PHOSPHATES.

A GEOLOGIC RECONNAISSANCE IN SOUTHEASTERN IDAHO.

By A. R. Schultz and R. W. Richards.

PURPOSE OF INVESTIGATION.

A reconnaissance examination of the part of southeastern Idaho located between the Wyoming boundary and meridian 112° and between parallels 42° 45′ and 43° 30′ was undertaken in 1911 with the purpose of collecting data for the elimination of nonphosphate lands from the phosphate reserves. After the close of the detailed field work in southeastern Idaho, the writers spent three weeks in the region south of Snake River and north of the areas examined in detail by Gale and Richards [1] in 1909, and by Richards and Mansfield [2] in 1910 and 1911. As a result of this reconnaissance examination 249,049 acres of withdrawn phosphate land has been restored to agricultural entry. The data collected during the examination indicate that not all of the phosphate land was included in the phosphate reserves as originally constituted by the withdrawals of December, 1908, and December, 1909. The old phosphate reserve boundary has been so modified and extended as to include all the known phosphate areas. Figure 32 shows the area examined in 1911 in detail (1911b), as well as the reconnaissance area (1911a), its relation to the areas surveyed in the preceding years (1909 and 1910) and described in Bulletins 430 and 470, and the extent of the phosphate reserve on July 1, 1912. Some of the land in the Caribou Range lying between Tincup and Garden creeks is probably underlain by phosphate beds at depths of less than 5,000 feet. These lands have not yet been included in the phosphate reserve, because it was found to be impossible during the short reconnaissance examination to determine the thickness of the overlying beds and to work out the necessary detailed structure to determine in what places the phos-

[1] Gale, H. S., and Richards, R. W., Bull. U. S. Geol. Survey No. 430, 1910, pp. 457–535.
[2] Richards, R. W., and Mansfield, G. R., Jour. Geology, vol. 20, 1912, pp. 681–709.

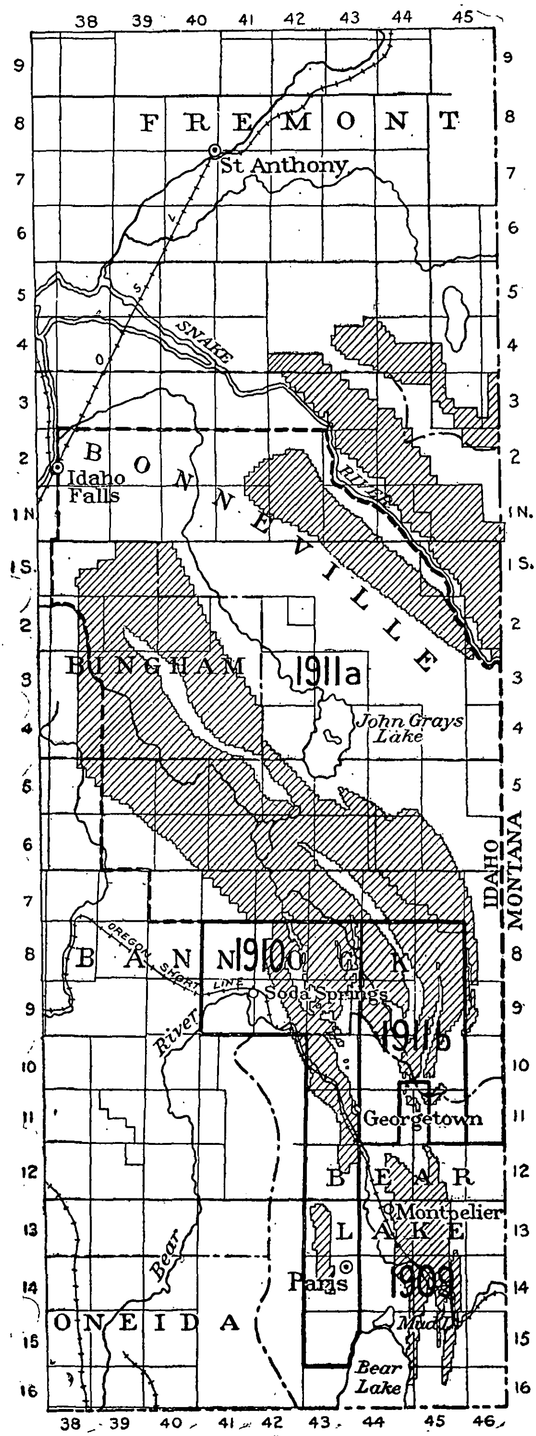


FIGURE 32.—Map showing phosphate reserve in Idaho July 1, 1912. Shaded areas indicate phosphate lands.

phate beds occur at depths less than 5,000 feet.

EARLIER WORK.

The entire area was examined in 1877 by geologists of the Hayden Survey and described in the report for that year. North of the forty-third parallel the examination was conducted by Orestes St. John, and south of that line by A. C. Peale. The geologic reports by these men include a fund of accurate infortion and represent reconnaissance work of high standard. In accuracy and quantity, however, the data given in the text in both reports are well in advance of the geologic maps which accompany them. The errors of the maps are solely responsible for the mislocation of the phosphate reserves as originally constituted, and the main results of the present examination comprise corrections of the errors in these old maps.

GEOGRAPHY.

The area examined includes about 2,000 square miles, all lying within the Snake River basin. The main drainage has a northwesterly trend and is carried by Blackfoot River, John Grays Lake and its outlet, Willow Creek, and Snake River. A large portion of the area is included within the Caribou National Forest and is mainly used for cattle and sheep grazing during the summer. A few ranchers control the greater part of the remainder of the area. Gray and Henry are the main trading points. Post offices are maintained at Alpine, Blowout, Glen, Gray, Henry, Herman, Irwin, Wayan, and Williamsburg.

Two main types of country are included in the area—the lava plains or plateaus and the rugged mountainous areas, which are made up of deformed sedimentary rocks, mainly sandstone and limestone.

GEOLOGY.

STRATIGRAPHY.

GENERALIZED SECTION.

The rocks of the region range in age from Cambrian to Quaternary. The stratigraphic column appears to be fully represented from the basal Carboniferous to the Cretaceous. At or near the end of Cretaceous time there was an interval of erosion which appears to have continued until the late Tertiary, and is indicated by a marked unconformity.

The following generalized section represents the range of conditions as they are now interpreted for this region:

Generalized section of the formations in southeastern Idaho south of Snake River.

	Feet.
Quaternary: Alluvium, travertine, and lava flows	?
Tertiary (Pliocene ?): Marls, marly limestones, and calcareous conglomerates; also lava flows	?
Unconformity.	
Cretaceous:	
Coal-bearing shales and sandstones of the Colorado group	Not determined.
Bear River (?) formation (gray limestones, calcareous sandstones, and dark-colored shales)	Not determined.
Cretaceous and Jurassic: Beckwith formation (red shales, sandstones, and conglomerates, with some limestone)	4,650
Jurassic: Twin Creek limestone (shaly limestone)	1,200–3,500
Jurassic or Triassic: Nugget sandstone (dark-red to white sandstone and quartzite)	1,000–1,900
Triassic:	
Ankareh shale (red shale with intercalated mottled limestone)	200– 670
Thaynes limestone (thin and thick bedded platy limestones)	700–2,000

	Feet.
Triassic—Continued.	
Woodside shale (rusty-brown to olive-green calcareous shales intercalated with muddy limestone lentils)	1,000-1,200
Carboniferous:	
Permian (?): Phosphoria formation[1] (Rex chert member at top over yellow to brown sandstones, brown to black shales, phosphate rock)	75- 627
Pennsylvanian: Wells formation[1] (sandy limestones, calcareous sandstones, and variable quartzites)	1,000-2,400
Mississippian:	
Upper Mississippian limestone (light gray, thick bedded)	1,130+
Madison limestone, lower Mississippian (thin bedded, dark gray to bluish gray)	1,000
Pre-Carboniferous: White quartzite (probably Ordovician) underlain by Cambrian sediments (limestones and quartzites, with beds of shale).	

