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GEOGRAPHY, GEOLOGY, AND MINERAL RESOURCES OF THE FORT HALL INDIAN RESERVATION IDAHO

BY

G. R. MANSFIELD

WITH A CHAPTER ON WATER RESOURCES

BY

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ABSTRACT OF REPORT.

Introduction.—The Fort Hall Indian Reservation, which was examined in 1913, includes about 800 square miles in Bingham, Bannock, and Power counties, Idaho, and has been partly included in the Idaho phosphate reserve. Its interesting history is briefly outlined.

Geography.—The reservation contains two mountainous regions with broad valleys and an intervening area of plains bordering Snake River. The maximum difference in elevation is about 4,500 feet, and the broader valleys range from about 4,400 to 5,800 feet in elevation. The drainage is all tributary to Snake River.

The topographic history covers at least parts of three physiographic cycles, which are described. The climate is semiarid, and the rainfall in the broader valleys, which is fairly well distributed throughout the year, is about 13 inches annually. Severe temperatures are exceptional. Favorable areas have somewhat more than three months of security from frost. The vegetation includes some valuable timber. Besides agricultural, grazing, timber, and water resources, there are extensive deposits of high-grade phosphate rock in the eastern part of the reservation and some fine placer gold along Snake River.

Geology.—The stratified rocks of the reservation include representatives of all the great systems, beginning with the Cambrian. Certain Mesozoic formations are more fully subdivided in this report than in previous reports.

Igneous rocks occur in some variety and great abundance. An occurrence of nepheline basalt is noted. There were at least four epochs of volcanic activity, extending from Pliocene into late Pleistocene.

The complex geologic structure is due to both folding and faulting. The folds of the eastern part of the reservation are important because of their relation to the phosphate deposits, which occupy synclines. Both reverse and normal faults are present, but the chief interest is in the reverse faults. A noteworthy fault named the Putnam overthrust is described. Aside from the records of unconformities, at least three epochs of deformation are noted and referred to the post-Cretaceous, the late Pliocene, and the end of the early Pleistocene.

The geologic history is sketched.

Geology of individual townships.—Some townships that are believed to contain phosphate are described in detail and are shown on a scale of 2 inches to 1 mile. Particular attention is given to geologic structure and to phosphate deposits, including estimates of acreage and tonnage.

Phosphate deposits.—It is estimated that the Fort Hall Indian Reservation contains 738,526,700 long tons of phosphate rock that averages 70 per cent tricalcium phosphate and that is considered available under the standard of the Geological Survey. For the western field as a whole, partial estimates available May 1, 1917, give approximately 5,464,082,000 long tons of high-grade phosphate rock.

The present demand for the western rock is small because of distance from markets and high cost of transportation. In 1915 the field supplied only 0.2 per cent of the production of the whole country. The Fort Hall deposits are less accessible from existing railroads than the phosphate beds near Georgetown and Montpelier.

The western phosphates are believed to be original sedimentary deposits formed through biochemical agencies.

Other mineral deposits.—Coal and metalliferous prospects on the reservation have yielded no production, but placer mining in the Fort Hall bottoms has brought small returns. Some ore that averages 22 per cent copper has been shipped from the Moonlight property, just south of the reservation. Extensive deposits of volcanic ash may prove a valuable resource.

Soils.—The soils are calcareous and differ to some extent in texture and composition. Qualitative tests show no water-soluble carbonates and slight traces, if any, of sulphates and chlorides.

Water resources.—The reservation lies entirely within the drainage basin of Snake River. The characteristics of the flow of that river and of its tributaries, Blackfoot River, Portneuf River, Bannock Creek, and Ross Fork, are fully described.

In the more mountainous portion of the reservation the ground water has not been developed. Numerous wells have been dug on the terrace near the agency, which are described. Large springs occur on the plains near Snake River, which are attributed to the collection of surface waters on the plains west of the river.

A system has been constructed for the irrigation of a large area near Fort Hall. Other areas are irrigated in the valley of Bannock Creek and along Blackfoot River. Sites for the development of water power exist along Blackfoot River, Ross Fork, and Bannock Creek. Lands along Snake River are included in an important reservoir site.

GEOGRAPHY, GEOLOGY, AND MINERAL RESOURCES OF THE FORT HALL INDIAN RESERVATION, IDAHO.

By George R. Mansfield.

INTRODUCTION.

The geologic examination of the Fort Hall Indian Reservation was undertaken by the United States Geological Survey at the request of the Office of Indian Affairs. A narrow strip of land along the east border of the reservation had been included in the phosphate withdrawals, and the principal object of the examination was the determination of the extent and character of the phosphate lands included in the reservation. Other mineral deposits were also noted. The work was assigned to the writer with instructions to proceed with an examination and mineral classification of the Fort Hall Indian Reservation. G. R. Mansfield, with J. W. Merritt and J. W. Clark as assistants, spent the four months July to October, 1913, in the prosecution of the work. In the middle of September, after the withdrawal of J. W. Merritt, the party was joined by C. A. Bonine and Wallace Lee, who rendered valuable assistance. The chief of the section of nonmetalliferous deposits, H. S. Gale, spent the last week in July with the party. He participated in the mapping and made valuable suggestions with regard to plans and methods of work. G. H. Girty, paleontologist, was with the party for three weeks in August and September and made a faunal and stratigraphic study of the Carboniferous and Triassic formations.

LOCATION OF THE AREA.

The Fort Hall Indian Reservation lies approximately between meridians 112° and 112° 45′ west longitude and between parallels 42° 30′ and 43° 15′ north latitude. It includes an area of approximately 800 square miles in 32 townships and partial townships in Bingham, Bannock, and Power counties, Idaho. The location of the reservation is shown in the index map (fig. 1).

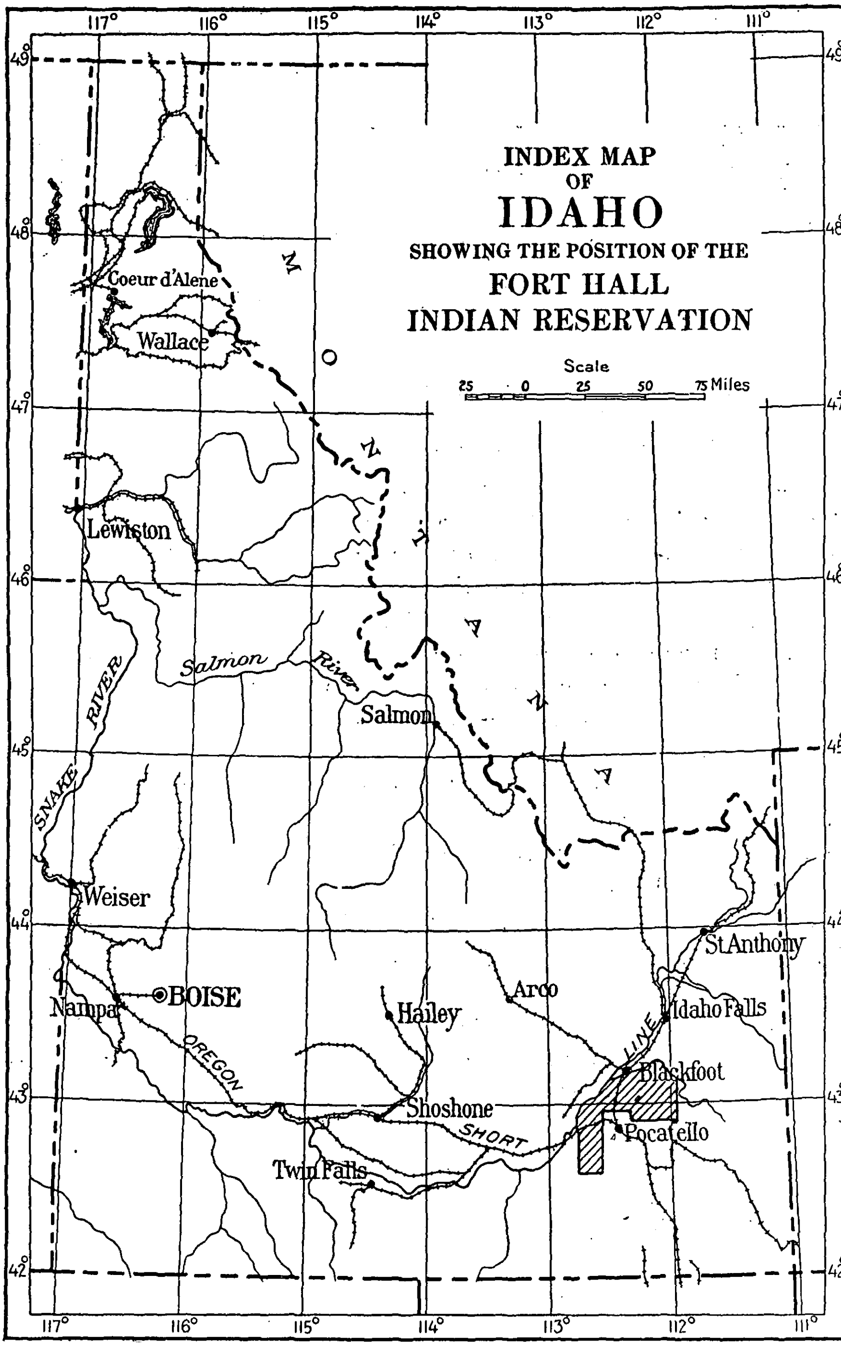


FIGURE 1.—Index map of Idaho showing the location of the Fort Hall Indian Reservation (shaded area).

The reservation lies on the northwest side of the Idaho phosphate reserve and includes a narrow strip of that district. The location

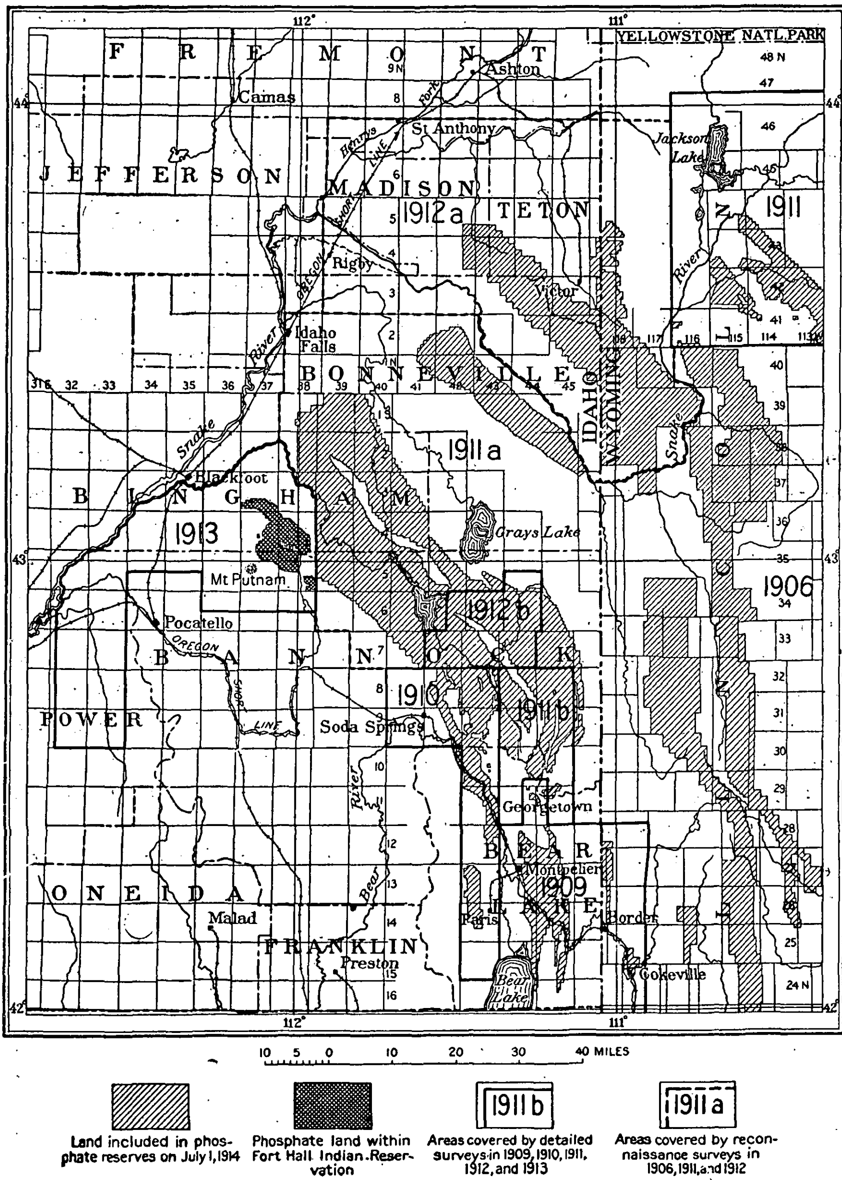


FIGURE 2.—Map showing the location of the Fort Hall Indian Reservation with respect to the phosphate reserve and the location of areas of the reserve examined in previous years.

of the reservation with respect to the phosphate reserve and to the areas examined in detail in previous years is shown on the accompanying map (fig. 2).

EARLY EXPLORATION AND HISTORY.

As far back as the later part of the eighteenth century this region was frequented by fur traders and trappers. The basins of Green, Bear, and Snake rivers abounded in valuable fur-bearing animals, and in the broad valleys the fur companies held their annual meetings for trade. Here also occurred many notable Indian conflicts.[1] An interesting picture of the country and of the activities of the trappers, traders, and Indians is given by Irving[2] in his account of the attempts of a party outfitted by John Jacob Astor to found a trading post at the mouth of Columbia River and also in his account of the adventures of Capt. Bonneville. The Astorians passed along Snake River on their way to the Columbia. Their party met with reverses at the hands of the Indians and endured many hardships.

Capt. Bonneville spent parts of two seasons in 1833 and 1834 in the area that is now included in the Fort Hall Reservation. At that time the region near the head of Portneuf and Blackfoot rivers was an extensive buffalo range. Capt. Bonneville spent a winter on Snake River near the Portneuf, where he noted the presence of fine springs of water. Some of these springs, he says, "gush out of the earth in sufficient quantity to turn a mill and furnish beautiful streams, clear as crystal and full of trout of large size."[3] The reference here, with little doubt, applies to Spring Creek and Clear Creek, with other lesser streams that rise on the plains of Snake River within the reservation. A chance associate of Capt. Bonneville was Nathaniel J. Wyeth, a trader of Boston, Mass., who in 1834 established a trading post on Portneuf River which he named Fort Hall. "Here for the first time the American flag was unfurled to the breeze that sweeps the great naked wastes of the central wilderness."[4]

The establishment and naming of Fort Hall is described by Wyeth in a letter, as follows:

> Since mine of June 21 from Hams Fork, I have, as I then proposed, built a fort on Snake or Lewis River, in latitude 43° 14′ N. and longitude 113° 30′ W., which I named Fort Hall, from the oldest gentleman in the concern. We manufactured a magnificent flag from some unbleached sheeting, a little red flannel, and a few blue patches, saluted it with damaged powder, and wetted it with villainous alcohol; and after all it makes, I do assure you, a very respectable appearance amid the dry and desolate regions of central America. Its bastions stand a terror to the skulking Indian and a beacon of safety to

[1] Gannett, Henry, U. S. Geol. and Geog. Survey Terr. Eleventh Ann. Rept., for 1877, p. 708, 1879.

[2] Irving, Washington, Astoria, 2 vols., Philadelphia, 1836; The adventures of Capt. Bonneville, U. S. A., in the Rocky Mountains and the Far West, Pawnee ed., vols. 1, 2, New York and London, 1898. H. H. Bancroft (Works, vol. 28, pp. 568–575, 1884) scathingly denounces Bonneville and his expedition and censures Irving for presenting the captain and his works in so favorable a light.

[3] Irving, Washington, The adventures of Capt. Bonneville, U. S. A., in the Rocky Mountains and the Far West, Pawnee ed., vol. 1, pp. 324–325, 1898.

[4] Idem, vol. 2, p. 329. See also Bancroft, H. H., Works, vol. 28, pp. 585–587, 1884.

the fugitive hunter. It is manned by 12 men, and has constantly loaded in the bastions 100 guns and rifles. These bastions command both the inside and the outside of the fort. After building this fort I sent messengers to the neighboring nations to induce them to come to it to trade, and am now about starting with an equipment of goods for the winter trade.

In his journal, under date of August 6 of the same year, Wyeth writes:[5]

Having done as much as was requisite for the safety of the fort and drank a bale of liquor and named it Fort Hall in honor of the oldest partner of our concern, we left it and with it Mr. Evans in charge of 11 men and 14 horses and mules and 3 cows.

The site of Wyeth's fort is marked by a monument on the northwest bank of Spring Creek near the bridge in sec. 18, T. 5 S., R 33 E., as shown on the map (Pl. III).

Frémont,[6] in his exploring expedition of 1843–44, descended Bannock ("Pannock") Valley to the region of the lower Portneuf. Fort Hall had then become a British trading post under the Hudson Bay Co. Frémont noted the agricultural possibilities of the region and collected a sample of the soil, the analysis of which is given on page 118.

Capt. Stanisbury[7] made a similar trip down the Bannock Valley in 1849. The region was also included in later surveys for the purpose of locating wagon roads in the late fifties and early sixties.[8]

The United States Geological and Geographical Survey of the Territories, in charge of F. V. Hayden, in the late sixties and seventies mapped a strip of country in eastern Idaho. The reservation was not included in the Hayden maps, but the eastern part of it was visited by several geologists attached to these surveys, and some account of the district is given in their reports, to which more extended reference will presently be made.

The reservation was established by act of Congress on July 3, 1868, ratified February 16, 1869, and proclaimed February 24, 1869.[9] The reservation as then constituted included a considerably larger area than at present. Various modifications of its boundaries have since been made, reducing its area until its present limits were determined by the act of June 6, 1902.[10]

[5] The correspondence and journals of Capt. Nathaniel J. Wyeth, 1831–1836, edited by F. G. Young: Sources of Oregon history, vol. 1, pts. 3–6 incl., pp. 146–147, 227, Oregon Univ. Contrib. Dept. Economics and History, Eugene, Oreg., 1899.

[6] Frémont, J. C., Narrative of the exploring expedition to the Rocky Mountains in the year 1842 and to Oregon and north California in the years 1843–44, London, 1846.

[7] Gannett, Henry, op. cit., p. 709.

[8] Gannett, Henry, op. cit., p. 710. Bradley, F. H., U. S. Geol. Survey Terr. Ann. Rept. for 1872, 1873. (Cites Capt. Mullan, Wagon road Rept., 1863.)

[9] Treaty between the United States of America and the Eastern Band of Shoshones and the Bannock Tribe of Indians: Stat. L., vol. 15, p. 673, 1869.

[10] Stat. L., vol. 31, p. 672, 1901. Other acts relating to lands of the reservation may be found in Stat. L., vol. 22, p. 148, 1883; vol. 25, pp. 452, 686, 1889; vol, 26, p. 1011, 1891.

Shortly after the establishment of the reservation, about 1870, the military post of Fort Hall was built in the valley of Lincoln Creek in sec. 13, T. 3 S., R. 36 E., about 30 miles northeast of the old trading post on the Portneuf. Fort Hall served as an important supply point for some of the survey parties under F. V. Hayden, who speaks in glowing terms of the kindness and hospitality of the officers in charge there. About 1878 the agency was transferred to its present site on Ross Fork Creek and the Oregon Short Line Railroad. This railroad, under the name Utah & Northern, was completed as far north as Blackfoot in the fall of that year. The former site has been given over to agriculture.

From 1908 to 1911 various surveys have been conducted by the United States Reclamation Service and the United States Geological Survey at the request of the Office of Indian Affairs for the purpose of investigating the irrigation and power possibilities of the streams of the reservation. An account of the results of this work is given in the chapter on water resources by W. B. Heroy.

GEOGRAPHY.

PHYSIOGRAPHIC DEVELOPMENT.

SUBAERIAL EROSION.

The Fort Hall Indian Reservation occupies part of an extensive mountainous region that is underlain chiefly by layers of rock of unequal hardness and so bent and broken by earth movements that the edges of many of the layers have long been exposed to the action of snow and ice, wind, weather, streams, and gravity—the processes summarized in the words subaerial erosion.

The action of such erosion, though of varying intensity, is continuous and may in time be expected to wear away the hardest rock and level off the roughest country if the conditions under which it takes place remain unchanged. Two types of changes, however, are likely to interrupt the leveling process, namely, renewal of earth movements and climatic variation. The first, by raising, lowering, tilting, or warping certain parts of the region, alters the grades of streams and perhaps induces other changes that may have far-reaching effects. The second, by varying the amount of precipitation or the temperature, may change the volume and grade of streams or otherwise affect erosive action. Thus it seldom happens that an extensive region is completely leveled by subaerial erosion. Usually the process is interrupted and renewed under different conditions, which impose their own effects upon the surface or topography of the country as developed during the preceding erosional period.

Such changes may have occurred several times in a given territory. They serve to divide the time during which erosion has acted into periods of greater or less length, which are conveniently termed cycles or partial cycles, in accordance with the degree of perfection in surface leveling attained before the interrupting changes occurred. Each cycle is distinguished by the topographic features developed in it. The records of earlier cycles are modified and may be nearly or quite obliterated during succeeding cycles. In the Fort Hall Indian Reservation three partial cycles have been identified. These are named, respectively, the Putnam, Gibson, and Spring Creek cycles. The changes by which they were brought about are briefly considered in the sections on structure and historical geology.

PUTNAM CYCLE.

The mountains of the reservation are in general characterized by smooth, rounded slopes and summits. The slopes descend in long, sweeping curves, which become more and more gentle toward broad valleys or basins. The branch valleys in the higher parts of the mountains are also rather open, with fairly gentle side slopes. The broader valleys and basins as a rule have been developed where conditions were favorable, as along the strike of relatively weak rocks. The intervening harder rocks, which generally trend north or northwest, form strike ridges that furnish numerous side branches for the main valleys and are cut through here and there by deep transverse valleys. In T. 4 S., R. 37 E., the trends are prevailingly southwest to northeast.

The sloping surfaces developed on the harder rocks are steeper than those on the weak rocks, and along the mountain sides the region of change between the steeper and gentler slopes is fairly well marked and constitutes the upper boundary of the so-called benches, which are the gentler portions of the long slopes that descend to the valleys.

The slopes of the mountains and the adjoining benches have been carved from rocks that are inclined at different angles. This fact and the relations between ridges, valleys, and rock structure and character mentioned above indicate that the cycle of subaerial erosion, which shaped the features, was of long duration. It had reached a stage which may be called "late maturity," because the rougher outlines of surface produced by the streams in earlier stages of erosion had been largely subdued and the valleys, which at first were narrow and steep-sided, had been greatly broadened at the bottom and made widely flaring at the top.

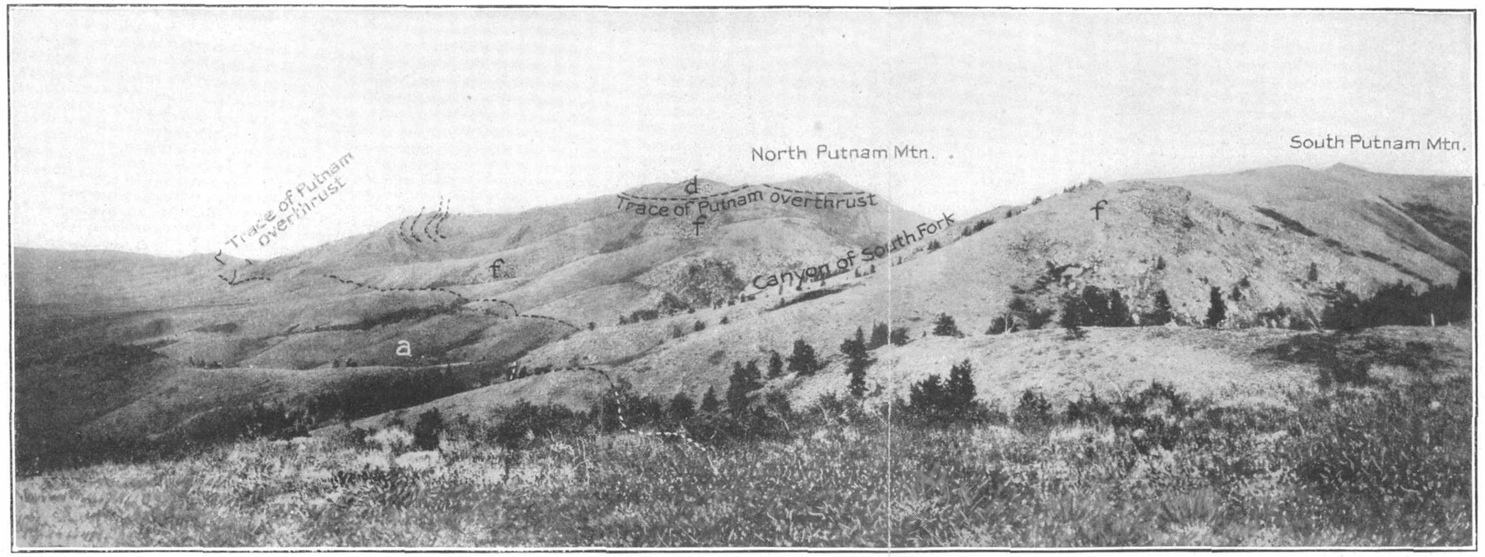
The hard rocks, however, were not all worn smooth. Rough, rocky remnants of the former upland occur here and there on some of the mountains and strike ridges, notably on North Putnam and South Putnam mountains, in the eastern part of the reservation, which are respectively 8,837 and 8,989 feet above sea level and are 2,000 to 4,000 feet higher than the floors of the neighboring valleys. These are the highest mountains in the reservation and are also the highest peaks of the northern part of the Portneuf Range. Similarly, Bannock Peak, in the southwestern part of the reservation, has an altitude of 8,321 feet, and the local difference of elevation thereabouts is 1,000 to 2,000 feet.

The erosion cycle which produced this late mature topography may be designated for future reference the Putnam cycle, from Mount Putnam, in the vicinity of which it is well developed. Plate I, *A*, illustrates this topography as seen from the southwest flank of Mount Putnam. The canyons shown in this view were carved in the succeeding cycle. (See also Pl. I, *C*.)

GIBSON CYCLE.

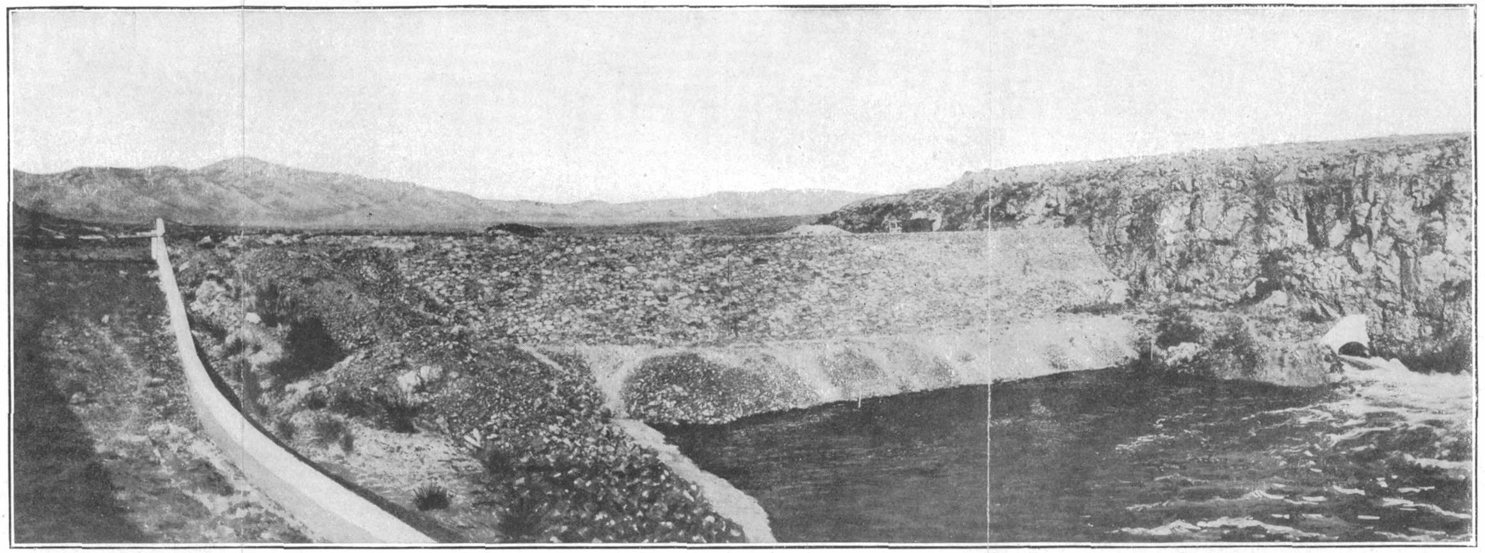
Moister climatic conditions accompanied by elevation or warping of the surface ushered in the Gibson cycle. The topographic features of the Putnam cycle have been modified by the cutting of steep-sided canyons, 500 to 1,500 feet deep, in the older valley floors in regions of harder rock. In most of these canyons the new valley floors have been somewhat widened, and there is room for a wagon road or trail. The benches have been cut away at their lower borders in many places and now end in steep slopes, locally as much as 100 feet high. The surface of the bench lands is cut by branching canyons and gullies, the larger of which have well-developed flood plains, and is divided by them into somewhat irregular strips. The flood plains merge at their lower ends with a broad plain, 6 to 8 miles wide, that extends toward Snake River. This plain lies at the base of the steep slopes at the lower ends of the benches. It is really a terrace; for near Snake River it is cut away and the present flood plain of that river intervenes at a level about 75 feet lower, near the mouth of the Portneuf. The broad upper plain is here called the Gibson terrace, from the little settlement of Gibson, which stands upon it. The cycle in which the Gibson terrace and the associated features described above were developed may be called the Gibson cycle.

In any physiographic cycle the erosive processes work backward along the drainage lines so that the lower portions of valleys with their relatively broader streams may have extensive flood plains while the tiny headwater streams are still walled in narrow canyons and gorges. Thus the divides are the last features of a region to be reduced by subaerial erosion. Although in the Gibson cycle erosion

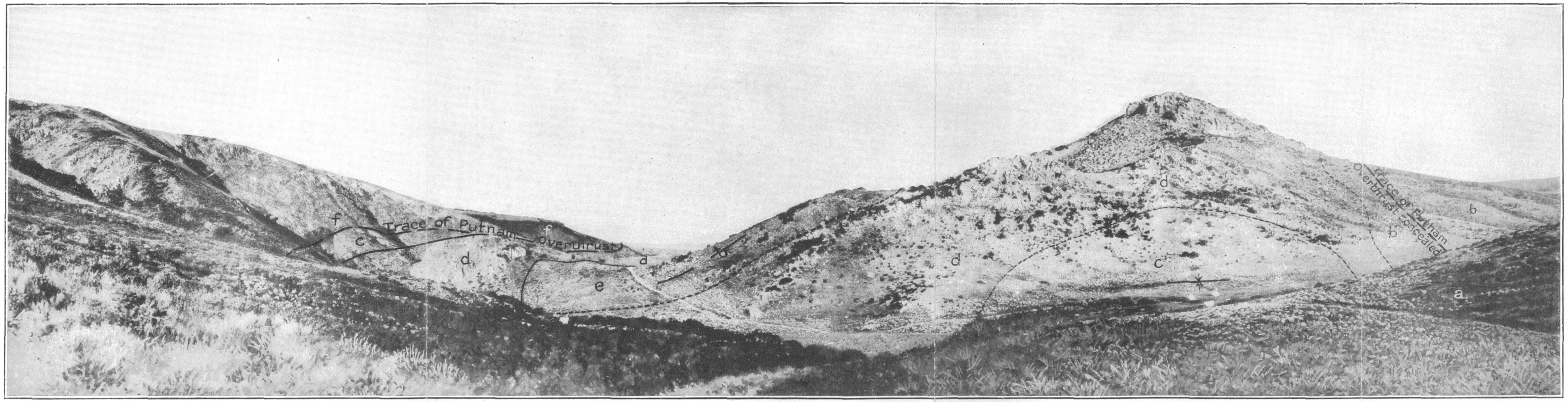


A. PANORAMA OF NORTH AND SOUTH PUTNAM MOUNTAINS.

View northeast from hill about 1 mile south of the canyon of the south fork of Ross Fork Creek, showing the topography of the Putnam cycle and some of the structural features of the ridge. *a*, Tertiary-Quaternary hill wash; *d*, Swan Peak quartzite; *f*, Brigham quartzite.



B. DAM OF BLACKFOOT RIVER RESERVOIR.



C. PANORAMIC VIEW WEST THROUGH THE NARROWS OF ROSS FORK CANYON.

Part of the course of the Putnam overthrust is shown, together with some of the Cambrian and Ordovician formations. The upper slopes show the topography of the Putnam cycle. The canyon around the little knoll (left center) represents the Gibson cycle. *a*, Tertiary-Quaternary hill wash; *b*, Salt Lake formation; *c*, Fish Haven dolomite; *d*, Swan Peak quartzite; *e*, Garden City limestone and later Cambrian beds; *f*, Brigham quartzite.

had made considerable progress at lower elevations, as above outlined, it had not affected noticeably the higher parts of the mountains and the divides except at a few places. The Gibson cycle was therefore much shorter than the Putnam cycle. It may be said to have reached an early mature stage of development.

Plate I, *A*, illustrates a portion of the more rugged topographic features of the Putnam cycle together with some of the canyons and dissected benches of the Gibson cycle.

SPRING CREEK CYCLE.

A third cycle has been well started in the vicinity of Snake River by the development of the broad flood plain known as the Fort Hall bottoms. This plain extends up the lower courses of Portneuf and Blackfoot rivers and of Bannock Creek. The inclination of the plain is slightly greater than that of the Gibson terrace, so that the difference in elevation between the two, which is greatest near the mouth of the Portneuf, diminishes and finally disappears up each of these streams. In the bench lands some of the streams have cut 10 feet or more below the level of their former flood plains, but few if any topographic effects have been produced in the hard rocks of the hills. The present streams are apparently smaller than those which cut the canyons of the Gibson cycle. In fact, some of these canyons now have no drainage channels except in their middle or lower parts. A stream in the northeast part of T. 4 S., R. 36 E., affords an example of this condition.

This cycle has been much shorter than either the Putnam or the Gibson cycles. It may be said to have reached only a youthful stage of development. For reference it may be called the Spring Creek cycle, from Spring Creek, a relatively large stream that rises and has its entire course in the Fort Hall bottoms.

VOLCANIC FEATURES.

Flows of lava which have solidified and the products of volcanism have played an important part in the physiographic development of the region. Hills capped by such lava are striking topographic features in the Bannock Valley region and in Tps. 3 and 4 S., R. 36 E., and elsewhere. Large dikes which have been eroded form prominent hills, as in the northeastern part of T. 8 S., R. 32 E., and the adjoining part of T. 8 S., R. 33 E. Volcanic ejecta constitute a considerable part of the materials upon which the bench lands have been developed and lie upon the surface of the Gibson terrace and the low hills of solidified lava to the east. A youthful volcanic cone that is illustrated in Plate IV surmounts similar hills in the southwestern part of T. 3

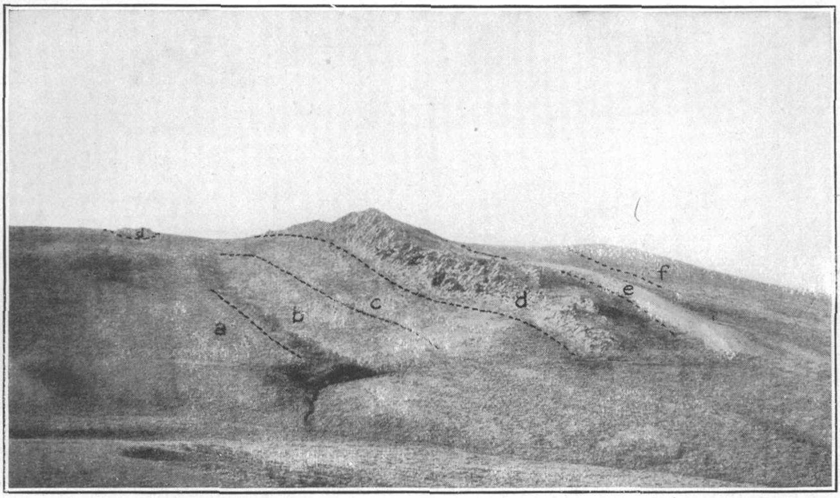
S., R. 36 E. Erosion of hardened lava has formed the canyon of Blackfoot River, 300 feet or more deep, along the northeast border of the reservation and the flat-topped hills or mesas in the northern part of T. 9 S., R. 32 E. Caving of the hardened lava has produced depressions, as in sec. 34, T. 8 S., R. 33 E.

DRAINAGE RELATIONS.

The drainage of the reservation shows a considerable degree of conformity to rock structure. Numerous valleys and ridges follow the strike of the rocks, as shown in Plate II, *A*. Some valleys have also been excavated along fault lines. The strike ridge in the vicinity of the southeastern part of T. 3 S., R. 37 E., is cut by a number of small northeastward-trending faults that have been followed by stream valleys. These faults have divided the ridge in such a way that when viewed from the southwest it resembles a row of nearly conical hills. The conformity of stream valleys to structure was more pronounced in the Putnam cycle than in either of the later cycles. In the Gibson cycle there were marked tendencies toward such conformity. It seems probable that the upper waters of Wood Creek in the vicinity of the southwest corner of T. 3 S., R. 38 E., formerly flowed northwestward into Lincoln Creek but were diverted by capture to a northeasterly course into the Blackfoot during that cycle. The stream that formerly occupied the lower valley of Wood Creek was enabled by a shorter course and steeper grade to work back rapidly enough to tap the other stream and thus effect the capture.

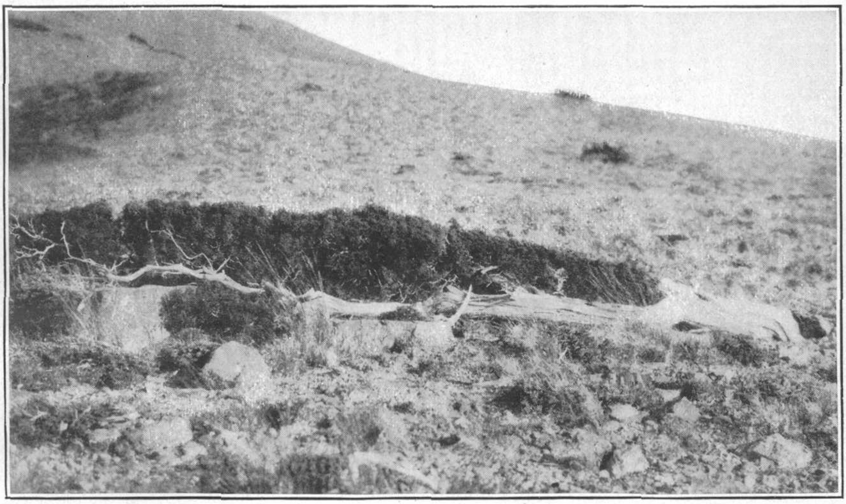
The Fort Hall Indian Reservation includes an eastern and a southwestern mountainous region separated by the broad plains of the Gibson terrace and the Fort Hall bottoms. All streams in the reservation are tributary to the Snake-Columbia system, and the water ultimately finds its way to the Pacific Ocean. In each of the three broad divisions of the reservation, however, there are important streams that deserve mention.

