especially near the margins of the flows. The surface of the basalt has a comparatively fresh and recent appearance, and the soil cover is thin except where it has been augmented by alluvial agencies. The number of flows has not yet been worked out in detail. It is evident that there are several, because of the intercalation of scoriaceous and tuffaceous lentils. The exact geologic range of the flows has not been determined, but it appears that some at least belong to the Tertiary and are of Pliocene age, while others, from their relation to the deformed beds of probable Pliocene age, are Quaternary.

The older lavas consist primarily of a massive flow which is uniform in composition but varies considerably in physical appearance. These rocks range from a few feet to a thousand feet or more in thickness and extend well up on the flanks of the Caribou, Snake River, Teton, and Bighole mountains. At the north end of each of these ranges the lava lies at elevations as high as the main part of the range, and within a short distance it completely conceals the northward extension of the Paleozoic rocks of which the range is composed. In the Teton Basin and along Snake River southwest of the Snake River Range large bodies of more recent Snake River basalt overlie the older flows. The basalt sheets are from a few feet to 200 feet thick and consist of dark-gray to bluish-black more or less vesicular rock containing some crystals of feldspars and ferromagnesian minerals.

The Tertiary beds on the west flank of the Caribou Range are overlain by igneous rocks or basalts similar to those which occur in the canyons farther to the north and west. The greater portion of the igneous rocks represents part of the extensive lava flows of the Snake River Plains, which have been referred in southern Idaho mainly to the Tertiary by Russell and in the Yellowstone National Park region to the Neocene by Hague and Iddings. There are, however, within this general area a number of subordinate cones, many of which are broken and shattered and undoubtedly served as the outlets for the later lavas that surround them. Some of these are of Pleistocene or Recent age, if the Tertiary beds are correctly determined as Pliocene.

STRUCTURE.

GENERAL FEATURES.

The geologic structure of the area examined is rather complex, and no attempt was made to decipher it in detail. The mapping of the phosphate beds on some of the streams in the area, however, permitted the structure of some of the larger units to be worked out with considerable accuracy. The main mountain ranges are more or less parallel and extend in a northwesterly direction across the area examined. The one farthest to the southwest south of Snake River is the Caribou Range. Northeast of the Caribou Range lie the Snake River and Salt River ranges, the former north and the latter south of Snake River and east of Salt River. Immediately to the northeast of these are the Bighole and Wyoming ranges, which in places lie so near to the Snake River Range as to be taken as a part of it. Northeast of these parallel mountain ranges, in the northeastern part of the area, lies a high range known as the Teton Mountains, which in western Wyoming extends in a northerly direction from Snake River to the Yellowstone National Park.

CARIBOU RANGE.

The Caribou Range, which forms the southern boundary of the area examined, has a very complex structure and consists of an anticlinorium, as indicated by the sections traversed by the writer[1] in the autumn of 1911, along Fall and Tincup creeks. A large thrust fault extends along the east flank of the Caribou Range and probably represents the northward continuation of the fault that lies for the most part in Snake and Salt River valleys, west of the Salt River Range. It is along this fault that the numerous hot springs referred to are located. Minor faulting was observed at several places in the Caribou Range, but no attempt was made to study the relation of these faults to one another.

SNAKE RIVER AND SALT RIVER RANGES.

The Snake River and Salt River ranges consist of a series of rugged peaks and hills that have a general northwesterly course, extending from western Wyoming to the great lava plains southeast of St. Anthony, Idaho. The ranges were formerly continuous but have been separated by Snake River, which has forced a narrow passage through them. The Snake River Range lies north of the canyon and the Salt River Range south of it. The ranges lie immediately east of

[1] Schultz, A. R., and Richards, R. W., U. S. Geol. Survey Bull. 530, figs. 33 and 34, 1913.

the broad valleys of Snake and Salt rivers, which separate them from the Caribou Mountains. The Snake River and Salt River ranges have a very complex structure and consist of parallel anticlines and synclines, which are in places overturned and closely folded and with which is associated considerable faulting. A large thrust fault extends along the east flank of the ranges and represents the northward continuation of the Absaroka fault.[1] This fault, in which the thrust has come from the west, approximately separates the Snake River and Salt River ranges from the Bighole and Wyoming ranges. As a result of this thrust rocks of Carboniferous age are brought in places into juxtaposition with rocks of Cretaceous (Colorado) age. A short distance west of and more or less parallel to the Absaroka fault is another fault, which marks approximately the western limit of the phosphate-bearing beds in the Snake River Range. All the phosphate exposures observed in this part of the range lie between these two faults. Minor faulting was observed at several places, but no attempt was made to work out the structure of the ranges completely or to study the relation of the faults to one another. The major faults above mentioned were observed along all the streams flowing west into Snake River along which traverses were made, and are therefore indicated on the map as continuous faults.

BIGHOLE MOUNTAINS AND WYOMING RANGE.

The Bighole Mountains and Wyoming Range lie immediately north and east of the Snake River and Salt River ranges, from which they are separated by the Absaroka fault and a low depression along the Greys River valley and the headwaters of Elk, Palisade, Pine, Moody, and Canyon creeks. These ranges also were once continuous and have been cut nearly at right angles by Snake River. The part of the old range north of Snake River is known as the Bighole Mountains, and the part south of the river as the Wyoming Range. The geology of the range is complex and as yet little known. The rocks are highly folded and are broken by large faults, the exact positions of which have for the most part not been determined. The large thrust fault that extends along the east side of these ranges was mapped by the writer in 1906 as far north as Snake River and represents the northwestern extension of the Darby fault.[2] Its position in the Bighole Mountains was determined only at two localities south of Victor, Idaho, in the vicinity of station 39 of the Hayden survey,[3] and west of Driggs, Idaho, in the vicinity of station 42. The stratigraphic relation of the beds along the fault in these two localities, the general trend of the mountain range, and the numerous large springs that lie

[1] U. S. Geol. Survey Prof. Paper 56, p. 109, 1907; U. S. Geol. Survey Bull. 543, p. 87, 1914.

[2] U. S. Geol. Survey Bull. 543, p. 84, 1914.

[3] Station numbers correspond to those used in St. John's report and are shown on the map (Pl. I).

along the fault line on the east flank of the mountains between stations 39 and 42 indicate that the fault here observed is probably the northward extension of the Darby fault, which lies along the east flank of the Wyoming Range. The stratigraphic relations of the beds along the east and west sides of the Darby fault are similar to those along the Absaroka fault; in places Carboniferous or older rocks on the west are brought into juxtaposition with Cretaceous (Colorado) rocks on the east.

TETON MOUNTAINS.

The Teton Mountains form one of the most imposing ranges in the Rocky Mountain region. They appear to be a large fault block upon which the little-disturbed Paleozoic rocks dip gently toward the west. The main part of the range rises with a singularly abrupt slope from the west side of Jackson Hole, which marks the approximate location of the fault along the east side of the range. It culminates in the rugged Grand Teton, the third highest peak in Wyoming, reaching an altitude of 13,747 feet. The main part of the range extends about due north and consists of a gentle westward-dipping monocline crossed at the north by a low anticline which trends northwest. Near the south end of the range the beds are somewhat folded and the main ridge is crossed by a low anticline, whose axis trends northwest, lies immediately north of station 43 of the Hayden Survey, and in its northwestward extension nearly parallels the Bighole Mountains. The low pass south of station 43 separates the Teton Mountains from the Bighole and Wyoming ranges and affords the only wagon road at the south end of the range from Teton Basin, Idaho, into Jackson Hole, Wyo. The rocks along the east slope of the range consist largely of granite, gneisses, and schists. On the west slope of the range the Paleozoic beds overlie the pre-Cambrian rocks and slope off more gently to the broad Teton Basin, which lies between the Teton and Bighole mountains. The broad open plain of the Teton Basin is floored with nearly horizontal Tertiary or later sediments. The outcrops of the Mesozoic rocks are buried by extensive lava flows, which are in turn partly concealed by the alluvium in the bottoms of the basins and by widespread moraines on the plateau farther north.

MINERAL DEPOSITS.

PHOSPHATE.

GENERAL FEATURES.

Rock-phosphate deposits of the same type as those in eastern Idaho in the vicinity of Montpelier, south of Snake River, were found by the writer in September, 1912, while engaged in a geologic reconnaissance examination north of Snake River in the vicinity of the Snake River and Bighole mountains. It is believed that commercial deposits of phosphate have not heretofore been generally known in this part of Idaho, and no sign was observed that these beds had ever been prospected for phosphate, although in a few places they have been prospected for coal.

The rock was found as float along the outcrop of the phosphate bed and in place along the central part of the Snake River Range, and was recognized by its physical characteristics. The more massive part of the bed, which is usually found as float, somewhat resembles a dark coarse granular limestone that may be mistaken on casual examination for a dark fine-grained basalt. It has an oolitic structure, is dark gray to black, is noticeably heavy in comparison with the sedimentary rocks with which it occurs, and on many of the weathered surfaces has a bluish-white coating. The oolitic structure, though constituting one of its most definite features, is in places somewhat obscure; in other places it is entirely missing and the bed may be composed entirely of shale-sandstone, or nonoolitic limestone, rich in phosphoric acid. By reason of the weaker constitution of the shaly rocks they commonly give way to weathering and decay at the surface, and the phosphate outcrop thereby becomes concealed wholly or in part, while the harder fragments of phosphate rock remain in the soil and are readily detected by one who is familiar with the appearance of the rock. In part of the area rock-phosphate float is but moderately abundant in the vicinity of the outcrops of the phosphate bed, but in other localities the surface is covered with numerous phosphate fragments.

The work done farther southeast in Idaho, where detailed examinations of the phosphate deposits have been made, and where sections of the phosphate shales, especially those immediately associated with the main phosphate bed have been measured and studied in detail, affords a good idea of the range of phosphate content which may be expected within the area covered by this report. Two of these sections, in Georgetown Canyon, T. 11 S., R. 44 E., and in T. 8 S., R. 44 E., Idaho, have been published.[1]

A detailed section of the lower part of the Phosphoria formation was measured and sampled in 1909, exceptionally favorable conditions of exposure being found in the Georgetown district, in T. 11 S., R. 44 E. The section of the phosphate-bearing strata in Georgetown Canyon shows the largest amount of high-grade phosphate rock and probably the highest average phosphoric-acid content of all the sections that have been examined in detail in the western phosphate fields. It represents presumably the upper limit of

[1] U. S. Geol. Survey Bull. 530, pp. 278, 280, 1913.

conditions which may be found on prospecting within the area of this reconnaissance. The other section of the lower portion of the Phosphoria formation was measured and sampled about 26 miles north of Georgetown Canyon, in the SW. ¼ SW. ¼ sec. 7, T. 8 S., R. 44 E. It shows the smallest amount of high-grade phosphate rock and also the lowest average content of phosphoric acid yet found in the sections measured in detail in the Idaho portion of the phosphate reserve, and will serve to illustrate the leanest conditions to be expected within the area of this reconnaissance.

DISTRIBUTION OF PHOSPHATE DEPOSITS BY STRUCTURAL DISTRICTS.

GENERAL CONDITIONS.

The distribution of the phosphate-bearing Phosphoria formation in the area examined can be inferred in part by examination of the accompanying map (Pl. I), on which the outcrops of the phosphate beds seen in the field are shown by lines with small crosses, and the inferred outcrops by light dash lines. The inferred positions in some parts of the field where the structure is complex and no examination of the phosphate beds was made are not indicated, although it is reasonably certain that the phosphate beds occur within well-defined limits, as along the east side of the Salt River and Snake River ranges, in the area between the Absaroka fault and the parallel fault to the west. The distribution of the Phosphoria formation also indicates in a general way the structure of the area. The phosphate beds in this area are very similar to those described by Gale, Richards, and Mansfield in their reports on the areas to the south. Only a few prospects have been opened on the phosphate beds in the area examined, and all of these were opened in search of coal. No attempt was made in the reconnaissance examination to prospect the phosphate outcrops, and therefore no detailed description of the beds can be given. Samples of float and fragments of rock in place picked up at several places show the presence of high-grade material and indicate that workable beds similar to those prospected farther south are undoubtedly present. A preliminary study of the phosphate rock was made and samples collected in some of the localities discussed below.

CARIBOU RANGE, IDAHO.

Phosphate rock of the same character as that in Georgetown Canyon, Idaho, was found in the Caribou Range at several places on Bear Creek, Indian Creek, Fall Creek, Pritchard Creek, and Garden Creek. One sample of rock obtained in Bear Creek yielded 28.93 per cent of phosphorus pentoxide (P_2O_5), or 63.36 per cent of tricalcium phosphate. No other analyses have been made of this rock. The general distribution of the phosphate deposits south of Snake River is shown on Plate I. However, as many of the formations overlying the phosphate beds thin greatly toward the north, and as the numerous parallel anticlines in the Caribou Range expose rocks ranging in age from Beckwith to Nugget (see generalized section, p. 14), it is very probable that detailed geologic and stratigraphic work will show that phosphate beds underlie at depths less than 5,000 feet much of the area in the Caribou Range south and west of the phosphate outcrops shown on Plate I. The general relations of the Phosphoria formation to the overlying and underlying beds in the Caribou Range are shown in the sections measured along Tincup Creek, Fall Creek, and Pritchard Creek.[1] The southeastward extension of the phosphate beds could not be traced, as the rocks are concealed beneath the gravel and alluvium along Snake and Salt rivers. It is probable, however, that the beds continue southeastward and connect with the phosphate beds observed in the vicinity of Afton Creek, on the west limb of an overturned anticline southwest of Virginia Peak, which may represent a part of the structural fold observed along the east side of the Caribou Range west of Snake River.

SNAKE RIVER AND SALT RIVER RANGES.

GENERAL DISTRIBUTION.

Deposits of phosphate rock were found at several places from the north end of the Snake River Range to the south end of the Salt River Range, but no attempt was made to trace the outcrop of the phosphate beds from one locality to another. Traverses were made across the Snake River Range along Pine, Rainy, Elk, and Indian creeks and along Snake River. Examinations were also made of the rock along some of the divides between these streams, particularly in the vicinity of Palisade Creek and north of Pine Creek. The general distribution and location of the phosphate deposits in this range are shown on Plate I and in greater detail on the traverse maps of areas along the streams (figs. 2 to 6). Most of the deposits lie along the east side of the range, in that part of the divide lying immediately west of the Absaroka fault. Although the beds have not been traced for any great distances beyond the localities where they were examined, it is reasonably safe to infer from what is known regarding the general structure of the range that the phosphate beds are more or less continuous from one locality to another. Owing to the complexity of detail in the structure of this part of the range, however, the outcrop of the phosphate bed is certain to be somewhat irregular, and even its approximate location can not be inferred until a more detailed examination of the entire region is made.

[1] U. S. Geol. Survey Bull. 530, figs. 33, 34, and 35, 1913.