PRE-CARBONIFEROUS ROCKS.

In the extreme southwestern portion of the area examined a white quartzite was found overthrust upon limestones of Mississippian age. The quartzite is lithologically similar to a quartzite seen in 1910 in vicinity of Soda Springs and there interpreted to be of Ordovician age; it here occurs in a similar discordant relation with Carboniferous rocks. Associated with the Ordovician rocks is a series of limestones and quartzites of Cambrian age, but no attempt was made to map the separate formational units.

CARBONIFEROUS AND TRIASSIC ROCKS.

General features.—In the course of these reconnoissance examinations it has been found advisable, for the small-scale mapping, to group the Madison limestone (lower Mississippian), the upper Mississippian limestone, and the Wells formation (Pennsylvanian) into one map unit, and the later Carboniferous (Permian ?) and Triassic formations into another map unit comprising the Phosphoria formation (Permian ?), the Woodside shale, Thaynes limestone, Ankareh shale (all of Lower Triassic age), and the Nugget sandstone (of either Triassic or early Jurassic age) and corresponding to the "Permo-Carboniferous" of the Fortieth Parallel Survey.

In the southern part of the region examined the area occupied by the Permian (?) and Triassic formations practically represents the extent of the lands which are regarded as containing phosphate in

[1] Richards, R. W., and Mansfield, G. R., Jour. Geology, vol. 20, 1912, pp. 681–709.

such quantities as will eventually be suitable for economic development. The beds overlying the phosphate deposits become much thinner toward the north, and in the northern part of the region the area that contains phosphate deposits susceptible of economic development should probably include the Twin Creek limestone and the basal member of the Beckwith formation.

The general distribution of the Mississippian and Pennsylvanian rocks is shown on the accompanying map. In all the areas rocks of both series outcrop, the Pennsylvanian lying conformably on the Mississippian. Richards and Mansfield have made a detailed study of the Mississippian and Pennsylvanian formations in the area lying immediately to the south and summarize them briefly as follows:

Madison limestone (*lower Mississippian*).—The basal Carboniferous rocks are dark bluish gray, relatively thin bedded cliff-making limestones. The base of the formation is not exposed, but the thickness may amount to 1,000 feet. The fauna collected from these beds includes small 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 the early writers.

Upper Mississippian limestone.—Above the Madison limestone, apparently in conformable succession, though the base is not exposed, occur about 1,130 feet of massive light to dark-gray limestones weathering white to light gray. Locally there is a zone of dark shale about 15 feet thick near the top. In places also there are 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.*

Wells formation (*Pennsylvanian*).—The upper Mississippian limestone is succeeded by about 2,400 feet of sandy limestones, calcareous sandstones, and quartzites of somewhat variable character. At the type locality in Wells Canyon, in T. 10 S., R. 45 E., the formation consists of three portions. The upper and lower portions are predominantly calcareous; the middle is mainly sandy. For these strata the name Wells formation has recently been introduced.[1]

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

[1] Richards, R. W., and Mansfield, G. R., Jour. Geology, vol. 20, 1912, pp. 681–709.

little crescents from the weathered surfaces of the limestone. The most important 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. This member is sparingly fossiliferous or nonfossiliferous. No fossils have yet been found in it.

The lower portion is from 100 to 800 feet thick. The rocks are cherty limestones with interbedded sandstones and are topographically important as cliff makers. They weather to gray or reddish colors. The base of the formation is marked by the Schizophoria horizon (Schizophoria, Marginifera, Composita, *Spirifer rockymontanus*, Bryozoa, etc.).

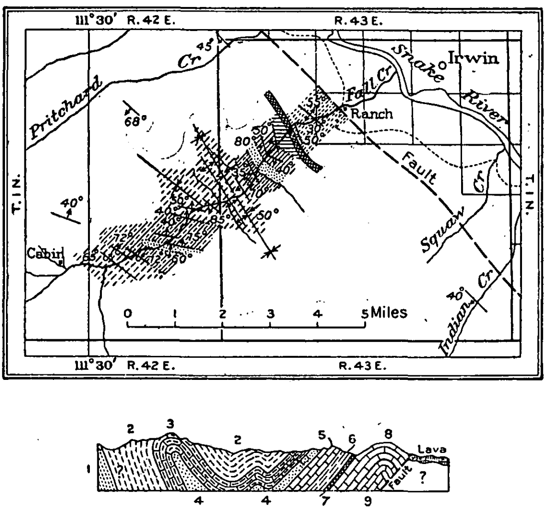


FIGURE 33.—Map and geologic section along Fall Creek, T. 1 N., Rs. 42 and 43 E., Idaho, made from a paced traverse along Fall Creek across part of the Caribou Range. 1, Bear River (?) formation (Cretaceous); 2, Beckwith formation (Cretaceous and Jurassic); 3, Twin Creek limestone (Upper Jurassic); 4, Nugget sandstone (Jurassic or Triassic); 5, Thaynes limestone and Ankareh shale (Lower Triassic); 6, Woodside shale (Lower Triassic); 7, Phosphoria formation (Permian?); 8, Wells formation (Pennsylvanian); 9, Madison limestone (Mississippian).

Phosphoria formation (Permian?).—The Phosphoria formation,[1] which is regarded as of probable Permian age, although it may prove to be Pennsylvanian, overlies the Wells formation conformably, so far as observed in the course of this examination. Its stratigraphic relation to the overlying and underlying formations is shown in the section on Fall Creek (fig. 33).

The Phosphoria formation carries the economically valuable deposits of phosphate of this and the surrounding region.

In the region immediately south of the area covered in the course of this reconnaissance the formation consists of two portions. 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 100 to 240 feet thick. The basal portion of the formation consists of 75

[1] Richards, R. W., and Mansfield, G. R., Jour. Geology, vol. 20, 1912, pp. 681–709.

to 627 feet of alternating brownish shales, brownish sandstones, compact fetid limestones, usually lenticular, with one, two, or three zones bearing beds of high-grade oolitic phosphate rock (containing 70 per cent or more of tricalcium phosphate), which range from 1 to 7 feet in thickness. The natural exposures within the area examined were not good enough to afford detailed sections, but in all the districts where its outcrop is indicated on the map the Phosphoria 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, includes a thin bed of high-grade rock phosphate. It is thought that careful measurements will show that the upper cherty portion of the formation occupies a relatively greater part of the entire section than it does to the south. The areal distribution of this formation is practically represented by the line of phosphate outcrop on Plate VI.

Lower Triassic formations.—The lower Triassic rocks, including the Woodside, Thaynes, and Ankareh formations, occur throughout the Caribou and Blackfoot ranges and were for the most part mapped by the Hayden Survey as part of the "Jura-Trias."

The Woodside shale conformably overlies the Phosphoria formation (Permian?) and is composed mainly of rusty brown to olive-green calcareous shales intercalated with muddy limestone lentils in which fossil shells are so closely matted that their specific characters are rarely discernible. Toward the top limestones become a prominent feature of the formation, and the distinction between this and the overlying Thaynes limestone depends mainly upon the recognition of a cephalopod zone containing Meekoceras at the base of the Thaynes.

The Thaynes limestone includes both thick-bedded and thin-bedded platy limestone. Lithologically it is usually characterized by a bluish-gray color on fresh fracture, but it weathers to light brown or buff and generally to an uneven sandy surface. The Meekoceras zone was noted in the Blackfoot Range at several places in the southeastern part of the field and in sec. 15, T. 4 S., R. 40 E., and secs. 6 and 11 T, 5 S., R. 40 E.

A red-bed series, composed of red shale and intercalated mottled limestone, 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 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 T. 7 S., R. 44 E., and in the canyons of Pritchard and Fall creeks, in T. 1 N., Rs. 42 and 43 E.

Nugget sandstone (Jurassic or Triassic).—The Nugget sandstone overlies the Ankareh shale and consists of massive red sandstone, with white conglomeratic sandstone at the base and top of the formation, in places 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 Nugget sandstone was recognized throughout the area examined, along the Lander trail, Tincup Creek, Fall Creek, Pritchard Creek, Willow Creek near the mouth of John Grays Outlet, and at several places in the Caribou and Blackfoot ranges.