The eastern mountainous region, which is roughly about 20 miles square, has four principal streams—Blackfoot and Portneuf rivers, which flow directly to the Snake; Lincoln Creek, a tributary of the Blackfoot; and Ross Fork Creek, a tributary of the Portneuf. The Blackfoot receives directly the drainage of the northern and northeastern borders of the district. Lincoln Creek drains much of the central and northern parts. The headwaters of the Portneuf occupy a broad basin in the eastern and southeastern regions. The Portneuf leaves the reservation in its southeast corner, and after a course of many miles to the south and west reenters it near the Gibson terrace, in the northeast corner of T. 6 S., R. 33 E. Ross Fork Creek has a



A. CHARACTERISTIC STRIKE RIDGE OF HIGHAM GRIT IN SEC. 13, T. 3 S., R. 38 E.

Note the comblike continuation of the ridge along the horizon. *a*, Nugget sandstone; *b*, Wood shale; *c*, Deadman limestone; *d*, Higham grit; *e*, Timothy sandstone; *f*, Portneuf limestone.



B. CEDAR TREE IN VIGOROUS CONDITION GROWING PROSTRATE BECAUSE OF EXPOSURE TO HIGH WINDS.

The tree is one of a group of similar trees on a high ridge in the NE. ¼ sec. 25, T. 9 S., R. 32 E.

large basin in the southwestern part of the eastern mountains and drains much of their central and western districts. It joins the Portneuf in the vicinity of the Gibson terrace, near the center of T. 5 S., R. 33 E.

The southwestern mountainous region forms a nearly rectangular area 20 miles long from south to north and 10 miles wide. The broad valley of Bannock Creek, which has a similar trend, divides the mountainous upland into two unequal parts, of which the western is more extensive but less rugged, except in the southern part. Rattlesnake Creek from the east and Moonshine and Starlight creeks from the west are the principal tributaries of Bannock Creek within the reservation. Michaud Creek, which is tributary to the Portneuf basin but is absorbed by the loose soil in the plains, drains most of the northeastern part of the district.

In the region of the Gibson terrace and the Fort Hall bottoms, Blackfoot and Snake rivers form, respectively, the northern and northwestern boundaries of the reservation. The Portneuf gathers most of the drainage except Bannock Creek, which flows west in T. 6 S., Rs. 33 and 32 E., and joins the Snake a short distance west of the reservation. In the lower part of its course the Portneuf is greatly increased in volume by receiving the waters of Spring Creek and Ross Fork with its large tributary Clear Creek. Numerous springs, large and small, supply the waters of Spring and Clear creeks, streams 60 to 100 feet or more wide, that originate and have their entire courses on the Fort Hall bottoms.

CLIMATE.

By W. B. Heroy.

The Fort Hall Indian Reservation lies on the eastern border of the Snake River plains but reaches eastward and southward into the mountain and valley region of southeastern Idaho. Though in general the climate of the region is semiarid, this diversity in topography is reflected in local climatic variations, the upland and mountain areas having a lower mean annual temperature and a greater rainfall than the plains.

The only climatologic station on the reservation is at Fort Hall. It was established in 1914, and the record is too short to be of much value. The records obtained by the Weather Bureau at a number of stations near the reservation afford, however, an indication of the climatic influences which prevail in this region. The stations at American Falls (1890 to present), Idaho Falls (1880 to present), and Pocatello (1899 to present) have been maintained for 18 years or more, a period of sufficient length to reveal cyclic tendencies. Stations at Blackfoot, Blackfoot dam, Chesterfield, Pebble, and Springfield were established more recently but serve to reveal local variations in climate, resulting from topographic and other influences. The normal monthly and annual precipitation at certain of these stations is given in the following table:

Average monthly and annual precipitation, in inches, at stations near the Fort Hall Indian Reservation, Idaho.

Station.	Elevation.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	Feet.													
American Falls....	4,341	1.66	1.22	1.58	1.27	1.63	1.09	0.65	0.50	0.76	1.15	1.33	1.30	14.14
Blackfoot..........	....	1.05	.76	.93	.86	1.60	1.03	.81	.65	.78	1.11	.88	.86	11.32
Chesterfield........	5,454	1.50	.97	1.36	1.00	1.85	1.44	.64	1.07	.85	1.09	.88	1.15	13.76
Idaho Falls........	....	1.62	1.12	1.56	1.08	1.70	1.54	.67	.76	.96	1.20	1.00	1.15	14.36
Pocatello...........	4,483	.66	.85	1.75	2.02	2.20	.99	.63	.56	.88	.98	.55	.86	12.93

In order to show the recent climatic history of the region the records above listed have been used as a basis for a diagram (fig. 3) which shows the variation in the annual rainfall for the years 1891

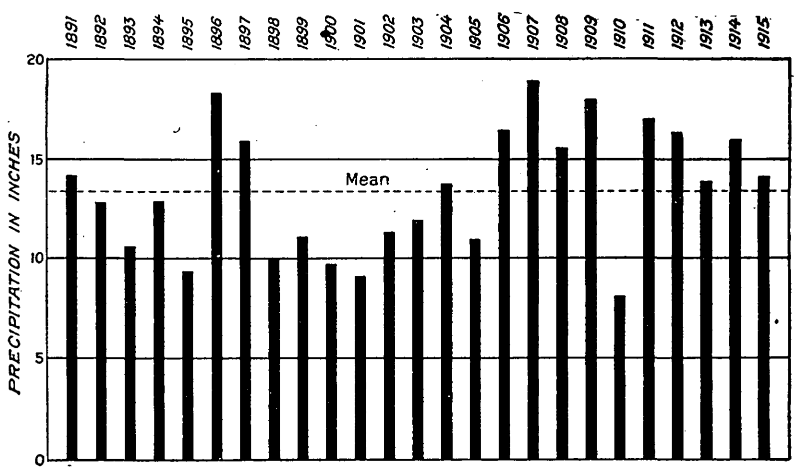


FIGURE 3.—Diagram showing variation in annual precipitation in vicinity of Fort Hall Indian Reservation during the years 1891 to 1915.

to 1915, inclusive. The rainfall given for each year is the average for the stations listed. The American Falls, Idaho Falls, and Pocatello records were used for the period 1891 to 1897. The Blackfoot record was substituted for the American Falls record for the period 1908 to 1915, as the latter record is incomplete. The other stations were used to fill gaps in the longer records.

The lowest average annual precipitation shown on the diagram is 7.94 inches, which occurred in 1910, and the highest is 18.78 inches, which occurred in 1907. The smallest annual precipitation recorded in this region was observed at Aberdeen in 1910, and was only 0.35 inch. The largest precipitation was 27.35 inches, which was observed at Pebble in 1911.

The mean annual rainfall for the entire period 1891 to 1915 is 13.38 inches. The most severe dry period recorded is that which includes the six years 1898 to 1903, the average for those years having been only about 10.5 inches. The period of greatest precipitation occurred in 1906 to 1909, the mean for these four years being 17.15 inches. The mean annual range of temperature in this region is from approximately −20° F. to +70° F.; January is the coldest and July the hottest month. The extreme range of temperature, however, is much greater, being about 130°. Certain relations of temperature are brought out in the diagram (fig. 4), on which are indicated the curve of the maximum, minimum, and mean monthly

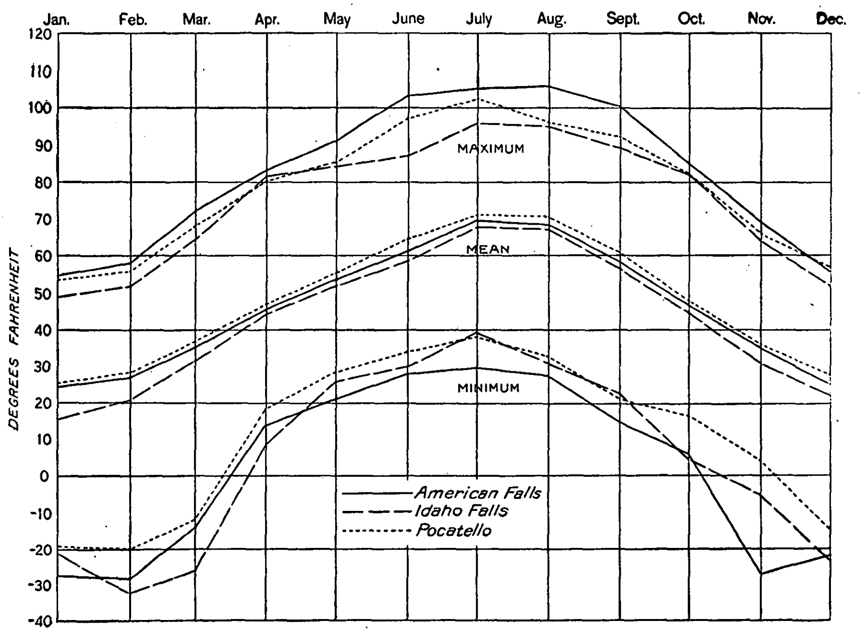


FIGURE 4.—Diagram showing relation between maximum, mean, and minimum monthly temperature at American Falls, Idaho Falls, and Pocatello, Idaho.

temperatures at the three principal stations—American Falls, Idaho Falls, and Pocatello.

As shown by a nine years' record the average date of the last killing frost in the spring at Pocatello is April 20 and that of the first killing frost in the autumn is October 12. The length of the growing season is thus about 175 days. At American Falls, as shown by a fifteen years' record, the corresponding dates are May 27 and September 8, and the length of the growing season thus indicated is 103 days. At Idaho Falls a four years' record indicates that the growing season averages 112 days in length, from May 22 to September 12. The much greater length of the growing season at Pocatello than at American Falls and Blackfoot may perhaps be due to the direction of the prevailing winds. At Idaho Falls the prevailing winds are from the northeast throughout the year and sweep down the Snake River valley. In contrast the winds at Pocatello are prevailingly from the southeast and come down the Portneuf Valley.

The season of security from killing frost in the more favorably located parts of the reservation is probably somewhat more than three months. Frosts, however, may occur during any of the summer months along some of the valley bottoms, though they are not frequent in July and August. The bottom lands are therefore not adapted to any but the hardiest crops. On the sides of the valleys, on slightly higher ground, the cold air does not linger, and the ground is adapted for cultivation.

VEGETATION AND ANIMAL LIFE.

Sage and other low brush occupy much of the lowlands, lower bench lands, and low hills of igneous rock in relatively dense growth, although there are more or less extensive areas of open grass land, as in the northern and central parts of T. 5 S., R. 36 E., the northern part of T. 7 S., R. 32 E., and elsewhere. The upper benches and the windward slopes are also largely open and covered with grass. Grassy meadows occupy most of the larger stream valleys.

The lower rocky hills and ridges are largely forested with cedar, but in areas where the older dolomites come to the surface there is a considerable growth of mountain mahogany (*Cercocarpus ledifolius*), as in the southeastern part of T. 5 S., R. 36 E., and the northeastern part of T. 6 S., R. 36 E. In fact, in these localities the mahogany was found to be a convenient guide to outcrops of the dolomite.

Aspen thickets, some of them almost impenetrable, occupy the lee slopes of many of the larger ravines both in the bench lands and in the hills. They are also abundant on the lee slopes of hills. The drifting snow, which has to a large extent determined the location of these thickets, has weighted their branches and overloaded their tops so that many of the trees are stunted, gnarled, and twisted and their branches are closely interlaced.

The higher and more rugged districts in the vicinity of the North and South Putnam mountains and of Bannock Peak support, in addition to large groves of aspen, excellent timber, including Douglas fir, lodgepole pine, and balsam. These districts also have extensive thickets of brush and are littered with much fallen timber, though there are also open grassy places.

Large game is scarce in the reservation. Two antelopes and the tracks of a bear were seen by members of the party. Probably, too, there are a few deer and elks, but none were seen. Coyotes are numerous. Small game is relatively abundant. There are rabbits by the thousand, together with some badgers, porcupines, and other smaller animals. Game birds, including members of the grouse and duck families, are abundant, and there are many other kinds of birds. There are many insects of different kinds, but no attention was given to genera and species. The flying ants proved a veritable pest. Fish are present in most of the larger streams but not in great numbers.

ADAPTATIONS OF LIFE TO ENVIRONMENT.

The grouping of the different types of vegetation has already been pointed out. This grouping is, without doubt, a response to environmental conditions in which the relative supply of moisture is probably the controlling factor, as is illustrated by the location of aspen thickets in the places where snowdrifts linger. In other places the type of soil may play an important part, as in the location of the mountain-mahogany groves and perhaps in the distribution of sage and the so-called oak brush in the lava hills in T. 4 S., R. 36 E. Where the dark volcanic sand is thick the sage gives way to the oak brush. This fact served as a guide in the study of the distribution of the volcanic sand.

The effect of the wind on vegetation on exposed slopes is noteworthy at a number of localities, particularly on a ridge in the NE. ¼ sec. 25, T. 9 S., R. 32 E., where stunted cedars, in vigorous growth, lay completely prostrate, pointing away from the prevailing wind, and some of them resembling couches of boughs. (See Pl. II, *B*.)

In the northern part of T. 4 S., R. 34 E., dunes have been formed of volcanic sand mingled with the finer sand of the Gibson terrace. A number of these dunes have been utilized by the Indians as the sites of burial places. These burial sites are marked by many high poles and by implements and personal effects of the deceased Indians.

An interesting item of organic response to environmental conditions was noted in the southwestern part of T. 7 S., R. 32 E., where the surface was underlain by weathered rhyolite. Ants, in search of uniform material for their mounds, had selected the quartz crystals weathered from the rhyolite and were thus living in veritable crystal palaces, which gleamed and glittered in the sunlight.

INDUSTRIES.

Outside of the reservation, as in Bannock Valley and elsewhere, the broad valleys are farmed from hillside to hillside. The plains are also devoted to raising potatoes, grain, and sugar beets. Within the reservation agriculture is being attempted by many of the

Indians under the guidance of district farmers, appointed by the Government. The agricultural developments, though promising, are not extensive and apparently as yet only partially successful. Much of the available agricultural land had not been subjected to cultivation at the time of the writer's examination. A considerable number of cattle and horses are pastured on the reservation, but the available pasturage was then only partially used.

NATURAL RESOURCES.

The timber of the higher districts furnishes fuel and building material. This resource is being utilized to some extent by the Indians.

The small game affords a supply of food in the open season, of which advantage is taken by the Indians. As others are prohibited from hunting on the reservation, this supply remains plentiful.

In addition to the agricultural, grazing, timber, and game resources, there are valuable deposits of phosphate rock in the eastern part of the reservation. These and other mineral deposits will be discussed more fully in a later part of this report.

Water is available for power and irrigation in parts of the reservation. Surveys and investigations in connection with this resource have been made under the authority of the Office of Indian Affairs. These are discussed in a later chapter by Mr. Heroy.

TRANSPORTATION.

The Oregon Short Line Railroad traverses the reservation north of the Bannock Valley district and west of the eastern mountainous district. Fort Hall has the only passenger and freight station within the reservation, but sidings are maintained at Michaud and at Gibson. Blackfoot and Pocatello are important railroad points just outside the reservation.

Much of the higher country is relatively remote from the railroad, but there are numerous roads in all except the most rugged districts. Stage and mail connections from the south are maintained at Chesterfield, about 3 miles southeast of the southeast corner of the reservation, and at Arbon, about 8 miles southeast of T. 9 S., R. 32 E.

POWER.

Power transmission lines cross the reservation in two localities. One line extends across the southwestern part of the reservation parallel to the railroad and carries energy from the water-power plant of the Southern Idaho Water Power Co., at American Falls, eastward to Pocatello. From Pocatello a line extends north to Blackfoot, also parallel to the railroad. This line supplies the agency buildings with light and power for the water-supply system.

GEOLOGY.

PREVIOUS GEOLOGIC WORK.

The observations of Bonneville and Frémont have already been noted (p. 12). The reports of the Hayden Survey have hitherto been practically the only source of information regarding the geology of the area now included in the Fort Hall Indian Reservation, and these refer only to the eastern part of the reservation.

In 1871 Hayden[11] traversed parts of this region on his way from Ogden to Fort Hall, in Lincoln Creek, and again from Fort Hall to Evanston, Wyo. He gives a brief account of his itinerary on each trip.

In 1872 F. H. Bradley,[12] in charge of one of the Hayden parties, traversed a portion of the eastern part of this reservation. In his report he gives an account of a stratigraphic section, the fossils from which as described by Meek have become well known through comparison with the Spergen fauna of the central States.

In 1877 A. C. Peale, in charge of one of the Hayden parties, crossed the southeastern part of the present reservation. In his report on the geology of the Green River district he discusses the drainage and geologic relations of the Portneuf Valley, Marsh Creek, and the Portneuf Range. He describes the structure of the Portneuf Range, of which Mount Putnam is the culminating point, as monoclinal, with an anticlinal axis a short distance to the west and with a synclinal depression on the east that was formerly occupied by an arm of the lake that once filled the upper Portneuf Valley.[13] He also refers to the age of the basalt and the character of the Pliocene deposits of the region.[14]

In the same year Orestes St. John, in charge of another Hayden party, traversed the eastern part of the reservation. He gives descriptions and geologic sections of the region north and northeast of Mount Putnam.[15]

The work of the members of the Hayden parties has been found to be correct in its general outlines. As may readily have been expected the work of the present party has served to supply a greater number of stratigraphic details and to call attention to the structural complexity of the region, which before was less clearly recognized.

[11] U. S. Geol. Survey Terr. Ann. Rept. for 1871, pp. 13–26, 1872.

[12] Bradley, F. H., [Report of the geologist of the Snake River division]: U. S. Geol. Survey Terr. Ann. Rept. for 1872, p. 206, 1873.

[13] Peale, A. C., U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1877, pp. 563–569, 1879.

[14] Idem, pp. 640, 643.

[15] St. John, Orestes, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1877, pp. 325–338, 1879.

In addition to the men above noted, whose work concerned the immediate area of the reservation, a number of other writers may be cited who have touched upon problems more or less directly connected with the geology of the Fort Hall Reservation.

J. S. Newberry [16] gives an account of the Tertiary deposits of the general region of which the Fort Hall Indian Reservation is a part, in which he considers them as the products of great Tertiary lakes.

G. P. Merrill [17] gives a description and analysis of a sample of volcanic ash collected by Peale from the Pliocene deposits of the Portneuf Canyon. (See p. 117.) Dall and Harris [18] note the capping of basalt upon beds of the Salt Lake formation east of Snake River and north of the Portneuf, which lies within the area of the reservation.

Lindgren and Knowlton [19] discuss the Payette formation of the Boise district, which in many respects resembles the so-called Pliocene beds farther east but is referred by them to the upper Miocene. Knowlton later referred the Payette formation to the Eocene.[20]

Russell [21] discusses the Snake River lava and calls attention to the fact that it is for the most part younger than the Columbia River lava. In the Snake River district the latest eruptions probably occurred within historical times, perhaps not more than 100 to 150 years ago. The Columbia River lava is deeply weathered to a soft claylike soil 60 feet or more deep, but the lava of the Snake River plains is still fresh.

Bell [22] describes Tertiary lake deposits in the vicinity of Pocatello and the Portneuf Valley. He ascribes the deposits to a great lake which he calls Lake Idaho (this usage is probably independent of earlier usages). The deposits according to his statement have a vertical range of 4,000 feet.

Kindle [23] discusses the occurrence of Silurian and Devonian rocks in the region southeast of the Fort Hall Indian Reservation. These rocks also occur in the reservation, and much of his discussion is doubtless applicable to this region.

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[16] Newberry, J. S., The ancient lakes of western America: U. S. Geol. Survey Terr. Fourth Ann. Rept., pp. 329–339, 1871.

[17] Merrill, G. P., Notes on the composition of certain "Pliocene sandstones" from Montana and Idaho: Am. Jour. Sci., 3d ser., vol. 32, pp. 199–204, 1886.

[18] Correlation papers; Neocene: U. S. Geol. Survey Bull. 84, pp. 286–287, 1892. Refers to U. S. Geol. and Geog. Survey Terr. Fifth Ann. Rept., for 1871, p. 25, 1872.

[19] Lindgren, Waldemar, The mining districts of the Idaho Basin and the Boise Ridge, Idaho; with a report on the fossil plants of the Payette formation, by Frank H. Knowlton: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 625–736, 1898.

[20] U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 104), p. 3, 1904.

[21] Russell, I. C., Geology and water resources of the Snake River Plains of Idaho: U. S. Geol. Survey Bull. 199, 1902.

[22] Bell, R. N., The origin of the fine gold of the Snake River: Eng. and Min. Jour., vol. 73, pp. 143–144, 1902.

[23] Kindle, E. M., The fauna and stratigraphy of the Jefferson limestone in the northern Rocky Mountain region: Bull. Am. Paleontology, vol. 4, No. 20, 1908.

The mining district in the vicinity of Pocatello is described by Weeks and Heikes [24] and by Bell.[25] A brief statement regarding this district is given in the present report on page 116.

J. P. Smith [26] in several papers gives an account of the marine Lower Triassic faunas of western America and their relationship to Asiatic and European faunas. He points out the lines of faunal migration [27] and describes the withdrawal of the Triassic sea, which was followed by the encroachment of the red beds.[28]

Girty [29] describes the fauna of the phosphate beds of the Park City formation, which are now separated out as a part of the Phosphoria formation.

Gale and Richards [30] and Richards and Mansfield [31] discuss the general geology and the phosphate deposits of neighboring regions.

Mansfield and Larsen [32] describe the occurrence and character of nepheline basalt in the Fort Hall Indian Reservation, and Mansfield [33] subdivides and discusses some of the Mesozoic formations of the same region.

STRATIGRAPHY.

GENERAL CHARACTER AND AGE OF THE ROCKS.

The rocks of the Fort Hall Indian Reservation include both sedimentary and igneous types. The sedimentary rocks present a rather full sequence from early Cambrian to Tertiary and Quaternary. Cretaceous rocks and some of the Tertiary formations are not present, but the other periods are all represented. Because of the sedimentary character of the phosphate deposits and their complex structural relation it was necessary to study the general stratigraphic

[24] Weeks, F. B., and Heikes, V. C., Notes on the Fort Hall mining district, Idaho: U. S. Geol. Survey Bull. 340, pp. 175–183, 1908.

[25] Bell, R. N., Idaho State Insp. Mines Eighth to Fourteenth Ann. Repts., 1906–1912.

[26] Smith, J. P., The border line between Paleozoic and Mesozoic in western America: Jour. Geology, vol. 9, pp. 512–521, 1901; On the distribution of Lower Triassic faunas: Idem, vol. 20, pp. 13–20, 1912; The middle Triassic marine invertebrate faunas of North America: U. S. Geol. Survey Prof. Paper 83, 1914. Hyatt, Alpheus, and Smith, J. P., The Triassic cephalopod genera of the United States: U. S. Geol. Survey Prof. Paper 40, 1905.

[27] Smith, J. P., Jour. Geology, vol. 20, p. 19, 1912.

[28] Smith, J. P., U. S. Geol. Survey Prof. Paper 83, p. 4, 1914.

[29] Girty, G. H., The fauna of the phosphate beds of the Park City formation in Idaho, Wyoming, and Utah: U. S. Geol. Survey Bull. 436, 1910.

[30] Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 457–535, 1910.

[31] Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pp. 371–439, 1911; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, 1914.

[32] Mansfield, G. R., and Larsen, E. S., jr., Nepheline basalt in the Fort Hall Indian Reservation: Washington Acad. Sci. Jour., vol. 5, pp. 463–468, 1915.

[33] Mansfield, G. R., Subdivisions of the Thaynes limestone and Nugget sandstone, Mesozoic, in the Fort Hall Indian Reservation, Idaho: Washington Acad. Sci. Jour., vol. 6, pp. 31–42, 1916.

section of the region. Attention was centered, however, upon the phosphatic shales and the strata that succeed them, for it is upon the character and attitude of these rocks that the classification of the land as phosphate or nonphosphate must depend. The Tertiary and Quaternary rocks cover large areas and conceal many important stratigraphic and structural features. Indeed, the interpretation of the structure is in places rendered difficult or even impossible in the absence of borings by reason of this cover. Doubtless, too, it conceals valuable phosphate deposits, whose presence and quality can not be determined without drilling.

The igneous rocks include lavas, dikes, and fragmental deposits that cover large areas and add to the difficulties involved in stratigraphic and structural studies. They are particularly abundant in the northern part of the Bannock Valley region and the western part of the eastern mountainous region.

The general map (Pl. III) has been compiled from the individual township maps that were mostly worked on the field scale of 1:31,680. These maps have been reduced and adjusted to the topographic map that was prepared by C. G. Anderson on the field scale of 1:192,000 and enlarged to the scale of 1:125,000.

A tabular summary of the general stratigraphy of the reservation is given below. A more detailed description of the rock units is given in succeeding pages, for it is upon the recognition of the characteristics set forth in these descriptions that interpretations regarding stratigraphy and structure must rest.

Stratigraphic section of the Fort Hall Indian Reservation.

Geologic age.	Formation.	Thickness (feet).	General character.
Quaternary.		Not measured.	Alluvium, travertine, basalt, quartz latite, rhyolite.
Tertiary (Pliocene?). .	Salt Lake formation.	Not measured.	Conglomerates, marls, and dense, nearly lithographic limestones and clays with interbedded volcanic ash and associated basalts, rhyolites, quartz latites, andesites, and tuffs Except the lavas, these beds weather to a prevailingly white soil.
	-Unconformity		
Jurassic.	Twin Creek limestone.	Estimated at not less than 2,500.	Yellow calcareous, fossiliferous sandstone with some beds of massive gray limestone. Laminated shaly gray limestone. Basal yellow calcareous sandstones, massive, with intercalated massive gray limestone that contains oyster shells.
	-Unconformity?		
	Nugget sandstone.	Estimated at 1,500±.	Brick-red and light-colored sandstones.
	-Unconformity?		

Stratigraphic section of the Fort Hall Indian Reservation—Continued.

Geologic age.		Formation.		Thickness (feet).	General character.
Triassic (?).		Wood shale.		200-250	Bright-red shale, weathering to red soil.
		Deadman limestone.		150±	Gray to purplish dense limestone of almost lithographic quality in some places; contains some gray and greenish chert.
		Higham grit.		500±	Coarse pink to white gritty or conglomeratic sandstone.
		—Unconformity—			
Lower Triassic.		Timothy sandstone.		800	Somewhat sugary yellowish to grayish sandstone in beds 1 to 3 inches thick, weathering with pinkish tinge.
		—Unconformity(?)—			
		Thaynes group.	Portneuf limestone.	1,500±	Siliceous, cherty gray to yellowish limestones in massive beds; contains rounded elongated nodules and streaks of chert; fossiliferous.
			Fort Hall formation.	800±	Yellowish and grayish limestones and sandstones. The limestones siliceous and cherty; the sandstones calcareous and fossiliferous.
			Ross Fork limestone.	1,350±	Dense gray nonfossiliferous thin-bedded limestone, olive-drab platy, calcareous shales, purplish gray thin-bedded and massive limestone that contains pelecypod and brachiopod faunas and ammonite zones near base.
		Woodside shale.		900	Olive-drab platy calcareous shales with interbedded reddish-brown limestones, more numerous near the top and crowded with pelecypods.
		—Unconformity—			
Carboniferous.	Permian.	Phosphoria formation.		500	Rex chert member about 350 feet thick (dark flinty shales, in some places massive chert; rarely grades into limestone). Phosphate shales about 150 feet thick (shales, impure limestone, and phosphate rock; main bed about 6 feet thick near base).
		—Unconformity in places			
	Pennsylvanian.	Wells formation.		2,400±	Upper member, siliceous gray dense cherty limestone 50 feet or more thick; not well developed. Sandy beds not well exposed, thickness not known, perhaps 200-400 feet. Massive cherty gray limestone, fossiliferous; base not seen; thickness estimated at not less than 2,000 feet.
	Mississippian.	Brazer limestone.		Not measured.	Massive gray and drab limestones, fossiliferous; top and base not seen; stratigraphy and thickness not determined.
		Madison limestone.		Not measured.	Bluish-gray limestone beds, 1 to 8 inches thick, with intervening shaly bands 3 to 6 inches thick; fossiliferous; top and base not seen.

Stratigraphic section of the Fort Hall Indian Reservation—Continued.

Geologic age.		Formation.	Thickness (feet).	General character.
Devonian.		Threeforks (?) limestone. Jefferson limestone.	Not measured.	Dark-gray massive limestones, more or less broken; sparingly fossiliferous. Identified by fossil collections and stratigraphic position.
Silurian.		Laketown dolomite.	Not measured.	Yellowish-brown to gray dolomitic limestone that contains imperfectly preserved silicified fossils. Identified by a single fossil collection.
Ordovician.		Fish Haven dolomite.	Not measured.	Gray to brown weathering dark dolomitic limestone commonly much shattered and veined, somewhat cherty; contains Richmond fossils.
		-Unconformity-		
		Swan Peak quartzite.	Estimated at 500.	White dense vitreous quartzite; a conspicuous cliff maker. Of Chazy (?) age.
		Garden City limestone.	Not measured.	Gray limestone, very cherty; chert forms rough surfaces and weathers reddish brown; in some localities the rock is bluish gray, relatively pure, and sparingly fossiliferous; of Beekmantown age.
Cambrian.	Upper and Middle Cambrian.	Formations not differentiated.	Not measured.	Dark-gray limestone that contains yellow sandy or cherty streaks and shows annelid trails; some beds are oolitic and contain brachiopods, trilobites, and other fossils. Also massive gray well-crystallized beds that weather brown; shales and some sandstone are also present. Formations not differentiated from each other nor everywhere differentiated from overlying Ordovician.
	Middle and Lower Cambrian.	Brigham quartzite.	Estimated not less than 1,000.	Reddish to purplish and pink dense siliceous quartzites, including gritty and conglomeratic facies.

CAMBRIAN SYSTEM.

The Cambrian system is well developed in the Fort Hall Indian Reservation. Although it was not practicable to differentiate and map the individual formations, much similarity was noted between the sections there exposed and the sections at Blacksmith Fork, Utah, and west of Liberty, Idaho, in the Montpelier district, described by Walcott. The section at Liberty is given here for comparison.[34]

[34] Walcott, C. D., Cambrian section of the Cordilleran area: Smithsonian Misc. Coll., vol. 53, pp. 6–9, 190–200, 1908.

Section of Cambrian strata on Mill Creek, west of Liberty, Idaho.

Series.	Formation.	Thickness (feet).	General character.
Upper Cambrian.	St. Charles formation.	1,197	Bluish-gray to gray arenaceous limestones, with some cherty and concretionary layers, passing at the base into thin-bedded gray to brown sandstone.
Middle Cambrian.	Nounan formation.	814	Light-gray to dark lead-colored arenaceous limestones.
	Bloomington formation.	1,162	Bluish-gray, more or less thin-bedded limestones and argillaceous shales; small rounded nodules of calcite are scattered irregularly through many of the layers of limestone.
	Blacksmith formation.	23	Gray arenaceous limestones in massive layers.
	Ute formation.	731	Blue to bluish-gray thin-bedded fine-grained limestones and shales, with some oolitic concretionary and intraformational conglomeratic layers.
	Spence shale [member of Ute limestone].	30	Argillaceous shales.
	Langston formation.	30	Massive bluish-gray limestone with many rounded concretions.
	Brigham formation.	1,000+	Massive quartzitic sandstones.

The St. Charles limestone is probably represented by some of the cherty gray limestones west of the quartzite hills in T. 4 S., R. 36 E., and perhaps on the north side of Mount Putnam in T. 5 S., R. 37 E. At the former locality a sandstone is associated with the limestones that may correspond with the Worm Creek quartzite member at the base of the St. Charles.

The Bloomington formation may be represented by the limestone just west of the narrows of Ross Fork Canyon in sec. 11, T. 5 S., R. 36 E. Here the limestone at the base corresponds lithologically to the Blacksmith limestone, which lies beneath the Bloomington, and limestone and shales follow below.

The Blacksmith limestone appears to be represented at a number of places.

Other limestones, some of them oolitic and containing intraformational conglomerates together with shales, come in near the massive quartzites, which with little doubt represent the Brigham quartzite.

The Brigham quartzite forms much of the exposed rock in the high country about North Putnam and South Putnam mountains. It is prevailingly dense, vitreous, iron-stained, reddish or purplish, and in many places gritty or conglomeratic. It has not been measured but is doubtless 1,000 feet or more thick. (See Pl. I, *A*, *C*, p. 16.)

The formations between the Brigham quartzite and the Swan Peak quartzite have been grouped in the mapping, the Garden City limestone and Upper Cambrian being mapped together and the remainder of the Cambrian being shown by a separate color pattern. The thickness of these rocks has not been determined but may be comparable to that given in the above section.

ORDOVICIAN SYSTEM.

GARDEN CITY LIMESTONE.

The Garden City limestone has not been differentiated on the map from the Upper Cambrian rocks. A number of fossil collections from it have been identified by Edwin Kirk, from localities along the west front of the quartzite hills in Tps. 4 S. and 5 S., R. 36 E.; secs. 25 and 28, T. 8 S., R. 33 E.; and doubtfully elsewhere. The following fossils have been identified by Edwin Kirk:

Locality Mt. 8, NW. ¼ NW. ¼ sec. 25, T. 8 S., R. 33 E.
- Dalmanella cf. D. pogonipensis (Hall and Whitfield).
- Maclurea cf. M. subannulata Walcott.
- Asaphellus sp.
- Crinoid and cystid fragments.

Locality Mt. 19, SE. ¼ SE. ¼ sec. 28, T. 8 S., R. 33 E.
- Maclurea sp.
- Crinoid fragments.

Locality M. 270, SE. ¼ NW. ¼ sec. 27, T. 4 S., R. 36 E.
- Asaphellus sp.
  - Probably same horizon as Mt. 8.

Locality M. 272, NW. ¼ SW. ¼ sec. 23, T. 4 S., R. 36 E.
- Sponge?
- Crinoid stems.

The rock is dark-gray limestone which contains much chert that weathers with rough surface, the chert becoming reddish. The fauna indicates Beekmantown age.

SWAN PEAK QUARTZITE.

The Garden City limestone is overlain by a dense white vitreous quartzite, called the Swan Peak quartzite, by correlation with the section of the Randolph quadrangle, Utah, that has been described by Richardson.[35] The rock is quite uniform in character and is only rarely conglomeratic. In places the quartzite shows cross-bedding and tubular cavities or linear markings suggestive of worm borings. The quartzite was not measured but is estimated to be about 500 feet

[35] Richardson, G. B., The Paleozoic section in northern Utah: Am. Jour. Sci., 4th ser., vol. 36, pp. 406–416, 1913.

thick. It is a conspicuous cliff maker and forms rugged topography. It constitutes the summit of North Putnam Mountain and of the quartzite hills north of Ross Fork Creek in Tps. 4 and 5 S., R. 36 E. (See Pl. I, *C*.) It also appears west of Bannock Peak in T. 9 S., R. 32 E.; in Rattlesnake Canyon, T. 8 S., R. 33 E.; in sec. 20, T. 5 S., R. 38 E., and elsewhere. Its vitreous, brittle character has caused it to be much fractured by the deformation to which it has been subjected, and it is commonly slickensided and iron stained. The abundance of its large fragments in the Tertiary deposits suggests that extensive masses of it are now concealed by this later cover or that overthrust or infolded areas of it, more extensive than those now remaining, have been removed by erosion. The Swan Peak quartzite is of Lower Ordovician (Chazy?) age.

FISH HAVEN DOLOMITE.

Above the Swan Peak quartzite is a series of dark-gray limestones correlated with the Fish Haven dolomite of the Randolph quadrangle, Utah, classified by Richardson.[36] The rocks are somewhat cherty. They weather light gray or brown, with a purplish tinge, and are usually much fractured and seamed with calcite. The chert appears in small round and irregular white or bluish nodules. The top of the formation has not been recognized, and no measurements of thickness have been made. Several collections of fossils have been identified by Edwin Kirk, as follows:

Locality Mt. 24, SW. ¼ sec. 1, T. 9 S., R. 33 E.
- Trochonema sp.
- Halysites gracilis Hall.
- Streptelasma sp.

Locality M. 30, NW. ¼ NW. ¼ sec. 36, T. 9 S., R. 33 E.
- Rhynchotrema perlamellosa (Whitfield).
- Dalmanella cf. D. meeki (Miller).
- Plectorthis cf. P. whitfieldi (Winchell).
- Streptelasma rusticum (Billings).

Locality M. 105, sec. 12, T. 5 S., R. 36 E.
- Streptelasma.

Locality M. 162, sec. 20, T. 5 S., R. 38 E.
- Rafinesquina sp.
- Streptelasma sp.

Locality M. 237, sec. 24, T. 4 S., R. 36 E.
- Halysites gracilis Hall.

Kirk states that the fossils are of Richmond age. The Fish Haven dolomite forms rugged ridges, as along the east boundary of T. 4 S., R. 36 E., where it is intensely shattered. The Ordovician and Cambrian rocks underlie the surface of the higher and rougher country

[36] Richardson, G. B., op. cit.

in the vicinity of North and South Putnam mountains and in the southern part of the Bannock Valley region.

SILURIAN SYSTEM.

LAKETOWN DOLOMITE.

The occurrence of Silurian rocks in the Fort Hall Indian Reservation is known from a single collection of fossils. The fragments that were collected at locality Mt. 37, SW. ¼ SW. ¼ sec. 24, T. 9 S., R. 33 E., were chiefly of one form, which was identified by Edwin Kirk as *Conchidium* sp., doubtfully Silurian. The rock is correlated with Laketown dolomite (Silurian) of the Randolph quadrangle, Utah, described by Richardson.[37] The extent and thickness of the beds have not been determined. The rock is a yellowish-brown limestone and contains abundant silicified fragments of fossils. The locality from which the collection was taken is a knoll just east of the big quartzite hill east of Bannock Valley.

DEVONIAN SYSTEM.

JEFFERSON LIMESTONE.

The presence of the Jefferson limestone is known from a single collection of fossils, Mt. 31, NW. ¼ NW. ¼ sec. 23, T. 9 S., R. 33 E. From this locality Edwin Kirk has identified two forms—*Stromatopora* sp. and Bryozoa (?).

The rock is a dense fine-grained black limestone, interbedded with dark-gray banded, dark-gray mottled, and light-gray fine-grained limestone. The thickness and extent of the formation have not been determined.

THREEFORKS (?) LIMESTONE.

Fossils of doubtful Threeforks age have been collected from two localities. Edwin Kirk has identified the following forms:

Locality M. 133, NE. ¼ SE. ¼ sec. 29, T. 5 S., R. 38 E.
- Atrypa reticularis Linné.
- Spirifer cf. S. disjunctus Sowerby.