PINE CREEK.

The lower part of Pine Creek lies on the Snake River basalt. About 2 miles up Pine Creek from the point where the stream crosses the west boundary of the Palisade National Forest rocks of Carboniferous age are exposed. The southwestern part of the range consists chiefly of Paleozoic limestones, in which numerous horn corals were observed. The beds along the west side of the range dip 20° to 50° W., but in the vicinity of the fault east of Flemming's ranch the dip ranges from 50° to 70° W. Some of the beds along this ridge appear to be older than the Madison limestone. This fault, in which the downthrow is on the east, brings the Woodside formation into contact with Paleozoic limestone on the west. Minor faulting was also observed in the hills north of Flemming's ranch, but the exact location of the faults was not determined. Farther up the stream, west of the forest rangers' station, is the overthrust fault, which is believed to be the northwesterly extension of the Absaroka fault. Along this fault line quartzite of Pennsylvanian age (Wells formation) is brought into contact with beds of Jurassic age (Beckwith formation) on the east. Between these two faults were noted the phosphate beds. The rocks in this belt are badly broken and distorted, and no attempt was made to trace the phosphate beds for any distance along their outcrop. It may be expected, however, that when these beds are mapped in detail the phosphate will be found at several places west of the Absaroka fault. Phosphate float was picked up near the middle of this belt, just east of a massive ledge of gray cherty limestone, but no phosphate rock was found in place at this locality. The general relation of the beds indicates that the phosphate should be present below the massive ledge. If the phosphate occurs in place here, there is a fault between it and the phosphate outcrop to the east. The phosphate outcrop west of the forest ranger's station rests upon a bed of white limestone, which in turn rests upon quartzite beds; both limestone and quartzite belong to the Wells formation. A sample of phosphate obtained north of the road, at locality J (see Pl. I), yielded 27.51 per cent phosphorus pentoxide (P_2O_5), or the equivalent of 60.1 per cent tricalcium phosphate ($Ca_3(PO_4)_2$. The entire Phosphoria formation here is approximately 375 to 400 feet thick and contains at least one bed of phosphate about 4 feet thick. The sample collected does not represent the richest phosphate layer but the entire part of the bed exposed. The general relations of the beds as observed along the line of traverse are shown in figure 2.

In the summer of 1910 Eliot Blackwelder examined the phosphate beds along Pine Creek and found that the phosphate series is exposed in the central part of the range in a band trending approximately

N. 50° W., parallel with the range itself. Regarding these deposits he makes the following statement:

Exposures of phosphate beds on Pine Creek are very poor, but it was possible to recognize a gray quartzite (Wells formation) overlain by gray limestone and about 75 feet of phosphatic shale. A sample of the shale gives on analysis 36.8 per cent tricalcium phosphate. The expected beds of rich oolitic phosphate rock were not found but may well be present, although concealed by wash, soil, and tuff at the point examined. The phosphatic shale is overlain by the fossiliferous limestone and massive chert beds generally associated in this region with the phosphate beds. On the whole, the general constitution of the phosphatic series in the Pine Creek section

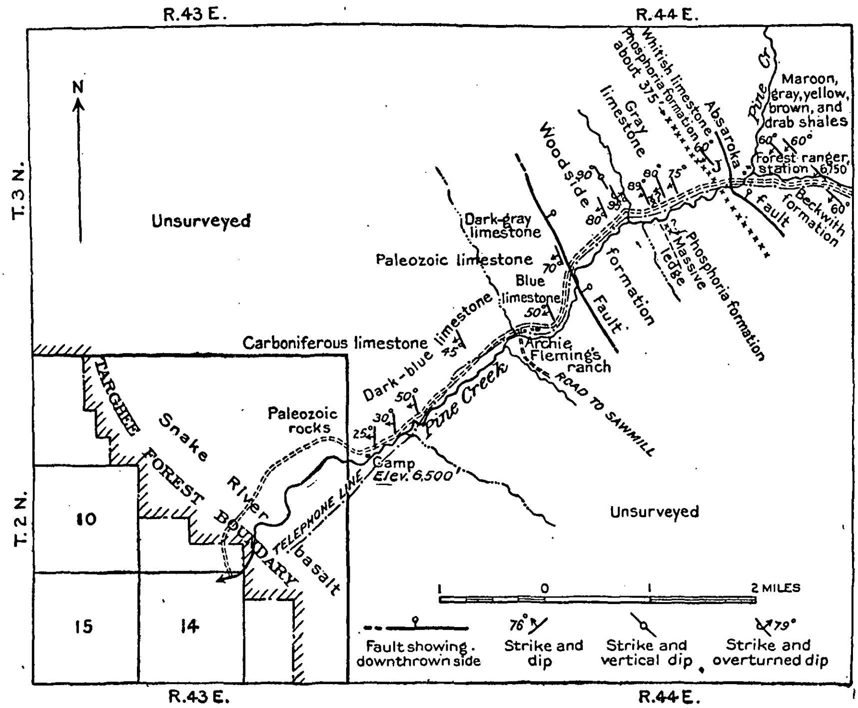


FIGURE 2.—Map showing traverse along Pine Creek, Tps. 2 and 3 N., Rs. 43 and 44 E., Idaho.

is so similar to that in the Preuss Range that it is safe to expect that phosphate deposits of notable value will be found in the Snake River Range when it is adequately explored.

RAINY CREEK.

The western part of the Snake River Range along Rainy Creek consists of rocks of the same kind as those observed on Pine Creek, for the most part of Paleozoic age. The range here is made up of several parallel folds, which are broken by faults. The anticline observed between Rainy and Palisade creeks forms the highest point of the Snake River Range at this place, and its axis passes through Baldy Mountain in a northwesterly direction, crossing the lower portion of Rainy Creek. The rocks exposed on the divide south of Rainy

Creek consists of Madison limestone and beds of Pennsylvanian (Wells) age. So far as known deposits of phosphate do not occur in this part of the range from Baldy Mountain east to the first fault shown on Plate I. If present they occupy the crests of the ridges and constitute remnants that have not yet been removed by erosion from some of the closely folded synclines.

The first prominent fault observed on going up Rainy Creek lies just east of the canyon on the south fork of the creek and may represent the southeasterly continuation of the westernmost fault observed on Pine Creek. The fault brings the Ankareh shale on the east into contact with the quartzite of the Wells formation on the west. The downthrow is on the east and is somewhat greater than on Pine Creek, although the general relations are the same. Farther up the stream

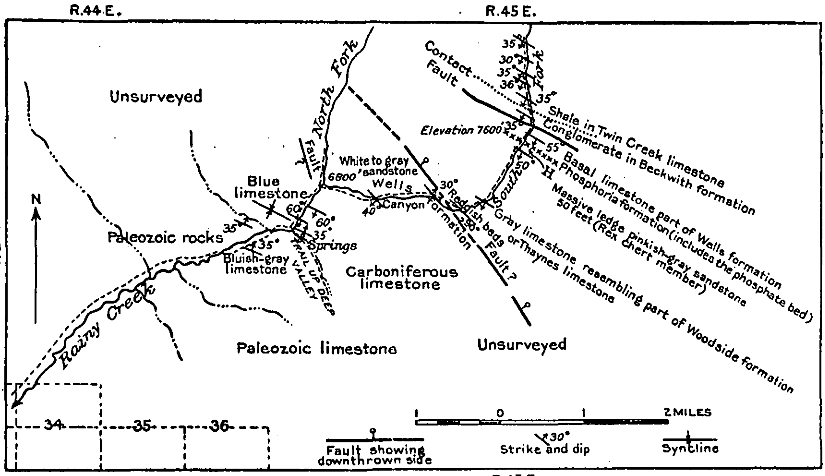


FIGURE 3.—Map showing traverse along Rainy Creek, T. 2 N., Rs. 44 and 45 E., Idaho.

the Absaroka overthrust brings the Beckwith formation into contact with the Wells formation on the west. The phosphate occurs between these two faults, immediately beneath a massive ledge of Rex chert 50 feet or more thick and above a bed of white limestone, which is the upper part of the Wells formation. A sample of phosphate rock was gathered at this locality (H, Pl. I) from the Phosphoria formation, which is about 375 feet thick. A phosphate bed 3½ feet thick yielded 31.69 per cent phosphorus pentoxide (P_2O_5), or 69.4 per cent tricalcium phosphate ($Ca_3(PO_4)_2$. A short distance east of the fault lies the contact between the Beckwith formation and the Twin Creek limestone, both of which strike northwest and dip 30°–35° SW. The general relations observed along Rainy Creek are shown in figure 3.

Phosphate deposits are also exposed on the north fork of Rainy Creek in much the same relations as on the south fork. H. Corbet, of Irwin, Idaho, states that a coal claim has been staked on these deposits and attempts have been made to develop it. Mr. Corbet was primarily interested to know if the material was coal, as he wished to determine whether or not a coal supply for Swan Valley could be obtained at this place. He furnished a sample of rock taken from the prospect on the North Fork (I, Pl. I), which yielded 17.08 per cent phosphorus pentoxide (P_2O_5), or 37.4 per cent tricalcium phosphate ($Ca_3(PO_4)_2$), and gave evidence of organic matter. The rock consists of a black carbonaceous shale such as is often found associated with the richer phosphate beds.

PALISADE CREEK.

Similar phosphate rock occurs between the two faults on Palisade Creek above the upper lake, which likewise has been prospected for coal. A sample of phosphate rock from this locality (G, Pl. I) reported to show the physical characteristics of coal was analyzed and yielded 12.69 per cent phosphorus pentoxide (P_2O_5), or 27.8 per cent tricalcium phosphate ($Ca_3(PO_4)_2$), and gave good evidence of organic matter.

Structural observations on the divide between Rainy and Palisade creeks east of the anticline that passes through Baldy Mountain and west of the first fault shown on Rainy Creek show that immediately east of Baldy Mountain is a low syncline in Carboniferous rocks whose axis strikes northwest. Immediately east of this low syncline is a gently folded anticline whose axis strikes N. 60° W. and exposes along its crest beds of Pennsylvanian age, a little lower stratigraphically than the beds exposed in the syncline. Farther east is another shallow syncline, to the east of which is a second sharply folded anticline whose east limb is cut by the fault. The west limb of the anticline strikes N. 60° W. and dips 30° SW.; the east limb strikes N. 40° W. and dips 70° NE. The beds exposed along the divide between Rainy and Palisade creeks appear to consist chiefly of the Madison limestone and the overlying Wells formation. At no place west of the fault in these two synclines were phosphate beds or the Phosphoria formation seen. In the block between the two faults, the eastern of which is the Absaroka, the Phosphoria formation is present and deposits of phosphate are known to occur. Similar deposits occur east of the Absaroka fault but lie at a considerable depth below the surface, though the exact depth can not be determined until a detailed stratigraphic study of the region has been made.

ELK CREEK.

No deposits of phosphate rock were seen near the line of traverse along Elk Creek. The main part of the Snake River Range is composed of rock of Paleozoic age. The rocks in this vicinity are highly folded and are broken by faults, the exact position of which has not been ascertained except along the line of traverse. Two main anticlinal folds trending in a northwesterly direction cut across Elk Creek, and with these folds are associated numerous minor folds and flexures. On the upper part of Elk Creek the same fault relations were observed as along Rainy and Pine creeks, but here the streams have cut through the phosphate beds and are now intrenched in rocks of the

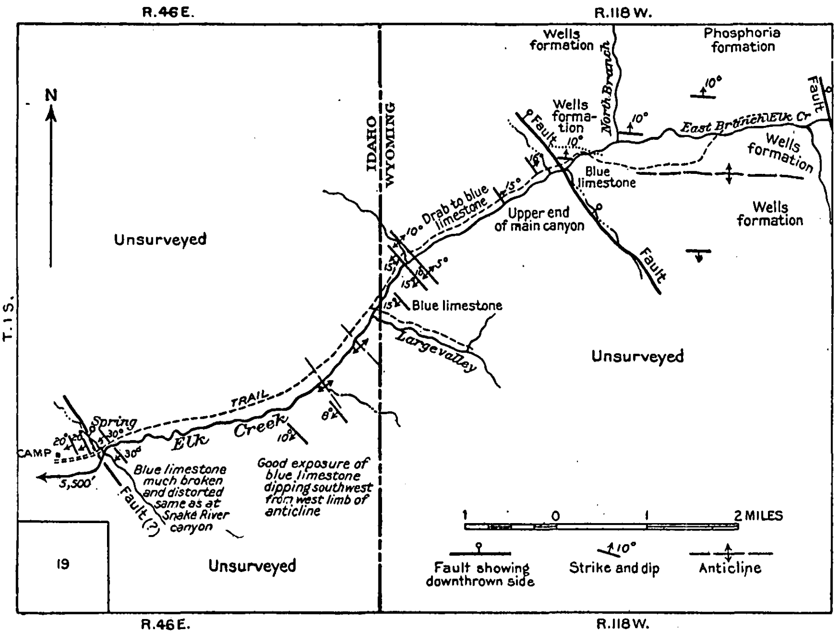


FIGURE 4.—Map showing traverse along Elk Creek, T. 1 S., R. 46 E., Idaho, and T. 39 N., R. 118 W., Wyo.

Wells and underlying formations. In the area between the two faults the phosphate-bearing beds are present in the ridges both north and south of the stream. From the traverse along the valley it appears that phosphate deposits occur near the crests of some of the ridges, but no attempt was made to trace the horizon or examine the separate hills to determine the presence and thickness of the phosphate beds. The general relations and the attitude of the phosphate bed along Elk Creek are shown in figure 4.

From the examination made in this vicinity it is apparent that no phosphate deposits occur in the Snake River Range west of the western fault shown in figure 4, as this part of the range consists of rocks older than the phosphate formation. The western flank of the range may terminate abruptly along a fault or it may represent the eastern limb of a closely folded syncline, but in either case the phosphate beds are not present between Snake River and the fault. Owing to the heavy cover of gravel, recent conglomerates, and lava flows that masks the underlying Paleozoic rock along the west flank of the range, the structure has not been satisfactorily determined.