JURASSIC AND CRETACEOUS ROCKS.

For convenience of mapping, the Jurassic and Cretaceous rocks overlying the Nugget sandstone in this region 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 Twin Creek limestone (Upper Jurassic), the Beckwith formation (Jurassic and Cretaceous), the Bear River (?) formation (Upper Cretaceous), and the overlying coal-bearing sandstones and shales of the Colorado group. The later Cretaceous Bear River (?) formation and Colorado group do not occur in the areas studied in detail but were observed throughout the northern part of the region west of the Caribou Range. As all these beds occur at a considerable distance stratigraphically above the phosphate horizon, very little study was made of their distribution.

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 exposed. The Twin Creek becomes thinner toward the north and is approximately 1,200 to 1,500 feet thick on Fall Creek, in the northern part of the Caribou Range. The beds of this formation are exposed in numerous parallel anticlines and synclines throughout the Caribou Range and are readily seen along Tincup and Fall creeks. They are also exposed on Willow Creek at the mouth of John Grays Outlet and in the northern part of the Blackfoot Range. In the northern part of the field they were for the most part mapped by the geologists of the Hayden Survey as a part of their Laramie formation.

The Beckwith formation overlies the Twin Creek limestone and is extensively exposed in the northeastern part of the area examined, particularly north and east of John Grays Lake. Extensive exposures of these beds were also seen in the north end of Little Gray

Ridge, west of John Grays Lake, and in the hills east of Willow Creek. Throughout the Caribou Range the Twin Creek and Beckwith formations are intimately associated with the numerous anticlines and synclines that cause the outcrops of these beds to parallel one another. The exposures of these beds and their relations to one another are indicated in the sections along Fall and Tincup creeks (figs. 33 and 34). The Beckwith formation consists of reddish or chocolate-colored sandstone and shale, associated with whitish to gray sandstone, limestone, and red conglomerates. The upper member consists of calcareous sandstone, red conglomerate, and massive gray limestone. Most of the Beckwith exposures were mapped by the geologists of the Hayden Survey as part of their Laramie formation.

Overlying the Beckwith formation, with apparent conformity, occurs a series of beds whose thickness was not determined. They consist of gray limestones, calcareous sandstones, dark-colored shales, brownish and gray sandstone, and light-drab calcareous deposits. Interbedded with these rocks are calcareous shales and thin beds of coal. The beds are very widely distributed 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. A hurried examination was made of these beds in the Fall Creek basin and 2 miles northeast of Herman (northeast of John 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 by Mr. Schultz from beds that resemble lithologically the Bear River formation of western Wyoming. A similar fossil bed was seen in the Fall Creek basin, where the creek enters the canyon. It is more than likely that St. John correlated these beds, as well as 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 John 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 which were mapped as Laramie by St. John in this general region are greatly desired.

TERTIARY AND QUATERNARY ROCKS.

On Snake River in T. 1 S., R. 45 E., near the mouth of Bear Creek, is a small area of calcareous conglomerates and inferior lithographic limestones which were provisionally mapped as Carboniferous by St. John,[1] but which appear in the light of the detailed studies that have been carried on farther to the south to be Tertiary lake beds, probably of Pliocene age. This correlation is made purely on lithologic and structural grounds.

On the north side of Indian Creek, near the southwest corner of sec. 5, T. 1 N., R. 45 E., at the north end of the Caribou Range, were seen some pinkish-gray clays and greenish, red, and drab sandstone and clays that resemble the beds of the Wasatch formation (Eocene) of western Wyoming and that may represent the northwestward extension of that formation.

The Tertiary beds on Indian Creek are overlain by igneous rocks or basalts similar to those which occur in the canyons farther west. South of Indian Creek the Tertiary sediments strike approximately east and west and dip about 45° S. The greater portion of the igneous rocks represent the southern lobes of the extensive lava flows of the Snake River Plains, which have been referred mainly to the Tertiary by Russell.[2] There are, however, within the area a number of subordinate cones, many of which are broken and shattered and undoubtedly served as the outlet for the later lavas surrounding them. Some of these are of Pleistocene or Recent age if the Tertiary beds are correctly determined as Pliocene.

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 McCoy Creek 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 entrenched itself in the lava beds. The largest of the alluvial bottoms occurs around John Grays Lake and marks in a way the former extent of this large inland lake.

STRUCTURE.

The geologic structure of the area examined is rather complex, and no attempt was made to decipher any of the structure in detail. The tracing of the phosphate beds, however, permitted all the larger units to be worked out with considerable accuracy.

Three main mountain ranges, more or less parallel, extend in a southeast-northwest direction across the area examined. The one

[1] St. John, Orestes, Report on the geological field work of the Teton division: Eleventh Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1879, pp. 325–508.

[2] Russell, I. C., Geology and water resources of the Snake River Plains of Idaho: Bull. U. S. Geol. Survey No. 199, 1902, pp. 1–192.

farthest to the northeast, south of Snake River, is the Caribou Range. Southwest of the Caribou Range lies the Blackfoot Range, and in the southwestern part of the area lies the northwest extension of the Soda Springs Hills.

The Caribou Range is by far the most complex of these ranges and consists of an anticlinorium, as indicated by the accompanying section, along Tincup Creek (fig. 34). 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. Minor faulting was observed at several places in the Caribou Range, but

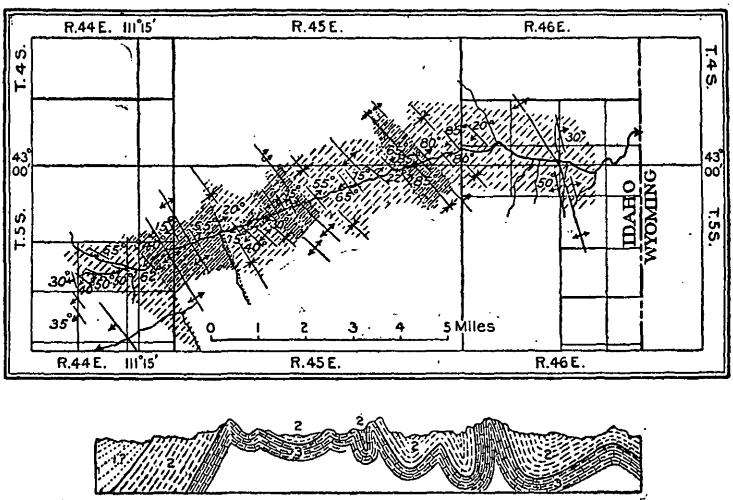


FIGURE 34.—Map and geologic section along Tincup Creek, T. 5 S., Rs. 44, 45, and 46 E., Idaho, made from a paced traverse along Tincup Creek across part of the Caribou Range. 1, Bear River (?) formation; 2, Beckwith formation; 3, Twin Creek limestone.

no attempt was made to study the relation of these faults to one another.

The Blackfoot Range consists chiefly of the crest of an anticline faulted along the northeast and southwest limbs. With these two major faults are associated numerous minor faults and folds that require considerable study before the history of the range can be worked out. It is believed that the fault along the northeast flank of the Blackfoot Range and south of John Grays Lake is the northward extension of the Bannock fault described by Richards and Mansfield.[1]

The Soda Springs Hills consist of a monoclinal uplift having a southeast-northwest trend and dipping toward the southwest. A large fault lies along the northeast side of the range and a similar fault occurs along the southwest. Both of these faults probably

[1] Richards, R. W., and Mansfield, G. R., Jour. Geology, vol. 20, 1912, pp. 681–709.

represent the northwest extension of the faults mapped by Richards and Mansfield[1] in the Soda Springs area and later correlated by them with the Bannock fault.[2]

MINERAL DEPOSITS.