Locality M. 297, sec. 12, T. 4 S., R. 36 E.
- Camarotoechia sp.
- Spirifer sp.
- Bucanopsis sp.

The rocks are massive bluish-gray limestones. Their extent and thickness have not been determined. In the range east of Bannock Valley in T. 9 S., R. 33 E., it has not been practicable to differentiate Devonian and Silurian rocks from the lower Carboniferous above nor from the Ordovician limestone below. In this locality the prephosphate rocks are grouped and mapped as undifferentiated Paleozoic.

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[37] Richardson, G. B., op. cit.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

MADISON LIMESTONE.

The Madison limestone, of lower Mississippian age, as represented in the Fort Hall Indian Reservation, is a relatively thin-bedded dark bluish gray limestone, that forms beds 1 to 8 inches thick, and contains intervening shaly beds 3 to 6 inches thick in some places. Some exposures show a rock of lighter color and in more massive beds. The formation occurs in a number of widely separated localities, including the rocky hill in the NW. ¼ sec 18, T. 4 S., R. 37 E.; several places in the ridge in the west part of T. 5 S., R. 38 E.; east of Bannock Valley along the line between Tps. 8 and 9 S., R. 33 E.; and in the vicinity of Bannock Peak, in T. 9 S., R. 32 E. The top and base of the formation have not been recognized nor the extent and thickness determined. The rocks, however, appear to occupy relatively small areas in some of the more rugged parts of the reservation, where they have been exposed by the erosion of faulted or folded strata. Fossils are rather numerous and include small cup corals, gastropods, spiriferoid and other brachiopods, trilobite fragments, and crinoids, which have been identified by G. H. Girty as characteristic of the Madison limestone. The formation as exposed on the reservation shows no unusual facies but appears to be similar to rocks of the same age in other parts of the Idaho field as described in previous reports.[38] According to G. H. Girty, the Madison fauna is of lower Mississippian age and corresponds to that of the basal portion of the "Wasatch limestone" of the Wasatch Mountains of Utah, as described by the early writers.

BRAZER LIMESTONE.

The upper Mississippian rocks of the Fort Hall Indian Reservation are referred to the Brazer limestone by correlation with the section of the Randolph quadrangle, Utah, described by Richardson.[39] The relations of the Brazer limestone to the Madison limestone have not been worked out, for the contact region has not been studied. In parts of the southeastern Idaho field previously studied the two formations are apparently conformable. Like the Madison, the Brazer is associated with rugged hills in widely separated parts of

[38] Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 473–474, 1910.

Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pp. 383–384, 1911; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, 1914.

[39] Richardson, G. B., op. cit.

the area. The Brazer is associated with the Madison at a number of the localities above mentioned. Its most extensive occurrence is in the ridge along the boundary between T. 9 S., R. 32 E., and T. 9 S., R. 33 E. The rocks are massive dark-gray to light-gray limestones, somewhat cherty but on the whole rather pure. The chert occurs in both streaks and nodules, and there are streaks or veinlets of calcite or aragonite. In some places the rock is finely crystalline and contains many crinoid stems. The extent and thickness of the formation have not been determined, but the thickness in the Bannock Valley district is probably not less than 800 to 1,000 feet. Some horizons are abundantly fossiliferous. The fauna includes *Productus giganteus*, *Syringopora*, *Schizophoria*, *Moorefieldella*, Bryozoa, and large cup corals with many fine septa, together with other forms. The formation presents no unusual facies, but agrees very well with descriptions given in the reports that have been cited.

In these accounts the similarity has been pointed out between the upper Mississippian fauna and the Spergen fauna identified by Meek from the divide between Ross Fork and Lincoln Valley. An attempt was made by G. H. Girty and members of the party to rediscover the locality in which the fauna identified by Meek occurred. It was found, however, that the descriptions of the locality were inadequate and that the locality probably lay outside of the Ross Fork drainage basin and outside the limits of the reservation.

PENNSYLVANIAN SERIES.

WELLS FORMATION.

The Brazer limestone is succeeded by about 2,400 feet of more or less siliceous and cherty limestone that contains sandy or quartzitic beds. This limestone is correlated with the Wells formation of the Montpelier quadrangle, Idaho, that has been described by Richards and Mansfield.[40] The base of the formation has not been seen, but in sec. 6, T. 4 S., R. 37 E., where the lower Wells adjoins the Brazer limestone, there has been considerable disturbance of the strata, probably involving faulting. Blackwelder[41] has reported an unconformity between the Pennsylvanian and Mississippian in Utah, but no such relationship has yet been recognized in the southeastern Idaho field.

In the type locality the Wells consists of three fairly well defined parts—limestone below and at the top and sandstones and quartzites in the middle. The formation as a whole is highly siliceous. The lower limestones are cherty and contain numerous sandy beds. The

[40] Richards, R. W., and Mansfield, G. R., The Bannock overthrust, a major fault in southeastern Idaho and northeastern Utah: Jour. Geology, vol. 20, pp. 681–709, 1912; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, 1914.

[41] Blackwelder, Eliot, New light on the geology of the Wasatch Mountains, Utah: Geol. Soc. America Bull., vol. 21, p. 530, 1910.

middle sandstone member weathers down largely to smooth slopes, on which lie rounded sandstone débris. The upper limestone is dense and siliceous, and bluish chert bands become more numerous and conspicuous toward the top. There is, too, a considerable fauna in the limestones. At the top the Wells is in some places unconformable beneath the overlying Phosphoria formation.

In the Fort Hall Indian Reservation the Wells maintains the above general characteristics but with some modifications. The lower limestone has increased to a thickness of about 2,000 feet and contains massive cherty limestones and some alternating beds of sandstone or quartzite. The middle sandstones, if present, are probably reduced in thickness and largely concealed beneath weathered slopes and later deposits. The thickness of the beds that occupy this interval is estimated at 200 to 400 feet. The upper limestone is prominent in some places, as in secs. 10 and 11, T. 4 S., R. 37 E., and sec. 36, T. 5 S., R. 38 E., where it is 50 feet or more thick, but elsewhere it is rather poorly developed. In some places there has been dislocation in the beds at that horizon, as in sec. 17, T. 5 S., R. 38 E., but in others the lack of development may be due to unconformity as probably in sec. 21, T. 4 S., R. 37 E.

The lower part of the formation is composed of dark bluish-gray limestone with chert in nodules and irregular streaks. Above this cherty limestone come yellowish and grayish sandy limestones, some of them in thin layers so arranged as to make massive ledges. Near the top of this limestone series the rocks are again gray and cherty.

The upper limestone series is very light in color and sandy. The chert near the top occurs in dark bands, in some places 4 to 6 inches thick, that are black rather than bluish and resemble some facies of the Rex chert. The rock is hard but not so fine textured and dense as in the region of the type locality. Also the absence of little silicified and crescentic fragments of brachiopods like those that project from weathered surfaces in the type locality is noteworthy here.

A red-bed layer is included in the Wells formation in sec. 15, T. 5 S., R. 35 E. Its stratigraphic position is probably in the sandy upper middle portion of the formation, but this could not be determined with certainty. It is apparently underlain by dark-gray fossiliferous limestones, which are assigned by G. H. Girty to the Wells.

Fossils occur at different horizons throughout the limestones but are more abundant in the lower part. The occurrence of *Fusulina* near the middle of the lower limestone series is noteworthy. Large cup corals, abundant Bryozoa, colonies of *Springopora*, *Spirifer rockymontanus*, and other forms were observed. One of the colonies of *Syringopora* measured 3 by 2 feet.

The Wells formation, like the Brazer and Madison limestones, occurs in widely separated districts in the eastern mountainous region and in the Bannock Valley region. The most extensive area lies in the northwest part of T. 4 S., R. 37 E., where the formation comprises the core of a large anticline that is somewhat complicated by faulting and minor folding. This area was studied by G. H. Girty and J. W. Merritt, but they found that a detailed stratigraphic section was not feasible.

PERMIAN SERIES.

PHOSPHORIA FORMATION.

Occurrence.—The Phosphoria formation, which represents the upper two members of the Park City formation as mapped in southeastern Idaho, southwestern Wyoming, and northeastern Utah in the reports for 1909 and 1910, has been described in previous papers.[42] It accompanies the Wells formation in the eastern mountainous district of the reservation but has not been recognized in the Bannock Valley region. The Phosphoria formation is exposed only in parts of four townships—T. 4 S., R. 37 E.; T. 4 S., R. 38 E.; T. 5 S., R. 37 E.; and T. 5 S., R. 38 E.—although float pieces of phosphate rock are found in parts of neighboring townships. The detailed distribution of the formation is shown on the large-scale maps that accompany the descriptions of those townships (pp. 83–91, 95–103).

Phosphate shales.—The phosphate shales, which constitute the lower member of the formation, are slightly exposed in the NE. ¼ NE. ¼ sec. 11, T. 4 S., R. 37 E., along the west side of a ravine. Also on low rocky points in the NE. ¼ SE. ¼ sec. 36, T. 5 S., R. 38 E., the SE. ¼ SE. ¼ sec. 21, T. 4 S., R. 37 E., and in the NE. ¼ NE. ¼ sec. 13, T. 5 S., R. 37 E., the phosphate float is so abundant as to amount practically to a slight exposure of the shales. It has not been practicable to make a complete section across the phosphate shales, but numerous paced measurements have been made across the belt occupied by float, the distance measured being that between the highest phosphate float and the highest float of the Wells formation. These measurements show some variations, but allowing for the angle of dip the shales appear to be about 150 feet thick. The thickness is thus comparable to that of the shales examined in the Montpelier and Georgetown districts farther southeast.

The fauna of the phosphate shales is somewhat extensive, although fossils are relatively rare in the beds of phosphate rock. G. H. Girty notes that the fauna presents an unusual and distinctive facies. He has selected from the forms described in his bulletin[43] the following list as characteristic:

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[42] Richards, R. W., and Mansfield, G. R., The Bannock overthrust, a major fault in southeastern Idaho and northeastern Utah: Jour. Geology, vol. 20, pp. 681–709, 1912; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, 1914.

[43] Girty, G. H., The fauna of the phosphate beds of the Park City formation in Idaho, Wyoming, and Utah: U. S. Geol. Survey Bull. 436, 1910.

Lingula carbonaria?
Lingulidiscina missouriensis.
Chonetes ostiolatus.
Productus geniculatus.
Productus eucharis.
Productus montpelierensis.
Productus phosphaticus.
Pugnax weeksi.
Pugnax osagensis var. occidentalis.
Ambocoelia arcuata.
Leda obesa.
Plagioglypta canna.
Omphalotrochus ferrieri.
Omphalotrochus conoideus.
Hollina emaciata var. occidentalis.

In the NE. ¼ NE. ¼ sec. 21, T. 4 S., R. 37 E., there is a bed of phosphate rock at the base of the shales, about 8 inches thick, which is composed largely of the fragments of shells. This bed was originally composed largely of carbonate of lime but is now apparently phosphatized, for an analysis of the rock shows the presence of 33.9 per cent of phosphorus pentoxide, equivalent to 74 per cent of tricalcium phosphate. This rock contains in addition large numbers of linguloid and discinoid shells and some pieces of bone. A fish spine was also found in the middle of the main phosphate bed in sec. 36, T. 5 S., R. 38 E.

Three partial sections of the phosphate shales were measured in trenches and test pits excavated by the Survey party. No other openings had been made in these deposits in the reservation. The sections in these openings and the percentage of phosphorus pentoxide contained in the samples that were taken are given in the following tables:

Partial section of phosphate shales in NE. ¼ NE. ¼ sec. 13, T. 5 S., R. 37 E., about 20 feet from section corner.

Character of beds.	P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	Thickness.	
	Per cent.	*Per cent.*	*Ft.*	*in.*
Shale, brown to light, sandy, broken, top not exposed.				
Phosphate rock, black, fine grained, hard, cherty (?)			1	3
Broken zone, shale and phosphate rock, brown to black			1	8
Phosphate rock, dark brown, finely oolitic, somewhat shaly, much broken, with interbedded shale			2	8
Shale, phosphatic, black to brown, with a few narrow bands of phosphate, much broken			4	9
Broken zone, mingled phosphate rock and shale, brown to yellowish			1	3
Phosphate rock, fine to coarse oolitic texture, beds up to 3 inches thick, dark gray to black, weathering yellowish, and in broken blocks coated white, including— *Inches.*				
Sample 5 ... 22	34.65	75.71	5	6
Sample 4 ... 22	34.59	75.57		
Sample 3 ... 22	32.64	71.31		
Phosphate rock, medium oolitic, brownish gray, with a few yellow sandy streaks; beds have a maximum thickness of 1½ inches, grading into thin shaly phosphate (sample 2)	23.98	52.31	1	5
Shale, yellowish brown, finely banded, iron stained, much broken and containing scattered phosphate nodules and streaks			2	6
Chert, with phosphatic nodules and fragments of discinoids, much broken				10
Shale, yellowish brown, sandy, with irregular phosphate streaks			3	0
Phosphate rock, medium to fine, oolitic; contains yellow sandy streaks (sample 1)	22.97	50.18	1	5
Sandy beds, yellowish brown, scattered phosphate nodules, banded, chert, black, broken; base not seen				6
			26	9

Partial section of phosphate shales in NW. ¼ NE. ¼ sec. 11, T. 4 S., R. 37 E., compiled from trench and three test pits.

Character of beds.		P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	Thickness.	
		Per cent.	*Per cent.*	*Ft.*	*in.*
Shales, black and purplish; base and top not exposed				2	6±
Not exposed				15±	
Sandy and shaly material, yellow; base and top not exposed				2	6
Not exposed				50±	
Limestone, black, fetid					8
Phosphate rock, irregularly bedded, black, nodular				1	0
Shale, brownish black; base not exposed				1	6
Not exposed				20	0
Shale, black, thin-bedded, top not exposed				1	0
Broken zone that contains fragments of phosphate rock and shale, much weathered, and calcareous material					6
Phosphate rock, broken, somewhat sandy, weathered; has a calcareous coating and a medium to coarse oolitic texture					3
Phosphate rock, medium to coarse, oolitic toward top, black to brown; white coating along bedding planes and joint surfaces; beds one-eighth of an inch to 3 inches thick including—	*Inches.*				
Sample 3	28	34.35	75.05	6	4
Sample 2	24	34.22	74.77		
Sample 1	24	32.62	71.47		
Phosphate rock, medium oolitic, thin-bedded, yellow, sandy streaks, white calcareous streaks, much broken and weathered				1	3
Fault, small, normal, plane vertical, downthrow on north, throw not shown but probably slight as same yellow material that occurs on south side lies under phosphate on north side.					
Broken sandy material that contains fragments of black chert and a few pieces of phosphate.					
				102	6

Partial section of phosphate shales in NE. ¼ SE. ¼ sec. 36, T. 5 S., R. 38 E., compiled from trench and six test pits.

Character of beds.	P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	Thickness.	
	Per cent.	*Per cent.*	*Ft.*	*in.*
Soil and other material.				
Shale, broken pieces, black to brown, somewhat phosphatic; contains small lenses and scattered oolites			2±	
Not exposed			48	
Soil and other material			1	0
Shale, brown			1	0
Not exposed			7	0
Soil that contains fragments of cherty limestone and shale			18±	
Phosphate rock layer, black, medium oolitic				1
Shale, black				7
Not exposed			16	
Limestone, deep drab				3
Shale, brown, with scattered oolites				3
Phosphate rock, black, medium oolitic				2
Shale, brown; base not shown			1	0
Not exposed			10	0
Phosphate rock, black, finely oolitic	31.40	68.7	1	9
Shale, brown				6
Not exposed			10	0
Shale, black, phosphatic			1	0
Not exposed			15	0
Limestone, scattered oolites				3
Shale, black, weathered brown			2	11
Limestone, black, fetid, fossiliferous; "Cap lime"			2	1
Main bed of phosphate rock, oolitic	33.02	72.1	2	1
	35.46	77.4	2	0
	33.14	74.1	2	0
Phosphate rock, sandy				6
Zone, weathered, yellow, sandy				9
Phosphate rock, hard, dense				3
Limestone, lower Phosphoria, fossiliferous.				
			146	5

The three sections all show the presence near the base of a phosphate bed 5 or 6 feet thick which contains on the average more than 70 per cent tricalcic phosphate. Much phosphatic material is distributed through the shales above the main phosphate bed, and at least one other bed of workable thickness and of nearly 70 per cent quality is shown in the section in T. 5 S., R. 38 E. In the Georgetown district still another bed of workable thickness and quality is shown near the top of the shales. This bed is usually difficult to open because of the large and abundant fragments of Rex chert that conceal the upper portion of the shale. It is possible that this bed is represented in the Fort Hall Indian Reservation, but its presence was not determined.

The "Cap lime" was present in only one of the three sections examined—that in T. 5 S., R. 38 E. Its absence in the other two sections may, perhaps, be due to the disturbance indicated by the broken zone above the main phosphate bed in those sections.

The fossiliferous limestone at the base of the section in T. 5 S., R. 38 E., was noted at only two other places besides the place where the section was measured—in the NW. ¼ NW. ¼ sec. 36, T. 5 S., R. 38 E., and the SE. ¼ SE. ¼ sec. 21, T. 4 S., R. 37 E. The rock is dark and fetid and contains large forms of *Productus* and *Spirifer*. The thickness was not determined but probably does not exceed 2 or 3 feet.

Rex chert member.—The Rex chert member, which overlies the phosphate shales, is represented chiefly by a dark, flinty shale that forms rounded hills and smooth slopes strewn with small angular fragments. In some places, as in secs. 2 and 11, T. 4 S., R. 37 E., and sec. 28, T. 5 S., R. 38 E., the Rex forms characteristic dark massive ledges of chert, and in one place, in the SE. ¼ SW. ¼ sec. 29, T. 5 S., R. 38 E., the chert appears to grade into a massive cherty limestone.

An unusual facies was observed by G. H. Girty and J. W. Merritt in the SW. ¼ NW. ¼ sec. 2, T. 4 S., R. 37 E. Here the rock is a yellow sandy shale and carries beds of earthy limestone. Its lithology is similar to Woodside shale though of somewhat more intense yellow color. The distinguishing feature is the presence of a distinctly Paleozoic fauna, which consists chiefly of the brachiopod *Ambocoelia* in abundance, together with pelecypods that suggest Paleozoic characteristics but are not definitely identified.

The Rex chert is generally nonfossiliferous, but at some places it contains spicules and casts of crinoid stems, in addition to brachiopods. G. H. Girty lists the following as the most characteristic species:

Productus multistriatus.
Productus subhorridus.
Spirifer aff. S. cameratus.
Spiriferina pulchra.
Composita subtilita var.

At a locality on Deer Creek, in the Preuss Range, Mr. Girty obtained the following fauna from the limestone facies of the Rex chert:

Amphoporella laminaria.
Productus nevadensis.
Productus eucharis.
Productus multistriatus?
Camarophoria n. sp.

No fossils were found in the Rex chert in the Fort Hall Indian Reservation.

At two or three places in the ridge in the west part of T. 5 S., R. 38 E., there are small areas of a grayish-yellow chert, more or less brecciated and associated with a light-gray limestone.

The identity of this chert is in doubt. It may be assignable to the Rex or perhaps to the Wells formation.

The thickness of the Rex chert, as measured in a section that includes Triassic beds, in secs. 1 and 2, T. 4 S., R. 37 E., is 350 feet.

TRIASSIC SYSTEM.

OCCURRENCE AND SUBDIVISIONS.

The Triassic system is well represented in the eastern mountainous region of the Fort Hall Indian Reservation, where it has been subdivided into five formations that aggregate 5,350 feet in thickness, classed as Lower Triassic. In addition three formations of somewhat uncertain age, which have a combined thickness of 900 feet, are doubtfully classified as Triassic. The Lower Triassic rocks are not exposed elsewhere in the reservation. The five formations into which they are divided are the Woodside shale, Ross Fork limestone, Fort Hall formation, Portneuf limestone, and Timothy sandstone. The Ross Fork, Fort Hall, and Portneuf comprise the Thaynes group. The three doubtfully Triassic formations are the Higham grit, Deadman limestone, and Wood shale. The Nugget sandstone, which overlies the Wood shale and was formerly considered as Triassic or Jurassic, is now referred to the Jurassic.

REVIEW OF NOMENCLATURE.

The names of some of the subdivisions mentioned in the preceding paragraph are comparatively new, and others are used in a somewhat different sense from that in which they have hitherto been employed, so that an outline of the steps by which these changes in nomenclature have come about may appropriately be given here.

The Woodside shale and Thaynes formation were first described by Boutwell[44] in the Park City district of Utah. He also described

[44] Boutwell, J. M., Stratigraphy and structure of the Park City mining district, Utah: Jour. Geology, vol. 15, pp. 434–458, 1907.

an overlying formation, chiefly of red beds, 1,650 feet thick, which he called the Ankareh shale. About the same time Veatch[45] described formations in southwestern Wyoming to which he gave Boutwell's names Woodside and Thaynes, but he also described a series of sandy beds above these, 1,900 feet thick, to which he gave the name Nugget formation. The lower 600 feet of the Nugget formation was described as made up of bright-red sandstones and shales, and the upper 1,300 feet as yellow thin-bedded sandstones and shales that weather dark brown. The two subdivisions were mapped separately by Veatch.

Gale and Richards[46] and later Richards and Mansfield[47] carried the nomenclature of Boutwell and Veatch into southeastern Idaho, employing the name Ankareh shale for the red beds above what was then regarded as the upper limestone of the Thaynes and below a conglomeratic sandstone near the base of the Nugget as exposed in Raymond Canyon, in the Montpelier quadrangle.

Boutwell[48] in a latter publication employed Veatch's term Nugget to designate the upper 500 feet of the beds which he had formerly included in his Ankareh shale.

The examination of the Fort Hall Indian Reservation in 1913 led the present writer to consider the Thaynes a group of three formations, the uppermost of which, now known as the Portneuf limestone, has an abundant and distinctive fauna and is about 1,500 feet thick. The rocks representing the Nugget sandstone of Veatch were also divided by the writer into four members, the lowest of which is a massive conglomeratic sandstone 500 feet thick, supposed to correspond with the conglomeratic sandstone at the Raymond Canyon section. Between the Portneuf limestone and this conglomerate there is a sugary yellowish sandstone 800 feet thick that was supposed to correspond stratigraphically with the Ankareh shale, though it contains no red beds, and this was called the Ankareh sandstone.[49]

The subdivisions as worked out in the Fort Hall Indian Reservation were carried eastward in succeeding field seasons into the Lanes Creek and Freedom quadrangles and thence southward into the Montpelier quadrangle and some of the regions formerly studied by

[45] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming: U. S. Geol. Survey Prof. Paper 56, pp. 50–56, 1907.

[46] Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 457–535, 1910.

[47] Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pp. 371–439, 1911; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, 1914.

[48] Boutwell, J. M., Geology and ore deposits of the Park City district, Utah: U. S. Geol. Survey Prof. Paper 77, pp. 42–59, 1912.

[49] Mansfield, G. R., Subdivisions of the Thaynes limestone and Nugget sandstone, Mesozoic, in the Fort Hill Indian Reservation, Idaho: Washington Acad. Sci. Jour., vol. 6, pp. 31–42, 1916.

Gale and Richards. The Portneuf limestone is divisible into three members, a lower and upper limestone, each of which carries a similar fauna, and a well-developed intervening red member consisting of interbedded sandstones and shales. The red member thickened southward whereas the upper limestone grew thinner in that direction. The upper limestone member of the Portneuf is believed to be the "limestone or calcareous shale" mentioned by Gale and Richards[50] as composing the upper member of their Ankareh shale, and the underlying "red bed" member of the Portneuf is believed to compose the lower member of their Ankareh shale, whereas the lower limestone of the Portneuf constitutes the top member of their Thaynes. The relationships here outlined are shown in the accompanying table.

If the subdivisions Portneuf, Timothy, Higham, Deadman, and Wood are to be retained, as seems desirable because of the detailed work in which they have been employed, the term Ankareh must be dropped from the nomenclature of southeastern Idaho. The retention of the name Ankareh for the sugary-yellow sandstone above the Portneuf limestone is inadvisable, both because of the difference in lithology and because the sandstone represents only a small part of the stratigraphic interval to which the name was originally applied. A new name, Timothy sandstone, is therefore here adopted for this sandstone.

The "main sandstone member of the Nugget," as it was previously called in the Fort Hall Indian Reservation,[51] is distinct and characteristic wherever exposed. It is recognized as a distinct mappable unit over a large area, for it is the same as the Nugget sandstone of Boutwell in the Park City district, Utah, the same as the Nugget sandstone of Schultz in the Rock Springs uplift of southwestern Wyoming, and the same as the upper member (major part) of Veatch's Nugget formation, as typically exposed at Nugget station, on the Oregon Short Line Railroad, in Lincoln County, southwestern Wyoming. Accumulated evidence supports the view that it is of Jurassic age. The name Nugget is therefore here restricted to this sandstone. The lower 600 feet of Veatch's Nugget, comprising his "red-bed member," is regarded by both the writer and Mr. Schultz, who has studied the rocks at the Nugget type locality, as the equivalent of the Higham grit, Deadman limestone, and Wood shale of the Fort Hall Indian Reservation, and there is no reason why they should be grouped with the overlying beds, for they are lithologically and stratigraphically distinct.

The Higham grit, separated from the underlying formations by a marked unconformity, and the succeeding Deadman limestone and

[50] U. S. Geol. Survey Bull. 430, p. 480, 1910.

[51] Mansfield, G. R., Subdivisions of the Thaynes limestone and Nugget sandstone, Mesozoic, in the Fort Hall Indian Reservation, Idaho: Washington Acad. Sci. Jour., vol. 6, p. 42, 1916.

Tentative correlation of stratigraphic units of different authors in reports on areas in northeastern Utah, southeastern Idaho, and southwestern Wyoming.

Boutwell. Park City district, Utah. [a]	Veatch. Southwestern Wyoming. [b]	Gale and Richards. Southeastern Idaho. [d]	Boutwell. Park City district, Utah. [e]	Mansfield. Fort Hall Indian Reservation, Idaho. [f]	Mansfield. Fort Hall Indian Reservation and neighboring areas in southeastern Idaho. [g]	Schultz. Rock Springs uplift, southwestern Wyoming. [h]	Age.
[Absent.]	Twin Creek formation, 3,500–3,800 feet.	Twin Creek limestone.	Twin Creek limestone to northwest.	Twin Creek limestone.	Twin Creek limestone, 2,500–3,000± feet.	Twin Creek limestone.	Jurassic.
Ankareh shales (red shales with interbedded coarse gray sandstones), 1,650 feet.	Nugget formation, 1,900 feet: Yellow thin-bedded sandstones and shales, weathering dark brown, 1,300 feet.	Nugget sandstone, 1,900 feet: Massive white sandstone.	Nugget sandstone (white sandstone with intercalated red shales), 500 feet.	Nugget sandstone: Main sandstone member, 1,500 feet.	Nugget sandstone (red and light-colored sandstones).	Nugget sandstone.	
	Red bed member (bright-red sandstones and shales), 600 feet.	Massive red sandstones and sandy shales.	Ankareh shale (red shales with interbedded coarse gray sandstones), 1,150 feet.	Wood shale member, 250 feet.	Wood shale (red).	Ankareh shale.	Triassic (?).
				Deadman limestone member, 150± feet.	Deadman limestone.		
				Higham grit member, 500± feet.	Higham grit.		
	[Unconformity [c]] [Absent?]	Ankareh shale (maroon and chocolate, some greenish beds), 670 feet.		Ankareh sandstone, 800 feet.	Timothy sandstone (yellowish).	Not recognized.	
Thaynes limestone (calcareous strata with sandstones and shales), 1,190 feet.	Thaynes formation, 2,400–2,600 feet.	Thaynes limestone, 2,000 feet.	Thaynes formation (limestone with sandstones and shales; "mid red" shale separates more calcareous upper part from more arenaceous lower part), 1,190 feet.	Thaynes group: Portneuf limestone, 1,500± feet.	Thaynes group, 3,600 feet: Portneuf limestone: Limestone.	Thaynes (?) formation.	Lower Triassic.
					Red sandstones and shales, 200–1,000 feet.		
					Limestone.		
				Fort Hall formation, 800± feet.	Fort Hall formation.		
				Ross Fork limestone, 1,350± feet.	Ross Fork limestone.		
Woodside shale, 1,180 feet.	Woodside formation, 500 feet.	Woodside shale, 1,000–1,200 feet.	Woodside shale (red shale), 1,180 feet.	Woodside shale, 900 feet.	Woodside shale.	Woodside shale.	

[a] Jour. Geology, vol. 15, pp. 434–458, 1907.
[b] U. S. Geol. Survey Prof. Paper 56, 1907.
[c] Veatch in his report did not mention an unconformity between the Nugget and Thaynes formations, but it is the belief of this writer and of Mr. A. R. Schultz, who has studied the rocks at the Nugget type locality, that there is an unconformity at the base of the Nugget there, and that the Higham grit will be found to represent the basal member of Veatch's Nugget formation. It is also their belief that the Wood shale will be found to constitute the upper part of Veatch's "red-bed member" of the Nugget, and that the Timothy sandstone is probably not represented in Veatch's section.
[d] U. S. Geol. Survey Bull. 430, 1910.
[e] U. S. Geol. Survey Prof. Paper 77, 1912.
[f] Washington Acad. Sci. Jour., vol. 6, pp. 31–42, 1916.
[g] U. S. Geol. Survey Bull. 713, 1920.
[h] U. S. Geol. Survey Bull. 702, 1920.

158145°—20. (To face page 44.)

Wood shale are also here treated as independent formations because they have been identified and mapped over considerable areas in the Cranes Flat, Lanes Creek, Freedom, and Montpelier quadrangles as well as in the Fort Hall Indian Reservation.

LOWER TRIASSIC FORMATIONS.

GENERAL CHARACTER.

The formations assigned to the Lower Triassic include 5,350 feet of shales, calcareous beds, and sandstones grouped in five formations, all of which except the Timothy sandstone are fossiliferous at certain horizons. The determination of age, as pointed out in the discussion of the Ross Fork limestone, is based upon ammonite zones, which here occur 900 to 1,200 feet above the top of the Paleozoic formations. The fossils of the overlying 4,000 feet of sediments are less distinctive, and the faunal relations of some of them, notably certain brachiopods of the Portneuf limestone, have not been fully studied. It is therefore possible, though perhaps not probable, that some of this thick sedimentary series may be of later age than Lower Triassic.

WOODSIDE SHALE.

The Woodside shale, which immediately overlies the Phosphoria formation, takes its name from the Park City mining district, Utah. It is composed mainly of yellow and olive drab, platy, calcareous, and sandy shale which contains thin beds of gray dense limestones that weather brown or purplish. The limestones are few and relatively far apart in the lower part of the section but are more numerous and thicker bedded near the top. Some of the limestones are crowded with pelecypod shells, principally *Myalina*. In Utah and near Paris, Idaho, some of the beds of the Woodside shale are colored red. In most of the southeastern Idaho region the formation is characterized by the yellowish or olive-drab tints above noted. Near the base, however, in the Fort Hall Indian Reservation, the beds have a distinctive reddish-brown tint and are relatively sandy.

The base of the Woodside shale, which in regions previously studied has been rather sharply marked by a lithologic and faunal change, is not so clear in the region under discussion. The Paleozoic fauna locally found above the chert of the Rex member necessitates the location of the Triassic boundary above that fauna, which occurs in brownish-yellow sandy shales and limestones not easily distinguished lithologically from the Woodside, although the faunas of the Woodside and Rex, where well developed, are very different. In fact, this difference is so great as to suggest the probability of a stratigraphic break, though no angular unconformity has been observed.

The top of the Woodside shale is somewhat arbitrarily marked by the base of the *Meekoceras* zone, which represents the entry of the first fossil ammonites recognized in the faunas of these formations. The *Meekoceras* zone in this region is not as abundantly fossiliferous nor as lithologically distinct as in some of the districts in the vicinity of Georgetown or Montpelier previously studied. The upper limestones of the Woodside are relatively massive and grade lithologically into those of the overlying Thaynes.

The thickness of the Woodside shale in the Fort Hall Indian Reservation is somewhat less than in the Georgetown and Montpelier districts. In this region the Woodside is about 900 feet thick.

Topographically the Woodside shale is marked by relatively smooth slopes with few exposures except near the top, where the massive limestones form important ledges.

THAYNES GROUP.

General character.—The Thaynes limestone was named in the Park City mining district, Utah. In northeastern Utah and in the Georgetown and Montpelier districts of southeastern Idaho the Thaynes forms platy, calcareous shales like the Woodside, and brown weathering muddy limestones with a massive limestone at the top. In the last-named district the Thaynes limestone is about 2,000 feet thick. Toward the north and northwest the formation becomes thicker and shows a marked tendency to differentiate into several members that can be mapped as units. In the Fort Hall Indian Reservation these beds have a total thickness of about 3,650 feet, yet according to G. H. Girty[52] fossils similar to those of the upper limestone were found by C. L. Breger in shales which underlie the shale formerly called Ankareh in Montpelier Canyon, Montpelier quadrangle. As a result of subsequent work this shale is now regarded as part of the Thaynes. Thus the thicker series of beds in this district occupies the same stratigraphic interval as the Thaynes limestone farther southeast, and it has been found advisable to subdivide it into three formations, the Ross Fork limestone at the base, the Fort Hall formation, and the Portneuf limestone.

Ross Fork limestone.[53]—The Ross Fork limestone takes its name from Ross Fork Creek, in the upper waters of which this limestone is well exposed. The base of the Ross Fork limestone lies conformably upon the Woodside shale and is marked by the "*Meekoceras*

[52] Personal communication.

[53] This limestone was previously described under the name Ross limestone. See Mansfield, G. R., Subdivisions of the Thaynes limestone and Nugget sandstone, Mesozoic, in the Fort Hall Indian Reservation, Idaho: Washington Acad. Sci. Jour., vol. 6, pp. 35–37, 1916.

beds" recognized by the Hayden Survey and referred to the Triassic and later referred by Hyatt and Smith [54] to the Lower Triassic.

The *Meekoceras* zone consists of gray to reddish-brown limestones about 50 feet thick, which contain numerous ammonites, the chambered shells of which appear on the weathered surface of the rock. In this region the fossils do not weather out so readily and the horizon is not so conspicuous as in the Georgetown district farther southeast. The *Tirolites* and *Columbites* zones, which have been recognized by Smith in the region of Paris, Idaho, 250 and 275 feet, respectively, above the *Meekoceras* zone,[55] have not been definitely recognized in the Fort Hall Indian Reservation, although there is some evidence of more than one ammonite horizon.

Above the *Meekoceras* zone for about 800 feet are massively bedded and thin-bedded gray to brown limestones, which contain large numbers of small brachiopods, chiefly *Pugnax* and terebratuloids, and pelecypods, *Myalina* and others, with intervening calcareous shales. The lithology of the shales and thinner-bedded limestones is much like that of the Woodside. The limestones have a sort of velvety appearance when weathered and are very fossiliferous. The presence of a small brachiopods in the massive limestones near the base is a convenient guide to the Ross Fork limestone, where the *Meekoceras* zone is not available.

The upper part of the Ross Fork limestone for about 500 feet consists of a dense calcareous gray to olive-greenish shale that weathers brown to yellow. These shales form conspicuous cliffs and are mainly nonfossiliferous.

The writer is indebted to G. H. Girty for the following faunal discussion of the Ross Fork limestone:

The fauna of the Ross Fork limestone consists chiefly of brachiopods, pelecypods, and cephalopods. The brachiopods and cephalopods are generally confined to zones which are narrow and possibly of small extent, but where found at all they are abundant. The brachiopods comprise a *Lingula*, a *Terebratula*, and a *Rhynchonella*, those terms being employed in a broad and general sense. The *Rhynchonella* closely resembles the Carboniferous species *Pugnax utah* and, as the Triassic occurs in the general region from which the type specimen was obtained, typical *Pugnax utah* may indeed be the Triassic form, as was suggested to me several years ago by Mr. Breger. A few specimens of a small *Discina* have also been collected.

The pelecypods consist mostly of pectinoids, of which there are many species. They probably include representatives of both the Pectinidae and Limidae, and they occur in some places in vast numbers, either alone or associated with other forms. Like most of these Triassic fossils, they belong to undescribed species, though one form can probably be referred to *Aviculipecten thaynesi-*

[54] Hyatt, Alpheus, and Smith, J. P., The Triassic cephalopod genera of America: U. S. Geol. Survey Prof. Paper 40, pp. 17 et seq., 1905.

[55] Smith, J. P., The distribution of Lower Triassic faunas: Jour. Geology, vol. 20, p. 17, 1912.

anus. Other types of pelecypods are much less common. The one most frequently found is similar to that described by White as *Volsella platynota*, but if my specimens really belong to White's species, I believe that it is a *Myalina*. A small alate shell, which may belong to *Bakewellia* or *Pteria*, has been found, and also forms which suggest the genera *Schizodus*, *Cardiomorpha*, and *Pleurophorus*. These last are so poorly preserved that their generic relations, even as based on external characters, are conjectural.

The cephalopods have been carefully investigated to the almost complete neglect of the rest of the Triassic fauna of this region. The Ross Fork limestone contains the most notable zone of the cephalopods—the *Meekoceras* zone. Nevertheless, the collections studied, which were not made with special reference to any one group of organisms, contain neither very numerous nor very complete specimens. The following species have been identified with more or less certainty: *Meekoceras mushbachanum*, *Meekoceras gracilitatis*, *Paranannites aspenensis*, *Ophiceras dieneri*, *Flemingites russelli*, *Clypites tenuis*.

Gastropods are so rare in the Ross Fork limestone that they might with little loss be neglected in a hasty survey of its fauna. One collection contains an abundance of small naticoid shells (*Natica lelia?*), but of much more interest is the occurrence in another collection of a species of *Bellerophon*. There can hardly be a doubt of the generic relationship of this form, which resembles the Pennsylvanian species *B. crassus*. The Bellerophontidae, though profusely developed in the Paleozoic and almost confined to that area, have been known in other parts of the world also to range up into the Mesozoic.

Fort Hall formation.—The Fort Hall formation is named from old Fort Hall, the site of which is in the valley of Lincoln Creek, a stream that is called on some maps Fort Hall Creek. The formation occupies a prominent ridge along the north side of this valley. The rocks lie conformably on the Ross Fork limestone. The dividing line is drawn on both lithologic and faunal grounds. There are four fairly well defined subdivisions.

(1) The base of the formation is a soft and somewhat sugary, yellow calcareous sandstone about 50 feet thick, which is sparingly fossiliferous and contains at one locality a bed of yellowish sandy limestone about 15 feet thick that carries plicated oyster-like pelecypods, terebratuloids, and other forms. This bed is overlain by white calcareous sandstone that weathers red or pink.

(2) Above these sandstones there is a gray or yellowish, siliceous dense limestone which contains large pectenoids and irregular cherty nodules and streaks that weather with a rough surface and project along the bedding planes. This limestone forms rough ledges and high points. The thickness of this series is estimated to be about 100 feet.

(3) At only two localities, secs. 36 and 26, T. 3 S., R. 37 E., there was observed above (2) a set of sandy and shaly gray limestones about 50 feet thick, including an oolitic bed 6 to 10 feet thick.