INDIAN CREEK.[1]

A foot-paced traverse was made on both the North and South forks of Indian Creek. The structure of the west flank of the Snake River Range in this vicinity is very similar to that on Elk Creek, in that the older Paleozoic rocks are partly concealed by gravel and nearly horizontal conglomerate beds that dip gently away from the mountains. It appears, however, that the west base of the main range coincides approximately with the synclinal axis in the Paleozoic rocks that cross Indian Creek just below the forks. The main part of the Snake River Range in this vicinity consists of Paleozoic rocks in every way similar to those observed on Elk, Rainy, and Pine creeks. The main anticline of the range crosses both the North and South forks of Indian Creek and is cut out by a fault a short distance south of the South Fork. This anticline probably represents the southward extension of the anticline that passes through Baldy Mountain east of Irwin and is the same as that observed on Palisade and Elk creeks. All the rocks west of the fault shown in the accompanying map (fig. 5) are older than the Phosphoria formation, and no phosphate deposits are known to occur in this part of the range. Beds of Pennsylvanian (Wells) age are exposed east of the fault

The sandstones of the Wells formation are overlain by the Phosphoria formation, which in turn is overlain by the Woodside and Thaynes formations. The traverse on the South Fork of Indian Creek was not carried far enough up the stream to encounter the phosphate beds, but it is apparent from the examination made that they are present on the upper part of this stream. On the North Fork of Indian Creek the phosphate bed was encountered immediately beneath the massive Rex chert member and immediately above the limestone member at the top of the Wells formation. The Phosphoria formation here is approximately 400 feet thick, and the phosphatic series about 75 feet thick. The rich phosphate bed was not measured but is believed to be from 3 to 4 feet in thickness. A sample collected from the phosphate bed on the north side of the creek (A, Pl. I) yielded 32.85 per cent phosphorus pentoxide (P_2O_5), or 71.78 per cent tricalcium phosphate ($Ca_3(PO_4)_2$).

The general relations of the Phosphoria formation to the overlying and underlying formations are shown in figure 5.

[1] This stream should not be confused with the Indian Creek in the Caribou Range.

Similar relations to those observed here may be expected along the upper part of South Fork of Indian Creek. On the divide between the two forks the phosphate deposits extend much farther west and may extend to the fault contact. The high ridge to the east is apparently underlain by the phosphate bed.

SNAKE RIVER.

The structural conditions along the west base of the Snake River Range on Snake River are similar to those observed on the streams to the north. The Paleozoic beds are closely folded and compressed, and in places they appear to be overturned. At the mouth of the

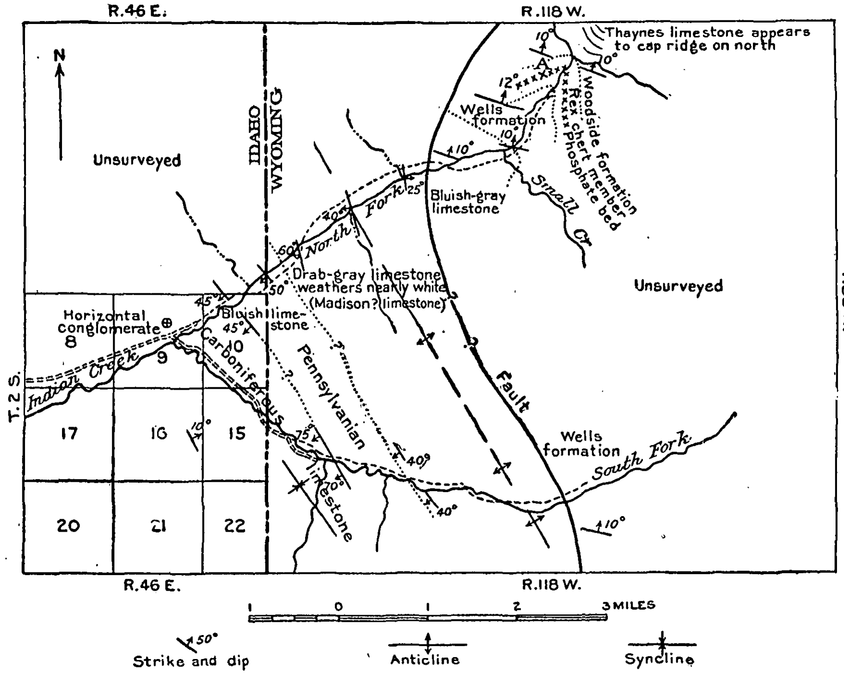


FIGURE 5.—Map showing traverse along Indian Creek, T. 2 S., R. 46 E., Idaho, and T. 38 N., R. 118 W., Wyo.

Snake River canyon the beds show clearly in wavy lines along bedding planes the effect of the compression strain. The anticlinal axis observed on Indian Creek is not present on Snake River, as it is cut out by the western fault. The Paleozoic beds west of the fault are the same as those on Indian Creek but here represent only the west limb of the anticline. The structure on Snake River in the belt between the western fault and the Absaroka fault is more complex than that observed on Indian Creek, as there are here three distinct anticlines trending approximately north. In this belt the phosphate deposits occur well up on the higher hills, there being no deposits of phosphate along the line of traverse, as Snake River has cut through the Phosphoria formation and exposes older beds throughout its course from the lower end of the canyon up to the Absaroka fault. On the north side of Snake River beds of the Phosphoria formation were seen in the higher hills and probably represent the southward extension of the beds observed along Indian Creek. It is not known whether the phosphate beds occur in the hills between Greys River and Snake River on the south side of the Snake. East of the Absaroka fault and west of the Wyoming Range the Phosphoria beds lie at a great depth, as in this area the surface exposures consist of beds of Cretaceous age. The outcrop of the Phosphoria formation along the west side of the Wyoming Range is described on pages 23–24. The

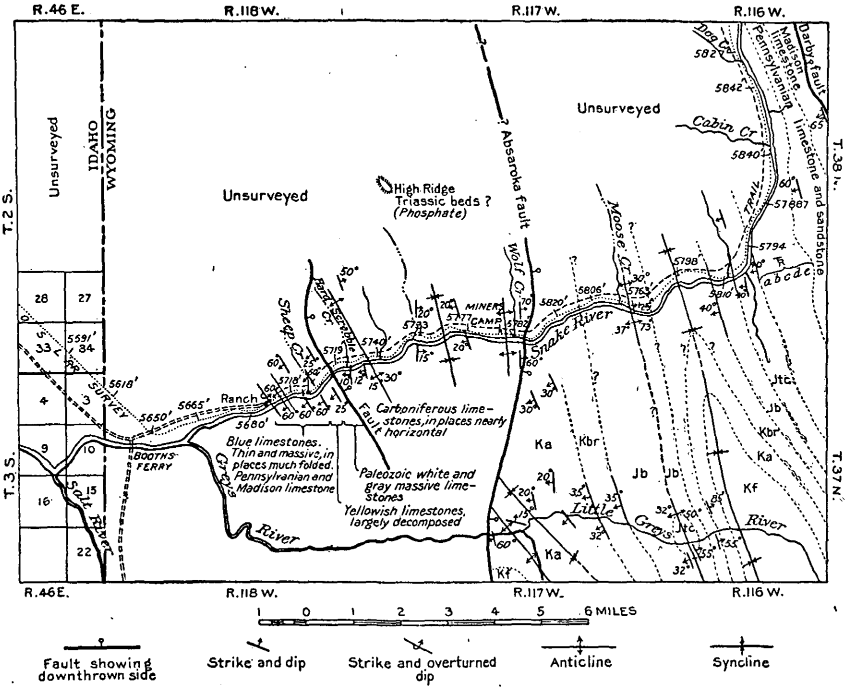


FIGURE 6.—Map showing traverse along Snake River canyon, Tps. 37 and 38 N., Rs. 116, 117, and 118 W., Wyo.

structure between the Absaroka fault and the Wyoming Range, so far as known, is shown in figure 6.

On this part of Snake River at least one pronounced anticline and one syncline that trend about north cross the river at nearly right angles. It is not known what beds are exposed along their axes in the region of Snake River. If the beds are closely folded, as they are in the vicinity of Little Greys River, beds of Jurassic age probably crop out along the crest of the anticline and beds of Cretaceous age along the axis of the syncline. The coal-bearing Frontier or Bear River formation may be present in the syncline as coal has been reported in this belt on Snake River. No examination was made of the beds along Snake River between the Absaroka fault and the mouth of Bailey Creek, and it is not known what beds are exposed at the surface.

In the course of this reconnaissance examination no observations were made south of Snake River, but it is known from earlier work in this region that the phosphate deposits occur at several points farther south. South of Virginia Peak the central part of the range consists of a syncline along which beds of Triassic age are exposed. The Salt River Range is terminated on the east by the Absaroka fault, which in this locality brings Mississippian limestone into contact with Cretaceous beds. The western part of the range consists of a northwestward-trending anticline, in places overturned. The phosphate beds crop out along the west flank of this anticline and along both limbs of the syncline in the central part of the range. Toward the north along both anticline and syncline older beds appear at the surface, and west and north of Virginia Peak all the phosphate beds have been eroded except possibly along the west flank of the anticline, where they may be concealed by the gravel and alluvium along Salt River. Whether or not the northwestward-trending anticline observed in this part of the Salt River Range is the southeastern continuation of the anticline observed near the mouths of McCoy and Bear creeks, east of the Caribou Range, was not determined.

As the Paleozoic formations run nearly parallel to the Salt River Range it is probable that south of Virginia Peak the phosphate deposits are found generally along the range, usually well up toward its crest, and there is reason to believe that they are not subject to great variations in richness along the outcrop. In 1910 C. L. Breger recognized the phosphate beds in the canyon of Swift Creek east of Afton, Wyo. He found at the base of the phosphate beds about 42 feet of gray limestone, overlain by 40 to 78 feet of soft shaly beds, including phosphate rock, overlain in turn by more than 100 feet of massive to thin-bedded chert. It is believed that there are two phosphate beds in the shaly strata here, the lower one at the base and the upper one about 45 feet above the base. The thickness of either is still unknown, but pieces of the float from the upper bed, consisting of massive black oolite, yielded on analysis 67.4 per cent of tricalcium phosphate. Since the preparation of this report a reconnaissance examination for phosphate in the Salt River Range has been made by G. R. Mansfield.[1]

[1] Mansfield, G. R., A reconnaissance for phosphate in the Salt River Range, Wyo.: U. S. Geol. Survey Bull. 620, pp. 331-347, 1915.

BIGHOLE MOUNTAINS AND WYOMING RANGE.

GENERAL FEATURES.

The Bighole Mountains and Wyoming Range lie immediately northeast of the Snake River and Salt River ranges and are, like them, terminated on the east by a pronounced fault. Deposits of phosphate have been observed at several places in these ranges, for the most part on the west side of the mountains, whereas in the Snake River Range the deposits lie on the east flank of the main mountain range. Phosphate outcrops were observed at several localities on the west slope of the Wyoming Range southeast of Snake River. On Snake River in the vicinity of Counts's ranch, several miles below the mouth of Hoback River, the Phosphoria formation and the overlying and underlying rocks were noted on the southwest flank of the range. In the Bighole Mountains the same beds were observed in the vicinity of station 39, south of Victor, Idaho, and on the west flank of the range in the vicinity of stations 40 and 42, but were not seen in the vicinity of the headwaters of Pine Creek, where the road crosses the divide from Teton Basin to Conant Valley on Snake River. It is believed that the phosphate beds here are cut out by the fault, as Cretaceous beds occupy the crest of the ridge. The phosphate outcrop was not found in the Bighole Mountains west of Victor and Driggs, Idaho, as the 8-inch cover of snow concealed it from view. From the structure and from the overlying and underlying beds it appears that deposits of phosphate occur in this part of the range, although locally, as in the upper part of Pine Creek, the phosphate bed may lie at a considerable depth below the surface. Although the beds have not been traced for any distance beyond the locality where they were examined, it is reasonable to assume that they are present in this range from the headwaters of Canyon Creek, west of station 42, southeastward to Snake River.

WYOMING RANGE SOUTHEAST OF SNAKE RIVER, IN THE VICINITY OF BAILEY CREEK.

In the summer of 1906, while the writer was mapping the geology southeast of Snake River, he recognized the Park City beds, which include the Phosphoria formation, on the west flank of the Wyoming Range and traced them from the southern part of Wyoming northward to Snake River. Phosphate samples were obtained at several localities toward the south, but none were collected in the vicinity of Snake River. The Phosphoria formation, including the phosphate bed, was not mapped separately at this time but grouped with the overlying Woodside and Thaynes formations. It is reasonably certain that the bed of phosphate occurs in this part of the range and overlies the Pennsylvanian sandstone and limestone that form the west slope of the range southeast of Snake River.

WYOMING RANGE IN THE VICINITY OF SNAKE RIVER.

In the vicinity of Counts's ranch, on the opposite bank of Snake River in the NE. ¼ sec. 32, T. 39 N., R. 116 W., there is a good exposure of the phosphate rock. The black material has long been supposed to be coal, and the deposit has been considered by the inhabitants as a possible source of coal for local use. Here, as at other places farther south, the deposit consists of approximately 60 feet of shale representing the phosphate rock. The richer phosphate beds alternate with black phosphate, shale, and limestone that carry a small amount of tricalcium phosphate. These phosphate beds are not the northward extension of the beds observed on the west flank of the range east of Bailey Creek but lie on the east side of the Darby fault. The northward extension of the Bailey Creek phosphate beds on the west side of the range passes beneath the gravel along Snake River and probably lies some distance west of the exposures at Counts's ranch. The beds on Snake River east of the Darby fault in the vicinity of Counts's ranch crop out in a closely folded anticline that crosses Snake River in a southerly direction and is broken by one or more minor faults. The structure of the range is much more complex in this vicinity than it is farther south, and considerable time would be required to work out the details and trace the phosphate outcrop northward to the vicinity of station 39, southwest of Victor, Idaho. Eliot Blackwelder visited the Snake River locality in 1910 and measured the following detailed section, which represents fairly well the Phosphoria formation in this part of the range:

Section of phosphatic beds in the northwest bank of Snake River opposite Counts's ranch, in sec. 32, T. 39 N., R. 116 W., Wyo.

	Ft.	in.
Top overlain unconformably by Tertiary conglomerate.		
Shale and limestone, gray-buff to brown, with thin black phosphatic seams here and there	20	
Phosphate rock, brown and nodular (21.2 per cent tricalcium phosphate)	2	6
Phosphate rock, black, soft, and shaly (random sample, 68.5 per cent tricalcium phosphate)	9	
Chert, dark gray	12	
Shale, black and probably phosphatic	4	
Chert and seams of limestone, passing gradually upward into cherty limestone with black shale partings	33	
Limestone, earthy buff to gray, with black chert nodules	20	
Sandstone, soft and white, with thin beds of gray chert	26	
Sandstone, fine, white, and very soft	6	
Limestone, pearl-gray, argillaceous	22	
Phosphate rock, black and oolitic		2½
Chert, massive, gray	6	

	Ft.	in.
Alternating thin beds of soft oolitic phosphate rock and hard black limestone (probably about 20 per cent tricalcium phosphate)	5	10
Massive brown phosphate rock (66.3 per cent tricalcium phosphate)	2	5
Limestone, brittle, black	1	
Phosphate rock, soft, black, granular (20 to 30 per cent phosphate)	3	
Limestone, brittle, black	2	6
Phosphate rock, soft and shaly (29.6 per cent phosphate)	4	6
Limestone, brittle, black	2	
Phosphate, black, shaly, and granular, with lenses of black limestone (average of entire bed, 20.3 per cent tricalcium phosphate)	12	
Limestone, brittle, black	1	3½
Phosphate rock, soft, shaly, and granular, with lenses of black limestone (average of entire bed, 31.2 per cent tricalcium phosphate)	12	
Limestone, hard, dark gray	9	
Sandstone, soft, argillaceous, gray	8	
Shale and limestone, smoky gray to buff	22	
Quartzite, white to buff (Wells formation)	47	

BIGHOLE MOUNTAINS SOUTH OF VICTOR, IDAHO.