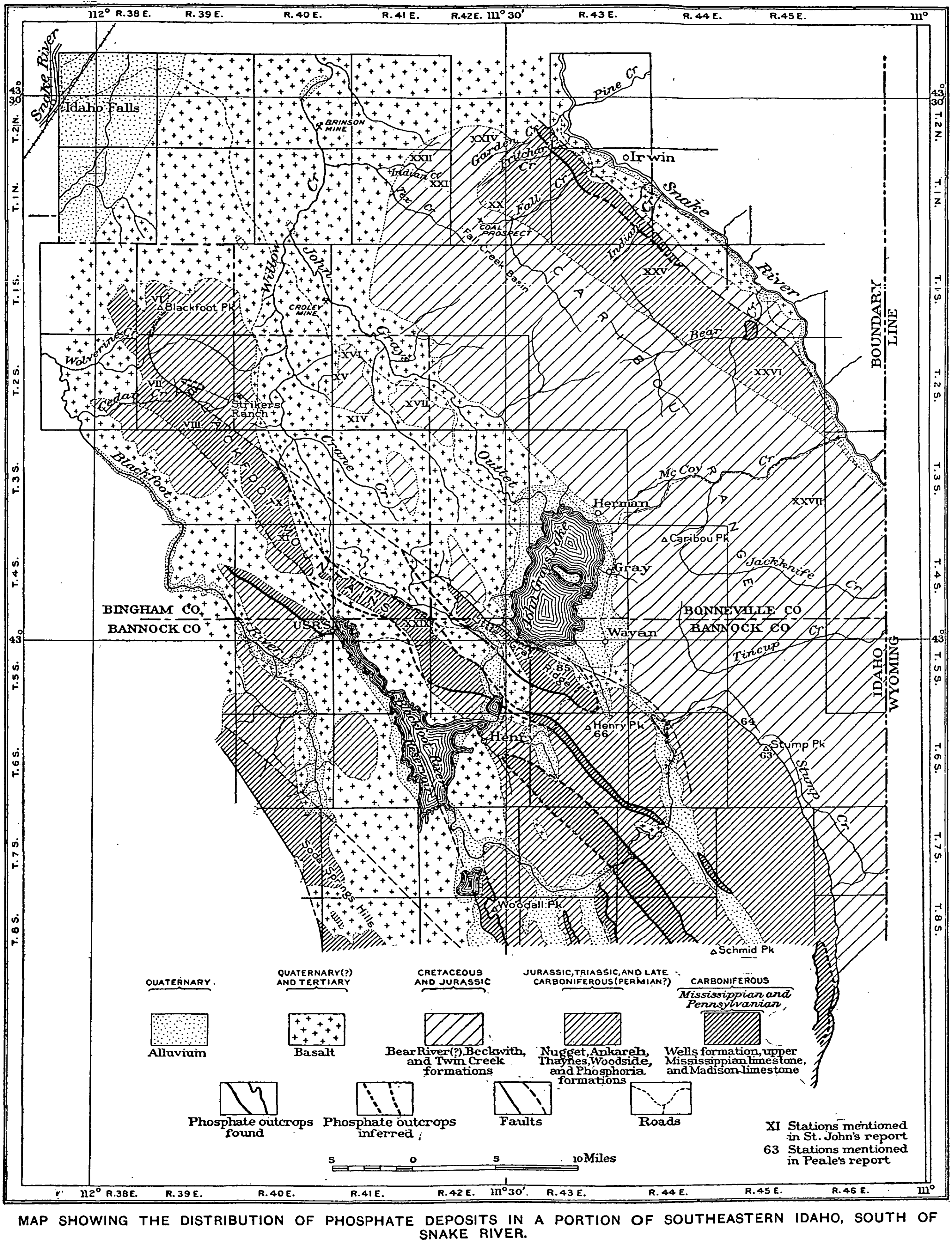
PHOSPHATE.

The distribution of the phosphate beds or Phosphoria formation in the area examined can be best understood by referring to the map (Pl. VI) accompanying this report. The outcrops of the phosphate beds seen in the field are shown by heavy black lines; the inferred outcrops by dotted heavy lines. The distribution of the Phosphoria formation also indicates in a general way the structure of the region. The phosphate beds in this region are very similar to those described by Gale, Richards, and Mansfield in their reports on the areas to the south. No phosphate prospects have been opened in the area examined and no attempt was made in the reconnaissance examination to prospect the phosphate outcrops, and therefore detailed descriptions of the beds are lacking. Samples of float and fragments of rock in place picked up at several places show the presence of high-grade material, and workable beds similar to those prospected farther south are undoubtedly present. Samples of high-grade phosphate rock were found in the following localities:

Diamond Creek, in T. 7 S., R. 44 E.
Lanes Creek, in T. 6 S., R. 44 E.
Several places on the southwest flank of Little Gray Ridge southwest of John Grays Lake, in T. 5 S., R. 43 E.
Southwest and northeast flanks of Little Gray Ridge, or southeast extension of Blackfoot Range, in Tps. 4 to 7 S., Rs. 41 to 44 E.
Northeast flank of Blackfoot Range east and southeast of Blackfoot Peak, in T. 1 S., R. 39 E., and west of Striker's ranch, in T. 2 S., R. 39 E.
T. 4 S., R. 40 E., northwest of the United States Reclamation Service dam on Blackfoot River.
Sage Valley, Tps. 8 and 9 S., R. 46 E.
Caribou Range:
- Several places on Bear Creek.
- Indian Creek.
- Fall Creek.
- Pritchard Creek.
- Garden Creek.

Two sections of the phosphate shales in the areas to the south which have been examined in detail will give an idea of the range of phosphate content which may be expected within this area.

[1] Bull. U. S. Geol. Survey No. 470, 1911, Pls. X, XI.
[2] Jour. Geology, vol. 20, 1912, pp. 681–709.



MAP SHOWING THE DISTRIBUTION OF PHOSPHATE DEPOSITS IN A PORTION OF SOUTHEASTERN IDAHO, SOUTH OF SNAKE RIVER.

The following detailed section of the lower part of the Phosphoria formation was measured and sampled in 1909 under exceptionally favorable conditions of exposure in T. 11 S., R. 44 E., in the Georgetown district.

This section contains the maximum amount of high-grade phosphate rock and probably the highest average phosphoric acid content of all the sections which have been examined in detail in the western phosphate fields. It represents, then, presumably an upper limit of conditions which may be found upon prospecting within the area of this reconnaissance.

Complete section of the phosphate-bearing strata in Georgetown Canyon, Idaho.

Field No. of specimen.		P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	Thickness.
		Per cent.	*Per cent.*	*Ft. in.*
144-A	Shale, calcareous, or muddy limestone, brown, weathering into irregular chip fragments; effervesces vigorously	3.5	7.7	25 6
144-B	Phosphate rock, oolitic, weathering brown or gray; effervesces slightly; lower 1½ inches somewhat cherty	35.8	78.4	6
144-C	Shale, hard, brown, calcareous at the top; effervesces vigorously	Trace.		1
144-D	Phosphate rock, coarsely oolitic, gray; effervesces vigorously	37.6	82.1	2 11
144-E	Shale, brownish, earthy, containing 6 inches of phosphate; effervesces considerably	10.0	21.9	1
144-F	Phosphate rock, including— *Ft. in.* (*a*) Phosphate rock, oolitic, hard, gray, calcareous 7 (*b*) Phosphate rock, medium, gray, oolitic 6 (*c*) Shale, phosphatic, light brown 4 (Sample shows considerable effervescence.)	21.9	48.0	1 5
144-G	Phosphate rock, including— (*a*) Phosphate rock, coarsely oolitic, gray, brittle 1 2 (*b*) Phosphate rock, finely oolitic, brownish gray 4 (*c*) Phosphate rock, coarsely oolitic, dark gray 2 (*d*) Phosphate rock, finely oolitic, brownish gray 4 (*e*) Phosphate rock, coarsely oolitic, gray 7 (*f*) Phosphate rock, finely oolitic, thin bedded 3 (*g*) Phosphate rock, coarsely oolitic, gray 1 4 (Sample effervesces slightly.)	33.3	72.7	4 2
144-H	Phosphate rock, including— (*a*) Phosphate rock, medium to finely oolitic, brownish gray 7 (*b*) Shale, phosphatic, brownish, somewhat oolitic 10 (*c*) Phosphate rock, coarsely oolitic 2 (*d*) Phosphate rock, shaly, brown 3	29.3	65.8	1 10
144-I	Phosphate rock, including— (*a*) Phosphate rock, coarsely oolitic, brownish-black streaks 1 1 (*b*) Phosphate rock, shale, brown, thin bedded 5 (*c*) Phosphate rock, coarsely oolitic, crumbly 4 (*d*) Phosphate rock, medium to coarsely oolitic 3 (Sample effervesces considerably.)	84.7	75.8	4 10
144-K	Shale, brownish to black, earthy composition, thin bedded, with a few limestone lenses; effervesces slightly	24.2	53.0	8 9
	Limestone, dark, compact, fetid			1 9
144-L	Shale, brownish to black, earthy; effervesces slightly	11.7	25.6	12
144-M	Shale, including— *Ft. in.* (*a*) Shale, brownish-black, earthy 7 (*b*) Concealed, not included in sample (probably same as *a* and *c*) 4 7 (*c*) Shale, brownish black, earthy 5 5	15.1	33.1	17
144-N	Shale, black, earthy; effervesces slightly	19.9	43.6	12