(4) The remainder of the section, estimated to be about 600 feet in thickness, consists of yellow to grayish cherty and sandy limestones

in thin beds, which are represented chiefly by fairly smooth slopes strewn with yellow and reddish sandy and cherty float fragments.

Fossil collections have been made at a number of places in the Fort Hall formation. G. H. Girty contributes the following faunal discussion of the formation:

The Fort Hall formation might appropriately be called the *Aviculipecten idahoensis* zone, for it is particularly characterized by that species, which occurs in most of the collections and in many of them is very abundant. With *Aviculipecten idahoensis* are associated a few other types of pelecypods, among which a large *Bakewellia* or *Pteria* and two or three species of pectinoid shells are the most common. There is also a form resembling *Myalina* (possibly the *Volsella platynota* of the Ross Fork limestone but smaller and less abundant), and several types which are too poorly preserved to be identified, but in general expression suggest *Myacites*, *Schizodus*, and *Pleurophorus*. A small naticoid (*Natica lelia?*) is rather abundant in places, but otherwise gastropods are practically absent.

In contrast to the preceding formation, the Fort Hall does not contain any cephalopods nor, with the single exception noted below, any brachiopods. As regards the pelecypods, the pectinoid shells, except *Aviculipecten idahoensis*, are much less abundant in the Fort Hall formation, and some of the species of the Ross Fork limestone appear not to occur there at all. On the other hand, *Aviculipecten idahoensis* appears to be restricted to the Fort Hall formation.

One collection shows a remarkable and interesting variant of the Fort Hall fauna. It is distinguished by the absence of most of the pectinoids, even of *Aviculipecten idahoensis*, and by the abundance of terebratulas, of which there are four or five varieties or species. Of the pelecypods the most noteworthy are a large *Lima* (new species) and a sharply plicated oyster, beside which there are two species of *Myacites?*, a large *Bakewellia?*, and one or two other forms. The gastropods are represented by *Natica lelia* and by another species, possibly a *Pleurotomaria*.

PORTNEUF LIMESTONE.

The Portneuf limestone is named from Portneuf River, at the head of which the limestone is well exposed. The rock is a massive siliceous and cherty, gray to yellowish limestone. The chert occurs in rounded and elongated nodules and in streaks. Silicified fossils, including *Spiriferina* n. sp.?, *Terebratula semisimplex* and other terebratuloids, and *Myaphoria lineata?*, project from the weathered surfaces.

The formation is fairly resistant to erosion and forms low, broad ridges and sloping interfluvial areas. Its thickness is estimated at about 1,500 feet, although there is some uncertainty because of complexities of structure.

In the Lanes Creek, Freedom, and Montpelier quadrangles farther east a well-developed red bed member, which consists of interbedded red sandstones and shales and ranges in thickness from 200 to 1,000 feet, occurs in the midst of the Portneuf limestone. In the

Fort Hall Indian Reservation this was not recognized and if present is much less conspicuous than in the other regions named.

Numerous collections were made from this formation by G. H. Girty, who furnishes the following faunal discussion:

The Portneuf fauna is the most varied and interesting of the three Triassic faunas of the Fort Hall Reservation. Echinoid spines occur in a number of localities, but they are not plentiful. On the other hand, segments of the stems of *Pentacrinus* are often found in great abundance. In two localities Bryozoa are abundant—small branching types, which superficially resemble the Carboniferous genus *Batostomella*. Several new genera and species are indicated by thin sections. Brachiopods are abundant but confined to two families. The Portneuf contains the horizon of *Terebratula semisimplex*, and several other terebratuloid types, which are apparently undescribed, are also found in this formation. An undescribed species of *Spiriferina* is present in many of the collections, and there may be a second species.

Pelecypod types are numerous, though many of the specimens are poorly preserved. No species is more common in this fauna than one which was figured by Meek as *Myophoria lineata?*. The locality of Meek's specimen is given as Weber Canyon and the horizon as Jurassic. I can not but think that there is some mistake in the stratigraphic position of his material, which was said to be above the quarry rock, the quarry, I assume, being then as now, in the Nugget sandstone. As compared with their abundance in the two lower formations, pectens are scarce in the Portneuf. A large form with very coarse ribs is present in several collections, and there are other species, both large and small. A large *Pteria* or *Bakewellia* has been found at many localities; also a Myalina or *Mytilus*. *Leda* is present, and *Nucula*, together with types suggesting *Pinna*, *Myacites*, *Pleurophorus*, *Astarte*, *Cucullaea*, and other forms. One locality has furnished a few specimens of *Ostrea*, not only a plicated form similar to that of the Fort Hall formation but also a smooth type.

The scaphopods, too, are represented in this fauna by one or two species of *Dentalium*.

Gastropods are less abundant than pelecypods, the only common type being a small *Natica*, probably *N. lelia*. Several small species of *Pleurotomaria?* have been collected, and also shells suggesting the genera *Holopea*, *Nerita*, and *Macrocheilina*. The most interesting representative of this type, however, is a beautiful little species which apparently belongs to the Carboniferous genus *Schizostoma*, or at all events to the euomphaloid group.

Cephalopods are practically absent in this formation, as they are in the Fort Hall. One specimen only was obtained; it is apparently identical with *Pseudosageceras intermontanum*.

TIMOTHY SANDSTONE.[56]

The Timothy sandstone derives its name from Timothy Creek in the Lanes Creek and Freedom quadrangles, east of the Fort Hall Indian Reservation. The sandstone is well exposed in those quadrangles and is cut by the creek.

The beds that occupy this stratigraphic interval are somewhat sugary, yellowish to grayish sandstones in beds 1 to 3 inches thick. They weather down into smooth depressions between the more resist-

[56] Previously described as Ankareh sandstone. Mansfield, G. R., op. cit., p. 40.

ant formations on either hand. The sandstone is generally of uniform character and in some places weathers with a pinkish tinge. Its thickness is about 800 feet.

The base of the sandstone here seems to rest conformably upon the massive and siliceous Portneuf limestone, and the top appears to be overlain conformably by the Higham grit. In the Montpelier quadrangle, farther east, however, there is evidence that the Timothy sandstone is at least locally unconformable with both the underlying Portneuf limestone and the overlying Higham grit.

No fossils have yet been found in the Timothy sandstone. In the Fort Hall Indian Reservation it appears to be more intimately associated with the underlying Thaynes group than with succeeding formations. It is accordingly considered Lower Triassic. The unconformity at its base in the Montpelier quadrangle suggests, however, that the sandstone may prove to be of later age.

TRIASSIC (?) FORMATIONS.

AGE.

The great thickness of the formations assigned to the Lower Triassic—5,350 feet—the unconformity at the base of the Timothy sandstone in the Montpelier quadrangle to the east, and the unconformity at the base of the Higham grit suggest that this formation, together with the overlying Deadman limestone and Wood shale, may belong to the Middle or Upper Triassic or may be of later age than Triassic. The search for fossils in these formations has thus far been unrewarded. They are therefore doubtfully classified as Triassic.

HIGHAM GRIT.

The Higham grit is named from Higham Peak, in sec. 23, T. 3 S., R. 37 E., the highest summit in the northeast part of the reservation, which is composed of this rock. The grit is a coarse, white to pinkish, gritty or conglomeratic sandstone, which is distinct lithologically from other rocks of the region and forms prominent topographic features. It forms bold strike ridges that are marked by rough craggy ledges in many places, as shown in Plate II, *A*. The pebbles are all of quartzite, so far as observed. No material derived from immediately underlying formations has been observed in the Higham grit. The formation here appears to be conformable on the underlying Timothy sandstone, but the abrupt change in lithology and the apparently gradual transgression of underlying Lower Triassic formations farther east and southeast indicate an unconformity probably of considerable importance. The rocks are much fractured, a feature which causes them to weather in pinnacled and castellated forms, and in many places they are slickensided, as a result of severe deformation. The thickness is about 500 feet.

The base of the Higham grit lies approximately 5,600 feet above the phosphate shales. Where an area is underlain by the Higham or later formations in normal position the phosphate lies too deep for recovery under present conditions.

DEADMAN LIMESTONE.

Stratigraphically above Higham grit and lying a short distance back of the crests of the ridges occupied by that formation lies a dense purplish-gray limestone of almost lithographic quality, which contains subordinate amounts of gray and greenish chert. This rock is called the Deadman limestone from Deadman Creek in the northeast part of T. 4 S., R. 38 E., near the headwaters of which it is exposed. The limestone is topographically resistant and in favorable places forms prominent ledges, as in sec. 25, T. 3 S., R. 37 E. Ordinarily, however, it is rendered inconspicuous by the proximity of the more resistant Higham grit. No fossils have been observed in this limestone, which is about 150 feet thick.

WOOD SHALE.

Next above the Deadman limestone in stratigraphic order there is a bright-red shale which weathers to a red soil. This rock is called the Wood shale, from Wood Creek, in T. 3 S., R. 38 E., which cuts across the shale and the overlying Nugget sandstone. It is less resistant than the adjacent rocks on both sides and occupies depressions or gullies. Locally pieces of gypsum lie here and there on the surface. Outcrops are few, but the shale may be traced by patches of bright-red soil. It is apparently 200 to 250 feet thick.

JURASSIC SYSTEM.

OCCURRENCE AND SUBDIVISION.

Jurassic rocks are exposed only in the northeastern part of the eastern mountainous region. They are divided into two formations, the Nugget sandstone, formerly regarded as Triassic or Jurassic, and the Twin Creek limestone.

NUGGET SANDSTONE.

As explained elsewhere (p. 44), the name "Nugget" is here restricted to the upper member or major part of the Nugget formation, as originally defined by Veatch. As thus restricted it is considered to be the equivalent of the White Cliff and Vermilion Cliff sandstones, from the upper part of which Gale[57] collected Jurassic fossils in the Uinta Mountain region of northwestern Colorado and northeastern Utah. Although the base of the formation in the Fort Hall Indian Reservation is apparently conformable upon the Wood shale, relations elsewhere suggest that an unconformity exists at this horizon. Two unconformities, one of which is probably extensive, occur, as previously noted, in rocks that lie between the Nugget and the fossiliferous rocks of the known Lower Triassic, and the stratigraphic unit which is believed to represent the Nugget within this interval has yielded only Jurassic fossils. For these reasons the Nugget sandstone is now referred to the Jurassic.

The Nugget sandstone succeeds the Wood shale, and consists in many places of brick-red, fine-textured sandstone in beds 1 to 6 inches thick, locally strongly cross-bedded, which form rounded hills that are strewn with angular, platy blocks weathered from the ledges. In other places the sandstone is somewhat firmer, coarser textured, quartzitic, and pinkish to whitish in color, weathering dark and forming slopes strewn with rough, blocky purplish talus. Markings that resemble footprints and other impressions were collected from these sandstones, but they proved to be too indistinct for identification. No other fossils have been found in the formation.

The stratigraphy of these sandstones has not been worked out, for the beds are involved in folds and faults, the details of which it was not practicable to determine, because the rocks are stratigraphically so far above the phosphate, which was the subject of investigation. The top of the sandstone is not exposed, or has not been recognized, for the overlying Twin Creek limestone cuts irregularly across the formation in a fault.

The thickness of the Nugget sandstone has not been measured, but it is estimated at not less than 1,500 feet.

TWIN CREEK LIMESTONE.

The detailed stratigraphy of the Twin Creek limestone, which overlies the Nugget sandstone, has not been worked out, but the formation may tentatively be divided into three parts:

1. Near the base a yellow calcareous sandstone with interbedded massive gray limestones crowded with oyster shells.

2. Thin-bedded, shaly whitish-gray and darker-colored limestone that weathers into chippy and splintery fragments. This is the part of the Twin Creek limestone that is exposed in the Montpelier and Georgetown regions farther southeast that have been previously studied.

[57] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, pp. 51, 52, 1910.

3. Yellow and grayish calcareous thin-bedded sandstone, more or less fossiliferous, together with some massive gray limestones.

The actual base and the top of the formation were not observed. Faults occur on both sides of the main area occupied by the Twin Creek in Tps. 2 and 3 S., R. 37 E., whereas in T. 3 S., R. 38 E., the formation is in large part overlapped by volcanic débris. In the Montpelier and Georgetown regions the Twin Creek limestone appears to be unconformable upon the Nugget sandstone.

A small area of massive limestones included in a fault block in sec. 31, T. 3 S., R. 38 E., is tentatively referred to the lower Twin Creek but may prove to be Triassic.

The fossils at several horizons indicate the marine character and Jurassic age of the formation.

The thickness of the Twin Creek limestone could not be measured in the Fort Hall Indian Reservation, but it appears to conform to the thickness observed in the regions described in the reports for 1909 and 1911 and is probably as great as 2,500 to 3,000 feet.[58]

TERTIARY SYSTEM.

SALT LAKE FORMATION (PLIOCENE?).

Beds of white marls or of dense yellowish to dove-colored limestones, together with generally light-colored conglomerates, composed of light or dark pebbles that have a white calcareous matrix, and some greenish clays and dark shales overlie unconformably the rocks of most of the older systems. Associated with these beds and interbedded with them are beds of white volcanic ash and greenish or yellow tuff or beds of partly waterworn volcanic débris. From the denser limestones in the SW. ¼ SW. ¼ sec. 1, T. 5 S., R. 36 E., fossils were collected and identified by W. H. Dall as internal casts of a gastropod which may be *Succinea* or *Lymnaea*, but which are not identifiable further. From one of the localities of marly limestone in the SW. ¼ NW. ¼ sec. 15, T. 5 S., R. 38 E., fossils were collected, which, according to the same authority, represent the internal casts of one or possibly two species of *Oreohelix* and one *Bifidaria*, both land shells and neither identifiable without more perfect material. The presence of *Oreohelix* suggests Pliocene age rather than early Tertiary.

From a locality in the SW. ¼ SW. ¼ sec. 23, T. 7 S., R. 33 E., where carbonaceous shales were exposed in an old coal prospect, plant remains were collected. These fossils were examined by F. H.

[58] Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 480–481, 1910. Richards, R. W., and Mansfield, G. R., Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, p. 32, 1914.

Knowlton and proved to be fragments of stems and bark not determinable.

The fossils thus far found are not of sufficiently determinative value to establish definitely the age of these deposits. Lithologically and topographically the beds resemble those that were examined in the Montpelier and Georgetown districts and that have been described in a previous report.[59] Topographically also they are generally distinct from the alluvium that forms the bottom lands, and at many places they are sharply demarked from them by steep slopes. In Bulletin 470 they are referred tentatively to the Salt Lake group of Hayden[60] and Peale.[61] The same correlation is tentatively made here, and the beds are called the Salt Lake formation. It should be noted, however, that these beds have lithologic resemblances to the Payette and Idaho formations of the Boise district. The Payette formation was first considered Miocene but later referred by Knowlton to the Eocene. The Idaho formation is Pliocene.[62]

In three places—the SW. ¼ sec. 1, T. 5 S., R. 36 E.; the SE. ¼ sec. 21, T. 4 S., R. 37 E.; and the NE. ¼ sec. 3, T. 4 S., R. 37 E.—red conglomerates occupy small areas. They resemble lithologically the Eocene conglomerates in the southern part of the Montpelier quadrangle. In the SW. ¼ sec. 1, T. 5 S., R. 36 E., the red conglomerate is steeply inclined and seems to grade conformably into the lighter-colored conglomerate series. The evidence at present is not sufficient to differentiate the red conglomerate from the others.

The Tertiary beds cover many of the lower hills and form broad, gently sloping benches that descend from the higher hills and occupy much of the broader valley country. In some places, as in T. 5 S., R. 38 E., these lower hills and bench lands are strewn with boulders, locally of great size, which consist of white quartzite and the older limestones. In other places, as in sec. 36, T. 4 S., R. 36 E., the light-colored conglomerate consists almost entirely of small fragments of Triassic shaly limestone.

The thickness of the Salt Lake formation has not been determined. On some of the higher slopes it is doubtless comparatively thin; at lower elevations it may amount to several hundred feet.

UNDIFFERENTIATED TERTIARY AND QUATERNARY ROCKS.

Associated with the bench lands are some great alluvial fans, as in the west side of Tps. 5 and 6 S., R. 38 E., and east of the south fork

[59] Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, p. 395, 1911. See also U. S. Geol. Survey Bull. 430, pp. 481–482, 1910, and Bull. 577, p. 33, 1914.

[60] Hayden, F. V., U. S. Geol. and Geog. Survey Terr. Fifth Ann. Rept., for 1871, pp. 154–155, 1872.

[61] Peale, A. C., U. S. Geol. and Geog. Survey Terr. Eleventh Ann. Rept., for 1877, pp. 588, 640, 1879.

[62] Lindgren, Waldemar, U. S. Geol Survey Geol. Atlas, Nampa folio (No. 103), 1904.

of Ross Fork Creek in Tps. 5 and 6 S., R. 36 E. These fans appear to bear the same relation to the higher hills as do the bench lands. They were doubtless deposited in the Putnam cycle of erosion when, as stated under the heading "Physiographic development," the bench lands were formed by the erosion of the weak Tertiary deposits. The erosional processes necessarily included a certain amount of aggradation by which materials of Tertiary age were rearranged and redeposited on lower slopes and in valleys. It has not been practicable in the mapping to differentiate between these rearranged light-colored materials and the Tertiary deposits, which they closely resemble. Areas in which Tertiary beds have been clearly differentiated have been mapped as the Salt Lake formation. Other areas which are underlain largely by Tertiary rocks but which include some of the redeposited materials are mapped as Tertiary and Quaternary. These deposits, together with the Salt Lake formation, underlie half or more than half of the surface of the reservation.

QUATERNARY SYSTEM.

SUBDIVISIONS.

Aside from the undifferentiated Quaternary deposits just mentioned three groups of Quaternary sediments have been identified and mapped, namely, older and recent alluvium and travertine.

OLDER ALLUVIUM.

A fairly sharp line of demarkation separates the older alluvium from the bench lands. A steep erosion slope truncates the lower ends of the benches in many places, whereas in others the lower ends of the benches form projecting fingers between which lie alluvial bottom lands. The erosion period that is represented by these steeper slopes apparently corresponds to the Gibson cycle and the surface underlain by the older alluvium constitutes the Gibson terrace. The older alluvium thus forms a broad plain 80 or more square miles in area in the northwest part of the reservation. The plain is generally marked by a very level surface with whitish soil and small pebbles. The pebbles, as exposed in the bluffs where crossed by the south line of T. 3 S., R. 34 E., consist of quartzite, quartz, chert, and igneous rocks, but there are few or none of limestone. The pebbles are subovoid to round and some of them are as much as 2½ inches in diameter. Many of them have calcareous coatings. On the Ross Fork road about 2 miles north of Fort Hall Agency the pebbles are cemented into a conglomerate. In some places boulders 1 foot or more in diameter are found on the surface.

Fossils were collected from the top of the bluff that overlooks Portneuf River in the SE. ¼ SE. ¼ sec. 9, T. 6 S., R. 32 E. The bluff here ranges from 25 to 50 feet in height. The fossils were weathered out on the surface of a coarse argillaceous sand 15 feet thick that forms the top of the bluff at this place. Below this sand down to the level of the Snake River flood plain is a fine white soil. The fossils were submitted to W. H. Dall, who reports that they are probably not older than late Pleistocene, as they are all of living species, including *Sphaerium striatinum* Lamarck, *Carinifex newberryi* Binney, and *Fluminicola nuttalliana* Lea.

North of Ross Fork Creek the surface of the older alluvium is covered for a considerable area with dark volcanic sand that forms low dunes in some places, as in the southwestern part of T. 4 S., R. 34 E.

RECENT ALLUVIUM.

Recent alluvial deposits form the present flood plain of Snake River (the Fort Hall bottoms) and the flood plains of the lower courses of its larger affluents in this region, including Portneuf River, Bannock Creek, and others. The recent alluvium is associated with the latest or Spring Creek erosion cycle. It is usually separated from the older alluvium of the Gibson terrace by steep bluffs. The recent alluvium is composed of material similar to that of the older alluvium, except that, so far as observed, the sand cover is absent.

TRAVERTINE.

Deposits of travertine occupy most of the SW. ¼ sec. 33, T. 4 S., R. 38 E., and the SE. ¼ SE. ¼ sec. 28 of the same township. There are other smaller areas in T. 4 S., R. 35 E., which are associated with and apparently overlie the basalt. These deposits appear on the surface in thin broken fragments, and are in a number of places serviceable as indicators of the proximity of basalt. The larger areas first mentioned are associated with active springs, and it is probable that in some of them, as in sec. 28, T. 4 S., R. 38 E., deposition is still in progress. The deposits associated with basalt may be the result of leaching and redeposition of calcareous material from overlying soils.

IGNEOUS ROCKS.

Igneous rocks occupy large areas in the reservation and are prominent topographically. Their extent is probably considerably greater than their outcrop, for they are interbedded with or intruded into the Tertiary and Quaternary deposits and are largely concealed by them in many places. For example, there is little doubt that the low hills which occupy the west part of T. 4 S., R. 35 E., northeast of Fort Hall Agency, are mainly basaltic, although the actual outcroppings of basalt are scattered rather than continuous.

The several types of rock that are represented range in chemical and mineral composition from basalt to rhyolite. In weathering also the igneous rocks present a corresponding variety of appearance. Thin sections have been made of the principal types, and these have been examined by E. S. Larsen, to whom the writer is indebted for the following identifications and descriptions:

Igneous rocks in the Fort Hall Indian Reservation.

Field No. of specimen.	Locality.	Name.	Petrographic notes.
C-37	NW. ¼ NW. ¼ sec. 30, T. 3 S., R. 36 E.	Augite-quartz latite.	Contains a few phenocrysts of plagioclase, augite, and iron ore in a fine groundmass, in part granophyric, in part spherulitic. Not far from a rhyolite.
C-31	SW. ¼ SW. ¼ sec. 21, T. 3 S., R. 36 E.	Rhyolite	Glass.
C-24	SE. ¼ NW. ¼ sec. 31, T. 4 S., R. 36 E.	Olivine basalt	Contains abundant laths of plagioclase, a less amount of olivine, considerable inter stitial augite, and a little glass. Apatite and iron ore are also present. The plagioclase is calcic labradorite. The olivine is partly altered to iddingsite.
Mt. 165a	SW. ¼ SW. ¼ sec. 7, T. 2 S., R. 38 E.	Rhyolite	A thin section shows a few crystals of orthoclase and plagioclase in a groundmass which is largely glass with incipient crystallization. Porous streaks are more coarsely crystalline and carry tridymite.
Mt. 163	SE. ¼ SW. ¼ sec. 13, T. 3 S., R. 38 E.	Olivine basalt	A fine-grained rock made up of abundant laths of labradorite feldspar, considerable augite, tiny crystals of olivine, and grains of black iron ore. There is much brownish interstitial glass.
Mt. 97	SW. ¼ SE. ¼ sec. 23, T. 6 S., R. 33 E.	Augite-quartz latite.	Contains crystals of quartz, andesine feldspar, and augite in a granophyric to spherulitic groundmass.
M-306a	NW. ¼ SE. ¼ sec. 21, T. 5 S., R. 35 E.	Pyroxene andesite	Contains abundant phenocrysts of labradorite, some of pale-green augite, and many of an altered iron-stained pyroxene. The groundmass carries, among other materials, iron ore, plagioclase, and an altered mafic mineral. The rock is much altered, and secondary carbonate, chlorite, serpentine, sericite, and other secondary minerals are abundant.
M-202	SW. ¼ NE. ¼ sec. 22, T. 3 S., R. 37 E.	Hornblende andesite	Contains phenocrysts of pale-green hornblende and a few of plagioclase in a very fine grained groundmass made up of imperfectly developed laths of plagioclase, grains of augite and magnetite, and considerable undetermined material, which probably contains both quartz and orthoclase. It carries inclusions of sandstone.
M-194	Sec. 17, T. 3 S., R. 38 E.	Hornblende-pyroxene andesite.	The specimen is taken from a fragment included in andesitic tuff. A thin section of the rock contains phenocrysts of sodic labradorite, brown hornblende, partly resorbed, abundant augite, and hypersthene. The groundmass makes up somewhat less than half the rock, is microgranular to granophyric, and is made up of quartz, orthoclase, plagioclase, magnetite, and apatite.
M-192a	SW. ¼ SE. ¼ sec. 18, T. 3 S., R. 38 E.	Nepheline basalt	A very fresh, highly basic rock. The phenocrysts, which are nearly equal in amount to the groundmass, are chiefly olivine together with some augite and biotite. The groundmass is fine textured and is largely augite with interstitial material, which has an index of refraction about equal to that of Canada balsam, is weakly birefracting, and may be nepheline. There is a little apatite and iron ore.
M-44	NW. ¼ SW. ¼ sec. 22, T. 7 S., R. 33 E.	Olivine basalt	Contains abundant crystals of calcic labradorite and considerable olivine and augite in a clouded groundmass, which is largely composed of augite in fernlike or irregular skeleton crystals. There is probably a little glass.

The basalts all carry olivine and are in general relatively fresh and scoriaceous. They are well developed in the Bannock Valley region, in Tps. 3 and 4 S., R. 35 E., and in the canyon of Blackfoot River in the northeastern part of T. 3 S., R. 38 E. Specimen M–192a, which represents a single isolated locality, is especially noteworthy because of its content of nepheline. Nepheline basalts are relatively rare in the United States, being known at only a few widely separated localities in Montana, New Mexico, and Texas. The nearest of these localities to the Fort Hall Reservation is Lloyd, in the Bearpaw Mountains of Montana, about 400 miles away. A more extended description of this rock has been given elsewhere.[63]

The andesites are most abundant in the southeastern part of T. 3 S., R. 38 E., and form the chief component of a large area of tuff in the same township. Several small andesitic dikes have been recognized. Specimen 306a represents a much altered rock, the field relations of which were not determined. It has not been differentiated in the mapping from neighboring basalts.

The augite-quartz latites are extensively developed in T. 6 S., R. 33 E., and T. 3 S., R. 36 E., where they form prominent hills. They appear to represent, in part at least, the latest phase of volcanic activity in the region, as they include the rock of the little cone in sec. 30, T. 3 S., R. 36 E. (See Pl. IV.) The volcanic sand which covers so much of the lava and alluvial areas in the northwest part of the reservation is apparently composed largely of the glassy form of this rock.

The rhyolites are well distributed from the Bannock Valley region toward the northeast along the lower hills. They are particularly well developed in Tps. 7 and 8 S., R. 32 E., where they form massive ledges. As a rule they are more or less crystalline, but in some places they are glassy. The rhyolites and augite-quartz latites are grouped together in the mapping. They were not distinguished in the field.

Several dikes occur in different parts of the reservation. These dikes are of acidic and basic or of intermediate composition. The most conspicuous dike forms the great rhyolite hill which runs northwest from sec. 18, T. 8 S., R. 33 E., into the adjacent township.

Beds of volcanic ash and of more or less water-worn volcanic débris occur in many places, more or less closely associated with the lavas. In T. 3 S., R. 38 E., there is a considerable area of andesitic tuff. The volcanic sand above mentioned is the most recent volcanic feature. It overspreads much of the Gibson terrace but has not yet been recognized on the Fort Hall bottoms.

[63] Mansfield, G. R., and Larsen, E. S., Nepheline basalt in the Fort Hall Indian Reservation, Idaho: Washington Acad. Sci. Jour., vol. 5, pp. 463–468, 1915.

The relative ages of the igneous rocks have not been worked out in detail, but there appear to have been at least four epochs of volcanic activity. An earlier basic or intermediate epoch, which was followed by an acidic epoch, is shown by included basic fragments in the great rhyolite dike mentioned above and by the fact that the andesitic tuff of T. 3 S., R. 38 E., is in places overlain by rhyolite. On the other hand, rhyolite is in several places overlain by basalt, as in the northwest corner of T. 8 S., R. 33 E., and in sec. 18, T. 2 S., R. 38 E. Finally both rhyolitic and basaltic areas are overspread in some places by the dark volcanic sand above mentioned.

There is some doubt about the identity of the basalts that are interpreted as belonging to the later series. The earlier basic series is known only from fragments in the rhyolite and in beds of volcanic débris that are overlain by rhyolite. These basalts may really be andesitic and related to the andesites that are overlain elsewhere by rhyolite.

There were several outpourings of basalt, as is shown by the successive flows that are exposed in the canyon of Blackfoot River. All the basalts mapped have been tentatively grouped in a single series. Some of the quartz latites are younger than the rhyolites, as shown by the dark volcanic sand. There are, too, some later acidic intrusives, which cut the basalt in secs. 15 and 21, T. 7 S., R. 33 E. These intrusives may be latites rather than rhyolites. and may be contemporaneous with or earlier than the volcanic sand.

The andesites appear to be the oldest members of the volcanic series, for in sec. 31, T. 2 S., R. 38 E., the andesitic tuff is overlain by rhyolite and also by white and yellow Tertiary and Quaternary conglomerates. It is not clear that they underlie the Tertiary and Quaternary rocks altogether. They are more probably intercalated with those rocks and, like the rhyolites and basalts elsewhere in the reservation, are contemporaneous with parts of those deposits.

The basalts appear to antedate the Gibson cycle, for pebbles of basalt occur in the gravels of the Gibson terrace, and large boulders of basalt lie here and there on its surface. According to the fossil determinations suggested above, the Gibson terrace is probably late Pleistocene. Thus the basalts and earlier solidified lavas probably range in age from Pliocene to early Pleistocene. The hardened lavas of the Snake River region have been in general assigned to the Pliocene or Pleistocene, whereas those of the Columbia River are older.[64] Unless the Tertiary deposits of the Fort Hall Reservation are considerably older than is now thought probable, most of the lavas of the reservation would not be older than the Plio-

[64] Russell, I. C., Geology and water resources of the Snake River plains of Idaho: U. S. Geol. Survey Bull. 199, 1902.

cene. The basalts of the Blackfoot Canyon may possibly belong to an older series, yet their relative freshness and general similarity to the other basalts of the reservation appear to be unfavorable to this view.

STRUCTURE.

The geologic structure of the reservation is complex and involves both folding and faulting. There has been more than one epoch of deformation. The extensive cover of Tertiary and later deposits, which together with much solidified lava conceals half to two-thirds of the older rock structures, makes their interpretation difficult. A number of structure sections are shown on the map (Pl. III). In some places the details of structure are so numerous and so small that they could not be worked out under the existing conditions. The more important structural features of the eastern part of the reservation are described in the accounts of individual townships (pp. 71–104.)

FOLDING.

The Paleozoic and Mesozoic rocks have all been folded to a greater or less degree, but many of the folds have been so faulted that they lack continuity. This is true of all the larger folds and of many of the smaller. The largest and most conspicuous fold is shown in part in the northeastern portion of the reservation. The southwest limb of a syncline enters sec. 13, T. 4 S., R. 38 E., and continues northwest nearly to Blackfoot River, where it passes under cover. This syncline is inclined toward the northeast and the southwest limb is overturned in that direction. The central portions and the east limb of this fold are concealed by igneous rocks, and later sediments, and the west limb is cut by several faults.

Similar synclines, or perhaps parts of a single syncline that trends northwestward, underlie the northeastern part of T. 5 S., R. 38 E. These synclines are largely concealed, but they are important because they contain phosphate beds at available depths.

Another similar phosphate-bearing syncline, which is interrupted by minor folds and broken by faults, occupies the southwest corner of T. 4 S., R. 38 E.

An anticline in the northwestern part of T. 4 S., R. 37 E., which also involves the phosphate, is noteworthy because its axis trends northeastward at about right angles to the trend of the other folds mentioned. Numerous faults are associated with this anticline, especially in the region of the northeast tip.

In the region of North and South Putnam mountains, in Tps. 5 and 6 S., R. 37 E., the Cambrian rocks have been folded in different ways, but the stratigraphy and structure of these rocks have not been worked out.

In the northeast corner of T. 5 S., R. 36 E., and northwestward into the adjacent township there is an anticline of Upper Cambrian limestone which is flanked by Ordovician quartzite. This fold is overturned toward the southwest, a remarkable feature, for in most places in the reservation and in the Montpelier and Georgetown districts farther southeast the inclination of the folds is toward the northeast.

In T. 9 S., Rs. 32 and 33 E., and T. 8 S., R. 33 E., there are various folds in the Paleozoic rocks. In general the rocks trend northerly and dip easterly. The stratigraphy and structure of these rocks have not been worked out in detail. Faults cut the folds at several places.

FAULTING.

Faulting played a conspicuous part in the geologic structure of the region. A detailed discussion of the numerous faults in the eastern part of the reservation is given in the descriptions of the individual townships involved. One fault, or group of faults, however, merits special description.

PUTNAM OVERTHRUST.

The southern half of T. 5 S., R. 37 E., is occupied by the high rocky ridges and hills adjacent to North Putnam Mountain. These hills are largely composed of Cambrian quartzite and other Cambrian and Ordovician rocks. At a number of places, notably North Putnam Mountain and the ridges to the east, the capping rock is the dense white vitreous Swan Peak quartzite of Ordovician age. This rock appears to arch gently up over the mountain from northwest to southeast, but it has been eroded and is now separated into large and small detached areas. One of these detached areas forms the summit of North Putnam Mountain. The relations of the Ordovician quartzite to the underlying rocks may be explained as the result of either unconformity or of overthrust faulting. The latter view is regarded as more probably correct for the following reasons:

1. The Swan Peak quartzite, where it lies upon the Brigham quartzite, generally shows no conglomeratic phase near the base and carries no recognizable fragments of the underlying rocks from which it might supposedly be derived if unconformable. Minor exceptions to this statement have been observed in a few places in T. 5 S., R. 37 E., where a few pebbles of the underlying quartzite are included in the Swan Peak quartzite.

2. The Swan Peak quartzite in T. 5 S., R. 37 E., transgresses several other members of the Cambrian and Ordovician, including limestones and shales, but shows no signs of modification in composition

such as might be expected if originally laid down over rocks of these types.

3. Examination of other portions of the reservation shows that all the Paleozoic systems are represented, and that under normal structural conditions a full sequence of formations might be expected.

In T. 4 S., R. 36 E., a fault (Pl. III, section B–B′), which has a computed westerly dip of 20°, swings around the north and east base of the quartzite and limestone hills that extend southward from sec. 23 into T. 5 S., R. 36 E. It causes Cambrian and Ordovician limestones and quartzites to lie against the Ross Fork limestone of the Thaynes group, which comes to the surface through the Tertiary conglomerate in several ledges about half a mile to the east of the base of the hill. Although the thicknesses of many of the intervening formations are not known, it is clear that this fault produces a break of considerable magnitude which is measured probably by thousands of feet.

In the northeastern part of T. 5 S., R. 36 E., the Swan Peak quartzite swings across Ross Fork Creek in the tip of an overturned anticline, which causes the underlying Cambrian and Ordovician limestones to be exposed in the valley of that creek and along the west flank of the range of hills to the north. Apparently this block of limestones and quartzites is continuous with the block of Swan Peak quartzite south of the creek, so that in some way the thrust faults of T. 4 S., R. 36 E., and T. 5 S., R. 37 E., are connected. The place and mode of connection, however, are concealed by the Tertiary and Quaternary deposits. The two faults combined, as suggested on the map, may appropriately be called the Putnam overthrust from North Putnam Mountain, the most conspicuous portion of the upper fault block.

East of the fault in T. 4 S., R. 36 E., is another fault which approaches it within half a mile at the nearest point and then recedes north and south. This fault has a computed westerly dip of 33°, but the obliqueness of structure section B–B′ (Pl. III) reduces it to 25°. This fault lies between the Triassic area on the west and Cambrian and Ordovician rocks on the east of the same series as those that comprise the quartzite and limestone hills to the west. The question is raised whether this fault may be a continuation of the Putnam overthrust to the west or a separate fault perhaps subsidiary to it. If the second view is accepted, a part of the underlying Triassic block appears to have been thrust forward over the next block of the older rocks to the east, or else a portion of Triassic rocks from a higher group of strata, now elsewhere removed by erosion, has been underthrust between the two Cambrian and Ordovician blocks. If this fault is a continuation of the fault to the west, the fault plane has not only been folded into an anticline but also inclined northeastward. It may be remarked in this connection that in T. 5 S., R. 37 E., the Putnam overthrust has been arched into an anticline and eroded but has not been overturned. In the Bannock overthrust,[65] 30 to 40 miles southeast, the fault plane has been both folded and overturned. There is then a precedent for this view as regards the Putnam overthrust, although it is perhaps wiser to consider this fault as a separate or a branch fault.

Another fault which is closely related to the Putnam overthrust and may be a branch of it lies along the boundary between T. 4 S., Rs. 36 and 37 E. This fault brings Cambrian and Ordovician limestones against Mississippian and Pennsylvanian rocks. This fault in turn is accompanied by subsidiary faults that form a zone of highly shattered rocks.

The dimensions of the Putnam thrust have not been determined. Its course within the reservation, exclusive of the more doubtful branches, extends 15 to 20 miles. To the northwest it is concealed by the Tertiary and Quaternary deposits. It is probably continued south of the reservation, but no examination of that region has yet been made. Plate I, *C*, shows a part of the region traversed by the Putnam overthrust and illustrates the character of some of the formations involved.

In secs. 14, 15, and 16, T. 5 S., R. 35 E., four faults are indicated that separate earlier from later Paleozoic rocks. These may be independent faults or separated parts of the same fault. They may also be related to the Putnam overthrust. The cover is extensive in this township, and the relations of these faults have not been worked out.

In the Bannock Valley region in Tps. 8 and 9 S., R. 33 E., and T. 9 S., R. 32 E., extensive faults separate the Cambrian and Ordovician from each other and from the Carboniferous rocks. (See Pl. III, section A–A′.) Along the southwest border of T. 8 S., R. 33 E., Cambrian and Ordovician limestones lie against the upper Mississippian Brazer limestone, and across the valley to the east similar Cambrian and Ordovician limestones with some Swan Peak quartzite lie against the lower Mississippian Madison limestone. In the southwestern part of T. 9 S., R. 32 E., Cambrian and Ordovician limestones with Swan Peak quartzite on the west lie against Pennsylvanian and older rocks on the east. It seems probable that these faults, which produce such similar effects, may be closely related or perhaps even connected beneath cover. The fault relations in the older rocks of Bannock Valley, T. 5 S., R. 35 E., and in the Putnam

[65] Richards, R. W., and Mansfield, G. R., The Bannock overthrust: Jour. Geology, vol. 20, p. 705, 1912.

overthrust are very similar, so that it is probable that they all are the result of the same deformative movements.

OTHER FAULTS.

In T. 7 S., Rs. 32 and 33 E., the rhyolites and basalts are normally faulted at several places and in T. 5 S., R. 35 E., the rhyolites have been similarly faulted. In T. 7 S., R. 33 E., the lavas on opposite sides of Bannock Valley are tilted away from each other with cliffs facing the valley. There is, therefore, some probability that this portion of Bannock Valley is in part of structural origin. Similarly the fault extending northwest from sec. 34, T. 7 S., R. 32 E., appears to have determined the location of the valley that coincides with it.

The general structural relations outlined above, together with additional details, are shown in the geologic structure sections that accompany the maps of individual townships (Pls. V to X) and in Plate III.