In the vicinity of station 39, in T. 2 N., R. 45 E., south of Victor, Idaho, the series of rocks exposed is the same as that observed east of Bailey Creek in the Wyoming Range, south of Snake River. (See fig. 6, p. 48.) The beds have practically the same relations and are terminated on the northeast by a pronounced fault, believed to be the northward extension of the Darby fault, that separates them from the beds along the west flank of the Teton Mountains, in the south end of Teton Basin. The oldest beds exposed in the vicinity of station 39 lie near the east base of the Bighole Mountains, where Carboniferous rocks, probably of Pennsylvanian age, occur. The Carboniferous rocks are exposed for a distance of several miles in a northwesterly direction along the fault contact, but the outcrop is cut out entirely by the fault before the beds pass beneath the gravels and valley fill along the west side of Teton Basin, only to reappear several miles to the northwest, in Tps. 4 and 5 N., R. 44 E., where they form a pronounced range of hills facing Teton Basin. The summit of the hill on which station 39 is located consists of Nugget sandstone that strikes N. 10° W. and dips 45° SW. This sandstone is overlain by a considerable thickness of dark-drab limestone and shaly beds of the Twin Creek formation. These beds may represent the eastern extension of the Twin Creek limestone observed on the upper part of Rainy Creek, as the strike and dip are in the same direction. It is very probable, however, that there is another anticlinal fold between these two localities. No examination was made of the intervening area, and the structure in this part of the range may be more complex than it appears from a distance. It is not probable, however, that the phosphate beds are exposed at the surface along a line joining these two localities. The Phosphoria formation and the overlying formations from the Phosphoria to the Nugget sandstone appear to be present in their normal position on top of the Carboniferous rock between station 39 and the crest of the range northeast of station 40, west of the Darby fault. As the ground was covered by a heavy fall of snow at the time of the writer's visit neither the phosphate bed nor any fragments of phosphate float were found, but the general structure of the region and the presence of the accompanying formations indicate that the Phosphoria formation occurs here and can no doubt be readily found under favorable conditions.

NORTH END OF BIGHOLE MOUNTAINS.

Northwest of station 39 along the strike of the beds all the formations overlying the hard pink sandstone (Nugget sandstone) apparently extend to stations 40 and 42 and beyond. There appear to be some minor displacements and secondary folds, but on the whole the structure is comparatively simple. Cretaceous beds form the main part of the divide where the road from Victor, Idaho, to the Snake River valley crosses the range. These beds contain coal and are believed to be of Bear River and Benton (Colorado) age and equivalent to the Bear River and Frontier coals in western Wyoming, south of Snake River. Whether or not the coals are continuous along this belt or whether the Frontier formation is present only in places between the Darby and Absaroka faults from Snake River northward to Canyon Creek, where the older beds are concealed beneath the lava flow, or whether the coal beds in this part of the range all belong to the Bear River formation, was not determined. Much of this area has never been mapped geologically, and coal prospecting has been restricted largely to the vicinity of Pine Creek, where considerable work has been done during 1911 and 1912 with more or less success.

The Carboniferous beds and those immediately overlying them appear to be cut out by the fault a short distance northwest of station 39, or they may have been eroded and lie buried beneath the gravels along Pine Creek, on the west side of Teton Basin. More detailed work will no doubt show what has become of these beds in the region of Pine Creek southwest of Victor. The entire series of Carboniferous rocks and overlying beds reappear north of station 40 and are apparently continuous from this locality northwestward to station 42 and beyond, where they pass beneath the lava-covered plains along the headwaters of Canyon Creek. The oldest beds in the section occur north of station 40, and it is believed that these beds are older than Mississippian. The crest of the ridge at station 42 consists of Madison limestone that strikes northwest and dips for the most part southwest. A little farther northeast, along the fault escarpment at the northeast extremity of the ridge, occur quartzites of Pennsylvanian age that strike north and dip 10°–65° E. Minor folding and faulting were observed along this part of the range, but time was not available to work out the structure in detail. Southwest of station 42 the beds strike N. 40° W. and dip 30° SW., and the entire series of beds overlying the Carboniferous are as fully developed in this vicinity as they are southwest of stations 39 and 40. The crest of the hills on which station 40 is located, like that at station 39, consists of hard pale-red or pink sandstone, which in places is almost quartzitic. For a considerable distance this ridge forms the main divide between Snake River and Teton Basin and is capped by this heavy massive quartzite or sandstone, which is probably equivalent to the Nugget sandstone of western Wyoming and eastern Idaho. Between this sandstone and the uppermost Carboniferous beds, composed of drab and gray cherty limestone, occurs a series of deep-red arenaceous shales and sandstones, with associated gray and drab limestone, which form a wide belt of brilliant-colored exposures in the northeast face of the ridge at station 40 and can be seen from a distance passing to the southwest of station 42 and beyond until they disappear beneath the lava plains. At the base of this series, overlying the Pennsylvanian beds, is the Phosphoria formation. Owing to the heavy cover of snow it was not practicable to try to locate the phosphate bed or to measure the thickness. From what is known of the geology and structure of this part of the range and from the reported prospects along the headwaters of Canyon Creek, where the continuity of the phosphate bed has been shown, it seems reasonably certain that the phosphate deposits are present throughout this part of the Bighole Mountains.

St. John,[1] in his report on the "Pierres Hole" (Bighole) Mountains, gives a section through station 40 and a profile showing the relations of the beds to one another in that part of the range along a line that passes through stations 40 and 42. The entire section described by him has not been examined, but it appears that the 2,000 feet of beds in his section numbered from 1 to 14 represent the Carboniferous and underlying beds. It is reasonably certain that they include beds of Pennsylvanian and Madison (lower Mississippian) age, and they may include some older beds at the base. The 2,500 feet of beds numbered from 15 to 26 represent the Phosphoria formation, Woodside formation, Thaynes limestone, Ankareh shale, and Nugget sandstone. The 1,200 feet of beds numbered from 27 to 34 probably

[1] St. John, Orestes, U. S. Geog. and Geol. Survey Terr. Eleventh Ann. Rept., pp. 425, 427, 1879.

represent the Twin Creek limestone. The 540 feet of beds numbered from 35 to 38 represent part of the Beckwith formation. It appears from his descriptions that this section contains no part of the overlying Cretaceous beds.

Northeast of station 42 a pronounced thrust fault, which is believed to be the northwestward extension of the Darby fault, brings the Carboniferous beds into contact with the Cretaceous and underlying beds on the east. The Cretaceous beds east of the fault belong to the Frontier formation and are of Benton age. In a hard ledge of sandstone on Packsaddle Creek, in the SW. ¼ SW. ¼ sec. 24, T. 5 N., R. 43 E., the writer found numerous fragments and several complete casts of *Inoceramus labiatus*, *Inoceramus erectus*, and other associated Frontier species, which place these beds and their associated coals in the Frontier formation. Several beds of coal occur in this formation and are discussed in more detail under the heading "Coal." The Frontier beds near the fault line strike N. 20°–35° W. and dip from 50° S. 70° W. to 60° S. 65° W. Toward the east at right angles to the beds the dip flattens slightly as far as the ridge in secs. 19, 30, and 32, T. 5 N., R. 44 E., which is composed of Jurassic beds. This ridge trends northwest and the beds dip 54° SW. East of the ridge the Frontier formation observed on the west side is again encountered. A few coal prospects have been opened in these beds, but they have not been thoroughly prospected. The beds strike north and dip 10° W.

The occurrence of Frontier coals both east and west of the Jurassic ridge, all of which dip toward the west, indicates an overturned anticline or a fault along the east side of the Jurassic ridge, which duplicates the Cretaceous beds. The structure is somewhat complex, and more detailed work is required to determine accurately the relation of the coal beds on the east and west sides. The overturning of the anticline, if it occurred, was probably due to the large thrust movement from the west. East of the anticline is an overturned syncline, east of which in turn is another low, flat anticline that probably represents the western margin of the broad, open synclinal trough of the Teton Basin. The Teton Basin syncline and the low anticline along its western margin are for the most part concealed beneath Tertiary lavas. The writer's observations in this part of the Bighole Mountains, made during a brief reconnaissance when much of the ground was covered by snow, agree fairly well with the results reported by St. John.[1] They do not, however, confirm his conclusions regarding the fault east of station 42, for this fault is thought to be a thrust fault instead of a normal fault as shown in his profile, which passes through station 42 across the north end of the range.

[1] St. John, Orestes, op. cit., pp. 430, 432, pl. 38.

No. 1 of St. John's section through station 42 represents the Tertiary lava that conceals the underlying formations in the Teton Basin. These beds dip about 15° E. Beds 2 to 4 represent in part the Frontier formation and the underlying Cretaceous rocks. Beds 5 to 12 represent the Jurassic beds exposed in a prominent ridge east of station 42 and are chiefly of Beckwith age, although some Twin Creek limestone is exposed in parts of the ridge. Beds 5 and 12 are believed to represent the same stratigraphic ledge. Beds 13 to 17 represent Cretaceous beds lying between the Jurassic ridge and the Carboniferous beds west of the Darby fault and include the Frontier formation. Bed 18 represents the Pennsylvanian and the Madison limestone west of the fault that forms the eastward-facing scarp of the main mountain range. The Jurassic ridge east of station 42 and the associated Cretaceous beds both east and west of the ridge disappear beneath the Tertiary lavas within a short distance to the north, but toward the southeast they extend to the western border of Teton Basin, where they have been eroded and are now covered by recent deposits. Coal beds of the Frontier formation may also occur beneath a large part of the Teton Basin east of the easternmost anticline observed, but no exposures of coal were seen on the east side of the Jurassic ridge east of the exposures on Horseshoe and Packsaddle creeks.

Although the phosphate beds probably underlie all of the Teton Basin syncline from the Darby fault east to the phosphate exposures along the west flank of the Teton Mountains east of Driggs and Victor, Idaho, no exposures of these beds were seen between the Darby fault and the east side of Teton Basin. If present these beds lie at a considerable depth below the surface.

TETON MOUNTAINS.

The Phosphoria formation is exposed in the Teton Mountains only near the south end along the western flank of the range. The east side of the range is bounded by a pronounced fault, and all the beds composing the range west of the fault to the west slope are older than the Phosphoria formation. Along the west slope of the range, where the Phosphoria formation crops out, the phosphate beds are poorly exposed. Farther north the lower slopes of the range are covered by gently westward-sloping sheets of Tertiary lava that conceal the phosphate and underlying beds. Phosphate deposits were observed by the writer in 1911 along the west slope of the range east of Victor, Idaho, between Moose and Fox creeks, but no section of the bed was measured. Eliot Blackwelder, in 1910 and 1912, examined the beds from the vicinity of Alta, Wyo., where they pass beneath the lava cover, southward to the south end of the Teton Basin. At the south end, where the Teton Mountains merge with the Bighole Mountains, the phosphate beds that underlie Teton Basin become folded in a sharp, compressed syncline between the Teton Mountains on the east and the beds west of the Darby fault northeast of station 39. The outcrop of the phosphate bed along this part of the range is shown on Plate I. Near the mouth of Coal Creek, in T. 41 N., R. 118 W., Wyo., an old coal prospect dump shows a soft black material which represents the location of the phosphate bed. The tunnel was dug about 25 years ago on the supposition that a valuable bed of coal could be opened at this place. The prospect is now badly caved, and a good section of the bed can not be measured without considerable prospecting or digging. Blackwelder, who visited the prospect in 1910, states that the phosphate bed appears to be several feet thick and ranges from soft black oolite to earthy phosphate rock. The oolite yields 52.2 per cent of tricalcium phosphate, and a general sample of all the material on the dump yields 20.8 per cent of tricalcium phosphate.

In 1911 John Cluff, of Victor, Idaho, was opening a prospect in the vicinity of sec. 15, T. 41 N., R. 118 W., with the expectation of finding a local supply of coal for Victor and the Teton Basin. He reports that the beds here strike northwest and dip 45° SW., and that the supposed coal bed is 5 feet thick. A sample of this material sent in for analysis yielded a trace of phosphorus pentoxide (P_2O_5) and showed evidence of organic matter supposed to be coal. From the sample it appears that the prospect was opened on the phosphatic series and represents the carbonaceous shale accompanying the main phosphate bed, which in places yields from 50 to 80 per cent tricalcium phosphate.

The only section of the phosphate beds available along the west flank of the Teton Mountains was measured by Eliot Blackwelder, in 1912, while mapping a part of the Grand Teton quandrangle. Most of the Phosphoria formation, the top of which has been in part removed by erosion and the base of which indicates a slightly eroded contact, is well exposed on the slope of the ravine between Darby and Fox creeks in what will probably be when surveyed sec. 29, T. 43 N., R. 188 W.

Section of Phosphoria formation on Darby Creek, Wyo.

[Measured by Eliot Blackwelder.]

	Feet.
Brown, cherty sandstones with tubular bodies of chert	30+
Massive friable gray dolomite with chert nodules and traces of marine fossils	19
White soft sandstone	1.5
Chiefly thin-bedded yellow and pink dolomite, chert and sandstone; concealed in part	21
Gray to buff shaly dolomite and chert	8
Yellow shale and argillaceous dolomite	7.5

	Feet.
Massive gray oolitic phosphate rock, containing 68.2 per cent tricalcium phosphate	0.8
Olive-gray chert	1.9
Gray oolitic phosphate rock, containing 73.2 per cent tricalcium phosphate	.9
Massive gray chert with dolomite	4
Fine-grained oolitic phosphate rock, containing 71.8 tricalcium phosphate	.6
Dense gray dolomite	.3
Pisolitic blue-black phosphate rock, containing 72.9 per cent tricalcium phosphate; white selected coarse pisolitic layer contains 75.9 per cent	1.5
Massive gray chert	1.1
Gray oolitic phosphate rock, containing 76.4 per cent tricalcium phosphate	.8
Dark-gray sandy phosphatic breccia, at the base of which is a slightly eroded contact	.5
	99.4

JACKSON HOLE AND VICINITY.