Complete section of the phosphate-bearing strata in Georgetown Canyon, Idaho—Continued.

Field No. of specimen.		P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	Thickness.
	Ft. in.	*Per cent.*	*Per cent.*	*Ft. in.*
144-O	1. Shale, brownish black, earthy 4 2. Limestone, single stratum (not sampled) 2 3. Shale, brownish black, earthy 4 4. Limestone, single stratum (not sampled) 2	21.2	46.4	12
144-P	Shale, black and dark brown, calcareous, earthy; effervesces considerably	25.8	56.3	6 2
144-Q	Shale, black and dark brown, calcareous, earthy; effervesces considerably	24.6	53.9	12
144-R	Limestone, shaly, brownish gray; effervesces vigorously	17.8	39.0	4 10
	Limestone, single stratum			11
	Limestone ("cap lime"), fine, dark gray, fossiliferous			2 3
144-S	Phosphate rock, main bed prospected, coarse to medium, oolitic, gray; contains two or three minor streaks of shaly material; effervesces slightly	36.8	80.4	6 4
144-T	Shale, brown, earthy; effervesces slightly	3.7	8.1	9
	Limestone, massive, underlying the phosphatic series. Thickness not determined.			
				139 11

Another detailed section of the lower portion of the Phosphoria formation which was measured and sampled about 26 miles north of the locality of the above section will serve to illustrate the leanest conditions to be expected within the area of the reconnaissance. This section contains the minimum amount of high-grade phosphate rock and also the lowest average content of phosphoric acid yet found in the sections measured in the Idaho portion of the phosphate reserve.

Complete section of the phosphate-bearing strata in the SW. ¼ SW. ¼ sec. 7, T. 8 S., R. 44 E. of the Boise meridian, Idaho.

Field No. of specimen.		P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	Thickness.
		Per cent.	*Per cent.*	*Ft. in.*
	Sandstone, white, fine grained, weathers brown			10
R 378-6	Shale, brown, sandy, with limestone lenses			47
	Limestone, grayish black, fine grained, compact, fetid			5
R 378-5	Phosphatic rock, black, coarsely oolitic	26.3	57.4	1
	Limestone, grayish black, fine grained, compact, fetid			6
	Shale, brown, with some oolitic streaks			1
	Limestone, grayish black, fine grained, compact, fetid			1½ 6
	Shale, brown, with some oolitic streaks			1
R 378-4	Phosphate rock, grayish black, medium oolitic	33.5	73.2	6
	Shale, brown, thin-bedded, slightly oolitic			1
R 378-3	Shale, brown, finely oolitic			10
	Shale, brownish black	6.6	14.4	8
	Limestone, gray, fine grained, fetid			2
	Shale, brownish black			4
R 378-2	Phosphatic rock, brownish black, finely to coarsely oolitic	29.4	64.2	1 1
R 378-1a	Phosphate rock, brownish black, shaly	17.2	37.6	1 4
R 378-1	Phosphate rock, brownish black, finely oolitic	27.5	60.1	1 4
				76½ 7

As many of the formations overlying the phosphate beds thin greatly toward the north, and the numerous parallel anticlines in the Caribou Range expose rocks varying in age from Beckwith to Nugget, it is very probable that detailed work will show that phosphate beds underlie at depths less than 5,000 feet much of the area in the Caribou Range not at present included in the phosphate reserve. The same is probably true of much of the territory northeast and southwest of the Blackfoot Range. The general relations of the Phosphoria formation to the underlying and overlying beds in the Caribou Range are shown in the section measured along Pritchard Creek (fig. 35).

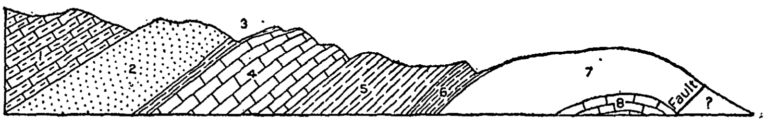


FIGURE 35.—Geologic section on Pritchard Creek, T. 1 N., R. 42 E., Idaho. 1, Twin Creek limestone; 2, Nugget sandstone; 3, Ankareh shale; 4, Thaynes limestone; 5, Woodside shale; 6, Phosphoria formation; 7, Wells formation; 8, Mississippian.

COAL.

Coal has been reported at several localities in the region covered by the reconnaissance examination and is believed to occur in beds of Cretaceous age. A coal prospect was opened several years ago in the Fall Creek basin, approximately in sec. 29, T. 1 N., R. 42 E. According to reports a coal of good grade was encountered, but on account of the distance from settlements no extensive development work was done. Owing to lack of time and the heavy fall of snow during the encampment of the reconnaissance party in this vicinity, it was impossible to make an examination of the coal prospect or of the beds in which the coal occurs.

According to reports, coal was discovered on Willow Creek in sec. 27, T. 2 N., R. 40 E. No examination was made of the beds in which the coal occurs. Ranchers on Willow Creek report that a Mr. Brinson was installing machinery and expected to mine coal during the winter of 1911–12. This prospect is known locally as the Brinson mine.

A somewhat similar occurrence of coal was reported on the west side of John Grays Outlet in sec. 24, T. 1 S., R. 40 E. The plat of this township shows a coal tunnel in the SE. ¼ sec. 24. This prospect has been opened for some time and is locally known as the Croley mine. No examination was made of the beds in this immediate vicinity or of the mine itself, and it is not known whether the reported coal occurs in Cretaceous beds or at some other horizon.

GOLD.

Placer mining has been carried on along Snake River, Tincup Creek, and McCoy Creek and its tributaries since 1860. The gold on these streams occurs in the gravels forming the terraces along the streams and in the deposits of bowlders, gravel, and sand filling the channels or forming the beds of the streams.

The bars of Snake River above the mouth of McCoy Creek are worked occasionally with fair results. No work was being done when the present party passed this part of the river. Placer sluicing on a small scale was being undertaken on the bench gravels at the junction of McCoy Creek and Snake River. The operators had just completed the sluice boxes and burlap tables preparatory for sluicing. Panning tests of the gravels made by the operators are reported to have proved to them that sluicing operations here can be successfully conducted. Sluice boxes and separating tables were seen at several points on Snake River above and below the mouth of McCoy Creek. Owing to lack of time and the fact that the ground was covered with 2 feet of snow when the party passed along Snake River these placer workings were not examined. For a more complete statement regarding the Snake River placers the reader is referred to a report on gold developments in central Uinta County, Wyo., and at other points on Snake River.[1]

Gold placers have been extensively worked near the headwaters of McCoy Creek in the vicinity of Caribou Peak and on the small streams heading on the east, south, and north slopes of the mountain. The largest of the hydraulic placers in the Caribou Peak region occurs on Iowa Gulch, where, it is asserted, a good clean-up is made each year. Hydraulic placer mining on a smaller scale is being done on the headwaters of Tincup Creek and on Ketchen Creek, a tributary of McCoy Creek. In 1911 a Mr. Barnes was engaged in placer work on Ketchen Creek and said that he had made over $1,000 during the months of August and September.