EPOCHS OF DEFORMATION.

Early epochs of deformation are recorded in the unconformities previously noted.

The youngest rock of the older group involved in folding and faulting is the Twin Creek limestone. The Tertiary and Quaternary deposits lie unconformably on these older rocks. The time interval between these formations is long—Jurassic to Pliocene(?). Within this interval several deformative epochs have been recorded in different parts of the western United States, and definite correlation of the deformative movements in the Fort Hall Indian Reservation with one or more of these can not be made without more complete data. There is, however, direct evidence of at least three deformative movements in the rocks of this region:

(1) The major deformation, which produced the main folds and the Putnam overthrust together with the other thrusts noted above, probably took place in the interval between the Cretaceous and Eocene. In a previous paper [66] it was suggested that the Bannock overthrust was produced during the interval of deformation and erosion between the Adaville and Evanston formations of southwestern Wyoming, discussed by Veatch.[67] A similar correlation might be tentatively made for this great deformative epoch in the Fort Hall Indian Reservation. To this epoch may probably be assigned the overturning of the synclines in the northeastern part of the reservation and the development of the sharp folds and strike

[66] Richards, R. W., and Mansfield, G. R., The Bannock overthrust, a major fault in southeastern Idaho and northeastern Utah: Jour. Geology, vol. 20, p. 704, 1912.

[67] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, p. 76, 1907.

faults in the Nugget sandstone and underlying Triassic (?) formations of the same locality.

(2) The plane of the Putnam overthrust has been deformed and eroded on Mount Putnam, and if the eastern fault in T. 4 S., R. 36 E., is considered a part of that thrust it has even been overturned. These movements were doubtless subsequent to the main deformative period and may have occurred in early or middle Tertiary time. There has been, however, some deformation of the beds regarded as probably Pliocene (Salt Lake formation) in this region, for limestones and conglomerates in secs. 1 and 2, T. 5 S., R. 36 E., have dips ranging from 35° to nearly vertical. In other localities also, as in secs. 10 to 15, T. 8 S., R. 33 E., beds of the Salt Lake formation have dips of 50°–75°. The deformation which produced these steep dips must have taken place late in Pliocene time or at the close of that epoch. Crustal movements appear to have been rather general at that time and probably the deformation of the thrust planes mentioned above may have occurred then and renewed movements may have taken place in the earlier folds and faults.

(3) The basalts, which overlie the Salt Lake formation and rhyolites in T. 7 S., R. 32 and 33 E., are normally faulted at several places. The rhyolite is also faulted in T. 5 S., R. 35 E. The fault scarps may be recognized in several places and are still comparatively fresh, as in the southwest corner of T. 7 S., R. 33 E. These faults are probably to be referred to the close of early Pleistocene time, for the basalts themselves are probably of post-Pliocene age. The faulting may have accompanied the uplift which inaugurated the Gibson erosional cycle, because in Bannock Valley the older alluvium which represents that cycle passes between the basaltic hills along the line that separates the basalts that dip eastward from those that dip westward.

GEOLOGIC HISTORY.

The earliest rock formation in the Fort Hall Indian Reservation is the Brigham quartzite, which according to Walcott is the overlapping shore deposit of Middle and Lower Cambrian time, along what is now the Wasatch Range, derived from the Uinta region. No fossils were observed in this formation in the reservation, but in the Liberty and Blacksmith Fork sections described by Walcott[68] annelid trails and trilobite tracks were found and in the upper part of the formation in the Liberty section characteristic Middle Cambrian fossils were found. The thickness of the deposit, which is 2,000 feet at the type locality near Brigham, Utah, together with its

[68] Walcott, C. D., Nomenclature of some Cambrian Cordilleran formations: Smithsonian Misc. Coll., vol. 53, pp. 9, 199, 1908.

locally cross-bedded and conglomeratic character indicate the long continuance of shallow-water conditions and the generally slow subsidence of the region with the advance of the Cambrian Sea. Barrell[69] has pointed out that thick deposits of coarse sediments are likely to be of nonmarine origin. Possibly a more detailed study of the Brigham quartzite will show that some of it may be of subaerial origin.

After its advance in Brigham time the sea held sway with some interruptions over the region of the reservation throughout Paleozoic and for part at least of Mesozoic time. The character of the sea, the position of the shores, the elevation of the adjacent lands, and the conditions of deposition changed from time to time as indicated by the changes in the lithology and fauna of the sediments. The occurrence of shales and sandstones in parts of the section indicate the admixture of relatively large amounts of detrital material from the land, due to such causes as elevation or silting up of the sea bottom or proximity to the mouths of great rivers. The occurrence of limestones, on the other hand, implies clearer seas, such as might be found in deeper waters at some distance from shore or in shallow water near some base-leveled land, where such materials as were carried from the land to the sea were largely in a state of solution. Changes in conditions of deposition are also accompanied by changes in the character of the fauna. Some types, such as pelecypods, usually frequent more muddy waters, whereas other types, such as corals, live best in clearer seas.

A notable reversion to shallow-water conditions, which was rather widespread, occurred in Ordovician time, when the Swan Peak quartzite was laid down. After the deposition of this formation there was a return to deeper-water conditions and limestones were deposited until the middle of the Pennsylvanian epoch, when sandstones and quartzites were again formed over wide areas. The evidence relating to Silurian and Devonian time is fragmentary, for the formations of those periods, though represented in a number of rather widely separated areas, are in many places not well developed, and their relations to the overlying and underlying rocks are not clear. However, in this region they are limestones, and so far as their relations with other rocks have been observed they appear to be conformable with the rest of the series. An unconformity between the Mississippian and Pennsylvanian has been identified by Blackwelder[70] in Weber Canyon, Utah, but this condition does not seem to have been general. After the sandstones of the middle Pennsylva-

[69] Barrell, Joseph, Some distinctions between marine and terrestrial conglomerates; Geol. Soc. America Bull., vol. 20, p. 620, 1909.

[70] Blackwelder, Eliot, New light on the geology of the Wasatch Mountains, Utah: Geol. Soc. America Bull., vol. 21, p. 530, 1910.

nian were deposited limestones were again formed for a time. Then came a most remarkable change.

In the Permian epoch there was more or less crustal disturbance throughout the North American continent, which resulted in the great Appalachian-Ouachita revolution in the East, and in different parts of the West in the interruption of marine deposition. In the region of the Fort Hall Indian Reservation and adjacent parts of southeastern Idaho, northwestern Wyoming, northeastern Utah, and southwestern Montana, there was marine deposition but under different conditions. The sea in these regions became smaller. A special fauna developed and a remarkable series of phosphate beds, phosphatic shales, and limestones were formed.

Although the Woodside shale of the Lower Triassic lies with apparent conformity upon the Phosphoria formation there is a marked lithologic and faunal change that indicates a corresponding difference in conditions of deposition and probable unconformity. The shales of the Woodside are highly calcareous, and many beds of limestone are included in the formation, especially near the top. Unlike the clear seas that must have prevailed during the deposition of the Rex chert member of the Phosphoria, the waters of the Woodside sea were to some extent roily, and the fauna was chiefly of pelecypods. These conditions lasted with some variations throughout the period of deposition of the Woodside and of the lower Thaynes. In the time of the middle and the upper Thaynes there was more or less alternation of shallower and deeper water together with the deposition of shaly and arenaceous beds in alternation with clearer limestones. The close of the Thaynes epoch was marked by deeper and clearer seas and the deposition of the heavy-bedded Portneuf limestone.

The change from the Portneuf limestone with its characteristic fauna to the overlying Timothy sandstone without a recognized fauna is well marked lithologically. The unconformity at the base of the Timothy in the Montpelier quadrangle indicates that at least locally the Thaynes group was subject to erosion and hence had been partly exposed before the Timothy was deposited. The change in conditions of deposition must also have been fairly marked, and it probably included a notable shallowing of the sea.

The coarse quartzitic débris, which forms the Higham grit, indicates another marked depositional change. The extent and uniformity of the grit in regions outside the reservation point to marine deposition as the most probable agent in its formation. The land probably stood higher with reference to the sea or the grades were steeper, so that coarser material was furnished by the streams to the waves than in preceding Triassic epochs. This change which apparently marks an unconformity, as indicated by conditions farther east, was rather widespread. The succeeding limestone and red gypsiferous shale appear to indicate deposition in a portion of the sea that was more or less cut off from free communication with other portions. Evaporation was sufficient to render the waters unfit for marine life and to cause the deposition of minor amounts of gypsum but did not continue to the point of saturation for chlorides. The succeeding red beds of the Nugget sandstone by their color and also by the occurrence of ill-defined markings resembling footprints suggest nonmarine deposition, but the generally even bedding and the character of the cross-bedding, where shown, are not entirely favorable to such a supposition. These beds may be in part nonmarine.

In regions to the east some erosion appears to have intervened between the deposition of the Nugget sandstone and the Twin Creek limestone. In the Fort Hall Indian Reservation the boundaries of the two formations seem to have been largely determined by faulting. During the deposition of the Twin Creek limestone normal sea water with abundant marine life occupied at least the northeastern part of the reservation, and in the large arm of the sea which included this area a thick body of calcareous sediment accumulated under conditions that differed in the earlier and later parts of the epoch but that remained quite uniform through much of it, as shown by the peculiar shaly character of a large part of the rock.

The sea persisted through the greater part of Upper Jurassic time but was probably excluded by deformative movements at the end of the Jurassic. No Cretaceous sediments are present in the reservation, but in neighboring regions to the east nonmarine Lower Cretaceous (?) beds occur in great thickness and in such coarseness as to imply steep grades for streams.

The land masses from which the Paleozoic and Mesozoic rocks were derived lay chiefly to the east and southeast, for the sediments appear to become more siliceous and coarser in those directions, but the nature and extent of these lands is unknown.

The next important event recorded by the rocks of the region is the great deformation which produced the many folds and overthrust faults already described. In the absence of evidence to the contrary this event is placed in the interval between the Cretaceous and the Eocene, when many of the great structural features of the West were developed.

The record of Tertiary events in this district is not very complete. The reservation must have suffered some of the deformation, volcanism, erosion, and aggradation that were experienced by other parts of the western United States during Eocene and Miocene time, but if so the features to be assigned to these periods have not been differentiated. The Tertiary deposits represented have been assigned tentatively to the Pliocene. Previous to their deposition long-continued erosion had reduced the hills to subdued outlines and had excavated broad valleys in which by the topographic revival of the region the deposits of the Salt Lake formation were laid down. Faulting may also have played some part in the formation of the basins which received these sediments as suggested by the volcanic phenomena noted below. These deposits were so abundant that they covered practically all the lower elevations in the reservation and even overspread some of the higher hills. They were doubtless in large part composed of materials deposited by streams, but some of the beds—marls and shales—were deposited in bodies of water. Volcanic phenomena played an important part during this epoch, and much volcanic material in the form of beds of tuff and ash, together with intermediate or basic and acidic lava now solidified, is included in the deposits. Deformation again occurred in the later part of this epoch of aggradation and disturbed the position of the deposits. Doubtless, too, it revived to a certain extent the fold and fault structures of the older rocks and warped or folded the existing thrust planes. Probably about this time also occurred outflows of basalt that now cap Pliocene (?) hills in T. 7 S., Rs. 32 and 33 E., and form the broad hills of igneous rock in Tps. 3, 4, and 5 S., R. 35 E. Possibly, too, the basalt of Blackfoot River, which is partly overspread with wash of Pliocene material, may have been outpoured at this time. This deformation was probably synchronous with the general movements that marked the close of the Pliocene elsewhere in the North American continent.

During the earlier part of Pleistocene time the older rocks and the Salt Lake deposits seem to have been eroded into the late mature forms of the present topography associated with the Putnam cycle. There are no evidences of Pleistocene glaciation in the region of the Fort Hall Indian Reservation. There are, however, numerous great boulders of quartzite and limestone that are scattered irregularly about over the surface of the Salt Lake deposits that might at first sight be attributed to glacial action. These are regarded as weathered from the surrounding weaker conglomerate.

The later Pleistocene epoch was ushered in by changes, which permitted erosion of the early mature canyons and associated topography of the Gibson cycle as described elsewhere (p. 16). In the vicinity of Mount Putnam the canyons of this erosion cycle are cut to depths of about 1,500 feet, but in some of the lower hills the canyons are less than 1,000 feet in depth. Along the inner margins of the Gibson terrace the top of the terrace is separated from the tops of the adjoining benches by steep slopes 75 to 100 feet high. The flatter grades developed in the Gibson cycle suggest that the rejuvenation activity of that cycle may have been in part due to more moist climatic conditions than those of the preceding cycle. There was doubtless also some broad upwarping of the region, for the normal faulting in the basaltic hills of T. 7 S., Rs. 32 and 33 E., appears to have preceded the development of the Gibson terrace in Bannock Valley. In the later part of this cycle probably occurred the latitic eruption, which covered so large an area in the northwestern part of the reservation with dark volcanic sand. It seems probable, too, that this cycle represents the part of the Pleistocene in which elsewhere glaciers were present and in which existed the great Pleistocene lakes of the Great Basin. The waters of Lake Bonneville, the largest of these lakes, for a time found outlet to Snake River by way of the Portneuf.

The recent or Spring Creek erosion cycle has been relatively short. Although broad flood plains have been developed during the cycle in the vicinity of Snake River and the lower courses of its larger affluents erosion has as yet made little headway in the hard rocks of the higher hills. The Snake River flood plain near the junction of Snake and Portneuf rivers, in T. 6 S., R. 32 E., stands about 75 feet below the Gibson terrace, but in the northwest corner of T. 4 S., R. 34 E., it is only 15 feet lower. In the valley of Ross Fork Creek and Bannock Creek the difference in elevation dies out upstream. Thus the grades of the flood plains developed in the Spring Creek cycle are steeper than those established in the Gibson cycle and cut across them at a faint angle. The cause of this difference in grade between the two sets of flood plains may be due in some measure to the introduction of a more arid climate than that of the Gibson cycle, for, if other conditions remain the same, rivers tend to develop steeper grades during a period of arid climate than during a period of moist climate. The introduction of the Spring Creek cycle may thus have been due partly to climatic and partly to deformational influences, but the relative proportion assignable to each influence has not been determined.

DESCRIPTIONS OF TOWNSHIPS.

As the examination of the Fort Hall Indian Reservation was made primarily for the purpose of studying the character and extent of its phosphate deposits, a more detailed description is given of those townships that are believed or known to contain phosphate. These townships are all in the eastern mountainous region.

T. 3 S., R. 36 E.

TRANSPORTATION FACILITIES.

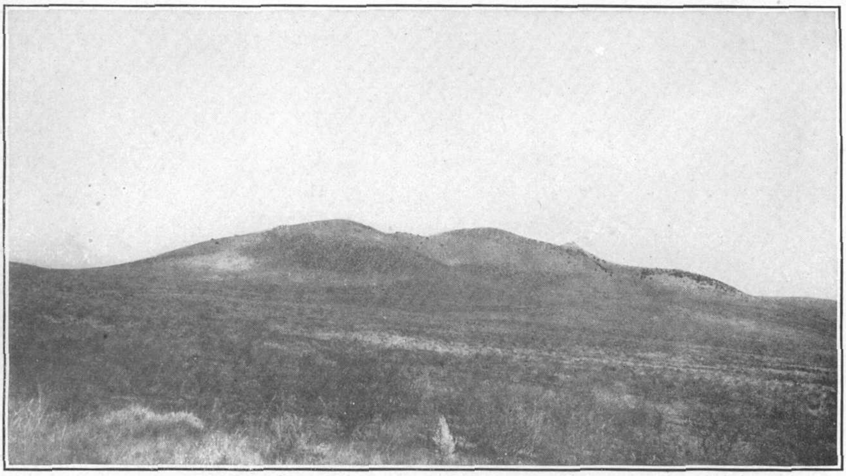
The Butte and Yellowstone branch of the Oregon Short Line Railroad runs through T. 3 S., R. 35 E., at a distance of 3 to 6 miles west of T. 3 S., R. 36 E. The city of Blackfoot is 3 miles from the northwest corner of the township. The site of the second old Fort Hall is near the center of sec. 24. From this point wagon roads run northwest to Blackfoot, southwest to Fort Hall, and southeast to Soda Springs.

GEOLOGY.

The main geologic features of the township are shown on the general map of the reservation (Pl. III). In the northeast corner of the township small areas of Nugget sandstone and Twin Creek limestone appear from beneath the Tertiary and Quaternary cover. No other formations of the older rocks are known to outcrop in this township, but in sec. 30, T. 3 S., R. 37 E., the Portneuf limestone of the Thaynes group occurs within a few hundred feet of the township line. These beds appear to strike southwest and doubtless enter the southeast corner of this township underneath the cover of later sediments.

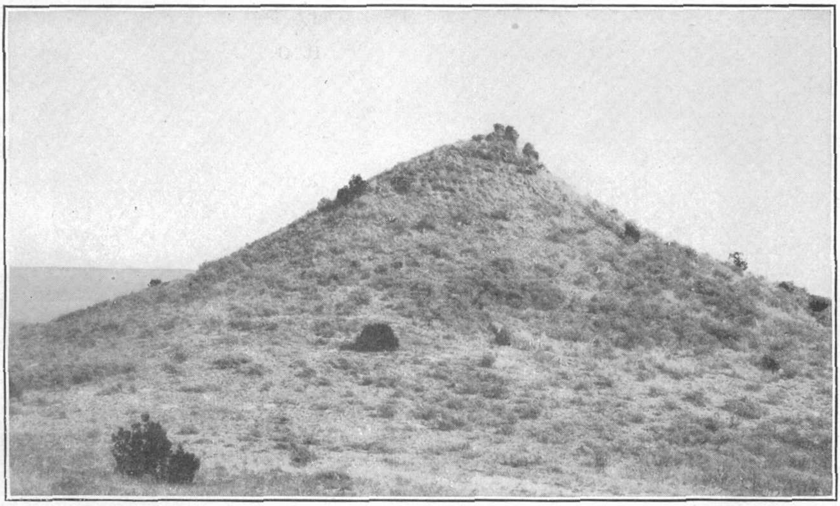
The Tertiary and Quaternary deposits include a group of sediments with associated beds of volcanic débris, probably of Pliocene age (Salt Lake formation), with perhaps some reworked material of Quaternary age. They probably cover most of the township but are overlain in large part by a cloak of dark volcanic sand. Alluvial deposits of Quaternary age occupy the valley of Lincoln Creek, in which the site of old Fort Hall, now a farm, is located.

The igneous rocks include augite-quartz latite, near rhyolite in composition and not differentiated from it on the map, and basalt. The relations of the igneous rocks to each other have not been carefully worked out, but it seems probable that there have been several alternate outpourings of acidic and basic volcanic rocks in this township and that the latest of them were acidic, the site of the eruption being probably the little symmetrical cone in the NW. ¼ sec. 30 (Pl. IV, *B*). This cone is composed of dark, partly devitrified glass, that seems to grade near by into augite-quartz latite. It has no crater but is composed of sheets of lava with outward quaquaversal dip. The texture of the rock in the cone is different from that in the neighboring flat-lying sheets. In the cone the rock has a granular, spheroidal texture, the individual granules being about one-eighth inch in diameter, together with irregular cavities an inch or more in diameter and balls of similar dimensions that have radial structure. These features suggest that this was a center of eruption of viscous lava. The dark volcanic sand that overspreads a large part of this township and parts of adjacent townships is composed largely of material similar to that which constitutes this cone. It may have been the product of an explosion preceding the upwelling of the lava that now forms the cone. Plate IV, *A*, shows the latitic hills, with the little cone, and Plate IV, *B*, gives a nearer view of the cone.



A. VOLCANIC HILLS (AUGITE-QUARTZ LATITE) IN THE NW. ¼ SEC. 30, T. 3 S., R. 36 E., SURMOUNTED BY LITTLE CONE.

View from a point about 1½ miles south.



B. NEARER VIEW OF THE CONE SHOWN IN *A*.

On the summit has been placed a bench mark of the United States Geological Survey.

PHOSPHATE DEPOSITS.

Athough there is no known outcrop of the Phosphoria and associated formations within this township, it may be postulated from conditions in secs. 30 and 31, T. 3 S., R. 37 E., and sec. 2, T. 4 S., R. 36 E., that the phosphate shales enter this township beneath cover about 500 feet south of the northeast corner of sec. 36, trend in a convex curve toward the northwest, and leave the township in the vicinity of the southwest corner of sec. 36. The dip in the NW. ¼ NW. ¼ sec. 29, T. 3 S., R. 37 E., is 50° SE., and in the SW. ¼ SE. ¼ sec. 31, T. 3 S., R. 37 E., the dip is 25°.

On the basis of this postulated structure there would be a belt about 5,500 feet wide in secs. 25, 26, 35, and 36 that would contain phosphate deposits within a probable depth of 5,000 feet. In view, however, of the complicated structure, especially faulting in the adjoining townships, and the extent of cover, it is not safe to assume the actual presence of the phosphate, and hence no estimate of the character and tonnage of the rock is attempted.

OTHER MINERAL DEPOSITS.

No mineral deposits of value have been recognized in the township. In the NE. ¼ SW. ¼ sec. 20 a buff fine-grained tuff has been opened, perhaps in a search for building material. It is, however, too soft to be of use for this purpose. In a locality near by the rhyolite has been opened, probably also in search of building material.

SOILS.

The alluvial deposits in Lincoln Creek can be irrigated and are partly cultivated in farms. The soils from the Tertiary and Quaternary formations, which occupy considerably dissected sloping benches, are in part available for dry farms. The sand-covered area has a soil too loose and incoherent for agriculture, but it may be utilized in grazing.

T. 4 S., R. 36 E.

TRANSPORTATION FACILITIES.

The Butte and Yellowstone branch of the Oregon Short Line Railroad runs 6 or 7 miles west of T. 4 S., R. 36 E. Fort Hall and Blackfoot are about equidistant from the center of the township, and there are well-traveled roads to each place. The road to Blackfoot is heavy because of the coarse and deep sand. A road to the Blackfoot Dam, Soda Springs, and other places, passes east along Ross Fork Creek in the southwest part of the township.

GEOLOGY.

STRATIGRAPHY.

The sedimentary rocks of the township range in age from Cambrian to Quaternary. The geologic features of this township are shown on the general map of the reservation (Pl. III). The oldest rocks recognized are cherty limestones of Cambrian and Ordovician age. They lie along the west flanks of the hills in the eastern part of the township and constitute much of the big hill in sec. 23 and vicinity. The east ridge which extends through secs. 24 and 13 is composed in part at least of rocks of these ages, but some of it may be Silurian or Devonian. The rocks of this ridge are sparingly fossiliferous and much broken, and it was not practicable to map the formations involved. The Swan Peak quartzite forms the crest of the ridge in secs. 26 and 35 and occurs in small detached areas elsewhere, mainly with synclinal structure. The Fish Haven dolomite overlies the Swan Peak quartzite along the east side of the ridge mentioned above and is probably the limestone that accompanies the quartzite on the west in sec. 14.

Fossils regarded by Edwin Kirk as probably of Devonian age, though possibly Madison, were found in the SW. ¼ NE. ¼ sec. 12. On the basis of these fossils the hills north of the main valley in the SE. ¼ sec. 12 are tentatively mapped as Devonian. Dark limestone much shattered and veined, along the east side of the ridge in sec. 13, may also prove to be Devonian but have not yet been recognized as such.

The high hill in the NW. ¼ sec. 18, T. 4 S., R. 37 E., about half a mile east of the township, carries Madison fossils, whereas the hill in the NW. ¼ sec. 6 of that township carries fossils of upper Mississippian (Brazer) age. The boundaries of these two formations have not been determined. At two localities in sec. 11 Carboniferous fossils of the Wells (Pennsylvanian) and upper Mississippian (?), respectively, have been found, but here again it has not been practicable to differentiate the formations. In the NE. ¼ NE. ¼ sec. 25 Wells limestone lies against Ordovician limestone, probably owing to faulting.

The Ross Fork limestone of the Thaynes group, without intervening lower formations, lies in close proximity to Ordovician limestones in the NW. ¼ sec. 23 and the SW. ¼ sec. 24. It outcrops also in the NW. ¼ sec. 2.

The Tertiary and Quaternary sediments form a cover that conceals much of the stratigraphy and structure of the township. The Quaternary deposits occupy the broad flat in the valley of Ross Fork Creek in the southwestern part of the township.

Igneous rocks, both rhyolites and basalts, occur in some places in the township. The rhyolites occupy the northern and north-central part, but basalts in small exposures are more widespread throughout the western part of the township. A belt of acidic glass accompanies the rhyolite in sec. 3 and beds of light-colored volcanic ash are interbedded with the rhyolites and Salt Lake beds in secs. 10 and 11 (Pl. XI, *A*). The so-called rhyolites are not true rhyolites, but rather are augite-quartz latite, very near rhyolites in composition and not differentiated in the mapping. The basalt contains olivine. The relations of the igneous rocks to each other have not been definitely worked out. It seems probable, however, that there have been several epochs of volcanic activity accompanied by alternating eruptions of acidic and basic rocks. The latest eruptive rocks appear to have been acidic and to have produced the dark volcanic sand that overlies the northwest corner of the township and is discussed in the description of T. 3 S., R. 36 E.

STRUCTURE.

The geologic structure of the township is complex and involves both folding and faulting, but the influence of faulting is predominant. The general structural features of the township are shown in the geologic section (B–B′, Pl. III).

Folds.—So far as the evidence has been interpreted the structure is marked by many relatively small folds rather than by fewer large ones. The two main ridges from sec. 23 southward and from sec. 24 northward are synclinal and anticlinal respectively, but in the eastern ridge particularly the rocks are much brecciated and seamed with calcite.

Faults.—The most pronounced structural features are two faults, which, though largely concealed, leave no doubt as to their reality and produce noteworthy structural discordance. These faults are discussed on page 63. (See structure section B–B′, Pl. III.)

The shattered condition of the rocks along the east side of the crest of the ridge in sec. 13 is the basis of the fault there shown. The rocks are comminuted and veined in a remarkable manner, but the rocks concerned are all of the earlier Paleozoic series, so that the postulated fault did not produce any great displacement. It is regarded as a branch of the great fault that enters the northeast corner of sec. 13 and that separates the older Paleozoic rocks from the Carboniferous and later rocks on the east. The small faults in the SE. ¼ sec. 12 represent similar shatter zones.

In the northeast corner of sec. 25 the lower part of the Wells formation lies against the older Paleozoic rocks. The Tertiary cover conceals all but a small area of this formation in this part of the township. The nearest ledges southwest of the overthrust fault lie nearly a mile to the northwest, and these expose the Ross Fork limestone. The rocks are thrown into several small folds, but the trend of the axes is roughly parallel to the course of the fault, and if continued would be likely to bring these Triassic beds into proximity with the Wells. The branch fault in sec. 25 is drawn to indicate such a possibility.

In sec. 14 a transverse normal fault cuts the overthrust and produces an offset in the quartzite and underlying limestone. A small rhyolite dike occurs along this line in the SW. ¼ sec. 14, and farther northwest a large flow of rhyolite comes in along the same general course. The downthrow here is probably to the northeast, because the limestones in that direction appear to represent higher formations than the Swan Peak quartzite, which on the southwest of the fault is caught here and there in little synclines.

Covered area.—Nothing can be stated with certainty regarding the structure of the covered area, but two suggestions may be made. The presence of the Cambrian and Ordovician area on the east side of sec. 21 and of the hill of Swan Peak quartzite in the northeast corner of sec. 20 suggests the continuance of the overthrust fault from sec. 22 beneath the cover westerly or northwesterly perhaps as far as the township line. It seems probable that to the south of such a line the underlying rocks are of the older Paleozoic series.

To the north of that line it seems probable that the underlying rocks are of Triassic age, though perhaps some may be of Permian or older Carboniferous age, because of the occurrence here and there of Triassic float, probably weathered from Tertiary conglomerates but not much rounded, and of phosphate float apparently from similar sources. In the northwestern part of the township the sand and igneous rocks so effectually conceal the sediments beneath that there is no clue to the underlying structure.

PHOSPHATE DEPOSITS.

The occurrence of abundant Triassic float and of some phosphatic float in the covered areas, together with actual ledges of Triassic limestones of the Thaynes group, all make it very possible that some of the northern and eastern portions of the township are underlain by phosphate deposits. The sections and analyses of the phosphate beds in Tps. 4 and 5 S., R. 37 E., make it probable that the phosphate would be of high grade and in beds of workable thickness. The presence of great faults and of extensive cover makes hazardous, however, any attempt to estimate the areas underlain by these deposits or to estimate their tonnage.

OTHER MINERAL DEPOSITS.

In secs. 10 and 11 are extensive beds of white volcanic ash (Pl. XI, *A*) which consists largely of fragments of glass with some feldspar that have a maximum diameter of about 0.1 millimeter but are mostly fine enough to pass through a 100-mesh screen. This material might be suitable for some scouring preparations. No other mineral deposits of value were recognized.

SOILS.

The volcanic sand in the northwestern part of the township is too coarse and incoherent for agriculture. The Tertiary slopes could be used for grazing or dry farming. The alluvium in Ross Fork Valley can be irrigated and is partly utilized in farms.

T. 3 S., R. 37 E.

TRANSPORTATION FACILITIES.

The city of Blackfoot, on the Oregon Short Line Railroad, is about 9 miles almost due west from the northwest corner of T. 3 S., R. 37 E. The distance by road is 4 or 5 miles longer. Two roads, high level and low level, respectively, pass up the valleys of Cold Creek and Lincoln Creek. The eastern two-thirds of the township is hilly, and the valleys trend northwest. Bold ridges between the valleys impede travel across country to the northeast.

GEOLOGY.

STRATIGRAPHY.

The stratigraphic succession in this township ranges from Pennsylvanian to Quaternary, but the highest of the well-consolidated sediments is the Twin Creek limestone.

Only a small area of Carboniferous rocks is known to be present in the township, and their position is somewhat doubtful. They are tentatively considered Pennsylvanian. The Phosphoria formation, if present, is concealed beneath the Tertiary rocks of the valley of Lincoln Creek.

The Woodside shale is exposed in two areas in secs. 34 and 35.

The Thaynes group is represented in two belts in the southern and northeastern parts of the township, respectively. Both belts are more or less broken by faults. In the northeast belt only the Portneuf limestone is represented. There are several small areas bounded by faults in secs. 15 16, and 24.

The Timothy sandstone also occurs in two general belts which accompany the Thaynes and is likewise broken by faults. In sec. 10 the Timothy is brought in by small broken folds.

The Nugget sandstone occupies much of the northern half of the township, where it forms big rounded hills. The Higham grit is a conspicuous topographic feature both in Higham Peak and in the NE. ¼ sec. 3. The Deadman limestone and Wood shale are also well represented.

The Twin Creek limestone is confined to the northeast corner of the township, to scattered areas in the northwest, and to an area apparently bounded by faults in secs. 14, 15, 22, and 23.

The Tertiary deposits underlie the sloping benches in the west and south and also lie in patches on some of the higher hills. Some of these patches are indicated, but their boundaries were not carefully ascertained.

A small area of alluvium in the valley of Lincoln Creek enters the township from the west.

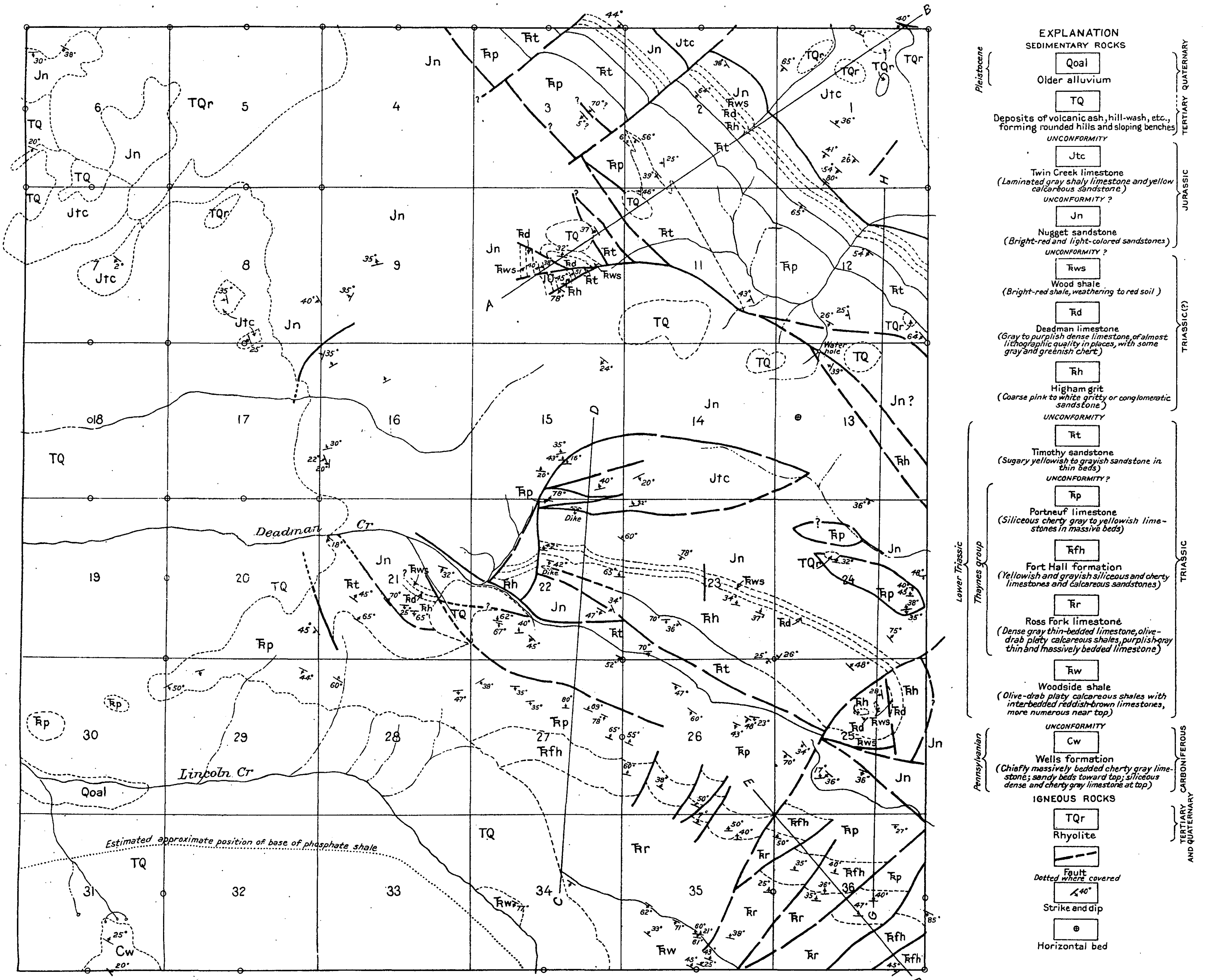
Igneous rocks, chiefly of the rhyolite group, occupy parts of the northeast and northwest corners of the township and form small patches elsewhere. Two dikes of approximately andesitic composition occur in sec. 22.

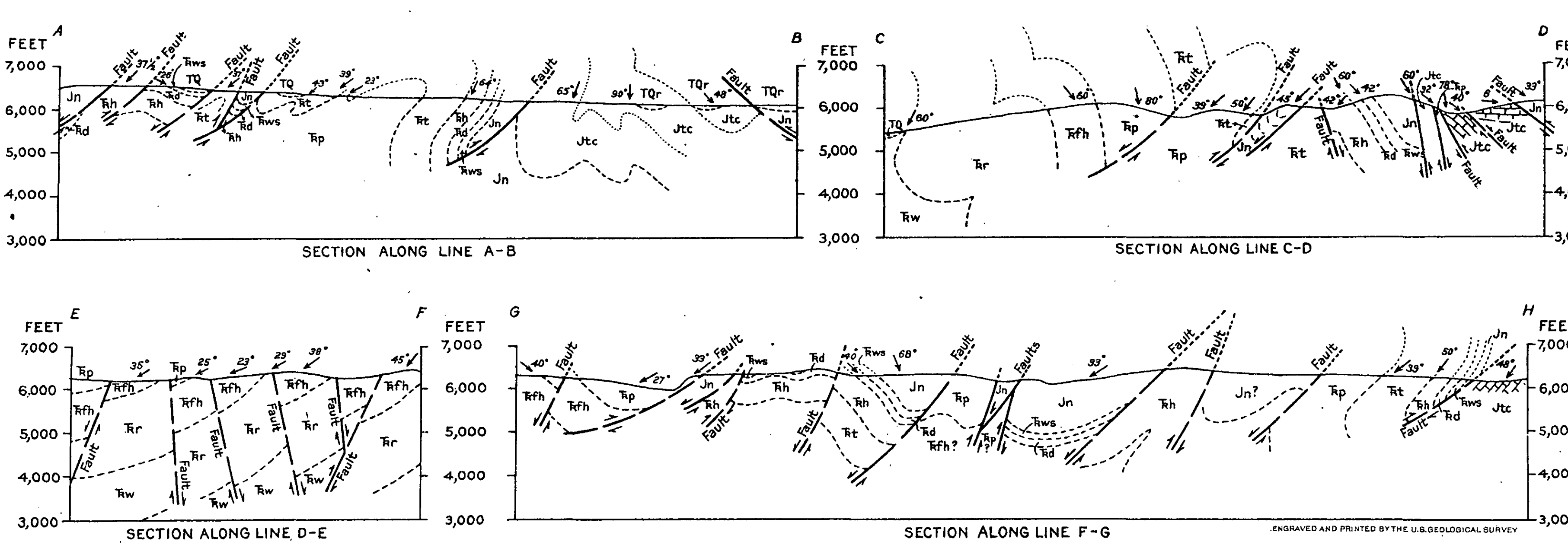
STRUCTURE.

Nearly a third of the township in the western and southwestern parts is covered with late sedimentary rocks and solidified lavas. The remainder of the township is marked by a great complexity of structure in which faulting plays the predominant part, although complex folding has also occurred. The structural relations postulated are shown in structure sections A–B, C–D, E–F, and G–H (Pl. V).

Folds.—The chief structural feature of the phosphate deposits is a portion of the great anticline that occupies so much of T. 4 S., R. 37 E. The Thaynes group swings in a long curve from sec. 36 to sec. 30 but is more or less broken by faults, especially in the southeast corner of the township. A series of more or less broken folds which trends northwestward and is mostly inclined or overturned toward the northeast occupies the remainder of the township.

Faults.—Both normal and reverse faults are present, but it is thought that the reverse faults have had the larger influence in the distribution of the rocks. The normal faults are chiefly associated with the northeastern end of the great anticline mentioned above, where they have produced many offsets, particularly in the Thaynes group. Some of these faults are illustrated in structure section E–F (Pl. V). Other normal faults offset the main structures elsewhere in the township, as in secs. 2 and 3. The other faults may





ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

DETAILED GEOLOGIC MAP OF T. 3 S., R. 37 E., WITH STRUCTURE SECTIONS

Scale $\frac{1}{48,000}$

0 ½ 1 2 Miles

1920

conveniently be described in connection with the structure sections that illustrate them.