No detailed examination has been made of the area in the vicinity of Jackson, Wyo., between the Teton, Hoback, and Gros Ventre mountains. Phosphate deposits are known to occur on the north and south sides of the Gros Ventre Mountains and at several places along the Hoback Range. The geology, structure, and phosphate deposits of these ranges are discussed more fully in previous publications.[1] The structure in the vicinity of Jackson is complex and is as yet only partly understood, owing to the widespread cover of the older rocks by Tertiary beds and alluvium along Snake River. For this reason exposures of phosphate rock are meager, and a detailed examination is necessary to determine the structure and distribution of the phosphate beds in this locality. Although phosphate exposures have not been found, it is known that phosphate occurs in this area. In secs. 17, 18, 19, and 33, T. 41 N., R. 116 W., fragments of phosphate rock were found in such relations as to indicate that the phosphate bed lies immediately beneath the surface. In the NW. ¼ sec. 33 Eliot Blackwelder in 1911 found in the soil and débris at a definite horizon just above the Pennsylvanian sandstone abundant quantities of weathered black oolitic phosphate rock, which occurs near the base of the Phosphoria formation. Samples of this float on analysis yielded 61.3 per cent of tricalcium phosphate. Outside of these two localities and the area south of Jackson, at the north end of the Hoback Range, no deposits of phosphate are known to occur in the area east of Snake River and north of the Wyoming Range.

[1] U. S. Geol. Survey Bull. 470, pp. 452–481, 1911; Bull. 543, 1914.

DEVELOPMENT OF PHOSPHATE DEPOSITS.

The phosphate industry in the Rocky Mountain region has made progress slowly. In 1913 approximately 5,919 long tons of phosphate rock was mined, of which 5,053 tons was sold for $18,167, an average price of $3.57 a ton. This production was less than 0.5 per cent of the entire phosphate production of the United States in 1913. In 1916 the proportion was only 0.08 per cent. Part of this lack of progress may be attributed to the fact that some of the early properties have been involved in litigation, part to the high cost of transporting the phosphate to localities where it is needed for depleted soils, and part to the fact that as yet comparatively few agriculturists fully appreciate the increased production possible by the use of phosphate fertilizer.

Thus far phosphate rock has been shipped in the West for commercial use from only a few localities in the West. All the localities at which small mines have been opened and from which rock has been shipped are in the Bear Lake region, in southeastern Idaho, northeastern Utah, and western Wyoming, where the deposits were first discovered. Slight as the development has been in these older localities, there is still a marked contrast between them and the area described in this report, for in this area the phosphate deposits have received practically no attention from the prospector, and their very existence seems to be unknown to him or to the inhabitants. What little prospecting has been done along the phosphate outcrop was undertaken with the idea of opening coal mines from which a supply of coal could be obtained for local use. The phosphate beds have been prospected in Wyoming for coal on Snake River south of Jackson Hole and at the mouth of Coal Creek, near the southeast end of Teton Basin; and in Idaho on Patterson Creek, on North Fork of Rainy Creek and Palisade Creek east of Swan Basin, in Burns Canyon, and on the headwaters of Canyon Creek, in the Bighole Mountains. Although coal has been reported from these beds at many places in the mountains north of Snake River, active prospecting was soon abandoned at these places and most of the prospect pits and tunnels are now so badly caved that they can not be explored and the phosphate beds can not be measured without much additional labor. Most of the old prospects were abandoned because the prospectors failed to discover coal of good grade and the real nature of the beds apparently remained unknown.

No detailed work has been done in this field on which to base an estimate of the quantity of phosphate rock available. It is apparent, however, from the reconnaissance examination that in the Snake River Range, Bighole Mountains, and Teton Range, particularly along the east side of Teton Basin, a large amount of phosphate is present. Every acre underlain by a flat bed of phosphate 4 feet thick would yield approximately 14,000 tons, and where the phosphate bed is steeply tilted the amount beneath an acre is much greater.

The phosphate beds along the southeast side of Teton Basin and in the Bighole Mountains are near the tracks of the Victor branch of the Oregon Short Line Railroad. In the Snake River Range they lie some distance from the Yellowstone branch of the Oregon Short Line, but are readily accessible by wagon roads up the Snake River valley from Rexburg and Rigby, Idaho. The Rigby route is one that offers no unusual difficulties for the construction of a railroad which with a short haul would place the phosphate on the main line of the Oregon Short Line from Butte, Mont., to Salt Lake City, Utah. The Oregon Short Line has made two preliminary surveys from Idaho Falls, Idaho, up Snake River to Jackson, Wyo., the first in 1905 and the second in 1912. As soon as this road is built it will bring railroad shipping facilities in the Snake River Range within a few miles of the phosphate deposits, as the road will extend along the west base of the range approximately parallel to the phosphate outcrop. The position of the alinement survey is shown on the map (Pl. I) by a single black line along Snake River from Jackson, Wyo., to the west boundary of the area, west of Prospect, Idaho. The completion of this railroad would materially alter the economic conditions of this part of Idaho and Wyoming, increase the agricultural population in Jackson Hole and Snake River and Salt River valleys, tend to make the district more popular than ever as the best hunting ground for big game in the United States, and greatly stimulate mining activities in the phosphate and coal fields.

UTILIZATION OF ROCK PHOSPHATE.

The mining of rock phosphate in eastern Idaho, Utah, and western Wyoming is controlled almost entirely by the concerns that manufacture and sell phosphate fertilizer, so that quotations of market value of the raw rock at the mines are not readily available and do not represent competitive values. All the rock phosphate now shipped from eastern Idaho or western Wyoming is sent to the Pacific coast, where it is used in the manufacture of fertilizers. In this treatment the rock is finely ground and combined with sulphuric acid in nearly equal parts by weight, forming acid tricalcium phosphate. This material when dried and pulverized constitutes the substance sold as superphosphate.

The principal use of the phosphate rock is to fertilize farm lands that are deficient in phosphorus, one of the three essential mineral plant foods which are not ordinarily present in agricultural soils in excess of the needs of growing plants, the other two being potash and nitrates. The need for phosphate will undoubtedly become more apparent with the deterioration of western grain lands. Furthermore, some of the virgin lands may be deficient in this material and would be improved by its application. Although, as principally used in fertilizers, phosphate is converted into the more readily soluble forms, recent experiments indicate that if the crushed rock is applied directly to the soil the phosphorus is gradually made available to the plants, and it is likely that in this form rock phosphate may find one of its most important future applications.

The chief obstacle to the development of the western phosphate industry at present is the high cost of transporting the bulky products and the lack of markets sufficiently near to warrant the exploitation of the deposits. Much of the agricultural land of the Western States is relatively new, and as its original phosphates have not been exhausted by past crops it is less in need of fertilizers, except where the virgin lands are deficient in phosphorus, than the older farm lands in thickly settled communities of the East and South.

The use of fertilizers is said to be fast increasing on the Pacific coast, also in other parts of the West where intensive farming is practiced. There will henceforth probably be a more rapidly growing market for fertilizer products in both the middle West and the far West, and it is to this territory that the western phosphate producer must look primarily for markets.

ANALYSES OF PHOSPHATE ROCK.

A number of samples representing phosphate rock in place and phosphate float were collected along the outcrop in the Caribou, Salt River, Snake River, Bighole, Wyoming, and Teton mountains, and these have been analyzed in the laboratory of the United States Geological Survey with the results set forth below. Many of these samples represent small pieces of rock from a part of the phosphate bed that is but poorly exposed. Although the material is the best at hand, the samples and analyses can hardly be considered truly indicative of the character of the material in the undisturbed bed, which may give much better results. The localities from which samples of rock phosphate or float were obtained are indicated on Plate I by letters A to J, beginning in the southeastern part of the area. Localities A to F are in Wyoming, and G to J in Idaho.

Analyses of phosphate rock from eastern Idaho and western Wyoming.

Wyoming.

Letter on Plate I.	Location.			Section of phosphate bed sampled.	Ft.	in.	Analysis of phosphate sample.				Remarks.
	T.	R.	Sec.				Al_2O_3.	Fe_2O_3.	P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	
	32 N.	118 W.	25, NW. ¼	Float sample from upper bed						67.4	Thickness of both beds unknown. Upper bed 40 feet above lower. Section on Afton Creek.
A	38 N.	118 W.	3, NW. ¼	Rock ledge	3–4		5.41	0.46	32.8	71.6	Indian Creek section (fig. 5, p. 47).
B	39 N.	116 W.	32, NE. ¼	Brown rock	2	6				21.2	Section on Snake River measured by Eliot Blackwelder, and separate layers sampled. See complete section, pp. 51–52.
				Soft black rock	9					68.5	
				Oolitic rock	5	10				20	
				Hard brown rock	2	5				66.3	
				Soft black rock	3					20–30	
				Soft shaly rock	4	6				29.6	
				Black granular rock	12					20.3	
				Soft granular rock	12					31.2	
C	41 N.	116 W.	33, NW. ¼	Float sample						61.3	Collected by Eliot Blackwelder in 1912 near Jackson, Wyo.
D	41 N.	118 W.	15, SE. ¼	Oolitic sample						52.2	Phosphate bed here appears to be several feet thick. Coal Creek section.
				Dump sample						20.8	General sample of all the material on the prospect dump.
E	41 N.	118 W.	16, NE. ¼	Supposed coal					Trace.		Shows evidence of organic matter. Trail Creek section.

F	43 N.	118 W.	29, N. ½	Float fragment					78.3	Collected by Eliot Blackwelder.
					Ft. in.					
				Gray oolitic rock	8				68.2	Darby Creek section. Measured and sampled by Eliot Blackwelder in 1912. See section, pp. 57-58.
				Gray oolitic rock	9				72.3	
				Fine oolitic rock	6				71.8	
				Black phosphate	1 6				72.5	
				Gray oolitic rock	8				76.4	
				Idaho.						
G	2 N.	45 E.	25	Supposed coal prospect		4.17	1.54	12.69	27.8	Palisade Creek. Unknown portion of bed. Prospected for coal. Shows evidence of organic matter.
H	2 N.	45 E.	16	Rock ledge	*Ft. in.* 3 6	.58	.61	31.69	69.4	Section on South Rainy Creek, exposure of rock-phosphate bed (fig. 3, p. 43).
I	2 N.	45 E.	8	Supposed coal prospects		3.91	1.44	17.08	37.4	North Fork of Rainy Creek. Unknown portion of bed. Prospected for coal. Shows evidence of organic matter.
J	3 N.	44 E.	28	Rock ledge	*Ft. in.* 4	1.79	.71	27.51	60.11	Section on Pine Creek (fig. 2, p. 42). Exposure of phosphate. No detailed section measured.
				Phosphate shale				16.8	36.8	Collected by Blackwelder in 1910. No section measured.
	1 S.	45 E.	32	Rock ledge	*Ft. in.* 4			28.93	63.36	Sample from 4-foot bed on north side of Black Creek; collected for desk use.

The analyses show considerable variation but they indicate the presence of some high-grade ore that contains approximately the equivalent of 70 per cent of tricalcium phosphate. The average of ore now being shipped from southeastern Idaho, northeastern Utah, and southwestern Wyoming runs about 70 per cent tricalcium or bone phosphate. Experience has shown, however, that weathered phosphate rocks are commonly enriched 3 to 5 per cent more, owing to the leaching of the more soluble lime carbonate, and that a deposit may therefore show a higher value at or near the surface than at greater depths. On the other hand, it should be remembered that commonly in a region like that examined only the harder and more siliceous fragments are found along the outcrop or exposed at the surface, and these may represent a lower value than the richer layers of the main phosphate bed.

COAL.

GENERAL OCCURRENCE.

Beds of coal have been found at several localities in this field and are at present being mined in a few places. Most of the coal beds that have been exploited are of Cretaceous age, belong to the Frontier formation, and represent the northward extension of the coal beds which are so extensively developed and on which active mines are located in southern Lincoln County, Wyo., from Cumberland northward to Fontanelle Creek, several miles north of Frontier. Beds of coal are also found in rocks stratigraphically below the Frontier formation, which probably represent the Bear River coals that have been prospected in the vicinity of Sage, Wyo., but on which no active mines are located. The coal beds in this formation consist of coaly shale with some impure, irregular lenses of coal, ranging in thickness from a few inches to 4 or 5 feet. As a rule the coaly portions of these beds are not persistent but wedge in and out. Lumps of usable coal may be obtained here and there, but commercial development on a large scale is impracticable. The coal beds are widely distributed but may readily be separated on structural features into three areas—the Willow Creek and Grays Lake area, the Pine Creek and Greys River area, and the Teton Basin and McDougal area. No special effort was made to map the coal beds in any of these areas or to collect sufficient data upon which to base a classification. Wherever possible notes on their occurrence were made, and in a general way the distribution of the coal-bearing rocks was ascertained while the phosphate beds were being examined, although the two for the most part do not occur near together. As a result of this preliminary reconnaissance examination 979,901 acres, included in an outstanding coal withdrawal in eastern Idaho, was restored to entry on May 19, 1913.

WILLOW CREEK AND GRAYS LAKE AREA.