The placer mines on Iowa Gulch were discovered in 1870, and since that time the Caribou district has had a fluctuating population. Although perhaps never remarkable for extraordinary yields in gold, the placers are said to give fair returns from year to year. The operators report that the chief difficulty in extracting the placer gold in the Caribou region is the scantiness of the supply of water, which lasts only about three months after the snow melts.

The auriferous gravels are reported to occur most abundantly in Bilks Gulch, which heads immediately east of the summit of Caribou Peak, and to be distributed all along Bilks Gulch and Iowa Gulch as far as McCoy Creek, a distance of about 5 miles. The gravels consist of abraded volcanic and sedimentary materials largely mixed

[1] Schultz, A. R., Bull. U. S. Geol. Survey No. 315, 1910, pp. 71–88.

with red and maroon shales, sandstones, and conglomerates of the Beckwith formation and with limestone from the Twin Creek or possibly the Thaynes limestone.

It is quite evident that the gold in these stream gravels is derived from the rocks in the vicinity of Caribou Peak. In an attempt to locate the lodes from which the gold is derived the entire region about Caribou Peak has been pretty thoroughly prospected. Tunnels and shallow excavations may be seen in the most extraordinary and unexpected places. Most of the old prospect cabins were abandoned at the time of the writers' visit, but a number of them showed evidence of recent occupancy. As the tops of the mountain slopes were covered by 2 feet of snow at the time it may be that operations were merely suspended for the winter. Numerous shafts and tunnels have been opened on supposed parent lodes, but so far as could be learned none of them have proved successful. It is reported that sufficient gold was found in a vein on the southeast side of Caribou Peak to justify the building of a 40-stamp mill. The mill was constructed and a tramway built between it and the mine. From all indications at the stamp mill very little rock has been handled. Samples were gathered from some of the rock in the tramcar, but no assays have been made of the material. A representative of the company could not be found at the mine or at the mill on the day the writers were at this locality, but prospectors in the vicinity reported that the mill was forced to close for lack of water.

The major part of Caribou Peak is composed of sedimentary Jurassic and Triassic rocks which have been affected by volcanic phenomena of great interest. The sedimentary beds have been metamorphosed to a greater or less extent by intrusive volcanic material and the shales in places seem to have been permeated by mineral vapors or solutions, to which may be attributed the "mineral pockets" found in these sedimentary beds. No attempt was made to work out the relation between the igneous and sedimentary rocks, to ascertain the extent of the influence of the intrusive rocks on the mineral deposits, or to map the productive placer ground or locate any of the veins or prospected lodes in this vicinity. It would require a more extended examination than it was possible to make in order to determine the variable character of the eruptive rocks, their relation to the sedimentary beds, and their influence as a cause for ore deposition.

COPPER.

Copper deposits[1] in the vicinity of Montpelier, Idaho, in the "Red Beds" of Triassic age, have been prospected for some time,

[1] Gale, H. S., Geology of the copper deposits near Montpelier, Bear Lake County, Idaho: Bull. U. S. Geol. Survey No. 430, 1910, pp. 112–121.

but their character or value below the surface has not been revealed. Prospecting of a similar nature has been carried on in the southern and eastern parts of the field on the same beds without apparent success. Some prospecting for copper has also been carried on in the Caribou Mountain region, presumably in beds of Beckwith age. It is reported that considerable quantities of copper were found in some of the prospects in this region, but from the abandoned workings it appears doubtful whether any of them yielded paying returns.

SALT.

Salt deposits in the form of rock salt and brine springs occur in Crow and Stump creek valleys, in the southeastern part of the area covered by the reconnaissance survey. Several of these springs were visited, but no study was made of the salt deposits. All the salt springs visited have been abandoned for years and the old cabins are nearly destroyed. These salt deposits have been described by Breger.[1]

[1] Breger, C. L., The salt resources of the Idaho-Wyoming border, with notes on the geology: Bull. U. S. Geol. Survey No. 430, 1910, pp. 555-569.

SOME FURTHER DISCOVERIES OF ROCK PHOSPHATE IN MONTANA.

By J. T. Pardee.

INTRODUCTION.

High-grade phosphate rock was discovered by the writer in the season of 1911 at three localities in western Montana from which it has not hitherto been reported. These are (1) in the Garnet Range, 6 miles north of Garrison; (2) at Philipsburg, on the south slope of Flagstaff Hill; and (3) half a mile east of Elliston, north of Little Blackfoot River. Rock phosphate was also discovered by R. W. Stone, of the Geological Survey, about 2 miles east of Cardwell (formerly known as Jefferson Island), on the Northern Pacific Railway, at the summit of the cliffy slope rising to the west from Jefferson River. As these discoveries were merely incidental to the prosecution of other geologic work, the deposits were not studied in any great detail nor their limits found. Enough was learned, however, to make certain that they are commercially valuable and of the same type as the phosphate found by Gale[1] near Melrose, Mont., in 1910, and that of the extensive Idaho-Wyoming field.[2]

The first three localities mentioned lie from 60 to 70 miles north and the fourth 40 miles northeast of Melrose; hence these discoveries may be said to extend the limits of the known phosphate field for those distances. (See fig. 36.)

Although the phosphate bed was probably once continuous over much of this general region, it is now found only in more or less detached areas as a result chiefly of deformation, igneous intrusions, and erosion that caused tilting, elevation, and in some places complete removal of the deposit or in other places its burial to a depth beyond that permitting commercial exploitation under present conditions. The location of the areas in which workable phosphate may be

[1] Gale, H. S., Rock phosphate near Melrose, Mont.: Bull. U. S. Geol. Survey No. 470, 1911, pp. 440–451.

[2] Gale, H. S., and Richards, R. W., Phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: Bull. U. S. Geol. Survey No. 430, 1910, pp. 457–535. Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: Bull. U. S. Geol. Survey No. 470, 1911, pp. 371–439.

expected is usually indicated with certainty by the bold outcrops of certain strata of the series that incloses the phosphate-bearing beds.