In structure section A–B (Pl. V) the faults are all interpreted as reverse. In sec. 10 the Nugget sandstone, together with the underlying Wood shale, Deadman limestone, Higham grit, and Timothy sandstone, are thrown into a series of small folds that are broken by faults. The yellow sandstone in the NE. ¼ sec. 10 is assigned to the Timothy on lithologic grounds, and therefore faults must separate it from the Nugget on either hand. There is some doubt as to the structure of the Twin Creek limestone in sec. 1 because of insufficient knowledge of the stratigraphy of that formation. The structure is, however, provisionally interpreted as synclinorial and as inclined northeastward. Along the northeast limb of the synclinorium, in the very northeast corner of the township, thin platy sandstones like those of the lower portions of the Nugget sandstone emerge from beneath the lava and lie above massive beds of Twin Creek limestone that are believed to represent the upper part of the formation. If these assignments are correct, a fault must lie between the two formations, and the Nugget here appears to be thrust southwestward over the Twin Creek.

In structure section C–D (Pl. V) the faults are interpreted as reverse. North of the center of sec. 22 the Timothy sandstone becomes abnormally narrow. Between it and the Higham grit belt a narrow zone on the hillside is strewn with fragments of andesite, although no ledge of this rock appears. The andesite here is doubtless weathered from a small concealed dike that comes in along the contact of the two formations and probably marks the trace of a minor fault, as indicated. Near the north line of sec. 22 the Nugget sandstone comes in contact with thin-bedded shaly Twin Creek limestone. These beds are probably not the basal beds of the formation, for in sec. 1 similar beds are underlain by perhaps 800 feet of yellow calcareous sandstones with associated beds of gray limestones, some of which are crowded with oyster shells. In sec. 22 and in the NW. ¼ sec. 23 these thin-bedded, shaly limestones have been metamorphosed and in sec. 22 there is also a small andesite dike. These facts indicate that the contact between the Nugget sandstone and the Twin Creek limestone is a fault and the direction of thrusting is believed to be toward the south.

Immediately north of the fault just mentioned a small rocky point in the valley has ledges of massive gray limestone that carry fossils which have been identified by G. H. Girty as indicative of the Portneuf limestone. Faunally and lithologically these beds are different from those either south or north. They are interpreted as being pushed up between thrust faults and wedged between two areas of Twin Creek limestone, for the ledges in the rocky point to the east carry an abundance of oyster shells. These "oyster beds" are repeated on the north side of the main valley in a series of low points along the valley side but have a somewhat different strike and dip. The discordant relations of the oyster beds appear to be due to faulting rather than to folding, and the fault is interpreted as reverse because of its relations to the Twin Creek area as a whole. An alternative view is offered in paragraph 1, below.

The contact of the Twin Creek limestone with the Nugget sandstone on the north is also regarded as a reverse fault because of the lack of accord in dip in neighboring outcrops of the two formations and because the Twin Creek bears no other evidence of unconformable relations with the Nugget. The structure of the areas of Twin Creek limestone is not clear. At least four interpretations may be offered:

1. The area may represent a relatively open and asymmetric syncline along the base of which movement sufficient to cut out some of the beds along the contact has taken place. If this interpretation is correct, the fault between the oyster beds might be normal. The interpolated Portneuf limestone and the relatively intense compression that seems to mark the region as a whole are unfavorable to this view.

2. The area may be in general a syncline that is overturned northeastward. This is in accord with the prevalent structure of the region but disagrees with the arrangement of the broken minor folds involved.

3. The syncline may be inclined southwestward. This interpretation is in accord with the arrangement of the minor folds in both the Twin Creek limestone and the adjacent Nugget on the southwest but disagrees with the inclination of the folds in the Thaynes farther southwest.

4. The Twin Creek and adjacent Nugget beds to the southwest may be part of a broken fan-shaped synclinorium that is bounded on the north by the Nugget overthrust toward the southwest and on the south by the Thaynes anticline, which is overthrust toward the northeast. This view is favored by the arrangement of minor folds and is in accord with the interpretation suggested for the Twin Creek area that is cut by the section A–B (Pl. V). It is represented in the section C–D (Pl. V).

In the structure section G–H (Pl. V) the first fault encountered is normal and offsets formations of the Thaynes. It is possible that the convergence of the two faults shown immediately to the west may influence the zone traversed by the section, but there is no evidence of such influence. In sec. 25 the Portneuf limestone is faulted against the Nugget sandstone, and this in turn against the Higham grit by faults interpreted as thrusts toward the northeast. In the NE. ¼ sec. 25 a broad undulating syncline of Higham grit with Deadman limestone and Wood shale is cut off on the northwest by a fault that appears to be the continuation of one of the normal faults to the southwest. This fault is also shown in the structure section E–F (Pl. V).

In sec. 24 there are two areas of Portneuf limestone which are bounded by faults and apparently surrounded by Nugget sandstone. The relations of these limestone areas to the Nugget are not clear. The limestone is traversed by several small, relatively open folds. Though the western terminations of these areas are uncertain because of cover of float and soil from the Nugget the eastern terminations are clearly defined by exposures of the Nugget sandstone. At least two interpretations of their structure may be suggested. (1) These areas may represent parts of a once larger overthrust block that elsewhere has been eroded away, unless the small area of Portneuf limestone in secs. 15 and 22 is so considered. Though a great overthrust has occurred in the older Paleozoic rocks to the south and southwest and though the Triassic rocks in this and adjoining townships have been greatly disturbed; no thrust capable of producing the lateral displacement that would be required to place the postulated block in its present position has been observed elsewhere in the area occupied by the post-Paleozoic rocks. (2) These areas may represent subordinate anticlinal areas thrust upward into the Nugget synclinorium. A similar structure seems to have occurred in connection with the Higham grit in the townships to the east and southeast and might be expected in the present locality. This interpretation is provisionally shown in the structure-section sheet (Pl. V) as more in accord with the structural habit of the region.

In sec. 13 a belt of Higham grit is indicated, though much of its course in this section is concealed by soil, because of the occurrence of Higham grit in the southeast corner of the section and again in the NW. ¼ NW. ¼. It is assumed that the structural relations observed in connection with this belt to the southeast continue into this township.

The other structural features shown in the section are continuations of those in the townships to the east and southeast.

Covered area.—Carboniferous rocks, probably of the Wells formation, enter sec. 31. Northward the stratigraphic succession, as indicated by the limestone ridge in secs. 30, 29, and 20 and by local exposures still farther north, appears to be the same as that already described. In secs. 4, 9, 16, and 15 the large rounded hills are more or less soil covered, but there are many exposures of the Nugget sandstone. There has doubtless been both folding and faulting, but not enough is known of these features to warrant any attempt at interpretation.

PHOSPHATE DEPOSITS.

Where the strata lie horizontal the depth of the phosphate bed below the base of the Timothy sandstone, according to the thicknesses assigned to the intervening formations, would be approximately 5,000 feet.

The Thaynes group enters sec. 36 and sweeps across the township in a flat curve, the last exposure being in sec. 30. On account of the complexities of structure shown in structure sections C–D and G–H (Pl. V), it seems probable that in some places steep dips within the Thaynes area would carry the phosphate bed below the depth of 5,000 feet, and in other places thrust faults would perhaps cut the bed out. For these reasons the boundary of the area estimated to contain phosphate at depths less than 5,000 feet is assumed to lie about half a mile southwest and south from the contact of the Portneuf limestone and the Timothy sandstone.

In secs. 24, 15, and 16 the Thaynes areas are so small and the structure so doubtful as not to warrant any estimate of their phosphate content.

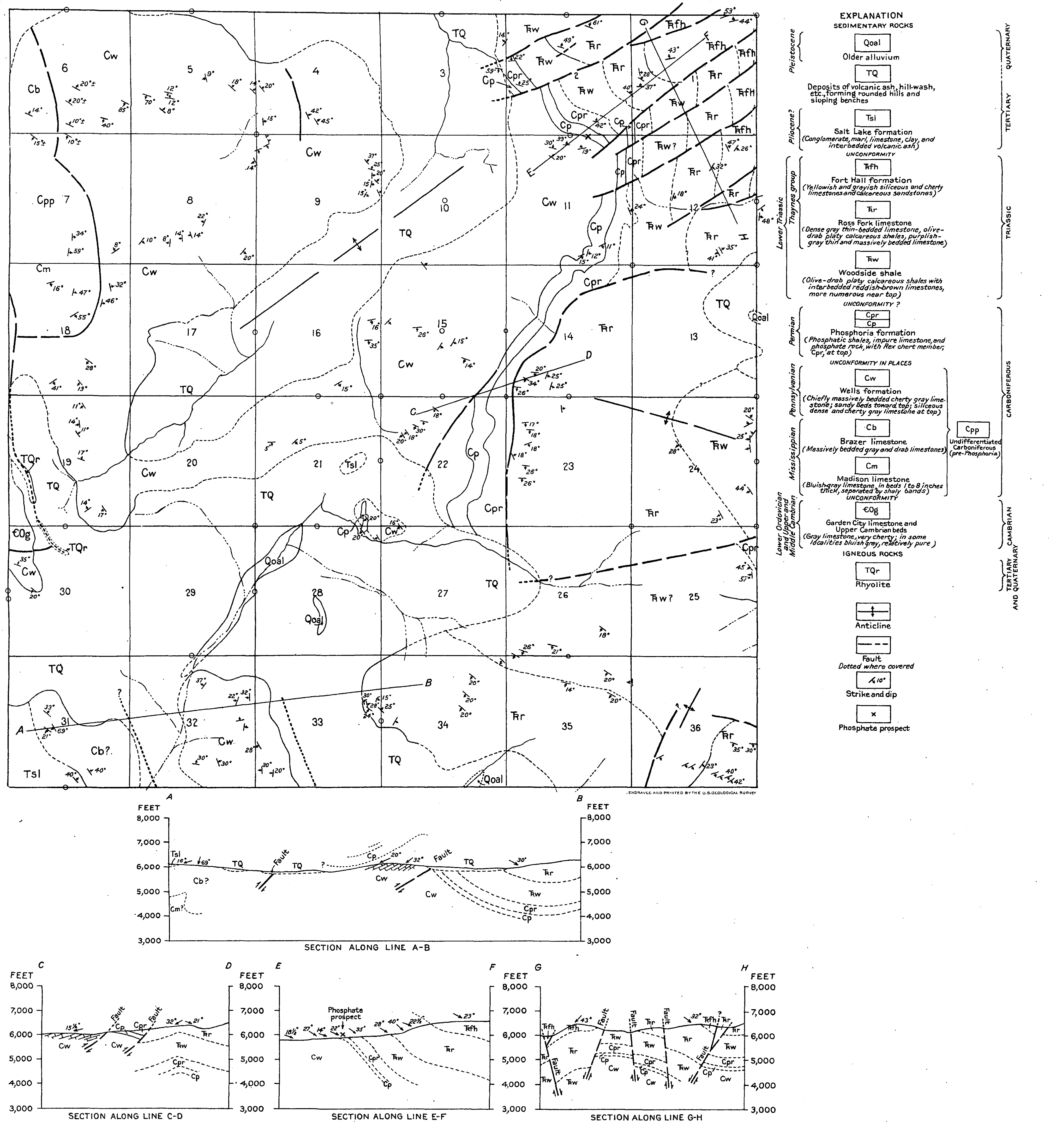
From sec. 12 northwestward a band of Portneuf limestone occurs, but here again the structure as shown in structure section A–B (Pl. V) is complex. Whatever phosphate deposits may be present are near the depth limit and occupy a relatively narrow band, the position of which can not be accurately determined from present data.

It is estimated that 4,520 acres in this township, practically all of which are in the basin of Lincoln Creek, are underlain by phosphate deposits at depths less than 5,000 feet.

In the NW. ¼ NE. ¼ sec. 11, T. 4 S., R. 37 E., the phosphate bed is 76 inches thick and shows an average content of 33.73 per cent of phosphorus pentoxide (P_2O_5), equivalent to 73.75 per cent tricalcium phosphate ($Ca_3(PO_4)_2$). (See p. 86.)

In the NE. ¼ NE. ¼ sec. 13, T. 5 S., R. 37 E., a similarly rich bed measures 66 inches in thickness, and in the NE. ¼ SE. ¼ sec. 36, T. 5 S., R. 38 E., the bed is 73 inches thick and of a similar high quality. (See p. 103.)

For this township it seems fair to assume a phosphate bed 6 feet thick that averages 70 per cent tricalcium phosphate. If the weight of 1 cubic foot of high-grade phosphate rock is taken as 180 pounds, 4,520 acres underlain by a 6-foot bed would yield in round numbers 94,925,800 long tons of high-grade phosphate rock. This estimate is on the assumption that the rocks are horizontal. They are, however, inclined at different angles, and the total amount is probably



DETAILED GEOLOGIC MAP OF T. 4 S., R. 37 E., WITH STRUCTURE SECTIONS

Scale $\frac{1}{48,000}$

0 ½ 1 2 Miles

1920

greater. This excess may perhaps be counterbalanced by loss due to faulting or shearing of the beds in the process of their dislocation.

UTILIZATION OF THE LAND.

The township as a whole is best adapted to grazing. The lower benches near Lincoln Creek and northward could probably be dry farmed.

T. 4 S., R. 37 E.

TRANSPORTATION FACILITIES.

The Butte and Yellowstone branch of the Oregon Short Line Railroad runs about 12 miles west of T. 4 S., R. 37 E. A road from sec. 3 leads northwestward 12 miles to Blackfoot and from sec. 32 a road leads southwestward and westward along Ross Fork Creek to Fort Hall, a distance of 15 miles or more. Both roads have easy grades, but the Blackfoot road traverses deep sand as it approaches Blackfoot River. The main road eastward along Ross Fork Creek enters the township in sec. 34. It crosses the divide in sec. 35 and descends to the Portneuf Valley.

GEOLOGY.

STRATIGRAPHY.

The rocks of the township are chiefly sedimentary, and range in age from Cambrian to Quaternary. A detailed geologic map of the township with structure sections is shown in Plate VI. A single dike of rhyolite, indicated by small patches and groups of boulders, lies near the western edge of the township in secs. 30 and 19.

The Cambrian and Ordovician rocks are confined to the rough wooded ridge along the west border and occupy only a small area in this township. They are dark limestones much shattered and veined. Silurian and Devonian rocks have not been recognized in this township, though fossils of doubtful Threeforks age were found in sec. 12, T. 4 S., R. 36 E.

Carboniferous rocks apparently underlie more than half of the township, though much of their area is concealed by Tertiary and Quaternary deposits. The Wells formation (Pennsylvanian) constitutes most of this area, although along its eastern border the Phosphoria formation (Permian) forms an important band, and in the northwestern part of the township both the Brazer and Madison limestones are found. The boundary between the last two formations has not been determined.

The Phosphoria formation is well developed. The phosphatic shale member is about 150 feet thick but forms a relatively broad band because of its low dip. Its course is easily traced much of the way by float of high-grade phosphate. The Rex chert member is chiefly represented by the flinty shale facies, though locally there are ledges of massive chert, as in the NE. ¼ SE. ¼ sec. 11. An interesting and new facies of the Rex that is lithologically similar to the overlying Woodside was discovered in the SW. ¼ NW. ¼ sec. 2 and has been described elsewhere (p. 41). The thickness of the Rex, as estimated from its dip and relations to other members of the section, is about 350 feet.

The Woodside shale is largely faulted out in secs. 23 and 14, and the Rex chert there lies against the Ross Fork limestone of the Thaynes group. Elsewhere the Woodside shale appears to occupy its normal position in the section, but its upper boundary is somewhat uncertain because of the difficulty in finding the *Meekoceras* zone. This zone has been located, however, in a number of places. The Woodside shale has a thickness of about 900 feet in the SE. ¼ sec. 2, where a section was measured northeastward up the hill and both boundaries were fairly distinct.

Only the two lower formations of the Thaynes group are represented in this township—the Ross Fork limestone, 1,300 feet thick, and the Fort Hall formation, 800 feet or more thick.

The Tertiary rocks form a blanket that covers large areas in this township. In the SW. ¼ sec. 31 there is a conglomerate that is composed chiefly of Triassic materials in a white calcareous matrix which has been differentiated and tentatively correlated with the Salt Lake formation. Doubtless much of the Tertiary area would be found to consist of similar materials if it was exposed. In the NE. ¼ SE. ¼ sec. 21 the conglomerate is deep red and in appearance resembles the Eocene conglomerates of the Montpelier quadrangle farther southeast. Like the similar conglomerate in sec. 1, T. 5 S., R. 36 E., it has nothing to support the suggested correlation except its color and the fact that it contains a larger proportion of pre-Triassic rocks than the other conglomerates that are exposed.

Quaternary deposits occupy relatively small areas along some of the streams.

STRUCTURE.

The structure of the township is complex and involves folding and faulting of both the normal and reverse types. Nearly one-fifth of the township is concealed by deposits of probably late Tertiary and Quaternary age.

Folds.—The main structural feature of the area is a large anticline that pitches gently northeast and is broken by faulting along its southeast border and in the axial region toward the northeast. The north and northwest borders are concealed. The core of this anticline is composed of Carboniferous limestones, chiefly of the

Wells formation, which show minor folds and faults, the details of which have not been worked out. The succession of formations and the structural relations at the tip of the anticline are illustrated in structure section E–F (Pl. VI). The main structural feature of the eastern part of the township, including sec. 13 and the sections to the south, is probably an anticline that has been faulted around the western tip and broken by a lateral fault. The rocks of this portion of the region are Triassic (Woodside and Ross Fork limestone). The boundaries of these two formations have been drawn on the basis of the strikes of the observed exposures and the few discoveries of the *Meekoceras* zone.

Faults.—Along the west border in sec. 19 ancient Paleozoic rocks of Cambrian and Ordovician (?) age lie against Carboniferous limestones (Wells to Madison). The ancient limestones are much shattered and veined with calcite, and along the contact zone are linear patches and boulders of rhyolite. In sec. 18 the Madison limestone lies against the Wells formation in apparent fault relation. This fault is interpreted as a branch of the main fault between the older and the later rocks.

In the NW. ¼ sec. 30 the lower limestones of the Wells formation lap around the Cambrian and Ordovician limestones at the south extremity of the rough west border ridge. The contact region where visited was concealed, but the fault interpretation is here preferred because of the highly brecciated condition of the older limestone series.

In secs. 31 and 32 there is a pronounced gap between limestone hills that may be in part of structural origin. It is in line with the main fault zone noted above, and it seems likely that a branch of this great fault may pass through the gap, as suggested in the description of T. 5 S., R. 37 E. (p. 90). The beds in the east hill rise stratigraphically to the west, whereas those in the west hill, which dip both easterly and westerly, are upper Mississippian or perhaps older Wells. There is scant room, unless a sharp anticlinal fold be assumed to that underlie the ascending series on the east. A fault is tentatively pass through the west hill, for these limestones to connect with those placed here in the structure section A–B (Pl. VI).

In sec. 33 a fault enters the township from the south along the east flank of the big limestone hill. Though its trace is concealed, the fault appears to be required by the proximity to the lower Wells of the Phosphoria formation, concealed here but partly exposed in the SE. ¼ sec. 4, T. 5 S., R. 37 E. The supposed structural relations are shown in structure section A–B (Pl. VI).

In sec. 36 faults enter from adjacent townships. These faults are briefly discussed in the descriptions of T. 5 S., Rs. 37 and 38 E. (pp. 90, 102).

In sec. 25 a fault appears to offset the Woodside shale and the Ross Fork limestone. It is possible that this fault may continue through sec. 27 and account for the relations of the Phosphoria formation and the Ross Fork limestone on opposite sides, respectively, of the broad valley in sec. 27. An alternative interpretation of this last feature is that the apparent termination of the Phosphoria may be due to the presence of a cross anticlinal axis, which causes the formation to turn back beneath cover toward the SE. ¼ sec. 21, where beds of the Phosphoria are exposed. In support of this view it may be noted further that phosphate float appears abundantly in connection with two exposures of weathered Tertiary (?) conglomerate, which may overlie parts of the Phosphoria formation in the NE. ¼ SE. ¼ sec. 21. The Phosphoria beds in the SE. ¼ SE. ¼ sec. 21, however, appear more like an isolated area, as if caught in a small syncline.

In secs. 23 and 14 the Ross Fork limestone abuts against the Rex chert in what appears to be a thrust fault. In secs. 22 and 15 heavy-bedded limestones of the Wells formation strike almost at right angles to the course of the phosphate shales, as determined by the distribution of phosphate float along the hillsides. Here, again, a thrust fault is postulated. The supposed relations of both these faults are shown in structure section C–D (Pl. VI).

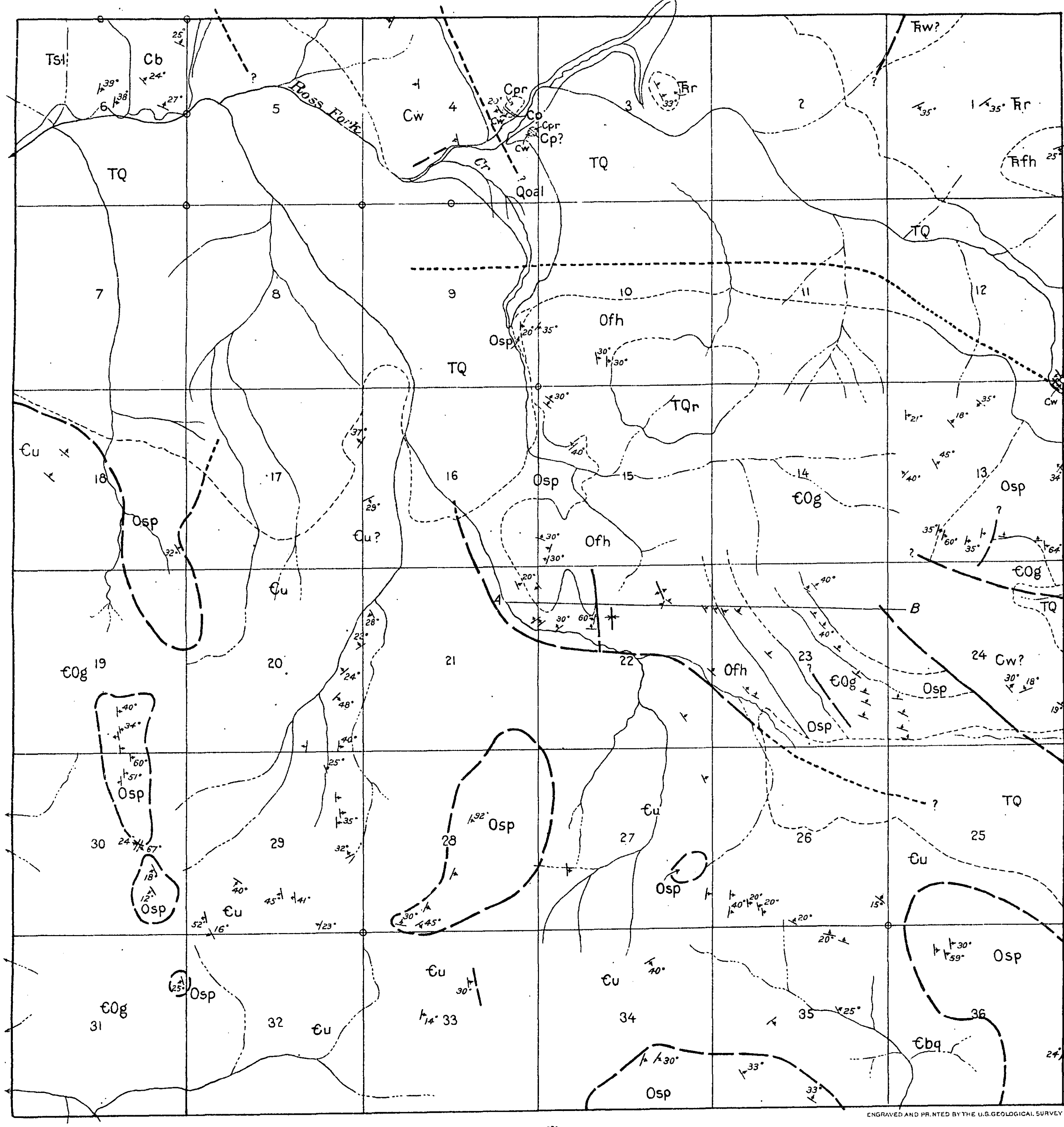
In the northeast corner of the township, in the marginal region of the great anticline of Carboniferous limestones, the overlying formations are cracked into numerous blocks by faults that are interpreted as normal and that produce offsets. These faults receive topographic expression in deep subparallel valleys and notches between the high points and linear hills that are so conspicuous here and in the immediately adjacent region on the north. The structural relations here suggested are illustrated in structure section G–H (Pl. VI). It is possible that the easternmost fault represented in sec. 12 may be reverse and perhaps connected with the fault shown in sec. 14.

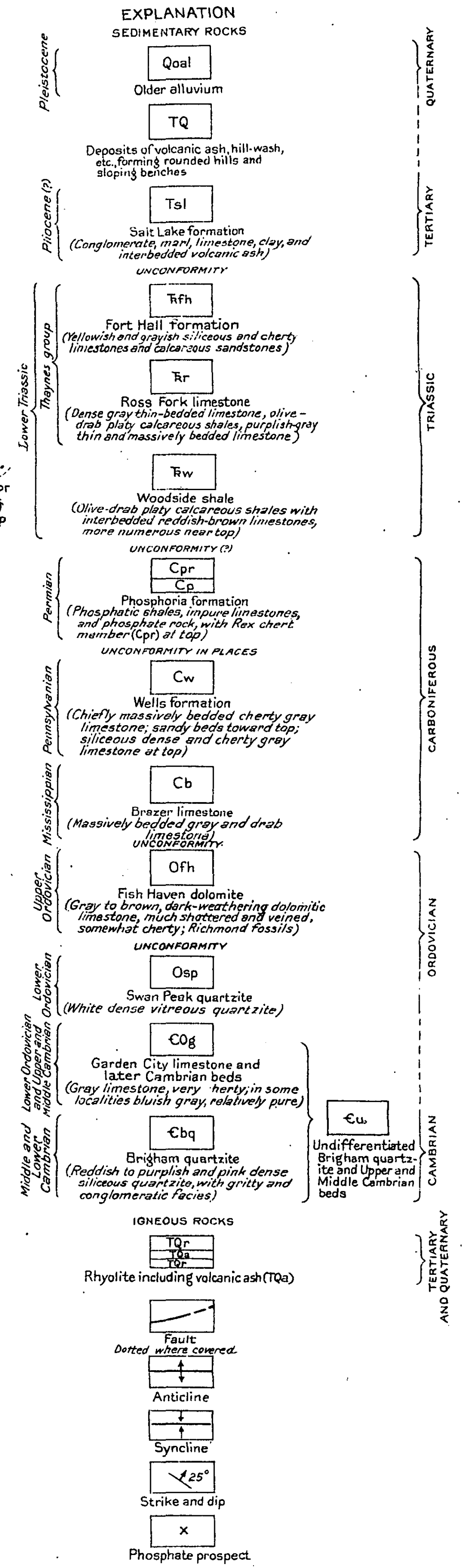
In the NE. ¼ NE. ¼ sec. 11 the zone occupied by the Phosphoria formation is concealed by a grassy slope, which is underlain with float of Rex and Woodside, together with much calcareous material, and the whole block appears to be offset toward the east.

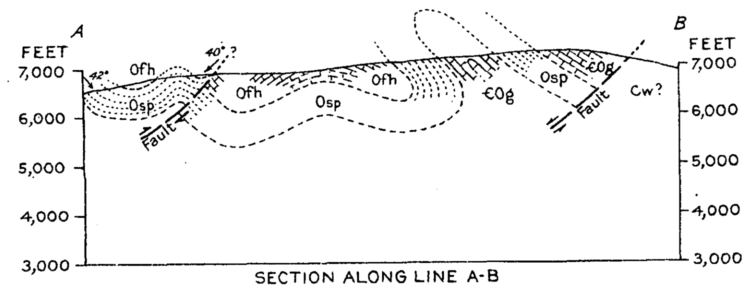
PHOSPHATE DEPOSITS.

It is estimated that an area equivalent to 9,760 acres in the eastern part of the township is underlain by phosphate deposits at a depth of less than 5,000 feet.

At station M 316, NW. ¼ NE. ¼ sec. 11, a section of the phosphate bed was made and samples were collected showing 76 inches of rock phosphate without notable partings and averaging 33.73 per cent







DETAILED GEOLOGIC MAP OF T. 5 S., R. 37 E., WITH STRUCTURE SECTION

Scale $\frac{1}{48,000}$

0 ½ 1 2 Miles

1920

P_2O_5, equivalent to 73.76 per cent tricalcium phosphate. (See p. 82.) In the NE. ¼ NE. ¼ sec. 13, T. 5 S., R. 37 E., and in the NE. ¼ SE. ¼ sec. 36, T. 5 S., R. 38 E., similarly high-grade beds were found to be 66 and 73 inches thick, respectively. (See pp. 91, 103.) The assumption of a 6-foot bed of high-grade rock for this township seems fair. The weight of such rock is assumed to be 180 pounds to the cubic foot, as in previous estimates. On this basis 9,760 acres underlain by a 6-foot bed would yield approximately 204,977,800 long tons of phosphate rock if the beds were horizontal. As the beds are not horizontal this estimate is too small. On the other hand, the folding and faulting of the beds may have occasioned some loss in quality or quantity to offset the gain due to inclination of the beds.

UTILIZATION OF THE LAND.

Much of the township is high and has rocky hills, though there are broad open valleys. The township as a whole is best adapted for grazing. Some of the lower slopes could perhaps be dry-farmed. A small area in secs. 28 and 29 could perhaps be drained and irrigated. It is now more or less marshy and has a heavy, somewhat alkaline soil.

T. 5 S., R. 37 E.

TRANSPORTATION FACILITIES.

The Butte and Yellowstone branch of the Oregon Short Line Railroad runs 12 to 15 miles west of T. 5 S., R. 37 E. The road from Fort Hall east to the Blackfoot Dam and points south runs along Ross Fork Creek in the north part of the township and two roads run southeast from sec. 16 through secs. 24 and 25 to the Portneuf Valley and Soda Springs. The south two-thirds of the township is high, rugged, and timbered, and is occupied by the Mount Putnam ridge and its associated hills.

GEOLOGY.

STRATIGRAPHY.

The geologic features of this township are shown on Plate VII.

With the exception of the patch of rhyolite in the NE. ¼ sec. 15 and vicinity all the rocks of the township are sedimentary and range in age from Lower Cambrian to Quaternary.

In the south half of the township the rocks are mainly Cambrian. The various members have not been differentiated, but certain resemblances between the rocks of this township and those of Walcott's

Cambrian section near Liberty,[71] in the Montpelier district, make it probable that many if not all the members of that section may be represented here. The most important Cambrian rock topographically is the Brigham quartzite, which is a massive pinkish to purplish or dark-red vitreous quartzite, often gritty or conglomeratic. Other members of the Cambrian are lustrous shales, grayish or reddish, together with dolomitic and well-crystallized limestones, with some shaly limestones.

The line between the Cambrian and Ordovician has not been determined in this township, but it is probable that here, as in the Montpelier district, it falls in the limestone series below the white vitreous Swan Peak quartzite. This quartzite lies in patches over Brigham quartzite and other Cambrian and Ordovician formations. It seems once to have overspread much of the south half of the township, probably as part of a great overthrust block now separated by warping and erosion into detached masses. Ordovician limestones lie above the Swan Peak quartzite, as in the SE. ¼ SE. ¼ sec. 16, but they have not been differentiated from other members of the series.

No Silurian or Devonian rocks have been recognized in this township.

An area of doubtful rocks occupies the SE. ¼ sec. 24 and extends northwest. The rock is red or pinkish calcareous sandstone, somewhat quartzitic in places, and with shaly beds. It does not appear to agree with the lithology of either the Brigham or Swan Peak quartzites. It might represent the Worm Creek quartzite member of the Upper Cambrian St. Charles limestone in the Montpelier district, but this member has not elsewhere been recognized in such mass in this district. It has tentatively been grouped with the Wells formation of the Carboniferous, which it resembles to some extent lithologically and which is represented in the ridge to the east in T. 5 S., R. 38 E. In a search a mile along the ridge no fossils were found. Its final assignment must await further study.

Carboniferous rocks are found is secs. 1 and 4 and in the NE. ¼ NE. ¼ sec. 13. They include representatives of the Brazer limestone (?), Wells, and Phosphoria formations, but they are separated by faulting. The Phosphoria formation outcrops clearly in the NE. ¼ NE. ¼ sec. 13 where the phosphate bed has been studied and sampled. (See p. 91.) The Rex chert member of the Phosphoria occurs in the flinty shale facies. In the NE. ¼ SE. ¼ sec. 4 phosphate float and chert float are so disposed as to suggest that the material is in place. These areas, however, are surrounded by the Tertiary cover and no actual ledges of the Phosphoria are visible, but in the northern patch a ledge, supposed to represent the upper Wells, was

[71] Walcott, C. D., Nomenclature of some Cambrian Cordilleran formations: Smithsonian Misc. Coll., vol. 53, No. 1, pp. 5-9, 1908.

found. The phosphate shales and Rex chert are estimated from measurements in T. 4 S., R. 37 E., to be 150 and 350 feet thick, respectively.

The Woodside shale enters the township in the NW. ¼ sec. 1, where it appears to be faulted. The *Meekoceras* zone has not been found in this township but has been found in secs. 35 and 36 in the township to the north. The thickness of the Woodside shale is estimated to be 900 feet.

The Ross Fork limestone and the Fort Hall formation, both of which are composed predominantly of calcareous shale, represent the Thaynes group in this township. The lower part of the Ross Fork limestone has conspicuous beds that form fine cliffs in secs. 1 and 3. The shales of the Fort Hall formation are dense and resist erosion, so that they form conspicuous hills in the SE. ¼ sec. 1. The thickness of the Ross Fork limestone is estimated at 1,300 feet, and that of the Fort Hall formation at more than 800 feet.

In sec. 6 a conglomerate, which is composed chiefly of Triassic material and a white calcareous matrix, is tentatively assigned to the Salt Lake formation and correlated with the Salt Lake beds of Hayden and Peale of probable Pliocene age. This conglomerate is included by St. John in his Carboniferous section.[72] The Tertiary deposits include sloping bench lands that yield a white calcareous soil and are overspread with gravels probably of Quaternary age but not differentiated. A small area of Quaternary deposits forms meadowland in the NE. ¼ sec. 9 and vicinity.

STRUCTURE.

The old Paleozoic rocks of the township are thrown into folds and apparently much faulted. Nearly a quarter of the area is concealed beneath deposits of probable Tertiary and Quaternary age. It was not practicable to work out the details of this highly complex structure. Only the broader features are described.

Folds.—The northwestern phosphate-bearing syncline of T. 5 S., R. 38 E. (section A–B, Pl. X), enters the northeast corner of this township, but in sec. 1 a cross anticlinal axis enters from the northeast, and the strike of the ledges swings from northwest to a little south of west. In the NW. ¼ sec. 1 this cross fold is accompanied by a fault, which appears to be necessitated by the strike relations of the *Meekoceras* zone in secs. 35 and 36, T. 4 S., R. 37 E.

Folding occurs in places in the older rocks of the township. The geologic section A–B (Pl. VII) shows the postulated structure of the Cambrian and Ordovician rocks in the north part of secs. 22

[72] St. John, Orestes, U. S. Geol. and Geog. Survey Terr. Eleventh Ann. Rept., for 1877, p. 329, 1879.

and 23. An anticlinal axis that trends northward apparently passes through secs. 20, 29, and 32.

Faults.—Faults have played an important part in the geologic structure of the township, and a number of faults are shown on the map, but further detailed stratigraphic study will be necessary before some of the relationships can be fully determined, and other important features are concealed beneath the broad covered areas in Ross Fork Valley and its tributaries.

The Putnam thrust (p. 62) is the most striking structural feature of the township.

In secs. 22 and 23 shales tentatively correlated with the lower part of Walcott's Cambrian section [73] appear to crowd too closely upon the Ordovician(?) quartzites and limestones on the north, and a thrust fault is therefore mapped as traversing the valley that heads to the southeast.

In sec. 24 the Ordovician(?) quartzite and limestones that occupy the ridge abut against the doubtful Carboniferous sandstones described above. Faults interpreted as reverse are therefore tentatively mapped on the southwest and northeast of these sandstones. The supposed structural relations are indicated in the geologic section C–D that accompanies the map of T. 5 S., R. 38 E. (Pl. X, p. 100).

In secs. 12 and 13 Cambrian and Ordovician limestones descend on the north to a broad valley that is occupied by later sediments. Triassic beds rise along the north side of this valley. The fault that here separates the early Paleozoic from the Triassic rocks is interpreted as a thrust and is concealed in the valley, but its postulated trace is indicated for a short distance on the map.

In secs. 9 and 10 the Cambrian and Ordovician rocks form a prominent point that terminates in a low cliff on the south side of Ross Fork Valley. Nearly a mile away to the north and in the general direction of the strike of the older rocks the Wells formation rises abruptly in high hills. The relations here suggest faulting, and a portion of the trace of such a fault is tentatively shown. This fault may prove to be continuous with that in secs. 12 and 13.

In sec. 4, along the east side of the prominent limestone hills, the lower part of the Wells formation abuts against the Phosphoria, which is largely concealed. There appears not to be space for the sharp fold that would be required to bring the upper Wells into normal relations with the Phosphoria, hence it appears that a fault, probably a thrust, marks the boundary of the Wells and Phosphoria in this section.

In sec. 5 is a broad gap between limestone hills. On the east side beds of the Wells formation ascend stratigraphically to the west.

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[73] Walcott, C. D., op. cit., pp. 5–9.

On the west side of the valley are beds of the upper Mississippian or lower Wells which dip in some places to the east and in others to the west. This gap is in line with a well-recognized fault in the adjoining township on the north, which brings Cambrian and Ordovician limestones against Carboniferous limestones. The conditions at the gap suggest faulting, hence a fault is tentatively indicated on the map, although its position is indeterminate because of the cover of later sedimentary rocks.

Secs. 7 and 8 and the W. ½ sec. 6 are completely covered with Tertiary deposits. However, the large amount of Triassic débris included in the Tertiary deposits in sec. 6, together with the actual outcrop of Triassic beds in the southeastern part of T. 4 S., R. 36 E., the adjoining township on the northwest, indicates the proximity of Triassic sediments. Between these rocks and the Cambrian and Ordovician quartzites and limestones to the south and west there must be a fault, perhaps the continuation of the thrust in sec. 12. The extent of the cover in the sections named makes it impossible to represent the fault on the map.

In the SE. ¼ sec. 10 and the immediately adjoining portions of the neighboring sections there is a patch of rhyolite that forms the top of a prominent hill. The position of the rhyolite at a point toward which several of the faults named converge suggests that the locus of the outflow of the rhyolite may have been determined by the convergence or intersection of faults.

PHOSPHATE DEPOSITS.