All the coal beds prospected in the Caribou Range occur along the west side of the range from Willow Creek, east of Idaho Falls, southeastward to the headwaters of Blackfoot River, southeast of Grays Lake. The beds are believed to be part of the Bear River formation

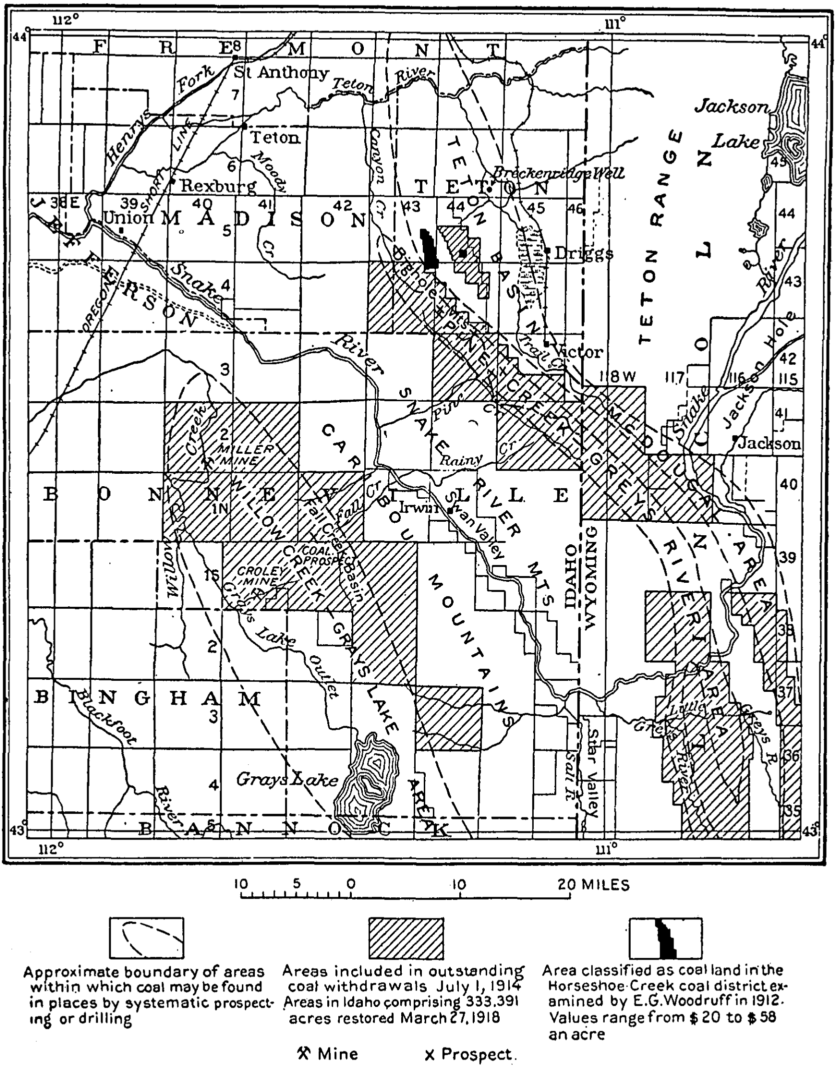


FIGURE 7.—Map showing outstanding coal withdrawals July 1, 1914, and the approximate location of the coal-bearing formations in the area examined in eastern Idaho and western Wyoming.

but may in places also include a part of the Frontier formation, although the writer has little information regarding their age or distribution. So far as known the coal has been opened at only three localities, information regarding which is given in the table of sections of coal beds in western Wyoming and eastern Idaho, on pages 73–75. Development work at one of these localities, the Miller mine, was begun in 1900 by the Canyon Coal Mining Development Co., which constructed a shaft, tunnel, road, buildings, and machinery at a cost reported at $6,000. In 1910 Mr. Miller, one of the members of the former company, filed application to purchase and was permitted to make payment of $1,600 for 160 acres of coal land at $10 an acre. Work was continued, and a shaft 40 feet deep and engine house and hoisting machinery were installed at an additional cost of about $2,500. The amount of coal that has been mined at this place was not determined. The area in which coal beds may be encountered by further prospecting is indicated in figure 7. For a further description of the geology of this part of Idaho the reader is referred to the paper by Schultz and Richards[1] already cited.

PINE CREEK AND GREYS RIVER AREA.

The coal in the belt extending from Pine Creek to Greys River occurs either in the Bear River or the Frontier formation and lies in the area between the Absaroka and Darby faults. The structure is complex, and the coal-bearing beds may not be present everywhere from the north to the south end of the belt. The Frontier formation east of the Absaroka fault has been traced from the vicinity of Hilliard, central Uinta County, Wyo., northward to Snake River, a distance of approximately 150 miles, and throughout this area the formation is coal bearing.[2]

The same belt of Cretaceous rock is believed to extend northward to the headwaters of Pine Creek, near the north end of the Snake River Range. The Frontier formation is known to be present between the Salt River and Wyoming ranges on Greys River and Little Greys River, south of Snake River, and may be present between the Bighole and Snake River ranges on the divide in Tps. 2 and 3 N., Rs. 44 and 45 E., where the road crosses from Teton Basin to Swan Valley. The coal beds on the divide strike N. 60° W. and dip 70° SW. They resemble more nearly the Bear River than the Frontier coals. At this locality several prospects have been opened and conssderable development work completed. It is reported that in T. 3 N., R. 44 E., $4,000 has been expended on improvements, in opening drifts and doing assessment work, in an effort to open the coal.

In the southern part of Lincoln County, Wyo., the Frontier formation and other Cretaceous rocks lie in a synclinal basin immediately east of the Absaroka fault. In places farther north the west limb of the syncline has been cut out by the overthrust fault. In the vicin-

[1] U. S. Geol. Survey Bull. 530, pp. 267-284, 1912.
[2] U .S. Geol. Survey Bull. 316, pp. 212-241, 1907; Bull. 543, 1914.

ity of Snake River (see fig. 6, p. 48) the structure of the beds between the Darby and Absaroka faults is much more complex, and the Frontier formation occurs in a syncline immediately west of the Wyoming Range and reappears on the west side of a parallel anticline east of the Absaroka fault. Similar structural conditions may be expected between the Absaroka and Darby faults north of Snake River. Some of the evidence obtained indicates that the anticline and syncline observed on Greys, Little Greys, and Snake rivers extends throughout much of the northern area. However, until more detailed work has been done and the coal beds have been traced along the strike of the formation, it is impossible to state how much of the area between the two thrust faults is underlain by coal. The beds are in places closely folded and broken by faults. The available coal data obtained in this part of the field, although meager, are given in the table of coal sections on pages 73–75.

TETON BASIN AND McDOUGAL AREA.

The coal observed in the area extending from Teton Basin, Idaho, to McDougal Gap, Wyo., occurs for the most part in the Frontier formation in a narrow belt along the east side of the Bighole Mountains and Wyoming Range. The only locality at which coals of Evanston age may possibly be found in this area is in the vicinity of Snake River south of Cheney, Wyo., but as the structure and age of the beds in that locality have not been definitely determined the coal may be part of the Frontier or some other coal-bearing formation. Most of the coal beds in this area lie immediately east of the Darby fault and terminate against it. In places, however, the coal beds lie in a syncline some distance east of the fault, which in these places is in contact with pre-Cretaceous sediments. The structure is somewhat complex east of the Darby fault, just as it is west of the fault, and the coal beds may not be present everywhere along the east side of the mountains. The Frontier formation has been traced from the north end of Thompson Plateau, in T. 29 N., R. 115 W., northwestward to Snake River in T. 39 N., R. 116 W., a distance of 60 miles. Throughout the greater part of this distance the formation dips toward the fault, which brings the coal beds into contact with the older beds west of it. In the vicinity of Snake River the structure is more complex and the coal beds lie some distance east of the fault, as explained above. A more complete description of the geology and the occurrence of coal in the belt south of Snake River is given in Survey Bulletins 316 and 543.

The same belt of Cretaceous rocks occurs northwest of Snake River and is believed to be coal bearing where present throughout most of the area to the north end of the Bighole Mountains. Near the south end of the Teton Mountains the rocks are closely folded, and most if not all of the Cretaceous beds have been removed by erosion. In that part of the range between station 39 and Trail Creek, or in the west flank of the Teton Mountains, the coal-bearing beds are believed to be absent, but farther northwest they occur in the same relation to the Bighole Mountains and the Darby fault as in the vicinity of Snake River and southward in western Wyoming along the east side of the Wyoming Range.

On the east bank of Snake River near the center of sec. 34, T. 40 N., R. 116 W., coal-bearing beds that are apparently conformable below the Almy formation were observed. Whether these coals belong to the Evanston, Frontier, or Bear River formation was not determined. They were examined hurriedly at only one locality, where they afford obscure plant remains that, together with their lithology and relation to the overlying conglomerates, afford a basis for their tentative correlation with the Evanston formation. If there is an unconformity between these beds and the gray calcareous conglomerate of the overlying Almy formation it is not apparent at this locality.

At the north end of the Bighole Mountains, along the east side of the thrust fault, the Frontier coals occur in at least two areas and probably underlie a large part of the valley lands of Teton Basin. Coals in this part of the Teton Basin coal field have been found and prospected from Mahogany Creek, in T. 4 N., R. 44 E., northward to Packsaddle Creek, in T. 5 N., R. 43 E., where the coal-bearing formation passes beneath the Tertiary lavas. The westernmost coal area in this part of the field lies immediately east of the Darby fault. The coal beds strike N. 40° W. and dip 45°–60° SW. The coal-bearing series has been traced for a distance of approximately 4 miles, and the continuity of the coals throughout this district has been demonstrated. Immediately east of this coal area is a prominent ridge of Jurassic beds that separates the coal-bearing rocks on the west from those on the east, as shown in figure 8. East of the Jurassic ridge only a few exposures of the coal-bearing beds were observed, and at only three localities have the beds been prospected. Coal has not been found exposed anywhere in the main part of Teton Basin east of the foothills of the Bighole Mountains, as the underlying rocks are within a short distance concealed by the Tertiary lava and Quaternary alluvium.

From a general study of the mountains surrounding the basin it is apparent that the structure is synclinal and that the basin may consist in part of Cretaceous strata that contain coal, concealed by the lava and alluvium. It has been reported that in a well drilled in 1903 on the old Breckenridge ranch, in the NE. ¼ SE. ¼ sec. 35, T. 6 N., R. 44 E., west of Haden, a 10-foot bed of coal was penetrated at a depth of 650 feet. A sample of the coal obtained from the drill cutting yielded

48.7 per cent fixed carbon.[1] The coal, if present as reported, probably belongs to the Frontier formation and is the same as that observed in western Wyoming and along the east flank of the Bighole Mountains. If the structure in Teton Basin is correctly interpreted and the beds lie in a broad, open syncline, coal similar to that observed along the Bighole Mountains probably occurs at comparatively shallow depths ranging from a few feet along the west margin of the syncline to approximately 3,000 feet along the lowest part of the syncline. The axis of the concealed syncline probably lies in the vicinity of Victor, Idaho, and extends northward approximately halfway between Canyon Creek and the Victor branch of the Oregon Short Line Railroad to the north margin of the area mapped in T. 7 N., R. 43 E. The supposed structure of this part of Teton Basin is shown in the accompanying section (fig. 8). The syncline above referred to lies immediately northeast of the anticline observed at the south end of the Teton Mountains, in the vicinity of station 43, and in the Bighole Mountains east of the Darby fault, in the vicinity of station 41. Whether these two anticlines represent the same anticlinal fold was not determined, as the beds were not traced from one locality to the other. If the Frontier beds were eroded along the axis of the syncline before the lava was forced over the surface no commercial coal will be found in the synclinal basin. The presence or absence of coal in this part of the field can best be determined by means of the drill.

Coal beds of Frontier age occur immediately east of the Jurassic ridge

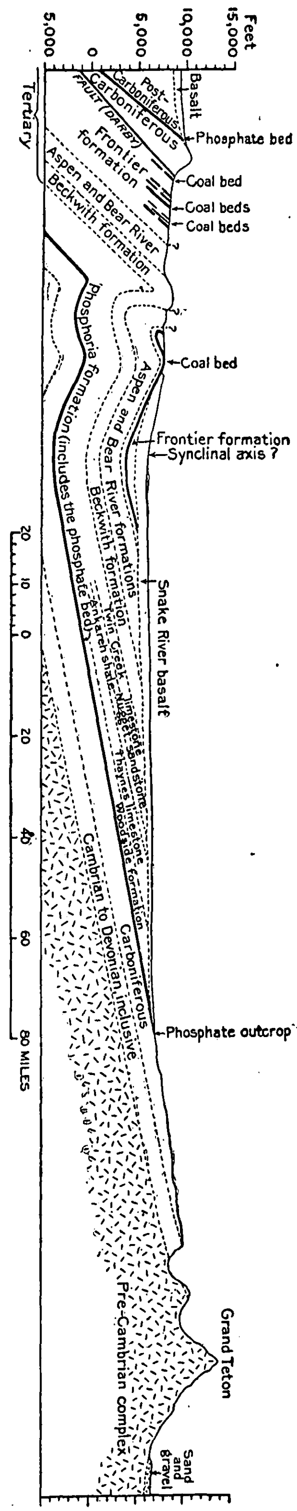


FIGURE 8.—Section from the north end of the Bighole Mountains, Idaho, across Teton Basin to the Teton Mountains in the vicinity of Grand Teton, Wyo.

[1] Bell, R. N., Idaho State Insp. Mines Rept., 1903, p. 65.

that crosses secs. 19, 30, and 32, T. 5 N., R. 44 E., in a southeasterly direction. Very little is known regarding the distribution of the coals in this locality, as the sedimentary beds are largely covered by Tertiary lavas. On Horseshoe Creek, between lava-covered hills to the north and débris-strewn hills to the south, the beds have been opened at three localities in the SW. ¼ sec. 28. One of the prospects lies north of the creek and another immediately south of it; the third is south of the wagon road that leads from Teton Basin to the Boise and Brown Bear mines. These prospects were the first to be opened in this vicinity. The property is locally known as the old Flann mine and was first opened in 1882 by Henry Flann, a prominent merchant of Rexburg, Idaho, who abandoned the enterprise before developing it into a producing mine. Later the Idaho Fuel Co. further prospected the coal at this locality and opened three drifts. Two beds of coal occur, ranging in thickness from 20 inches to 4 feet. They strike north and dip 10° W. The drift on the south side of the creek, according to report, was driven for 150 feet, and the one on the north for 100 feet. The prospect opening south of the road was driven down the dip. The extent of the coal encountered and the length of the slope were not determined, as the opening is now caved and the coal in part concealed. A thickness of 2 feet of coal was measured above the caved débris. The size of the dumps at these three prospects indicates that considerable work has been done and some coal taken out.

Similar coals are reported to occur farther south, on Mahogany Creek, but these were not visited. About half a mile east of the prospects on Horseshoe Creek lava caps the hills and forms the mountain slopes on both sides of the creek and covers gentle slopes out into Teton Basin. The area in which coal-bearing rocks are exposed is therefore small and confined chiefly to the valley of Horseshoe Creek and its tributaries, although the same beds may crop out on Mahogany Creek and other small streams toward the southeast.

West of the Jurassic ridge coal has been traced from Horseshoe Creek north to Packsaddle Creek. This area, examined by the writer in a cursory way, was studied in more detail in the fall of 1912 by E. G. Woodruff,[1] who spent several days in mapping the coal beds in this vicinity, collecting data so that the coal lands could be appraised and classified. Some of the data on this area here presented were obtained from him. Woodruff found that only a small part of the area contains coal beds which the miners in the field considered thick enough to work in 1912. The coal lands in this part of the field range in value from $20 to $58 an acre. The coal beds crop out along the slope near the foot of the escarpment and dip toward the over-

[1] Woodruff, E. G., The Horseshoe Creek district of the Teton Basin coal field, Fremont County, Idaho: U. S. Geol. Survey Bull. 541, pp. 379-388, 1914.

thrust fault. The beds are cut also by numerous small faults, as is well shown in the Brown Bear mine, where seven faults cut the coal bed in a distance of approximately 1,200 feet. The rock and coal outcrops are badly caved, so that it is difficult to trace them for any considerable distance without the aid of a drill. The coal prospects that have been opened on Horseshoe and Packsaddle creeks, according to report, disclose seven separate coal beds that range in thickness from 2 to 10 feet and are comparatively free from bony coal or waste material. The most extensive development work has been done on the Brown Bear, Boise, Horseshoe, and Packsaddle mines, although considerable prospecting has been done at several other places in the district. These four properties cover the strike of the coal-bearing rocks for a distance of 3 miles, throughout which the continuity of the coals has been fairly well proved. Only the Brown Bear and Boise were producing mines at the time of the writer's visit. Mining and prospecting had been carried on, however, at other places in the field, but the work had apparently been discontinued.