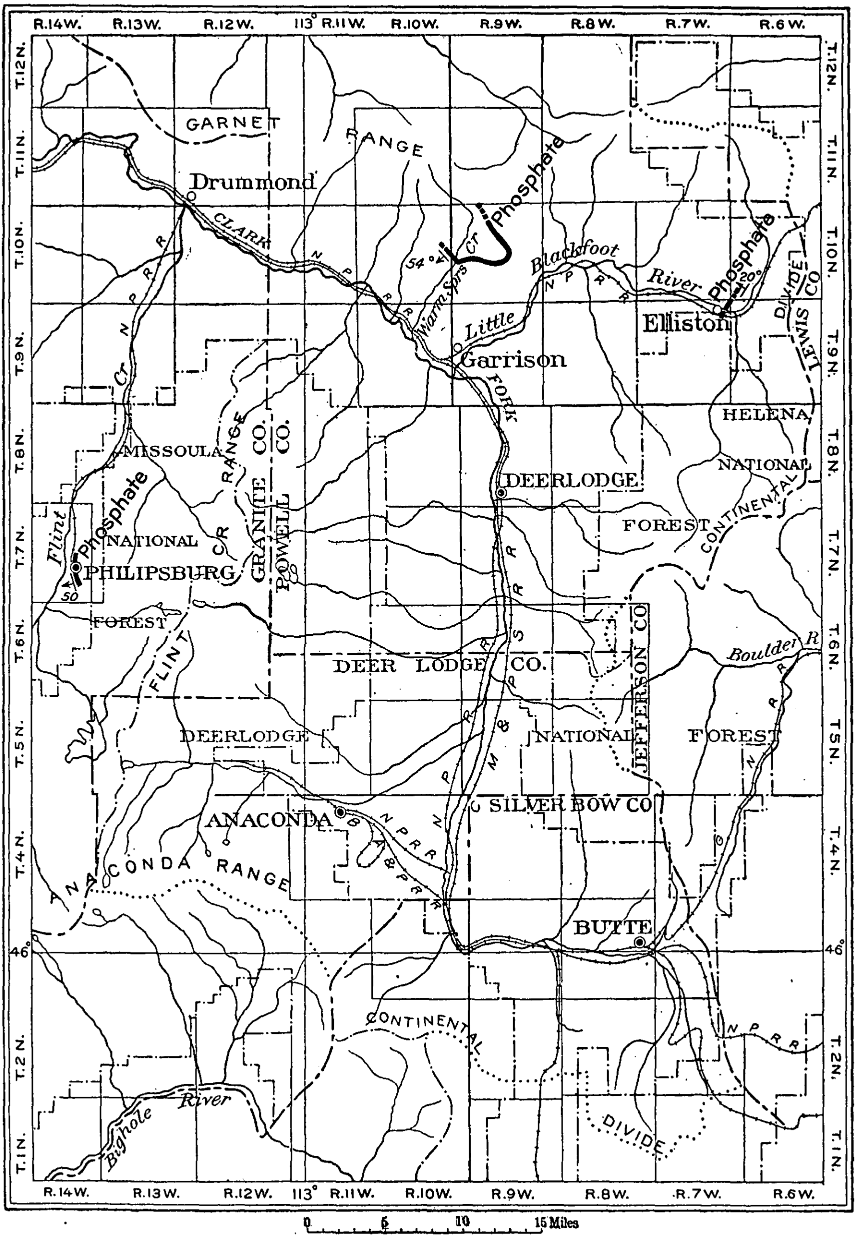


FIGURE 36.—Map showing location of recent discoveries of phosphate rock in Montana.

STRATIGRAPHY AND STRUCTURE.

GENERAL OUTLINE.

The phosphate bed is found in rocks of Carboniferous age. In this region these strata vary somewhat from place to place, but certain of them are persistent, outcrop boldly, and if the upper members are present almost always serve to mark phosphate localities. These key strata are:

1. Beds of chert, usually limy or sandy and variable in thickness, but always closely associated with the phosphate and usually lying just above it.

2. A rather pure and massive quartzite of moderate thickness (a member of the Quadrant formation) that lies beneath the phosphate, separated usually from it by a few feet of limy shale.

3. A thick, massive limestone, known as the Madison limestone, that underlies the quartzite, from which it is separated usually by some red shale that also belongs to the Quadrant formation.

These beds are, as a rule, steeply tilted and their major structural lines trend in general northwest and southeast.

LOCAL DESCRIPTIONS.

Garnet Range area.—The lower part of the following section was measured along the canyon of Warm Spring Creek, north of Garrison, and the upper part in the foothills north of Drummond.

Section showing stratigraphic succession of beds in the Garnet Range area, Mont.

Geologic age.	Formation.	Description.	Thickness (feet).
Lower Cretaceous	Kootenai formation	Gray-blue limestone; abundant small gastropods.	100
		Mostly purple shale; some beds of gray-greenish and buff sandstone.	1,050
Lower Cretaceous(?)	Kootenai(?) formation.	Mostly gray buff-weathering limestone with a thin bed of greenish sandstone.	300
		Flinty gray to dull-colored argillite, obscurely variegated; thin bed of blue limestone at base.	725
Upper Jurassic(?)	Ellis(?) formation	Gray sandstone containing grains of black that give it a peppered appearance; conglomeratic at base.	500
Upper Jurassic	Ellis formation	Buff-weathering shales and limestones; some purplish and greenish layers.	75
Pennsylvanian	Quadrant formation	Chert and quartzite	150
		Phosphate	8
		Pure quartzite, massive, yellow stained	250
		Red shale, locally mottled with cream-colored spots.	300
Mississippian	Madison limestone	Gray to blue limestone; abundant crinoid fragments, etc.	1,000

The main structural feature of this area is an anticline whose axis coincides nearly with the northwest-southeast diagonal of the township (T. 10 N., R. 9 W. Montana principal meridian). This fold ends like an upturned boat keel near the southeast corner of the township. It brings to the surface a series of rocks extending from the upper portion of the Cretaceous on its outer flanks to the Madison limestone at its crest. The outcrops of these beds, including that of the phosphate, trace a series of U-shaped curves open to the northwest. The approximate position of the phosphate outcrop is shown on the map (fig. 36). Dips on this bed vary from 54° in the canyon of Warm Spring Creek to 30° or less at the rounding of the "keel." The anticline is cut transversely by a number of small faults with downthrow to the northwest, the aggregate result of which is to

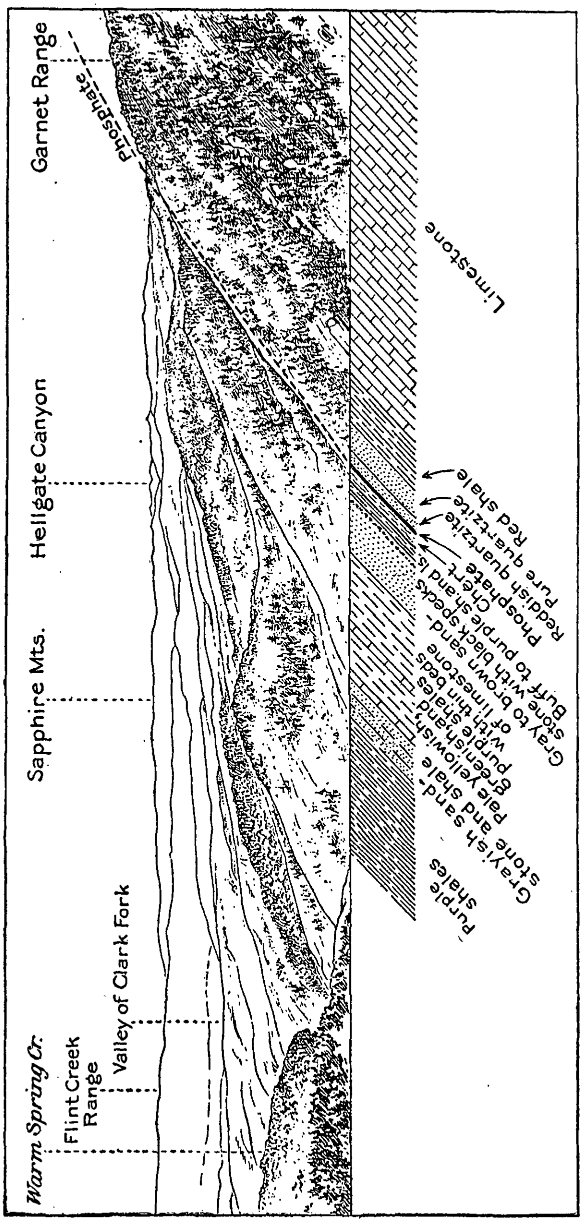


FIGURE 37.—View looking westward across Warm Spring Creek canyon from point 6 miles north of Garrison, Mont., in the western part of T. 10 N., R. 9 W.

narrow the U traced by the phosphate outcrop. Figure 37 is a view looking westward across the canyon of Warm Spring Creek.

Philipsburg.—The following section, shown at Flagstaff Hill, is from measurements by F. C. Calkins,[1] supplemented by the writer.

[1] Unpublished field notes, 1908.

Section at Philipsburg, Mont.

Geologic age.	Formation.	Description.	Thickness (feet).
Upper Jurassic	Ellis formation	Buff-weathering limestone and shale	100
Pennsylvanian	Quadrant formation	Brownish sandstone, quartzitic	120
		Cherty limestone and shale	35
		Phosphate bed	([a])
		Siliceous limestone	35
		Quartzite	220
Mississippian	Madison limestone	Massive white to gray limestone	1,000

[a] Not measured.