The extensive cover in the northeastern part of the township causes some uncertainty as to the boundary of the phosphate and post-phosphate rocks. It is estimated, however, that about 3,120 acres are underlain by phosphate at depths less than 5,000 feet. In the NE. ¼ NE. ¼ sec. 13, close to the section corner, a trench that was made by the Survey party across the phosphate bed exposed 66 inches of phosphate rock without partings. Samples taken across the bed showed an average content of 33.96 per cent phosphorus pentoxide, equivalent to 74.20 per cent tricalcium phosphate. (See p. 87.) The weight of this rock, as shown by earlier determinations, is about 180 pounds to the cubic foot. On this basis 3,120 acres underlain by a 5½-foot bed would yield 55,744,200 long tons of high-grade phosphate rock if the strata were horizontal. The beds are, however, inclined at rather large angles, so that the actual amount of rock present should exceed the estimate. In view of the faulting and cover near the margins of the deposit, it is probably wiser not to add to the above estimate.

UTILIZATION OF THE LAND.

The high hills in the south half of the township afford excellent timber and pasturage. The smoother portions of the benches in the north part could be dry farmed and the lower slopes and meadows irrigated. In the SW. ¼ NW. ¼ sec. 5 an excellent stand of timothy was observed in connection with some unoccupied ranch buildings. In the SE. ¼ sec. 4 and vicinity there is a partly fenced meadow that is utilized for wild hay.

T. 3 S., R. 38 E.

TRANSPORTATION FACILITIES.

Roads in the southwestern and northwestern parts of T. 3 S., R. 38 E., lead to Blackfoot, 15 miles or more to the west, the most accessible railroad point. The southwestern part of the township is traversed by prominent ridges and deep valleys which have a difference in elevation of about 1,000 feet. In the northeastern part long, sloping benches cut by streams descend to Blackfoot River, which here occupies a picturesque walled canyon 200 to 300 feet deep in basalt.

GEOLOGY.

STRATIGRAPHY.

More than half the area mapped is underlain by igneous rocks and their derivatives. The sedimentary series includes only Triassic and Jurassic formations, and some of the Tertiary conglomerates. The geologic features of this township are shown on the map (Pl. VIII).

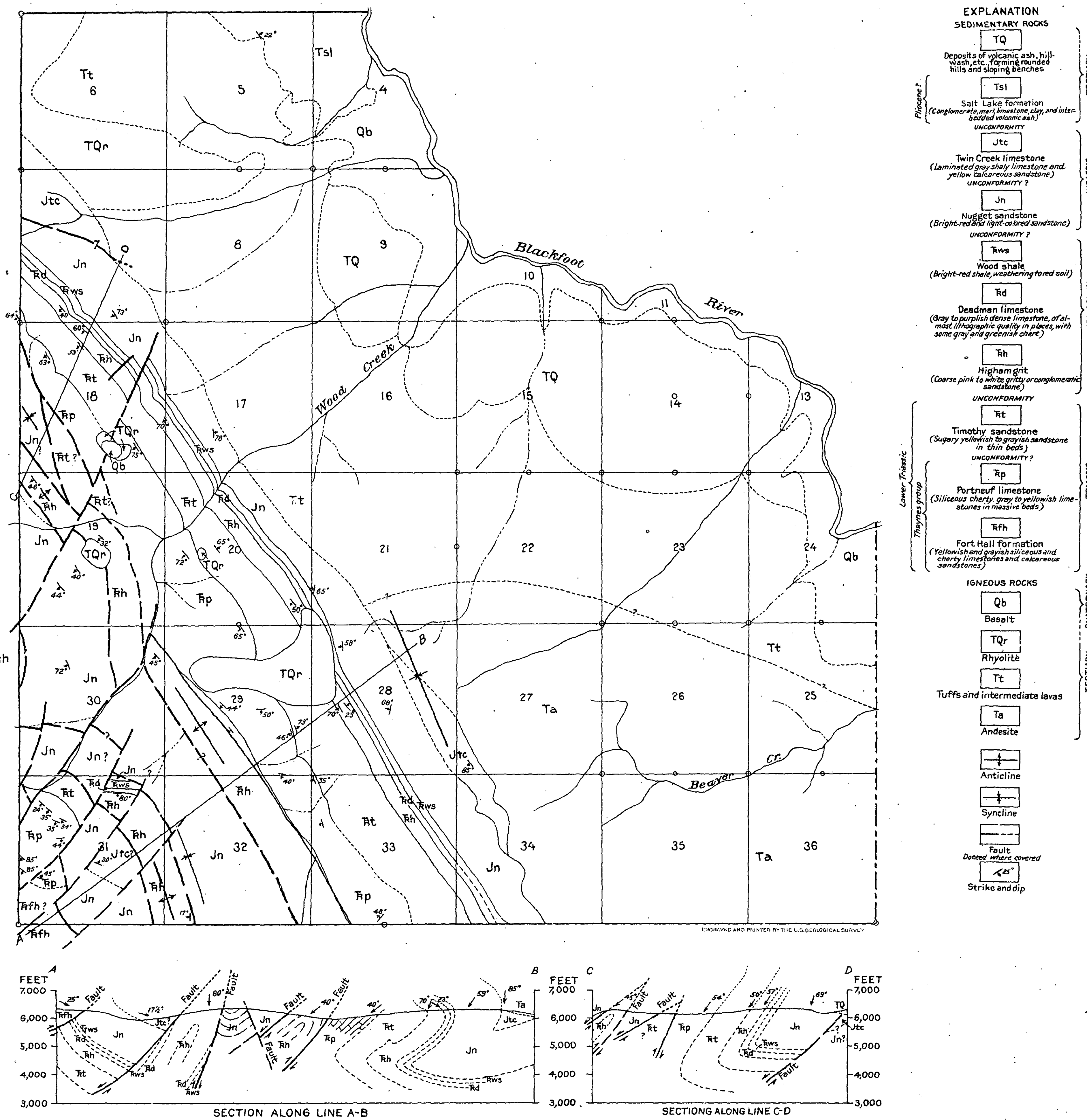
The oldest sedimentary rocks examined in this township belong to the Fort Hall formation of the Thaynes group. The rocks are calcareous shales with some sandy beds and some limestones. Above these comes the Portneuf limestone, which consists of cherty and siliceous limestones rather massively bedded and topographically resistant.

The Timothy sandstone above the Thaynes is a soft yellow, rather thin-bedded calcareous sandstone.

The Higham grit, Deadman limestone, Wood shale, and Nugget sandstone are characteristically developed in this township. Plate II, *A* (p. 18), shows a strike ridge formed by the Higham grit.

The Twin Creek limestone occupies two relatively small areas, one in secs. 6 and 7 and the other in secs. 27, 28, and 34.

The Tertiary rocks are whitish and yellowish calcareous conglomerates that are assigned to the Salt Lake formation of probable Pliocene age.



DETAILED GEOLOGIC MAP OF T. 3 S., R. 38 E., WITH STRUCTURE SECTIONS

Scale $\frac{1}{48,000}$

0 ½ 1 2 Miles

1920

The igneous rocks are rhyolites, andesites, andesitic tuffs, and basalts. From the relations in the township to the north it appears probable that the andesites and andesitic tuffs are the oldest, followed by the rhyolites and basalts, and that all are of late Tertiary or Quaternary age. A particularly interesting rock occurs in the SW. ¼ SE. ¼ sec. 18. This is the nepheline basalt that is described on page 58.

STRUCTURE.

Sedimentary rocks occupy the southwestern part of the township and are greatly disordered. Folding and faulting have occurred, but faulting is more conspicuous. The folds thus far recognized have all been faulted to a greater or less degree.

Fold.—The west limb of a large syncline that enters from T. 4 S., R. 38 E., passes from the SW. ¼ sec. 34 northwestward through sec. 7. This limb is inclined steeply westward and indicates that the syncline is asymmetric or overturned toward the northeast. The east limb of this fold is concealed beneath solidified lavas and fragmental volcanic rocks, and is probably more or less faulted, for in sec. 7 it is partly transgressed by a fault that passes beneath the cover. The west limb is marked by local minor folding and perhaps thrust faulting, for in several places patches of igneous rock lie along its course, and one of these, in secs. 28 and 29, is of considerable size. Also in sec. 18 this limb is offset twice by normal faults.

Southwest of this big syncline lies an area of Nugget sandstone with underlying formations in apparently synclinorial structure, though much faulted. Among these formations are two belts of Higham grit, which are interpreted as anticlinal, or perhaps in places as isoclinal, for in the southwest belt the Deadman limestone and Wood shale are absent through faulting, but the Nugget sandstone lies on each side of the belt. In the other belt, in secs. 32 and 29, the east side forms the east boundary of the synclinorium and the relation is not so clear, but farther northwest in secs. 19 and 18 this belt apparently has Nugget sandstone on each side without the Deadman limestone and Wood shale that should intervene.

In the same region also a band of Timothy sandstone apparently lies against the Nugget sandstone on the west and a somewhat narrow belt of the Portneuf limestone on the east. Faults are drawn on both sides of the Timothy here because on the west side the three formations below the Nugget are apparently missing, and on the east side there is not enough room for the Portneuf limestone. There is perhaps a little uncertainty in the identification of the Timothy here, for the determination is based on pieces of float that lie on a smooth slope, and there is sometimes difficulty in distinguishing pieces of the Timothy from some of the softer and more yellowish beds of the Nugget sandstone. The same difficulty was encountered in two localities in the township on the west.

In sec. 31 the rock formations of the township become parts of a large northeastward-trending anticline that forms an important structural feature of T. 4 S., R. 37 E. The beds in sec. 31 curve around from southeast to northwest in response to the anticlinal structure, but the anterior part of the anticline has been spread by a number of normal faults that produce offsets and slight or moderate displacements.

Faults.—The principal fault is the one that separates the overturned syncline on the northeast from the Nugget synclinorium on the southwest. This fault is interpreted as a reverse fault, as are also the other strike faults, because of their intimate relations with the folds and because of the strong lateral compression that the rock formations have endured.

Normal faults cut these structural features at nearly right angles, particularly in the southwest corner of the township.

The main features of both groups of faults have already been mentioned in the discussion of the folding. The structure sections drawn along the lines A–B and C–D (Pl. VIII) illustrate the structural interpretations above outlined. The normal faults are illustrated in structure section G–H (Pl. VI, p. 82).

PHOSPHATE DEPOSITS.

As the exposed sedimentary rocks are all post-phosphate it is probable that phosphate beds underlie much of the township. The rock formations here represented are for the most part, however, far above the phosphate horizon, so that the phosphate rock would lie considerably deeper than 5,000 feet. A band of Portneuf limestone passes northwestward from sec. 33. This rock, if in normal position, would be underlain by phosphate within workable depths. However, it is overturned toward the northeast and faulted along its west border. It is doubtful, therefore, if any significant deposits of phosphate rock occur within 5,000 feet of the surface along this zone. In sec. 31 both the Portneuf limestone and the Fort Hall formation occupy a small area. These formations would both normally be underlain by phosphate deposits at less depths than 5,000 feet, but in view of the supposed folding and thrust faulting, as well as the normal faulting, it is doubtful if more than a few acres, if any, contain workable phosphate deposits.

UTILIZATION OF THE LAND.

The township as a whole is best adapted for grazing. Dry farming would perhaps be successful on the lower benches that slope toward Blackfoot River.

T. 4 S., R. 38 E.

TRANSPORTATION FACILITIES.

Blackfoot, on the Oregon Short Line, is 15 miles or more by road northwest of T. 4 S., R. 38 E. Bancroft, another railroad point, lies to the south about 20 miles by road. A stage line from Bancroft to Chesterfield comes within about 12 miles of the township. Fort Hall, a third railroad point, is 20 miles or more west of the township. Fairly good roads connect this township with each of these railroad points.

GEOLOGY.

STRATIGRAPHY.

Both igneous and sedimentary rocks are represented in the township. The sedimentary rocks range from Carboniferous (Wells formation) to Quaternary in age.

The Wells formation is confined to the southwest corner of the township, where it is involved in a number of broken folds.

The Phosphoria formation accompanies the Wells and appears to extend eastward under Tertiary and Quaternary deposits as far as the S. ½ sec. 22. Its northern limits east of the NW. ¼ NW. ¼ sec. 20 are not known because of cover and possible faulting. The outcrop of the phosphatic shales is confined to narrow bands in association with the Wells formation in the southwest corner of the township.

The Woodside shale accompanies the Wells and Phosphoria in the southwest corner and forms small patches elsewhere. It may perhaps underlie the Tertiary and Quaternary cover in secs. 21 and 28 and vicinity.

The Ross Fork limestone occupies three small areas in secs. 18, 22, 23, 26, 31, and 32. It may also underlie parts of the covered area in secs. 16, 17, 18, and 21, but of this there is no definite knowledge. The Fort Hall formation occupies a broad area in secs. 6 and 7 that extends and narrows eastward and southeastward. It makes the prominent ridge that extends from sec. 23 to sec. 9. The Portneuf limestone belt is separated from the Fort Hall formation by belts of Nugget sandstone and Higham grit[a] that are faulted between the two upper formations of the Thaynes group.

The Timothy sandstone, Higham grit, Deadman limestone, and Nugget sandstone outcrop with apparent conformity in belts that extend northwest from sec. 13. The Wood shale is believed to be present but was not differentiated from the overlying sandstones in this township, but the Deadman limestone was differentiated and

[a] On Plate IX the belt of Higham grit has inadvertently been mislabeled.

mapped. The failure to differentiate the Wood shale is probably due to the fact that at the time this township was mapped the subdivision of these rocks had not been considered, and the Wood shale was probably grouped with the overlying red sandstone. The belts of Nugget sandstone and Higham grit that lie between the upper members of the Thaynes are each faulted on both contacts.

The Twin Creek limestone is not exposed in this township but may underlie the igneous rock in sec. 2 and vicinity, for in T. 3 S., R. 38 E., it lies east of the Nugget sandstone and passes beneath similar igneous rock on the east.

In the southeast corner of the township there is a weathered conglomerate which consists of boulders and pebbles of the older sedimentary rocks and some solidified lavas. This conglomerate is tentatively assigned to the Salt Lake formation of probable Pliocene age.

The central part of the township and many of the slopes from the hills are covered with a deposit that yields a white calcareous soil and that is commonly more or less overstrewn with pebbles and rock fragments, which may have been in part weathered out from Pliocene (?) beds or perhaps in part rearranged by erosion. These deposits have not been differentiated but are probably mostly Tertiary, though possibly in part Quaternary.

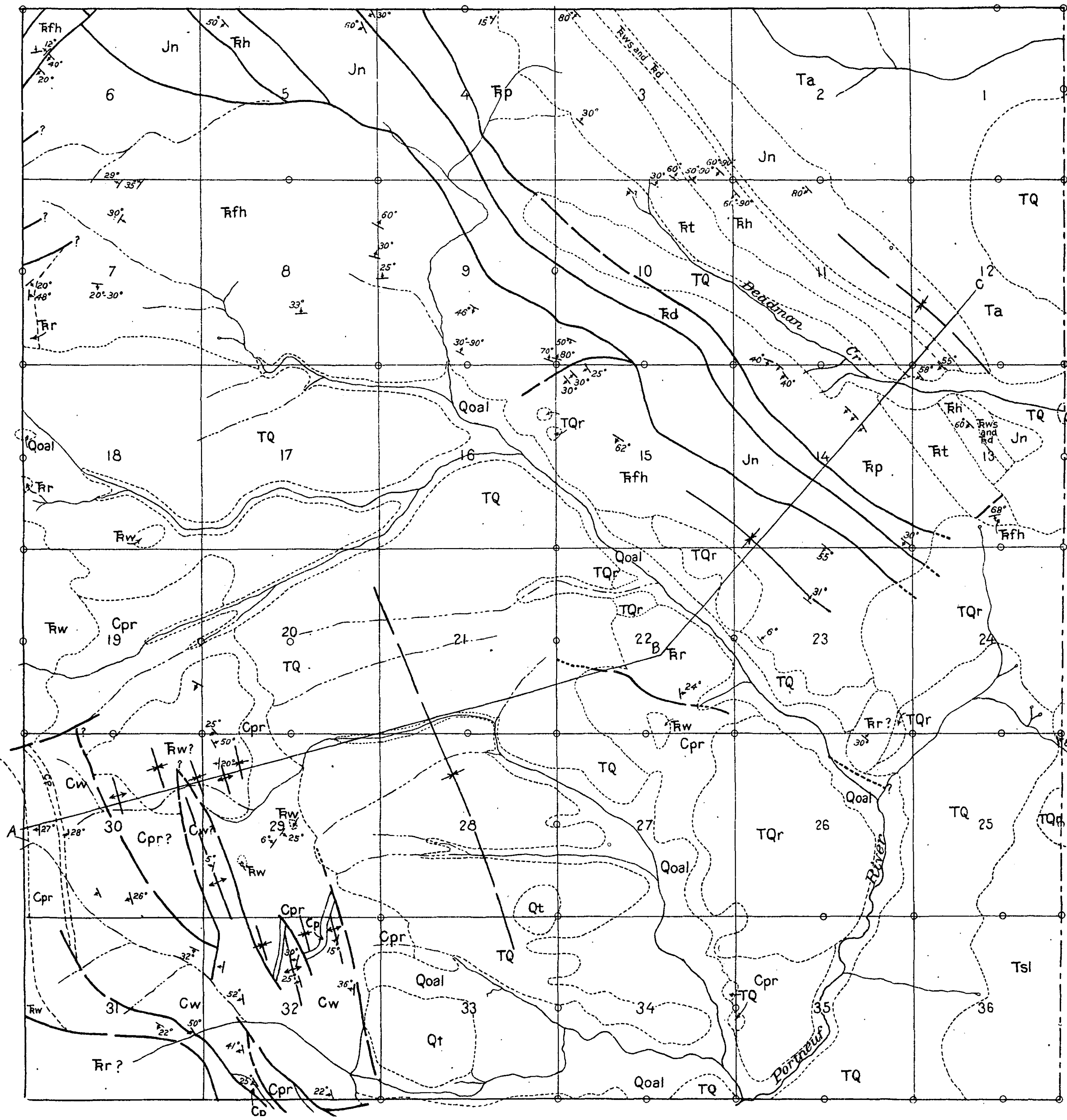
Quaternary alluvial deposits occupy the larger valley bottoms. In secs. 33 and 28 there are considerable deposits of travertine. In both areas springs are now associated with the travertine. The spring in sec. 28 is said to be thermal, but no temperature measurements were made.

The igneous rocks are intermediate or acidic and correspond approximately to andesite and rhyolite. They occupy extensive areas in the eastern half of the township and are either of Pliocene or Pleistocene age.

STRUCTURE.

The structure of the township is complex and its interpretation is rendered difficult by the large areas of late sediments and igneous rocks that conceal the older rocks beneath. The older rocks have been subjected both to folding and faulting, although the effects of the faulting are more conspicuous.

Folds.—The structural feature which has the greatest effect on the phosphate deposits is a broad, shallow syncline, which trends about N. 20° W. and which occupies the south-central part of the township. There is an element of doubt in the interpretation of this feature, because this portion of the township is occupied by a broad valley and is covered largely with late sediments. The occurrence of Rex chert apparently in place on the east and west sides of this valley,



EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY

Probably Pleistocene and Recent

- Qt — Travertine

Pleistocene and Recent

- Qoal — Older alluvium
- TQ — Deposits of volcanic ash, hillwash, etc., forming rounded hills and sloping benches

TERTIARY

Pliocene?

- Tsl — Salt Lake formation (*Conglomerate, marl, limestone, clay, and interbedded volcanic ash*)

UNCONFORMITY

JURASSIC

- Jn — Nugget sandstone (*Bright-red and light-colored sandstones*)

UNCONFORMITY ?

TRIASSIC(?)

- Ꞧws — Wood shale (*Bright-red shale, weathering to red soil*)
- Ꞧd — Deadman limestone (*Gray to purplish dense limestone, of almost lithographic quality in places, with some gray and greenish chert*)
- Ꞧh — Higham grit (*Coarse pink to white gritty or conglomeratic sandstone*)

UNCONFORMITY

TRIASSIC

- Ꞧt — Timothy sandstone (*Sugary yellowish to grayish sandstone in thin beds*)

UNCONFORMITY ?

Lower Triassic — *Thaynes group*

- Ꞧp — Portneuf limestone (*Siliceous, cherty gray to yellowish limestones in massive beds*)
- Ꞧfh — Fort Hall formation (*Yellowish and grayish siliceous and cherty limestones and calcareous sandstones*)
- Ꞧr — Ross Fork limestone (*Dense gray thin-bedded limestone, olive-drab platy calcareous shales, purplish-gray thin and massively bedded limestone*)
- Ꞧw — Woodside shale (*Olive-drab platy calcareous shales with interbedded reddish-brown limestones, more numerous near top*)

UNCONFORMITY ?

CARBONIFEROUS

Permian

- Cpr / Cp — Phosphoria formation (*Phosphatic shales, impure limestone, and phosphate rock, with Rex chert member, Cpr, at top*)

UNCONFORMITY IN PLACES

Pennsylvanian

- Cw — Wells formation (*Chiefly massively bedded cherty gray limestone; sandy beds toward top; siliceous dense and cherty gray limestone at top*)

IGNEOUS ROCKS

TERTIARY AND QUATERNARY

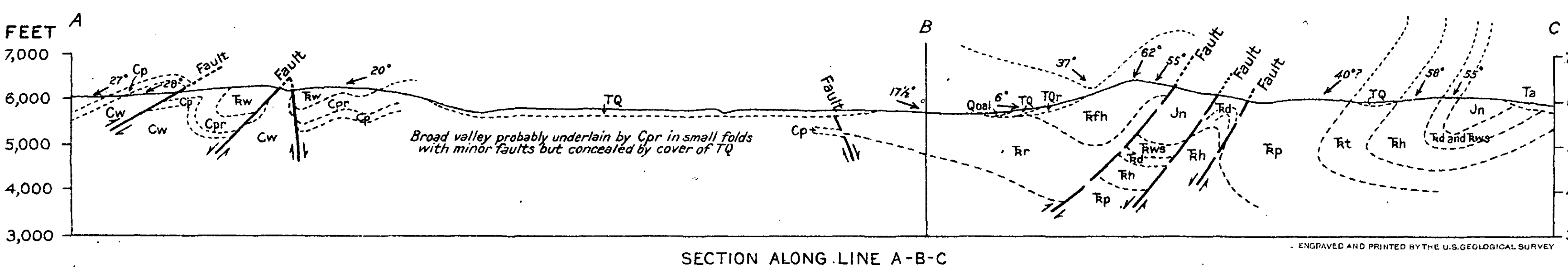
- TQr — Rhyolite
- Ta — Andesite

Anticline

Syncline

Fault
Dotted where covered

Strike and dip



SECTION ALONG LINE A-B-C

DETAILED GEOLOGIC MAP OF T. 4 S., R 38 E., WITH STRUCTURE SECTIONS

Scale $\frac{1}{48,000}$

0 ½ 1 2 Miles

1920

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

together with the abundant occurrence of fragments of float from the Rex in the later deposits, is thought to justify the view above expressed. Along the west margin of the syncline in secs. 32, 29, and 30 there is anticlinorial structure and overturning and overthrust faulting toward the northeast. On the east side the syncline is cut by a normal (?) fault that brings the Ross Fork limestone against the Rex in sec. 22. In the NW. ¼ NW. ¼ sec. 30 the phosphate beds are cut off by a fault that may prove to be a continuation of the fault just mentioned. The occurrence of successively higher formations to the northwest indicates a gentle pitch in that direction.

It is supposed that the northeastern part of the township, northwest of sec. 13, contains the west limb of a large overturned syncline, which involves formations that range from the Portneuf limestone to the Nugget sandstone. The east limb of this fold is concealed beneath andesite. The highest beds of the syncline exposed in this township are those of the Nugget sandstone, but in the township to the north the Twin Creek beds appear east of the Nugget and thus suggest a northwesterly pitch.

Along the southwest flank of the ridge in secs. 15 to 23 there is a synclinal fold in the Fort Hall formation, which is not overturned but has the steeper limb on the east side. Portions of other folds lie in the faulted Nugget sandstone and Higham grit on the east.

The folds above described are indicated in the structure sections drawn along the line A–B–C (Pl. IX).

Faults.—The faults appear to be chiefly of the reverse type and for the most part to have accompanied the folding. The fault that offsets the phosphate deposits in the NW. ¼ NW. ¼ sec. 30 is, however, apparently normal. It may be continuous with the fault in sec. 22 and with a postulated concealed fault in sec. 26, where similar structural conditions apparently obtain. Small normal faults enter the northwest corner of the township, but these are more fully described and illustrated in the description of T. 4 S., R. 37 E. (See Pl. VI.)

The Fort Hall formation is thrust upon the Nugget sandstone from the NE. ¼ NE. ¼ sec. 23 northwestward through secs. 5 and 6, where it transgresses other disturbed areas of the Nugget and Higham formations.

East of the Nugget sandstone but without the normally intervening Wood shale and Deadman limestone lies the Higham grit. Both the sandstone and the grit are broken and slickensided, and the sandstone seems to be overthrust upon the grit.

East of the Higham grit belt lies a series of Triassic beds, beginning with the Portneuf limestone, that dip steeply westward but rise stratigraphically eastward. The accordance of the trend of this fault with the thrust faults and axes to the southwest renders unlikely its interpretation as normal, yet, as younger beds lie to the southwest, the interpretation as an overthrust would seem to imply movement from the northeast toward the southwest, which is contrary to the direction of thrust more commonly observed in this region. An alternative interpretation as underthrust is suggested, in which the older beds on the northeast have been underthrust beneath the younger beds to the southwest. The structure section B–C (Pl. IX) shows that there is a tendency toward a rude fan structure suggested by the asymmetric syncline in the ridge immediately southwest and the supposed overthrust syncline on the northeast. Such a structure is favorable to the underthrust interpretation. Possible fan structure has been suggested in explanation of certain features in T. 3 S., R. 37 E., already described (p. 80). In sec. 5 two faults that are interpreted as thrusts pass beneath the overlapping block of the Fort Hall formation. These faults cut out the Wood shale and Deadman limestone that should normally intervene between the Higham grit and the Nugget sandstone.

The complex of faults in the southwestern part of the township is apparently an accompaniment of the overturned folding along the west border of the large syncline. These faults are interpreted as reversed faults.

In secs. 23 and 15 along the southwest flank of the ridge patches of rhyolite suggest a fracture and possible displacement of the beds. The dips and thicknesses of the beds involved do not, however, justify the interpretation of a fault there.

The fault relations suggested are illustrated in the structure sections drawn along the line A–B–C (Pl. IX).

PHOSPHATE DEPOSITS.

Although the Portneuf limestone, if horizontal, would be underlain by the phosphatic shales at depths somewhat less than 5,000 feet, that formation is both overturned and faulted in such manner as probably to preclude the occurrence of phosphate within the 5,000-foot limit in that belt. Southwest of the fault between the Fort Hall formation and the Nugget sandstone there is a broad belt that extends southeast across the township which is probably underlain by the phosphatic shales at depths less than 5,000 feet. Much of this area is covered by Tertiary and Quaternary deposits and some by igneous rock. There is also some disturbance in the structure, but the outcrops around the margin of the area suggest that the covered region is underlain by the lower postphosphate rocks rather than by prephosphate or higher postphosphate formations. After deducting the igneous areas, except the area in sec. 26, which is retained because of the relative positions of the Rex chert and the Ross Fork limestone, and a zone half a mile wide along the fault northeast of the Fort Hall formation, it is estimated that 12,200 acres are underlain by phosphate at depths less than 5,000 feet.

In sec. 11, T. 4 S., R. 37 E., the phosphate bed includes 76 inches of material that has an average content of 73.76 per cent tricalcium phosphate ($Ca_3(PO_4)_2$). In sec. 13, T. 5 S., R. 37 E., the phosphate bed is 66 inches thick and has an average content of 74.19 per cent tricalcium phosphate, and in sec. 36, T. 5 S., R. 38 E., the phosphate bed is 73 inches thick and has an average content of 74.5 per cent tricalcium phosphate. (See pp. 87, 91, 103.) Although there are no exposures in T. 4 S., R. 38 E., it seems reasonable to infer from evidence in the neighboring townships the presence of a phosphate bed at least equal to the minimum thickness measured with a content of 70 per cent or more tricalcium phosphate. The weight of a cubic foot of such rock according to previous determinations is about 180 pounds. On this basis 12,200 acres underlain by a bed 66 inches thick would yield approximately 234,870,000 long tons of phosphate rock.

As a large part of the area containing phosphate is relatively low, receiving or transmitting drainage from the neighboring hills, it is probable that half to two-thirds of the tonnage above estimated may lie below groundwater level.

UTILIZATION OF THE LAND.

The alluvial bottoms and lower benches could be farmed, and water is available for a considerable part of it. The hills afford pasturage.

T. 5 S., R. 38 E.

TRANSPORTATION FACILITIES.

Bancroft, on the Oregon Short Line Railroad, is about 14 miles due south of T. 5 S., R. 38 E. The distance by road is somewhat greater. Fort Hall, another railroad point on the Oregon Short Line, is about 20 miles northwest of the township. Good roads lead to both these places. Stage and mail connections are maintained between Bancroft and Chesterfield, about 6 miles southeast of the township.

GEOLOGY.

STRATIGRAPHY.

The rocks of the township are chiefly sedimentary, but a few small patches of rhyolite occur in the northeastern part.

The sedimentary rocks range in age from Cambrian to Quaternary. The Cambrian and Ordovician rocks are not distinguished here in mapping except the Swan Peak quartzite (Ordovician), which is topographically prominent in the western and southwestern parts of the township. The other members of the Cambrian and Ordovician are limestones and lustrous shales in the ridges in the southwestern part of the township.

Silurian rocks have not been identified in this area.

A single fossil collection in the NE. ¼ SE. ¼ sec. 29 was doubtfully assigned by Edwin Kirk to the Devonian Threeforks limestone. This collection was taken near a small fault that is not shown on the map. The neighboring rocks were determined as Madison limestone by G. H. Girty. The Devonian has not been differentiated from the Carboniferous in the mapping of this township.

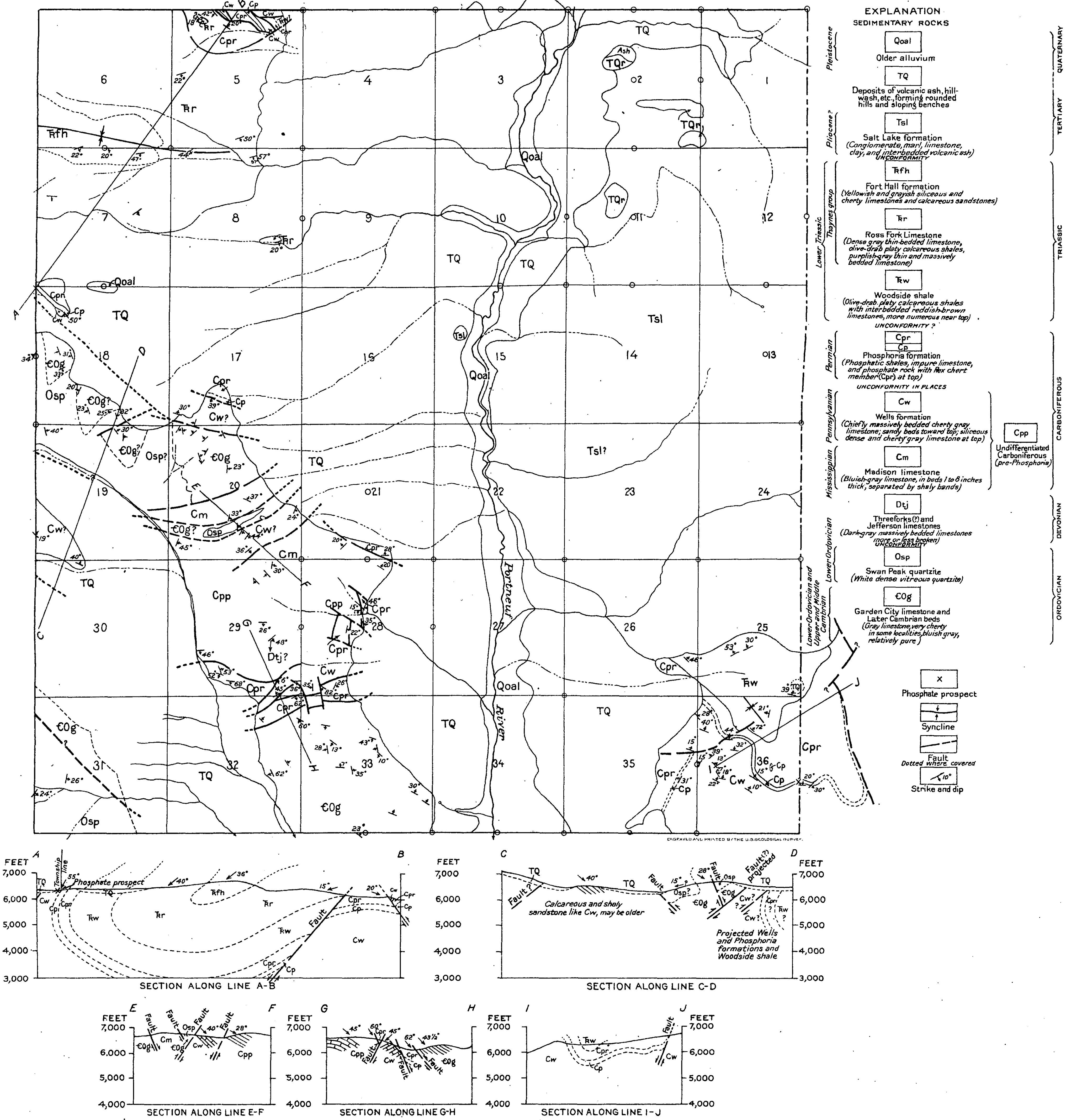
All members of the Carboniferous are represented in the ridge of sec. 29 and vicinity, but, with the exception of the Phosphoria formation, none have been differentiated in the mapping because of the complex structure of the ridge and the detailed study necessary for such differentiation. An area of sandstone in the SW. ¼ sec. 19 has been doubtfully assigned to the Wells formation on lithologic grounds, but it may prove to be considerably older. The Wells formation underlies a large area in secs. 35 and 36 and occurs in more or less detached areas in the western ridge and in secs. 18 and 5.

The Phosphoria formation occurs in faulted areas in the western ridge, in secs. 17, 18, 7, and 5, and in a large area in sec. 36 and vicinity. In secs. 28, 29, 32, and 33 the Rex chert member forms characteristic massive chert beds. In sec. 29 the chert grades more or less into the limestone facies. Elsewhere the Rex chert has the flinty shale facies. The phosphatic shales are best exposed in the northwest corner of sec. 18 and in sec. 36.

The Woodside shale is exposed in the syncline in sec. 36 and vicinity and doubtfully in the NE. ¼ sec. 5. It has not been recognized elsewhere in the township.

The Thaynes group, in the northwest corner of the township, is represented chiefly by the Ross Fork limestone, but the higher hills in the vicinity of the SW. ¼ sec. 6 carry the Fort Hall formation.

Much of the township east of the Portneuf Valley is covered with a bouldery deposit that appears to be weathered from a late conglomerate and is tentatively correlated with the Salt Lake formation of probable Pliocene age. The boulders in many places are large, several feet in diameter, and angular. Many of them are white quartzite of the Swan Peak type. They lie in different positions and are apparently not in place, though they can not have been moved far. However, no ledges from which they might have come are exposed in the vicinity. Associated with these coarser deposits are beds of white marl with numerous gastropod remains. Exposures occur in the NW. ¼ sec. 15 and across the river near by. Much of



DETAILED GEOLOGIC MAP OF T. 5 S., R. 38 E., WITH STRUCTURE SECTIONS

Scale $\frac{1}{48,000}$

0 ½ 1 2 Miles

1920

the remainder of the township is covered by a bouldery and pebbly deposit, probably similar in origin to that just described but not definitely differentiated. This is probably chiefly Tertiary but may be in part of Quaternary age.

Alluvial deposits of Quaternary age form a relatively narrow belt along Portneuf River. They are usually rather distinctly separated from the Tertiary beds of the bench lands by steep slopes.

STRUCTURE.

The geologic structure of the township, where exposed, is complex and involves overturned folding and faulting, both of the normal and of the reverse types. Fully half of the township is concealed beneath a cover of late deposits, but it seems fair to conclude that the complexities noted elsewhere continue under this cover.

Folds.—The main structural features of the township, so far as the phosphate deposits are concerned, are parts of two synclines in the northwest and southeast corners respectively of the township. These two portions of synclines are possibly parts of the same general syncline and may be continuous beneath the cover. In view of the structural complexities of other parts of the township, the continuity of the syncline can not safely be assumed, although it may be noted that both parts are of similar type, namely, asymmetric, overturned toward the northeast, and faulted along the northeast border. The strike of the small exposure of the Thaynes group in the SE. ¼ sec. 8 and of the Wells formation in the SW. ¼ sec. 17 suggests that the northwest syncline is terminated somewhere near the middle of the township. This appearance may, however, be due to a cross anticlinal axis, such as that which turns the strike of the ledges to the south of west in sec. 6 and adjoining parts of the neighboring townships. The northeast border of this syncline is interpreted as a thrust because of its apparently irregular outline. The southwest border is marked by a minor fault in the SW. ¼ sec. 17. The structural features here suggested are shown in geologic section A–B (Pl. X).

The structure of the southeast syncline is shown in geologic section I–J (Pl. X).

Folding has also occurred in the complex ridge that extends southeastward from secs. 18 and 19. Here the folds are broken by many faults, and it has not been possible to work out the structure in sufficient detail to ascertain the number and character of the folds.

Faults.—Two large faults, interpreted as thrusts, are particularly noteworthy. The first separates the complex ridge with rocks ranging in age from Cambrian to Phosphoria from the adjacent phosphate-bearing syncline on the northeast. The trace of this fault is largely concealed by late sediments, but it is believed to enter the township in the NE. ¼ sec. 18 and to continue along the border and lower slopes of the ridge toward the center of the township. The position of these older rocks along the border of a large syncline that is inclined northeastward leads to the interpretation of this fault as a thrust the plane of which is inclined to the southwest. (See geologic sections A–B and C–D, Pl. X.)

The second important thrust crosses the ridge in the NE. ¼ sec. 32 and the NW. ¼ sec. 33, where it appears to have been slightly offset by normal (?) faults. Here the Cambrian and Ordovician limestones and shales lie against a complex of Permian (Phosphoria) and Pennsylvanian (Wells) rocks. The relationship is not entirely clear on the basis of present evidence, but the fault is tentatively interpreted as a thrust. (See geologic section G–H, Pl. X.)

The scant representation of Silurian and Devonian rocks in the Fort Hall region, together with the lack of opportunity to measure the thickness of the formations below the Phosphoria and the complex structure of the rocks involved, all make impossible any definite statement of the amount of dislocation produced by these thrusts. It seems safe, however, to infer that the dislocation may measure several thousand feet.

Additional faults in considerable number occur in the same ridge and some of these have been tentatively interpreted in sections G–H, E–F, and C–D (Pl. X). The complete determination of the structure here awaits more detailed and larger-scale studies than were practicable during the present investigation.