The Brown Bear mine is the chief producer in the field and has been operated since 1904. The mine consists of a horizontal rock tunnel, 325 feet long from the surface to the coal bed, and two horizontal entries, one to the north 950 feet long and the other to the south 250 feet long, both following the strike of the bed, which is N. 40° W. The bed ranges in thickness from 4 feet 5 inches at the north end to 5 feet 3 inches at the south end and dips 40°–50° SW. The mine is worked by the room and pillar method. The rooms are turned up the pitch along a drift or entry at 60-foot intervals, center to center. The center of the room is driven ahead, and the coal is undermined with a pick along a softer layer, 1 inch to 16 inches thick, that lies on the floor of the mine, and blasted down with a back hole and a small charge of black powder. The broken coal slides down a chute at the narrow outlet of the room and is hauled to the entry. The mine is well ventilated by raises to the surface and cross courses through the pillars. A good deal of the coal produced in 1912 was sold at the mine as mine run for $2.50 a ton. Some of it was screened and sold for $3.50, and the slack was sold for 50 cents a ton.

The Boise mine was not selling coal at the time of the writer's examination, but arrangements had been made to mine a few tons daily for use in Teton Basin. The coal bed here is 38 inches thick, is entirely free from bone and waste of any kind, and lies between beds of shale. The mine consists of a rock tunnel 150 feet long, that crosscuts the strata, and an entry 200 feet along the bed from the point where the tunnel enters the coal. The mine was opened in 1904 and has been supplying some excellent coal at irregular intervals since that time.

The Horseshoe mine is near the southeast corner of the NW. ¼ NW. ¼ sec. 6, T. 4 N., R. 44 E., and was opened by the Horseshoe Coal Co. prior to 1902. The bed is approximately 10 feet thick and dips 66° SW. The small dump at the mouth of the mine indicates the extent of the workings and represents the waste taken out in mining. The development work consists of a single entry, 500 feet long, extending north into the side of a steep hill where the bed was exposed. Although badly caved the mine can be entered for a distance of 200 feet or more, and good sections of the bed measured. Several thousand tons of coal was extracted and sold at the mine for $2 a ton. The mine was poorly developed, and this in part furnishes an explanation why the work at this locality soon became dangerous and the prospect was abandoned.

The Packsaddle mine lies in the NE. ¼ sec. 26 and the NW. ¼ sec. 25, T. 5 N., R. 43 E. There are two openings at this place, both of which are badly caved, so that it was impossible to determine the relations of the workings in the lower one to those in the upper one. The dump at the mouth of the mine contains some good coal, and the general improvements, including a Victor standard scale, mine buildings, miners' cabin, and coal road, indicate that considerable work was done here and some coal mined. No coal is exposed in the mouth of the lower entry, the small sticks or poles used in timbering are broken, and the entrance to the coal bed is cut off by caved ground, so that no data as to the character or thickness of the coal were obtained. Some coal has also been taken from the upper drift. This entry likewise was badly caved, but coal exposed at its mouth indicates that the bed is more than 2 feet 3 inches thick—no doubt much more, as the caved material conceals the lower part of the bed. The entire bed is reported to be 9 feet thick and to terminate against a fault. The mine was opened in 1906, and work was continued for a year or more before the property was abandoned. On the ridge just south of the abandoned mine the gray sandstone strikes N. 20° W. and dips 50° SW.

SECTIONS OF THE COAL BEDS.

The location of the prospect pits which were examined during this survey or from which reports have been obtained and the sections of coal beds exposed in them are given in the following table. The mines, prospect pits, surface diggings, and coal exposures are numbered consecutively from 1 to 37, beginning at the southeast corner of the field, and the numbers agree with those used on Plate I. Nos. 1 to 10 are in Wyoming and Nos. 11 to 37 in Idaho.

Sections of coal beds in eastern Idaho and western Wyoming.

Wyoming.

No. on Plate I.	Location.			Formation.	Section of coal.	Ft.	in.	Analysis. No.	Remarks.
	T.	R.	Sec.						
1	36 N.	117 W.	18, SW. ¼	Frontier	Coal	3		4323	Surface prospect west of Greys River. Coal slightly weathered.
2	37 N.	116 W.	1, SW. ¼ SE. ¼	Frontier	Coal	3	6	4302	Surface prospect; lower 15 inches dirty; upper 2 feet clean. Bed lies about 40 feet lower than No. 3.
3	37 N.	116 W.	1, SW. ¼ SE. ¼	Frontier	Coal	3	9	4301	Bed has a 7-inch parting and lies about 40 feet above No. 2. Surface prospect.
4	37 N.	116 W.	1, NW. ¼ SE. ¼	Frontier	Coal	4	6	....	Surface prospect.
5	37 N.	116 W.	1, NW. ¼ SE. ¼	Frontier	Coal	7	6	....	Two prospects opened by G. B. Budd.
6	37 N.	116 W.	1, W. ½ SE. ¼	Frontier	Coal	20		....	Surface prospect.
7	37 N.	116 W.	1, SW. ¼ SE. ¼	Frontier	Coal and bone Clay, white Coal[a] Clay Coal.	1 1 3 1	 6	4003	Surface prospect. Coal slightly weathered.
8	38 N.	116 W.	11, NW. ¼ SW. ¼	Frontier	Coal	2	3	....	Surface prospect. Coal dips 5° E.
9	39 N.	116 W.	27, SW. ¼ SW. ¼	Frontier (?)	Coal (?).			....	Coal indications reported on General Land Office township plat.
10	40 N.	116 W.	34, SW. ¼ NE. ¼	(?)	Shale. Coal Clay.	 1	 5	4002	Probably same as Evanston (?) coal beds surface prospect along bank of Snake River. Coal badly weathered.

[a] Bed sampled.

Sections of coal beds in eastern Idaho and western Wyoming—Continued.

Idaho.

No. on Plate I.	Location.			Formation.	Section of coal.			Analysis. No.	Remarks.
	T.	R.	Sec.						
11	1 S.	40 E.	24, SE. ¼ SE. ¼	Bear River or Frontier (?).	Coal (?).			....	Croley mine. General Land Office plat shows coal tunnel.
12	1 N.	42 E.	29	Bear River or Frontier (?).	Coal		4?	....	Fall Creek basin. Prospect in which good grade of coal occurs.
13	2 N.	40 E.	34, SE. ¼ NE. ¼; NE. ¼ SE. ¼; 35, SW. ¼ NW. ¼; NW. ¼ SW. ¼.	Bear River or Frontier (?).	Coal	3	6?	....	John Miller mine. Shaft 40 feet deep. Some coal mined.
14	3 N.	44 E.	24	Bear River or Frontier.	Coal	2	4	....	Surface prospect. Opened by Pine Creek Coal Co., June 26, 1912.
15	3 N.	45 E.	19	Bear River or Frontier.	Coal	4		....	Surface prospect. Opened by Pine Creek Coal Co. Reported 4-foot bed.
16	4 N.	44 E.	35, SE. ¼ SW. ¼	(?)	Coal (?).			....	Coal indications reported on General Land Office township plat, 1910.
17	4 N.	44 E.	19, SW. ¼ SW. ¼	(?)	Coal (?).			....	Coal indications reported on General Land Office township plat, 1910.
18	4 N.	43 E.	19, SW. ¼	(?)	Coal (?).			....	Coal indications reported on General Land Office township plat, 1910.
19	4 N.	43 E.	2, SE. ¼ SW. ¼	(?)	Coal (?).			....	Coal indications reported on General Land Office township plat, 1910.
20	5 N.	44 E.	28, SW. ¼	Frontier	Coal	2+		....	Entry driven down dip. Entrance caved.
21	5 N.	44 E.	28, SW. ¼	Frontier	Coal	{1 to 4	8	}	Prospect entry reported to be driven 100 feet.
22	5 N.	44 E.	28, SW. ¼	Frontier	Coal	{1 to 4	8	}	Prospect entry reported to be driven 150 feet.
23	5 N.	44 E.	32, NW. ¼	(?)	Reported coal blossom	4		....	Prospect pit 10 feet deep. Not in Frontier formation.

24	4 N.	44 E.	6, NW. ¼	Frontier	Coal [a] Sandstone Coal [a] Coal, bony Coal, crushed [a]	1 3 1 3	11 10 4 9 3	15116	Horseshoe mine. Single entry 500 feet long. Section measured 200 feet from mouth of entry.
25	4 N.	44 E.	6, NW. ¼ NW. ¼	Frontier	Coal	2	2		Abandoned entry 50 feet long. Same bed as No. 26.
26	4 N.	43 E.	1, SE. ¼ NE. ¼	Frontier	Coal	3			Surface prospect. Opened on same bed as No. 25.
27	4 N.	43 E.	1, SE. ¼ NW. ¼	Frontier	Coal fragments				Small prospect in slump material contains fragments of coal
28	5 N.	44 E.	31, SW. ¼ SW. ¼	Frontier	Shale Coal Shale Coal Shale	 3 1 4 	2 8 10 3 4		Surface prospect. Probably same bed as that opened at Nos. 24 and 29.
29	5 N.	43 E.	25, SE. ¼ SE. ¼	Frontier	Coal	5±		15115	Brown Bear mine. Horizontal rock tunnel 325 feet; 1,200-foot drift.
30	5 N.	43 E.	25, SE. ¼ SW. ¼	Frontier	Coal	3	2		Boise mine. Rock tunnel 150 feet. Coal entry 200 feet.
31	5 N.	43 E.	25, NW. ¼ NW. ¼	Frontier	Coal on dump; bed not seen.				Lower opening at Packsaddle mine. Entry caved.
32	5 N.	43 E.	26, NE. ¼ NE. ¼	Frontier	Shale Coal	? 2	 3		Upper opening at Packsaddle mine. Entry caved.
33	5 N.	43 E.	24, SE. ¼ SE. ¼	Frontier	Coal	3	4		Surface prospect.
34	5 N.	43 E.	24, SE. ¼ SE. ¼	Frontier	Coal	1	1		Surface prospect.
35	5 N.	43 E.	24, SE. ¼ SE. ¼	Frontier	Coal Coal, bony Coal		8 3 8		Surface prospect.
36	5 N.	43 E.	24, SE. ¼ SE. ¼	Frontier	Coal	3	4		Abandoned entry. Bed appears to be badly crushed.
37	5 N.	43 E.	24, SW. ¼ SW. ¼	Frontier	Coal Shale Coal	1 1	7 10 1		Prospect pit 6 feet deep.

[a] Bed sampled.

CHARACTER OF THE COAL.

The coal is bituminous and rather free from impurities. According to report some of it has been coked with fair success. However, the tests made in an agate mortar gave noncoking results. Most of the coal is badly shattered, as would be expected in a region where so much faulting has taken place. As a result of this shattered condition a large percentage of the coal in mining comes out fine. Even the larger pieces are so broken that they do not readily stand handling, and much of it is necessarily marketed as slack. The present market for the coal produced in this field is largely confined to the settlers who live within hauling distance of the mine. The coal is extensively used by the farmers to run their steam engines during the plowing, seeding, and harvesting seasons, and by the thrasher and header crews. In 1912 it sold at the mine for $3.50 a ton for lump coal, $2.50 for run-of-mine, $2 for the small sizes, and 50 cents for slack. A good deal of the lump coal is hauled to St. Anthony and other railroad settlements, where it generally commands $1 a ton more than the coal that is shipped in from the Mississippi Valley region, as it is apparently much better, has a higher heating value, and contains less ash.

Samples of coal from the Frontier formation have been collected for analysis from several localities in this region and the results are given in the following table. The sampling was done according to the regulations of the United States Geological Survey, which require that the sampled face must be cleared of weathered coal, powder stains, and surface impurities. A channel is then cut across the bed to obtain the sample, and at the same time large partings or lumps of impurities are rejected. The sample is collected on a sampling cloth, then broken up to pass through a ½-inch mesh sieve, mixed thoroughly, quartered, and mixed again, and finally the sample is placed in a sealed can to be forwarded to the chemical laboratory.

Analyses of coal samples from Frontier formation of eastern Idaho and western Wyoming.

[First five analyses made at United States Geological Survey fuel-testing laboratory; F. M. Stanton, chemist in charge. Last two analyses made at the Pittsburgh laboratory of the Bureau of Mines; A. C. Fieldner, chemist in charge.]

No. on Plate I.	Location.	Laboratory No.	Air-drying loss.	Form of analysis.[a]	Chemical analyses. Proximate. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heat value. Calories.	British thermal units.
1	Greys River, SW. ¼ sec. 18, T. 36 N., R. 117 W.	4323	3.6	A	7.8	36.3	54.3	1.62	0.27	5.35	70.34	1.43	20.99	7,095	12,770
				B	4.4	37.6	56.3	1.68	.28	5.14	72.97	1.48	18.45	7,360	13,240
				C	....	39.3	58.9	1.76	.29	4.86	76.29	1.55	15.25	7,695	13,850
				D	....	40.0	60.0	....	.30	4.95	77.66	1.58	15.51	7,830	14,100
2	Wyoming Range, SE. ¼ sec. 1, T. 37 N., R. 116 W.	4302	2.3	A	6.8	33.4	53.6	6.18	.62	4.81	69.45	1.52	17.42	6,750	12,160
				B	4.6	34.2	54.9	6.33	.64	4.65	71.09	1.55	15.74	6,910	12,440
				C	....	35.9	57.5	6.63	.67	4.35	74.52	1.63	12.20	7,245	13,040
				D	....	38.4	61.6	....	.71	4.65	79.82	1.75	13.07	7,760	13,970
3	Wyoming Range, SE. ¼ sec. 1, T. 37 N., R. 116 W.	4301	6.0	A	10.7	30.7	54.3	4.28	.78	5.34	66.18	1.45	21.97	6,355	11,440
				B	5.0	32.6	57.8	4.55	.82	4.98	70.41	1.54	17.70	6,765	12,170
				C	....	34.3	60.9	4.79	.87	4.65	74.11	1.62	13.96	7,120	12,810
				D	....	36.1	63.9	....	.92	4.88	77.84	1.71	14.65	7,475	13,460
7	Wyoming Range, SE. ¼ sec. 1, T. 37 N., R. 116 W.	4003	4.6	A	10.1	32.9	53.3	3.70	.38	5.27	66.94	1.29	22.42	6,465	11,640
				B	5.7	34.5	55.9	3.88	.40	4.98	70.17	1.35	19.22	6,775	12,200
				C	....	36.6	59.3	4.11	.42	4.61	74.43	1.43	15.00	7,185	12,940
				D	....	38.2	61.8	....	.44	4.81	77.62	1.50	15.63	7,495	13,490
10	Snake River, NE. ¼ sec. 34, T. 40 N., R. 116 W.	4002	7.9	A	18.3	23.2	34.4	24.08	.30	4.12	42.03	.57	28.90	3,695	6,650
				B	11.2	25.2	37.4	26.16	.33	3.51	45.63	.62	23.75	4,010	7,220
				C	....	28.3	42.2	29.48	.37	3.55	51.42	.70	15.48	4,520	8,130
				D	....	40.2	59.8	....	.52	3.62	72.92	.99	21.95	6,405	11,530
29	Brown Bear mine, SE. ¼ sec. 25, T. 5 N., R. 43 E.	15115	8.3	A	11.5	37.2	47.0	4.30	.54	5.94	68.09	1.40	19.73	6,720	12,090
				B	3.4	40.6	51.3	4.69	.59	5.47	74.25	1.53	13.47	7,325	13,190
				C	....	42.0	53.1	4.86	.61	5.27	76.89	1.58	10.79	7,590	13,660
				D	....	44.2	55.8	....	.64	5.54	80.82	1.66	11.34	7,975	14,360
24	Horseshoe mine, NW. ¼ sec. 6, T. 4 N., R. 44 E.	15116	4.3	A	7.7	39.7	50.4	2.2	.38	....	....	....	....	7,155	12,880
				B	3.6	41.5	52.6	2.3	.40	....	....	....	....	7,475	13,460
				C	....	43.0	54.6	2.4	.41	....	....	....	....	7,755	13,960
				D	....	44.1	55.9	....	.42	....	....	....	....	7,945	14,300

[a] A, Coal as obtained in the mine; B, coal dried at a temperature of 30° to 35° C.; C, moisture-free coal; D, coal free from moisture and ash.