The strike here is a little west of north and the dip about 50° W.

Elliston.—The section along Little Blackfoot River at Elliston is as follows:

Section at Elliston.

Geologic age.	Formation.	Description.	Thickness (feet).
Upper Jurassic(?)	Ellis(?) formation	Gray sandstone, cross-bedded, specked with black.	500
Upper Jurassic	Ellis formation	Buff-weathering limestone and shale	75
Pennsylvanian	Quadrant formation	Cherty limestone and quartzite	100
		Phosphate	([a])
		Pure quartzite	200
Mississippian	Madison limestone	Gray to blue limestone, crinoid fragments, etc.	([a])

[a] Not measured.

The average strike of these beds is N. 30° E. and the dip 20° W.

Cardwell.—The section exposed by the steep slope west of Jefferson River [1] is as follows:

Section at Cardwell.

Geologic age.	Formation.	Description.	Thickness. Ft.	Thickness. in.
Upper Jurassic	Ellis formation	Quartzite sandstone	50	
Pennsylvanian	Quadrant formation	Cherty limestone	50	
		Phosphate		6
		Brown shaly limestone	1	
		Phosphate		6
		Brown shaly limestone		8
		Phosphate		6
		Cherty limestone	100	
		Red limestone	150	
Mississippian	Madison limestone	Massive gray limestone	1,000	

These beds dip northwest and across the river to the northeast are cut off by a fault.

THE PHOSPHATE.

Physical character.—Float rock phosphate is but moderately abundant in the vicinity of outcrops of the phosphate bed. The fragments are small, blocks as large as a foot through being rare. Because of a closely spaced parting or fissility parallel to the bedding the phosphate rock readily splits into thin slabs and blocks, and the

[1] Stone, R. W., unpublished field notes, 1911.

absence of large fragments in the surface mantle is thus explained. The float can be most readily distinguished from other rocks by means of its finely oolitic texture, thin bluish-white coating on weathered surfaces, and greater heaviness. The fresh fracture is usually black to brownish.

Thickness and assay value.—The section of the bed exposed by Warm Spring Creek, in sec. 19, T. 10 N., R. 9 W., as determined from a small artificial exposure, is shown below. The analyses were made in the laboratory of the United States Geological Survey by J. G. Fairchild. They show the presence of a bed of high-grade phosphate more than 4 feet thick and some leaner beds.

Section and analyses of phosphate bed in the Garnet Range.

Section.	Analyses.	
	P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.
	Per cent.	*Per cent.*
Cherty sandstone		
Cherty phosphate (3 feet 3 inches)	17.3	37.7
Black phosphate (4 feet 4 inches)	32.4	70.7
Cherty phosphate (3 feet 3 inches)	22.7	49.5
Cherty quartzite		

The formula $Ca_3(PO_4)_2$ represents tricalcium phosphate, or, as it is more commonly termed, "bone phosphate." Material containing 60 per cent or more of tricalcium phosphate is considered high grade. Analyses of float from other portions of this township show a phosphoric acid content equivalent to 57.6 to 79 per cent of bone phosphate. The following analyses of samples from Flagstaff Hill, Philipsburg, from the slope north of Little Blackfoot River just east of Elliston, and from the locality near Cardwell were made by Mr. Fairchild.

Analyses of phosphate rock from western Montana.

Description.	P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.
Cardwell.	*Per cent.*	*Per cent.*
Loose fragment below outcrop; dark in color, finely oolitic	23.9	52.2
Loose fragment below outcrop; light in color, coarsely oolitic	27.6	60.3
Loose fragment below outcrop; dark in color, oolitic texture inconspicuous.	18.0	39.3
Loose fragment below outcrop; light brownish color, coarsely oolitic	24.5	53.6
Philipsburg.		
Float, black phosphate	30.9	67.5
Cherty phosphate from ledge	23.5	51.3
Brownish phosphate from ledge	12.3	26.9
Elliston.		
Float, grayish-black phosphate	30.0	65.5

At neither Philipsburg nor Elliston was the thickness of the bed determined. The outcrops show that in each place it is at least 1 foot and the distribution of float indicates that it is probably more, about the same as in the Garnet Range locality.

Amount, accessibility, and uses.—Although detailed work upon which to base a tonnage estimate has not yet been done, it is apparent from the examination made that in the Garnet Range at least a large amount of phosphate is present. For instance, 14,000 tons would be the yield of an acre underlain by a flat bed of phosphate 4 feet thick. Where the phosphate bed is steeply tilted the amount beneath an acre is much greater.

The phosphate at both Philipsburg and Elliston is near the tracks of the Northern Pacific Railway; that at Cardwell lies near the Chicago, Milwaukee & Puget Sound and Northern Pacific railways; and that north of Garrison is readily accessible by two wagon roads, one going directly north from that place, the other up the valley of Warm Spring Creek. The latter route is one that offers no unusual difficulties for the construction of a railroad that would, with a haul of about 6 miles, place the phosphate on the main line of either the Northern Pacific or the Chicago, Milwaukee & Puget Sound Railway.

The principal use of phosphate rock is to fertilize farm lands that are deficient in phosphorus, one of the three essential mineral plant foods, the other two being potash and nitrates. The need for it will become more apparent with the deterioration of western grain lands. There is also the possibility that some virgin lands may be deficient in this material and would be improved by its application. The rock phosphate is largely used as a fertilizer, both in finely ground form applied to the soil without chemical treatment, when it is known as "floats," and also after treatment with sulphuric acid, which makes the fertilizing constituents of the rock readily available as plant food.

That the phosphate beds may, by thus creating a demand for sulphuric acid, aid in the solution of the smelter smoke problem is suggested by Gale.[1] That great quantities of sulphurous acids are daily escaping at Anaconda is a matter of common knowledge. Nowhere does this fact appear more impressive than from a viewpoint situated on the phosphate outcrop north of Garrison, from which the vast column of smoke pouring out of the smelter stack 35 miles away, at times clouding the whole Deer Lodge Valley, can be plainly seen.

[1] Gale, H. S., Rock phosphate near Melrose, Mont.: Bull. U. S. Geol. Survey No. 470, 1911, pp. 448–450.

SURVEY PUBLICATIONS ON PHOSPHATES AND OTHER MINERAL FERTILIZERS.

The following papers relating to phosphates and other mineral materials used as fertilizers have been published by the United States Geological Survey or by members of its staff. Further references will be found under the head of "Gypsum."

The Government publications, except those to which a price is affixed, may be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The one marked "Exhausted" is not available for distribution but may be seen at the larger libraries of the country.

Blackwelder, Eliot, Phosphate deposits east of Ogden, Utah: Bull. 430, 1910, pp. 536-551.

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MOSES, O. A., The phosphate deposits of South Carolina: Mineral Resources U. S. for 1882, 1883, pp. 504–521. 50c.

ORTON, EDWARD, Gypsum or land plaster in Ohio: Mineral Resources U. S. for 1887, 1888, pp. 596–601. 50c.

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PURDUE, A. H., Developed phosphate deposits of northern Arkansas: Bull. 315, 1907, pp. 463–473. 50c.

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STOSE, G. W., Phosphorus ore at Mount Holly Springs, Pennsylvania: Bull. 315, 1907, 474–483. 50c.

——— Phosphorus: Mineral Resources U. S. for 1906, 1907, pp. 1084–1090. 50c.

STUBBS, W. C., Phosphates of Alabama: Mineral Resources U. S. for 1883-84, 1885, pp. 794–803. 60c.

VAN HORN, F. B., The phosphate deposits of the United States: Bull. 394, 1909, pp. 157–171.

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WEEKS, F. B., and FERRIER, W. F., Phosphate deposits in western United States: Bull. 315, 1907, pp. 449–462. 50c.

WILBER, F. A., Greensand marls in the United States: Mineral Resources U. S. for 1882, 1883, pp. 522–526. 50c.

MINERAL PAINT.

SURVEY PUBLICATIONS ON MINERAL PAINT.

The following publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

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