Sample 4323 was collected from a shallow prospect on the west side of Greys River a few miles south of the mouth of Little Greys River, in what is known as the Greys River coal field. The sample was taken a few feet below the surface and represents a coal of good quality, which nevertheless may have been partly altered by weathering.

Sample 4302 was collected from a prospect pit in the Wyoming Range that had been exposed to the atmosphere for more than a year, and as a result the coal had no doubt been considerably altered. The lower part of the 3 feet 6 inch coal bed is composed largely of bone, but the upper 2 feet, which was sampled, is a good clean coal. The sample was taken 40 feet stratigraphically below sample 4301.

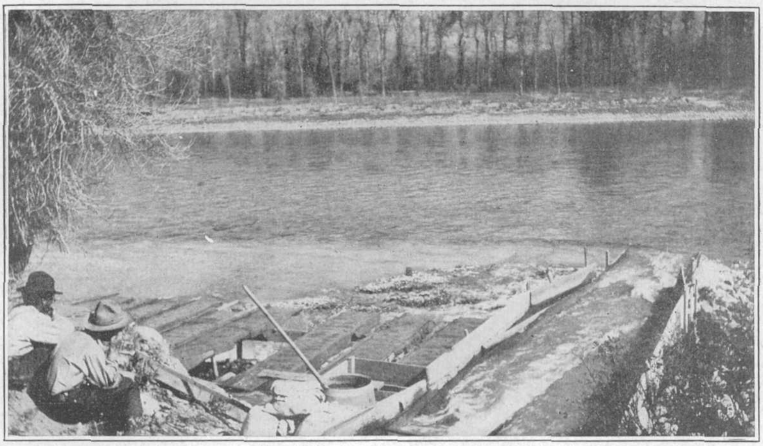
Sample 4301, from a shallow prospect in the Wyoming Range, represents a coal bed 3 feet 9 inches thick which was moderately weathered. The sample as collected does not include a 7-inch parting that is present in the bed at this point. The coal bed lies approximately 40 feet stratigraphically above sample 4302, and the coal is of the same quality.

Sample 4003 was collected from a surface prospect in the Wyoming Range, in which the coal bed clearly shows the effects of weathering. The 3-foot bench of coal that lies near the middle of the measured section (see table, p. 77) is the only part of the bed included in the sample.

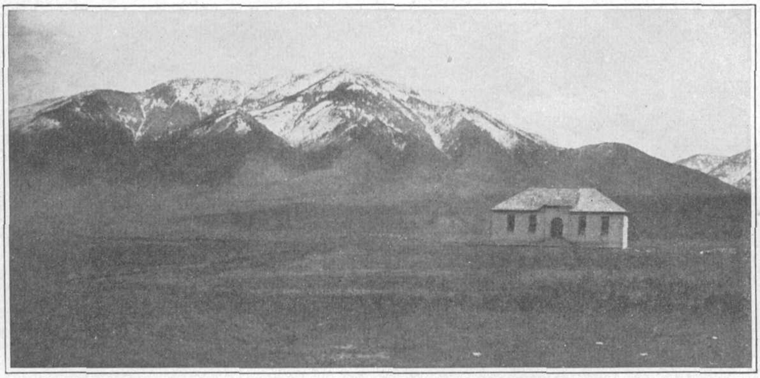
Sample 4002 was taken from a cut in a coal bank on Snake River, where 1 foot 5 inches of coal was exposed. It represents a surface outcrop in which the coal was so greatly altered by weathering that the sample does not fairly represent the quality of the coal.

Sample 15115, collected by E. G. Woodruff in 1912 from the Brown Bear mine, in the Bighole Mountains, was taken from the end of the north entry, 950 feet from the portal, where mining had been done recently and where the coal was unweathered. This sample is believed to represent the coal in its normal condition as taken from the mine.

Sample 15116, collected by E. G. Woodruff in October, 1912, from the abandoned Horseshoe mine in the Bighole Mountains, was moderately weathered. It was taken at a point 200 feet from the portal from a face that had been exposed for more than a year. The surface of the bed was cleaned until apparently fresh coal was obtained, but it seemed probable that some change which had not altered the physical appearance of the coal may have taken place, because the mine is in a fairly dry climate and had remained open to the unrestricted circulation of the air for a long time. Nevertheless, the sample gave a higher calorific value than the unweathered coal from the Brown Bear mine. This result is probably to be explained in

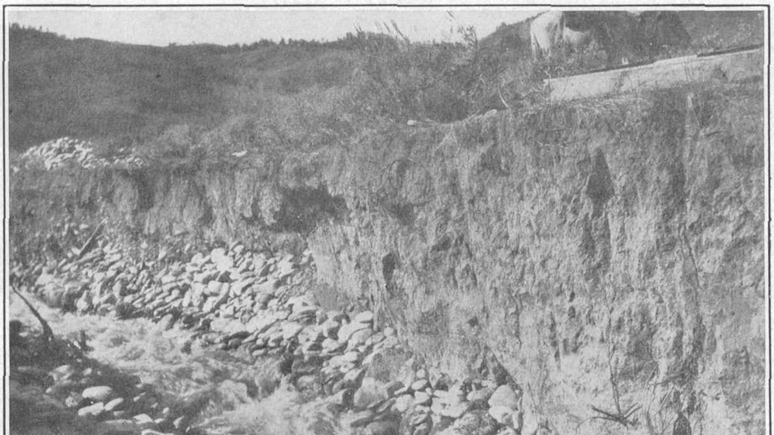


A. BURLAP TABLES ARRANGED FOR SAVING FINE GOLD NEAR THE MOUTH OF McCOY CREEK ON SNAKE RIVER, IDAHO.



B. PUBLIC SCHOOL BUILDING AT IRWIN, IDAHO, CONSTRUCTED OF RHYOLITE BLOCKS QUARRIED IN THE VICINITY.

Baldy Mountain, a part of the Snake River Range, in the background.



C. AURIFEROUS GRAVELS AND ALLUVIUM CARRYING FINE FLAKES OF GOLD.

Note large pebbles along sluicing ditch from which finer material has been washed.

part by the smaller amount of ash in the Horseshoe sample and the fact that very little alteration had taken place in the coal bed during its exposure to the circulation of the air.

GOLD AND OTHER MINERALS.

Placer mining has been done along Snake River and its tributaries since 1860. The gold on these streams occurs in the gravels that form terraces along the streams and in the deposits of boulders, gravel, and sand that fill the channels or form the beds of the streams. A small placer working was observed on Snake River just below the mouth of Wolf Creek. At the time of visit the work had been discontinued for the winter, and no details regarding the gravels were obtained. The deposits along Snake River are more fully described in Survey Bulletins 315, 530, and 543. There are no metalliferous mines in this region, and only a little desultory prospecting is carried on. Most of it has been done in pre-Cambrian rocks in the Teton Mountains, where a little lead, silver, and copper have been reported. Structural material, lime, cement, clay, and road dressing may be obtained in many localities. Excellent building stone is obtained from the Tertiary rhyolite, which has been extensively used for public buildings and private dwellings in certain parts of the area. The rock is soft enough to be easily quarried and firm enough to be dressed to any desired shape. (See Pl. II.)

Reports of occurrences of oil in eastern Idaho have been received from time to time. If the anticline along the west side of Teton Basin has a closed structure, there may be oil in this part of the field. An oil well was drilled in 1903 some distance east of the synclinal axis that passes through the basin. The following statement regarding this well was furnished in the fall of 1906 by Mr. Spencer Clawson, 131 South Main Street, Salt Lake City, Utah:

> The president of the Fremont County Oil, Gas & Coal Co., W. E. McDonald, a native of the oil section of eastern Indiana and later of Florence, Colo., visited the Teton Valley in 1900 with a view, it is said, of purchasing a ranch; he negotiated with me for 800 acres of land at the crossing of Teton River near Hayden and made a payment upon it; later he called and stated that there were very strong surface indications of the presence of oil on the land, his long residence in the Indiana and Colorado oil fields qualifying him to judge.
>
> I paid but little attention to the man or his enterprises, and he returned to his former home in Colorado, organized the Fremont County Oil, Gas & Coal Co., and vigorously prosecuted the work of boring for oil on the ranch of David Breckenridge, which joined the lands Mr. McDonald had purchased from me on either side; his difficulties were great, as it was about 30 miles to Rexburg or St. Anthony, the nearest railroad point, and transportation of engine, boiler, pipe, etc., was both difficult and expensive; but he was a man of perseverance, though of moderate resources, and he expended the capital of the company, some $6,000, before he found anything that indicated values. His enthusiasm was unbounded, and through great effort he procured more money and continued his work.

In the fall of 1903 his 8-inch drill struck a seam of coal at a depth of about 650 feet, and he told me that he had driven 10 feet into the seam without reaching the footwall; he then withdrew his drills in order to sink the 10-inch pipe casing.

The supply of pipe being exhausted, he suspended operations and returned to Colorado for more material and money. On his way east he stopped at Salt Lake City and urged me to join him in his efforts to develop the coal and oil, which he asserted would be struck at greater depth.

As he failed to make the second payment on the purchase price of the land, I was unable to render him the financial aid he desired. I never saw Mr. McDonald again, but subsequently learned that he was taken ill in Florence, Colo., and after a brief illness died in a hospital there.

The enterprise was abandoned by his administrators; his creditors removed the engine, boiler, drills, etc., leaving only the derrick and the 10-inch pipe casing in the well. The land was sold by the sheriff and was purchased by me for the interests that formerly owned it.

Another source of oil that promises to be of some value occurs at the same horizon as the phosphate deposits in Montana, Idaho, and Wyoming—that is, in the Phosphoria formation. The phosphate on applying heat to the rock is not driven off by distillation but remains in the ash. Evidence of petroleum or bituminous compounds in rocks of this age has been observed over wide areas by the writer, who has worked on the phosphate deposits, but few, if any, tests have heretofore been made to ascertain the quantity of oil. Small remnants of samples of phosphate rock, E, G, H, I, and X, collected in Idaho and western Wyoming for phosphate determinations, were also tested for oil.

Tests of phosphate rock containing oil in eastern Idaho and western Wyoming.

[Chase Palmer, U. S. Geological Survey, and C. S. Reeve, Office of Public Roads and Rural Engineering, analysts.]

No.	Location.	Laboratory No. (Office of Public Roads and Rural Engineering.)	Phosphorus pentoxide (P_2O_5).	Tricalcium phosphate ($Ca_3(PO_4)_2$).	Specific gravity.	Petroleum.		
						Dry distillation (gallons per ton).	Carbon tetrachloride extraction.	Carbon disulphide extraction (per cent).
E....	Trail Creek, Wyo., NE. ¼ sec. 16, T. 41 N., R. 118 W.	12781	Trace.	Trace.	1.93	A little oil[a]	Little......	0.34
G....	Palisade Creek, Idaho, sec. 25, T. 2 N., R. 45 E.	12782	12.69	27.8	2.33	Little oil distillate.[a]	Very little...	.79
H....	South Fork of Raney Creek, Idaho, sec. 16, T. 2 N., R. 45 E.	12783	31.69	69.4	2.24	A little oil[a]	.....do......	.98
I.....	North Fork of Raney Creek, Idaho, sec. 8, T. 2 N., R. 45 E.	12784	17.08	37.4	2.64	.....do[a].....	.....do......	1.19
X....	Young's ranch, southwest of Lander, Wyo., sec. 8, T. 31 N., R. 99 W.	12785	24.3	53.16	2.31	3.17.........	Some........	4.89

[a] Mr. Reeve omitted the dry distillation of these samples because so little material was submitted as to make it practically impossible to obtain results of any value.

The rocks in the region where the samples were obtained have been subjected to extreme pressure and affected by metamorphism, as shown by the faulting and squeezing manifested at many places and by the crystallization of the limestone. A considerable part of the organic matter that was originally in the rock may therefore have undergone partial distillation, a supposition that in turn may account for the relatively small quantity of oil obtained from these rocks. If the rocks in which the small quantities of oil are found have already undergone partial distillation, the question arises, What has become of the distillate? Where the rocks are exposed the oil has undoubtedly escaped, and this may account for the slight yield on extraction from rocks that give off a strong odor of petroleum. Where the rocks are not exposed they may have been a source of supply of petroleum in areas where the structural conditions are favorable to its accumulation. It may therefore be possible that commercial accumulations of oil have been formed in these older Paleozoic rocks. If this should be true, it would open up a new field for exploration in this part of the Rocky Mountain region. Thus far the Lander oil field in Wyoming seems to be the only place where oil has been obtained in commercial quantities from rocks of the same age, though indications of oil at this horizon have been noted at several other places in Wyoming and Utah.

WATER POWER.

This area affords one conspicuously good opportunity for developing large quantities of water power, near the mouth of the Snake River canyon. Throughout the remainder of the area there are numerous localities where small plants can be installed whenever suitable markets are developed. The creeks that flow from the Caribou, Snake River, Salt River, Bighole, Wyoming, and Teton mountains are all permanent, and in their canyons there are many places where dams can be built to advantage and small power of low head developed. There are, however, very few falls of any consequence and only a few localities, as in the canyon of Snake River and in the canyon of North Fork of Teton River, where considerable head may be obtained. Snake River is the only stream in which a large body of water is available.

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