Other faults enter the township from the west, but these are more clearly shown in the adjacent township (T. 5 S., R. 37 E.). A brief discussion of them is given in the description of that township (p. 90).

PHOSPHATE DEPOSITS.

A thick bed of high-grade phosphate rock has been found and sampled in secs. 18 and 36. The outcrop of the phosphate shales in secs. 17 and 18 is alined well with that in sec. 36. Postphosphate rocks lie on the northeast side of this line. These facts suggest that much of the northeastern part of the township may be underlain by valuable phosphate rock within workable limits. However, the extensive cover and the complex structure of the exposed parts of the older sedimentary rocks make it unwise to estimate the phosphate resources of the covered area except of those parts relatively near the exposed areas. It is estimated that 8,120 acres are underlain by available phosphate rocks. The complexly faulted small areas of Rex chert in secs. 28, 29, 32, and 33 are not included in this estimate.

About 180 acres included in the above figures lie east of the reservation boundary in secs. 25 and 36.

In the prospect made by the Survey party just over the township line from the northwest corner of sec. 18 the phosphate bed was found to have a thickness of 66 inches and an average content of 33.96 per cent phosphorus pentoxide (P_2O_5) equivalent to 74.19 per cent tricalcium phosphate ($Ca_3(PO_4)_2$). In the NE. ¼ SE. ¼ sec. 36 in this township the prospect made by the Survey party showed the phosphate bed to be 73 inches thick with an average content of 34.37 per cent phosphorus pentoxide, equivalent to 74.5 per cent tricalcium phosphate. (See pp. 82, 87.) The weight of such rock from previous determination is about 180 pounds per cubic foot. On the assumption that the lower thickness is the average for the area, it is estimated that this township contains as a minimum 148,008,900 long tons of high-grade phosphate rock, at a depth of 5,000 feet or less. The estimate assumes that the rocks are horizontal. The rocks are, however, inclined at different angles, so that the estimate should fall somewhat below the actual content of the phosphate beds. In view of the complex structure of the township it seems wise to leave this difference as an additional margin of safety for the estimate given.

UTILIZATION OF THE LAND.

The alluvial meadows can be irrigated and farmed, and some of the lower benches can doubtless be dry-farmed. The higher ground affords pasturage. The township as a whole is being utilized at present to some extent for cattle grazing, and outside the reservation line for sheep grazing.

T. 6 S., R. 38 E.

TRANSPORTATION FACILITIES.

The nearest railroad point to T. 6 S., R. 38 E., is Bancroft, on the Oregon Short Line Railroad, 12 to 15 miles south. A stage line runs from that point to Chesterfield, about 3 miles southeast of the reservation. An excellent road connects this township with Chesterfield and Bancroft.

GEOLOGY.

The geologic features of the portion of the township included in the reservation are shown on the general map (Pl. III).

The greater part of the district examined is occupied by the broad valley of Portneuf River, and its alluvial meadows and older sloping bench lands are underlain by Tertiary and Quaternary deposits.

The older rocks exposed in the west half of the district are all of Cambrian and Ordovician age and are folded and probably faulted as well, though the details of the structural features have not been worked out. A broad patch of Swan Peak quartzite (Ordovician) overlies different members of the Cambrian in secs. 6 and 7 in a fault that is interpreted as a part of the Putnam thrust. (See pp. 62–65.)

East of Portneuf River in secs. 1 and 12 Carboniferous rocks of the Wells formation appear. Between these rocks and the Cambrian and Ordovician rocks west of the river it seems probable that a fault intervenes, but its position is concealed by the thick cover of later sediments that occupy the valley. In secs. 32 and 33, T. 5 S., R. 38 E., the Cambrian and Ordovician rocks are faulted against the Rex chert member of the Phosphoria. Numerous other faults occur in that township, so that faults may reasonably be expected in the region between the older and younger Paleozoic rocks of this township.

PHOSPHATE DEPOSITS.

In the SE. ¼ sec. 35, T. 5 S., R. 38 E., the Phosphoria formation advances southwest toward this township but passes beneath the Tertiary cover a short distance north of the township line. Float of phosphate is abundant near the north quarter corner of sec. 2. It seems probable then that phosphate rock enters the NW. ¼ NE. ¼ sec. 2 beneath the cover, but its course and extent beneath the cover can not be determined from present data. The probability of faulting renders unlikely any considerable continuation of the Phosphoria formation in this township. For this reason no estimates of possible phosphate deposits are presented for this township. It may be noted, however, that the phosphate in sec. 36, T. 5 S., R. 38 E., shows a thickness of 73 inches without partings and an average content of 34.37 per cent phosphorus pentoxide, equivalent to 74.5 per cent tricalcium phosphate. A description of the phosphate beds there exposed is given on page 103.

UTILIZATION OF THE LAND.

Much of the bottom and bench land can be irrigated and farmed or dry-farmed. Hay, oats, and potatoes are raised at Faulkner's ranch, in secs. 3 and 4. The hills to the north, east, and west afford pasturage and some timber.

MINERAL RESOURCES.

PHOSPHATE DEPOSITS.

GENERAL SUMMARY OF TONNAGE ESTIMATES.

The tonnage estimates in the preceding township descriptions include only the figures for the areas examined in detail in 1913. Although approximate, they relate only to the main bed, which lies near the base of the phosphate shales, and thus exclude some workable high-grade rock and much lower grade rock that may eventually become workable. Several areas of considerable size that may contain valuable phosphate deposits at workable depths are also excluded because they are covered with late deposits which conceal the underlying structure to such an extent as to make hazardous any estimate of the phosphate content. The estimates are based on the best data available and are believed to be conservative.

Estimates of phosphate rock available in the townships considered in this report.

	Long tons.
T. 3 S., R. 37 E	94, 925, 800
T. 4 S., R. 37 E	204, 977, 800
T. 5 S., R. 37 E	55, 744, 200
T. 4 S., R. 38 E	234, 870, 000
T. 5 S., R. 38 E	148, 008, 900
	738, 526, 700

Estimates for the western field.

	Long tons.
Total for area examined in 1913	738, 526, 700
Total for area examined in 1912 [74]	1, 889, 480, 200
Total for area examined in 1911	1, 347, 370, 000
Total for area examined in 1910	1, 158, 970, 000
Total for area examined in 1909, minus 90,000,000 tons estimated for Georgetown district, which is duplicated in total for 1911	156, 950, 000
	5, 290, 296, 900

Stone and Bonine[75] report for the Elliston field, Mont., 86,000,000 short tons (equivalent approximately to 76,785,700 long tons), and Pardee[76] reports for the Garrison and Philipsburg fields, Mont., a total of 97,000,000 long tons. These amounts added to the amounts previously tabulated make a total of approximately 5,464,082,000 long tons.

[74] Report in preparation.

[75] Stone, R. W., and Bonine, C. A., The Elliston phosphate field, Mont.: U. S. Geol. Survey Bull. 580, p. 383, 1914.

[76] Pardee, J. T., The Garrison and Philipsburg phosphate fields, Mont.: U. S. Geol. Survey Bull. 640, p. 223, 1917.

Additional areas have been examined in detail in Idaho, Wyoming, and Utah since 1913, for which estimates are not yet available, and considerable portions of the reserve yet remain to be surveyed. Thus it appears that the figures given will eventually be greatly increased.

UTILIZATION OF WESTERN PHOSPHATE.

At present the western phosphate is but little utilized, although its chemical and physical constitution would make relatively easy its manufacture into superphosphates by the mixture of about equal parts of ground rock and sulphuric acid. The demand for fertilizers in the Pacific coast district is moderate and is readily met by the companies now in operation. The future development of the deposits depends in large measure upon the growth of the demand for fertilizers in the Central and Eastern States and upon the adoption of some method of manufacture which will enable the producers to deliver the phosphoric acid in concentrated form, so that the high cost of transportation may be offset. The manufacture of "high-grade" superphosphates as a means to this end has been discussed by Gale in a previous report.[77] Several processes for making soluble phosphates have also been reviewed by Phalen.[78]

In spite of the present small demand for this rock there can be no doubt that the growing recognition in this country of the importance of the proper use of fertilizers will sooner or later make this western phosphate field the scene of one of the Nation's most important industries.

The situation of the deposits of the Fort Hall Indian Reservation with respect to existing railways is less favorable than that of the phosphate beds near Sage and Cokeville, Wyo.; Montpelier, Paris, and Georgetown, Idaho, and the Elliston and other fields in Montana. Favorable grades, however, exist in the valleys of the upper Portneuf River and of Ross Fork Creek for spur tracks from the Oregon Short Line Railroad. These spurs would bring shipping facilities within short hauling distances of the deposits.

DEVELOPMENT AND PRODUCTION.

The true nature of the phosphate rock seems first to have been recognized in 1889 in Cache County, Utah.[79] Beds of phosphate were also independently discovered in 1897 in Rich County, Utah,[80] but it

[77] Gale, H. S., U. S. Geol. Survey Bull. 470, pp. 449–451, 1911.

[78] Phalen, W. C., Phosphate rock: U. S. Geol. Survey Mineral Resources, 1915, pt. 2, pp. 239–242, 1916.

[79] Richter, A., Western phosphate discovery: Mines and Methods, vol. 2, p. 207, 1911.

[80] Jones, C. C., The discovery and opening of a new phosphate field in the United States: Am. Inst. Min. Eng. Trans., vol. 47, pp. 192–216, 1914.

was not until about 1904 that any systematic exploration or development of them took place.

Three companies soon entered the field, and in 1906 shipping was begun from Montpelier, Idaho, and Cokeville and Sage, Wyo. The known deposits at that time were grouped in scattered localities within a comparatively few miles of the junction point of the three States, Idaho, Wyoming, and Utah. In 1909 the Geological Survey began the detailed examinations, which with some interruptions have been continued since and are still far from completion. These examinations have shown the area underlain by phosphate to be far greater than was at first supposed and have revealed the presence of enormous bodies of high-grade rock. Unfortunately, the companies engaged in mining the rock became involved in litigation concerning the legality of their locations. This litigation, together with the long distance from available markets and high cost of transportation, has prevented any extensive exploitation of the deposits. By 1916 five companies were represented in the field, but only two of them were active at that time and production was very small. In 1917 the waning industry experienced a sharp recovery, and four companies, one of them new, were operating. There was also a general improvement in market conditions, which, if maintained, may result in more extended development of the deposits.

Although the field is the largest within the United States, and, as far as known, the largest in the world, production has thus far been small because of the adverse conditions. From the beginning, in 1906, when figures first became available, until 1918 the total production amounted to 91,992 tons for the entire field, an average of only 7,076 tons annually for the 13-year period. A maximum of production appears to have been reached in 1912, when it amounted to 11,612 long tons, valued at $49,241.[81] From that time the quantity marketed grew smaller, until in 1916 it was 1,703 tons, valued at $5,350, and represented only about 0.08 per cent of the total for the entire country.[82] In 1917 under the revived demand the output was 15,096 long tons, valued at $41,756, an increase in production of 786 per cent compared with 1916.[83] The average price per ton was $2.77, which was 37 cents per ton less than in the preceding year.

The impetus given by the war to agriculture leads directly to larger utilization of phosphate rock and its derivatives as fertilizer. As the beneficial effects of the application of the phosphates to the

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[81] Phalen, W. C., Phosphate rock: U. S. Geol. Survey Mineral Resources, 1913, pt. 2, pp. 276–277, 1914.

[82] Stone, R. W., Phosphate rock: U. S. Geol. Survey Mineral Resources, 1916, pt. 2, p. 32, 1918.

[83] Idem, 1917, pt. 2, p. 11, 1918.

soil become more generally realized, the demand for the rock should be permanent and increasing.

STATUS OF WESTERN PHOSPHATE LANDS.

In Utah, Idaho, Wyoming, and Montana the great bulk of the deposit is on public lands, though some has passed into private hands. The public lands are withdrawn from entry pending examination and classification. Agricultural entry on these lands is permitted, but mineral rights are reserved by the Government. No estimates of the acreage of phosphate land in private ownership are available, but the acreage of the outstanding withdrawals of public land in the States named is shown below:

Outstanding phosphate withdrawals, July 1, 1918.

	Acres.
Utah	302,465
Idaho	1,015,717
Wyoming	998,592
Montana	287,883
	2,604,657

In addition to the above areas 4,080 acres in the Fort Hall Indian Reservation, Idaho, and 20,576 acres in the Wind River Indian Reservation, Wyo., have been examined in detail, formally classified as phosphate land, and restored for entry. In all there are 2,629,313 acres of public land which will ultimately be available for entry and exploitation in addition to the lands privately owned.

ORIGIN OF THE DEPOSITS.

The origin of the western phosphate deposits has an important commercial bearing, for if they were residual, like those of the brown rock of Tennessee, or of secondary origin, they might be expected to pass at comparatively shallow depths into unleached low-grade phosphate or even into phosphatic limestones. Thus the valuable deposits would be limited to a comparatively short distance from the outcrop, and the great body of rock under cover in the synclines would be valueless. Absolute certainty on this point probably can not be reached without deep drilling. On the other hand, the phosphate beds have been observed in many parts of the region and under many conditions by a number of geologists, and everywhere they appear to be true bedded deposits, analogous to coal or limestone, and retain their thickness and quality over wide areas. For these reasons they are regarded as original sedimentary deposits, and it is considered probable that they maintain in depth the characteristics displayed at the surface. Upon this assumption rest the estimates given for the western field.

The sources of the phosphoric acid and the methods of its accumulation are to a considerable degree subjects of speculation, but it will perhaps be helpful to summarize opinions thus far advanced and to indicate the probable direction of solution of the problems involved.

The first detailed accounts of the western phosphates are contained in papers of Gale and Richards [84] and Blackwelder.[85] These authors regard the phosphates as original marine sedimentary deposits, and Gale and Richards give a very brief summary of the hitherto recognized sources of phosphorus and the method of its accumulation as phosphates [86] through the agency of organic and physicochemical processes.

Because of the relative scarcity of organic remains in the actual phosphate beds Richards and Mansfield [87] were inclined to place greater emphasis on physicochemical than on organic sources and agencies.

Blackwelder has contributed two important later papers. In the first [88] he gives an interesting suggestive account of the cycle of changes undergone by phosphorus from its mineral form in apatite through solution, assimilation by plants or animals, deposition on the sea bottom or on land, accumulation into deposits, burial, deformation, and metamorphism back to apatite again. Many subcycles are included, and individual atoms of phosphorus may have had widely different histories. In the second [89] he gives in abbreviated form as derived from available literature a view of organic accumulation, which is substantially repeated here for reference. In the ocean special conditions of currents and temperature, together with other factors not yet understood, may have induced the wholesale killing of animals over large areas and the accumulation of putrefying matter on the sea floor in moderate and shallow depths. Decomposition through the agency of bacteria produced ammoniacal solutions, which dissolved the solid calcium phosphate in bones, teeth, brachiopod shells, and tissues. The abundance of putrefac-

[84] Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 457–535, 1910.

[85] Blackwelder, Eliot, Phosphate deposits east of Ogden, Utah: U. S. Geol. Survey Bull. 430, pp. 536–551, 1910.

[86] Gale, H. S., and Richards, R. W., op. cit., pp. 461–462.

[87] Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pp. 376–377, 1911; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, p. 74, 1914.

[88] Blackwelder, Eliot, The geologic rôle of phosphorus: Am. Jour. Sci., 4th ser., vol. 42, pp. 285–298, 1916.

[89] Blackwelder, Eliot, Origin of the Rocky Mountain phosphate deposits: Geol. Soc. America Bull., vol. 26, pp. 100–101, 1915. (Abstract.)

tive material also prevented the existence of organisms attached to the bottom, and most calcareous shells descending from the surface were probably dissolved by the abundant carbonic acid arising from decay. For physicochemical reasons, already partly understood, the phosphatic material was quickly redeposited in the form of hydrous calcium carbophosphates, locally filling, incrusting, and replacing shells, teeth, bones, and other material, but especially forming small rounded granules of colophanite and finally a phosphatic cement among all particles. The granular texture is ascribed chiefly to physicochemical conditions, such as result in the formation of oolitic greenalite, limonite, aragonite, and similar minerals. After having been formed in quiet water some of the granules were reached by bottom-scouring currents and incorporated in clastic deposits and in some places were strewn over eroded rock surfaces and so became constituents of basal conglomerates.

The latest contributor to the discussion of the origin of the western phosphates is Pardee,[90] who is inclined to look with disfavor upon the view that unusual or abundant sources supplied phosphates rapidly to the sea. He points to the existence of glacial conditions elsewhere in Permian time and suggests that cool temperatures may have prevailed during the deposition of the western phosphates. Carbon dioxide (CO_2) is retained most abundantly by waters of low temperature, and this gas is supplied not only from atmospheric sources but also from organic substances that decompose in sea water or on the sea floor. Conditions would thus be unfavorable for the growth of coralline limestone or for the chemical precipitation of lime. Moreover, in such waters limy objects would tend to be dissolved and the formation of limestones composed of shells and skeletons of marine organisms would be hindered. Therefore, on the assumption that the precipitation of phosphate was not checked, that material would accumulate in relatively pure form. The great volume of the deposit (see the estimates of tonnage, p. 105) needs no further explanation than the continued or extensive application of the process that initiated the formation of the phosphate.

The western phosphates are agreed by all who have seen them in the field to be original marine deposits, analogous to those of Tunis, Algeria, England,[91] and Egypt, and to the blue phosphate of Tennessee. The physiographic conditions of their deposition are little known, but there are at least six lines of evidence which throw light upon the problem and from which it may be possible to deduce a working hypothesis.

[90] Pardee, J. T., The Garrison and Philipsburg phosphate fields, Mont.: U. S. Geol. Survey Bull. 640, pp. 225–228, 1917.

[91] Blackwelder, Eliot, The geologic rôle of phosphorus: Am. Jour. Sci., 4th ser., vol. 42, p. 294, 1916.

1. The fauna, according to Girty,[92] is quite different from the Carboniferous faunas of the Mississippi Valley and even among western faunas has an extremely individual and novel facies. Thus the area of deposition, though of great extent, must have been separated or nearly so from the main ocean.

2. Analyses of higher-grade phosphate rock, like that which constitutes the main bed, show generally less than 12 per cent of SiO_2, Al_2O_3, Fe_2O_3, and MgO, all added together.[93] Silica forms the greater part of this amount, and some of it may be of organic origin. It thus appears that detrital material from the land is largely absent from the deposit. This condition may be explained in several ways: The deposit may have been laid down in relatively deep water, like some of the modern oozes; or the water of deposition, though shallow, may have been too far from land to receive much detritus from that source; or the lands adjacent to the waters of deposition may have been so low, through base-leveling or otherwise, that they furnished little clastic material to the sea; or, according to an earlier suggestion of Hayes,[94] strong marine currents may have swept away the fine terrigenous material, leaving only the phosphatic oolites. The physiographic conditions changed from time to time during the deposition of the phosphatic shales, for beds of shale, sandstone, and limestone, some of which are more or less phosphatic, are interbedded with the more nearly pure phosphate.

3. The period of deposition may have been long. The time required for the deposition of the phosphate beds and the accompanying Permian strata is not known, but some data permit suggestive comparisons. Though there is at least local unconformity at the base of the Phosphoria formation, this is not regarded as indicating any great time interval. The top of the formation may also be marked by an unconformity, and the faunal change above is very pronounced. The time interval here may be large, but, on the other hand, the faunal change may have been produced by the geographic changes of the late Permian or early Mesozoic without greater lapse of time here than elsewhere. The phosphatic shales, with which are grouped some nonphosphatic or lean shales, sandstones, and limestones, are about 150 feet thick, and of this thickness the actual beds of phosphate rock form only a small proportion. The Phosphoria formation as a whole, representing all the known Permian of the region, is about 500 feet thick. The Permian section in Kansas,

[92] Girty, G. H., The fauna of the phosphate beds of the Park City formation in Idaho, Wyoming, and Utah: U. S. Geol. Survey Bull. 436, p. 8, 1910.

[93] Gale, H. S., and Richards, R. W., op. cit., p. 465.

[94] Hayes, C. W., Tennessee phosphates: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, p. 534, 1896.

according to Prosser,[95] is about 2,000 feet thick; in Texas the Permian formations are reported to be 5,000 feet thick[96] and in Oklahoma 2,600 feet thick.[97] If these deposits may be regarded as having been laid down during time intervals at all similar, it is obvious that the deposition of the Phosphoria formation of Idaho was at a much slower rate than the accumulation of Permian strata in the regions named farther east. It seems at least reasonable, therefore, to attribute the thickness and richness of the phosphatic strata to long-continued slow deposition under conditions which excluded for considerable intervals the accumulation of terrigenous material and of carbonate of lime.

4. The ordinary processes of bacterial decay give rise to ammonium phosphate, which, according to Clarke,[98] has been experimentally shown to react upon mineral substances in such manner as to produce phosphates resembling those actually found. Blackwelder[99] states that such experiments have been carried out by several investigators and that the conditions are such as may readily occur on the sea bottom where organic decomposition is in progress. Thus calcareous shells become phosphatized, and even such organic material as excretory pellets and bits of wood is known to have been altered in the same way. Bones, which initially contained about 58 per cent of tricalcium phosphate, have their organic matter replaced by phosphatic minerals, thus raising the ratio to 85 per cent or more.

5. The oolitic texture so characteristic of much of the western phosphate is doubtless closely connected with the origin of the rock. In a well-presented discussion of the origin of oolites Brown[1] concludes that the older oolitic beds of Pennsylvania were probably all originally laid down as beds of calcareous oolites composed of the mineral aragonite. As this mineral is unstable under ordinary conditions of the formation of rocks it soon began to change. Where solutions carrying other substances, such as silica or iron, were present the oolites were more or less completely replaced—for example, the siliceous oolites or the Clinton ore.

6. Calcareous oolites are now forming at a number of places, notably in the region of the Florida Keys and the Bahamas, where

[95] Prosser, C. S., Revised classification of the upper Paleozoic formations of Kansas: Jour. Geology, vol. 10, pp. 703–737, 1902.

[96] Cummins, W. F., Report on the geology of northwestern Texas: Texas Geol. Survey Second Ann. Rept., p. 398, 1891.

[97] Beede, J. W., Invertebrate paleontology of the upper Permian red beds of Oklahoma and the Panhandle of Texas: Kansas Univ. Sci. Bull., vol. 4, No. 3, p. 136, 1907.

[98] Clarke, F. W., The data of geochemistry, 3d ed.: U. S. Geol. Survey Bull. 616, p. 523, 1916.

[99] Blackwelder, Eliot, The geologic rôle of phosphorus: Am. Jour. Sci., 4th ser., vol. 42, p. 294, 1916.

[1] Brown, T. C., Origin of oolites and the oolitic texture in rocks: Geol. Soc. America Bull., vol. 25, pp. 745–780, pls. 26–28, 1914.

they have been studied by Drew [2] and Vaughan.[3] Drew has shown that in these regions denitrifying bacteria are very active and are precipitating enormous quantities of calcium carbonate largely in the form of aragonite. Vaughan shows that this chemically precipitated calcium carbonate forms spherulites or small balls, which, by accretion, may become oolitic grains of the usual size, or it may accumulate around a variety of nuclei to build such grains. He reaches the conclusion that all marine oolites originally composed of calcium carbonate, of whatever geologic age, may confidently be attributed to this process. Drew's studies of the distribution of denitrifying bacteria have shown them to be most prevalent in the shoal waters of the Tropics. In combining the results of Drew and Murray, Vaughan considers that great limestone formations, whether composed of organic or chemically precipitated calcium carbonate, were laid down in waters of which at least the surface temperatures were warm if not actually tropical.

Among the deductions from the preceding data, which may serve as a partial tentative working hypothesis for the origin of the western phosphates, may be mentioned the following:

1. The phosphatic oolites and their matrix were probably deposited originally as carbonate of lime in the form of aragonite.

2. The waters were probably shoal and of warm or moderate rather than of cold temperature.

3. The lands that bordered the depositional area were low and furnished little sediment to the sea. Thus far the supposed depositional conditions agree with known modern conditions in the Florida region.

4. The phosphatization of the oolitic deposit was probably subsequent to its deposition rather than coincident with it, for Drew shows that the activities of denitrifying bacteria reduce the nitrate content of the sea water and hence the growth of marine plants and of animals dependent upon them. Such conditions are favorable for the deposition of the carbonate but not of the phosphate of lime.

5. Cooler temperature in the waters of deposition, perhaps induced by changes in the character or direction of marine currents, checked the activities of the denitrifying bacteria and hence the conditions favorable for the formation of oolitic limestone. At the same time plant and animal life increased in the waters and furnished the decaying matter necessary for the phosphatization of the oolitic lime-

[2] Drew, G. H., On the precipitation of calcium carbonate in the sea by marine bacteria, and on the action of denitrifying bacteria in tropical and temperate seas: Carnegie Inst. Washington Pub. 182, Papers from the Tortugas Laboratory, vol. 5, pp. 9–53, 1914.

[3] Vaughan, T. W., Preliminary remarks on the geology of the Bahamas, with special reference to the origin of the Bahaman and Floridian oolites: Carnegie Inst. Washington Pub. 182, Papers from the Tortugas Laboratory, vol. 5, pp. 47–54, 1914.

stone in the general manner set forth in Blackwelder's account given above. Perhaps Pardee's idea of glacial climate may have a bearing in this connection.

6. The temperature change may have been sufficiently abrupt to cause the death of multitudes of certain marine animals, as suggested in Blackwelder's account. This material would be sufficient to produce a fairly rapid phosphatization of the oolitic limestone. Such an assumption, however, is not compulsory, because the phosphatic shales as a whole were doubtless formed slowly, and there was time for sufficient accumulation and trituration of organic remains to produce the observed phosphatization before the moderate crustal changes that permitted the introduction of the clastic material which buried the phosphate bed.

7. The conditions set forth above, which were outlined particularly with reference to the main phosphate bed, probably were repeated on a less extensive scale for the lesser beds. Shaly partings or minor shale beds in the phosphate might be the result of local seaward drift of land-derived silts after some unusual or protracted storm.

8. The sea in which the phosphate was deposited was closed on the east, south, and west but may have had connections with the ocean northward and northwestward, for Girty[4] notes faunal resemblances that are traceable into Alaska, Asia, and eastern Europe, and Adams and Dick[5] report the discovery of phosphate at apparently the same horizon in Alberta.

COAL PROSPECTS.

Two prospects for coal have been opened by the Indians in T. 7 S., R. 33 E. One of these prospects is in the NW. ¼ SW. ¼ sec. 23 and the other in the SW. ¼ SW. ¼ sec. 15. The prospect in sec. 23 was opened in carbonaceous plant-bearing shales associated with the Tertiary rocks. Specimens of these plant remains were collected and submitted to F. H. Knowlton, of the Survey, for identification, but they proved to be fragments of bark and stems that were not determinable. There are two small pits about 20 feet apart, each exposing about 2½ feet of beds. The rock is too shaly to be of value for coal.

The prospect in sec. 15 is opened in a small, nearly vertical dike of obsidian or black volcanic glass that is intruded between basalt and white volcanic ash. The ash is here baked and discolored brown. This prospect is locally called the Smut mine. There are three small pits on a low knoll just north of the high basalt hills, east of Bannock Valley. Several tons of the basalt have been removed in the process of making the openings.

[4] Girty, G. H., op. cit., p. 9.

[5] Adams, F. D., and Dick, W. J., Discovery of phosphate of lime in the Rocky Mountains: Canada Commission of Conservation, Ottawa, 1915.

METALLIFEROUS DEPOSITS.

Prospects.—In the saddle south of Bannock Peak, near the center of sec. 34, T. 9 S., R. 32 E., an old abandoned shaft and a dump were found. The material on the dump was highly ferruginous but showed no valuable minerals. A similar ferruginous zone, not prospected, was found on the ridge in the SE. ¼ SE. ¼ sec. 25 that leads to the high rocky hill to the northeast. At this locality there were large float fragments 2½ to 3 feet thick of highly ferruginous material. The actual vein was not seen. An assay of a sample of this material showed only a faint trace of gold.

Gold placers.—The Fort Hall Indian Reservation includes along Snake River some placer deposits of fine gold that have been locally prospected and worked in the region of the Fort Hall bottoms. Horse Island, which lies just outside the reservation and is really a continuation of the Fort Hall bottoms, also contains placers that have been worked. These deposits have been described by Hill,[6] from whose account the following statement is compiled.

The bottoms have an average elevation of 8 to 10 feet above the normal water level of Snake River. Water stands 2 feet below the surface at the north end of the bottoms and 9 feet below at the south end.

Gray to black sandy loam that locally contains considerable clay forms most of the surface material, but gravels occur at a few places, irregularly distributed over the bottoms. In general, the gravel bars do not cover much more than an acre, but here and there they cover several acres. The bars are more numerous and larger nearer the river.

There is no doubt that gravels similar to those along the present channel of Snake River underlie all the Fort Hall bottoms. The sandy loam extends from 2 feet to 12 feet below the surface.

From the distribution of the gravels it is thought that they represent the tops of buried bars, such as are now found along the present channel of the Snake, and from analogy it is thought that the rich gravels are of rather small extent, corresponding to the skim-bar gravels of the present stream.

Bedrock was not found in the Fort Hall bottoms. Basalt forms the west bank of the river at several places but does not occur east of the river. Similar gravels overlie partly consolidated clayey sand in the terrace east of the bottoms, and these may prove to be the bedrock of the bottoms. Lava 10 feet thick, which has a strong westerly dip, was encountered at a depth of 75 feet in a well in the vicinity of the Fort Hall Agency. On account of its pronounced

[6] Hill, J. M., Notes on the fine gold of Snake River, Idaho: U. S. Geol. Survey Bull. 620, pp. 271–294, 1915.

westerly dip it would probably be found at considerable depth if it extended under the bottoms.

The gravels of the Fort Hall bottoms average less than 1 cent to the yard in gold. The skim-bar gravels, which have been worked each year after high water, carry at least 65 cents a yard in fine gold and perhaps as much as $2 to $3 a yard. The skim bars, however, form a minor part of the total amount of the gravels of the Fort Hall bottoms.

Considerable placer mining has been done in the past on Horse Island, but of late the gravels have received little attention. The surface of the island is 6 to 10 feet above the normal water level of Snake River, and conditions are generally similar to those of the Fort Hall bottoms.

Rockers were used in working most of these gravels, though some on the Elliott ground at the north end of the island were worked with a "machine." Horse-drawn scrapers were used to remove the soil and at the machine settings to bring the gravels from the pit to the sluice.

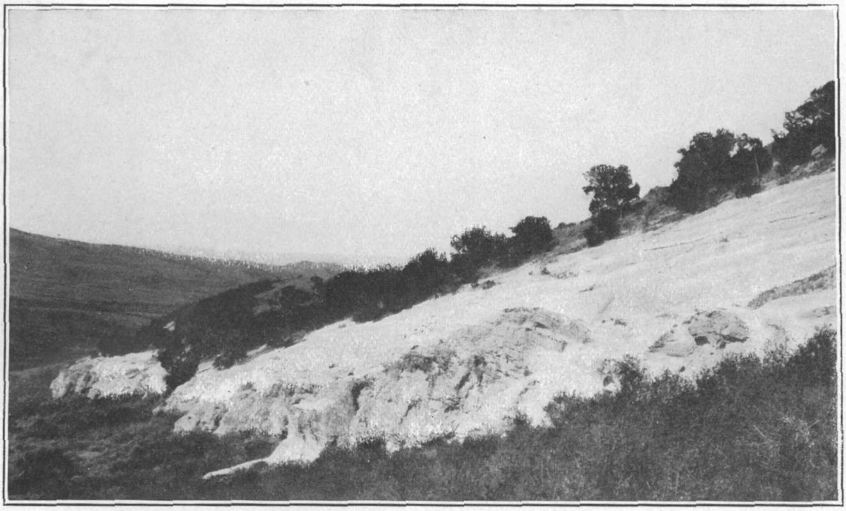
Apparently the pay gravels follow more or less well-defined lines or bars, which have a somewhat crescentric shape and are the tops of old high-water bars like those that are deposited in the present stream channel.

Fort Hall mining district.—In the vicinity of Pocatello, south of the reservation, there are a number of metalliferous prospects which comprise what has been called the Fort Hall mining district. This region has been described by Weeks and Heikes[7] and by Bell.[8]

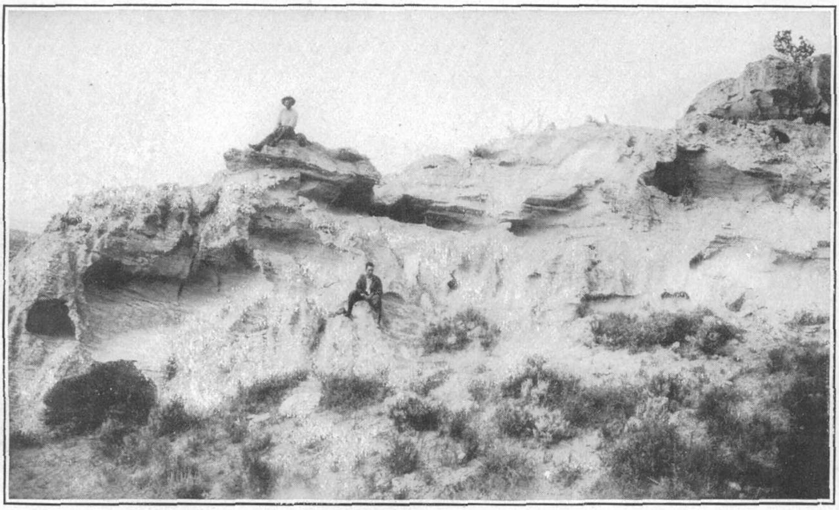
The following notes are furnished by E. L. Jones, jr., who examined the ore deposits of the Fort Hall district in September, 1916, for data to be incorporated in a general report on the ore deposits of the State. There are numerous prospects in the Fort Hall district, but only two of them have produced small quantities of ore—the Moonlight of the Pocatello Gold & Copper Mining Co., 9 miles northeast of Pocatello, and the Fort Hall Mining Co., 8 miles southeast of Pocatello. From the Moonlight mine two carloads of ore were shipped in 1904, and in 1916 a shipment of 9 tons, which had an average content of 22 per cent copper, 8.3 ounces silver, and 0.005 ounce gold to the ton, was sorted from the dumps. The deposits are small irregular replacements along fractures in a conglomeratic shale of Ordovician (?) age. Underlying the conglomeratic shale and intercalated with other shale beds there are masses of schistose gray and green igneous rocks that are probably altered disabase. The ore is mainly chalcopyrite, which is replaced near the surface by secondary minerals—chalcocite, bornite, and malachite. The Fort

[7] Weeks, F. B., and Heikes, V. C., Notes on the Fort Hall mining district, Idaho: U. S. Geol. Survey Bull. 340, pp. 175–183, 1908.

[8] Bell, R. N., Reports of the Idaho State Inspector of Mines, 1906–1912.



A. CHARACTERISTIC EXPOSURE OF VOLCANIC ASH IN SEC. 11, T. 4 S., R. 36 E.



B. EXPOSURE AND WIND SCULPTURE OF VOLCANIC ASH ON STARLIGHT CREEK, T. 8 S., R. 33 E.

Hall mine is opened by 8,000 feet of tunnels and drifts which cut conglomerate, shale, sandstone, quartzite, and limestone beds of Ordovician (?) age. The ore occurs as veins and seams in a sharply folded limestone bed, and it is composed of chalcopyrite, pyrite, and subordinate galena in a calcite and quartz gangue. Two carloads of ore have been shipped from the property, the last one in 1916.

VOLCANIC ASH.

In different localities in the reservation, including parts of Tps. 7, 8, and 9 S., R. 32 E.; Tps. 6, 7, 8, and 9 S., R. 33 E.; Tps. 4 and 5 S., R. 35 E.; Tps. 3 and 4 S., R. 36 E., and probably other townships, there are extensive deposits of white volcanic ash included in the Tertiary rocks. In some exposures beds 30 to 50 feet thick have been observed. (See Pl. XI.) With the kind assistance of H. G. Ferguson the writer examined under the microscope some of the material of better grade. It contained very little extraneous matter and consisted largely of tiny fragments of volcanic glass and some glassy feldspar. The fragments of glass contain tiny tubes and vesicles and some crystallites. The ash is mostly consolidated into beds that break into easily friable pieces.

A characteristic sample of the better material, when crumbled between the fingers, all passed through a 40-mesh screen and about three-fourths of the sample passed through a 100-mesh screen, forming a fine white flour.

The material resembles the ash of Nebraska as described by Merrill,[9] Barbour,[10] and others and also resembles material collected by Peale in Idaho and Montana and described by Merrill.[11] Some of the samples thus described were taken by Peale from Marsh Creek and the Portneuf Canyon, regions adjacent to the Fort Hall Indian Reservation. Merrill gives the following analysis of the sample from Portneuf Canyon:

Analysis of sample of volcanic ash from Portneuf Canyon, Idaho.[12]

Ignition	6.00
Water	1.60
Fe_2O_3 and Al_2O_3	16.22
SiO_2	68.92
CaO	1.62
MgO	Trace.
Na_2O	1.56
K_2O	4.00
	99.92

[9] Merrill, G. P., U. S. Nat. Mus. Proc., vol. 8, p. 99, 1885.
[10] Barbour, E. H., The deposits of volcanic ash in Nebraska: Ann. Rept. Nebraska State Board Agr., 1896.
[11] Merrill, G. P., Notes on the composition of certain "Pliocene sandstones" from Montana and Idaho: Am. Jour. Sci., 3d ser., vol. 32, pp. 199–204, 1886.
[12] Merrill, G. P., idem, pp. 201–202.

The sample yielded water readily in the closed tube and fused readily with swelling before the blowpipe. Many of the fragments contained bubbles and tubelike cavities.

The Nebraska ash finds many uses. Under the name "pumice" it is used in scouring and polishing preparations. Similar uses may some day be found for the abundant ash deposits of the reservation.

SOILS.

The soil of the Fort Hall bottoms, which is composed of recent alluvium, is mostly a fine light-grayish clayey soil with an intermixture of a small amount of fine sand. It is very calcareous and readily effervesces with dilute hydrochloric acid. Qualitative tests show no water-soluble carbonates and slight traces, if any, of sulphates and chlorides. Frémont, in his exploring expedition of 1843–44, collected a sample of the soil from the river bottom near Fort Hall, which was then a trading post of the Hudson Bay Co., on Portneuf River, about 9 miles above the mouth. He gives the following analysis of the sample:[13]

Analysis of soil in river bottom near Fort Hall.

Silica	68.55
Alumina	7.45
Carbonate of line	8.51
Carbonate of magnesia	5.09
Oxide of iron	1.40
Organic vegetable matter	4.74
Water and loss	4.26
	100.00

In some places the soil is more sandy and locally gravels appear. The moister areas are overgrown with rushes and other marsh plants. The drier meadows are utilized chiefly for their wild hay.

The Gibson terrace, which is composed of the older alluvium, has a more sandy soil and more gravels are exposed at the surface. The soil appears to be chemically similar to that of the Fort Hall bottoms below. This flat is farmed and yields excellent crops of potatoes, alfalfa, and some grain outside the reservation, where water is available for irrigation. It is also being farmed to some extent within the reservation.

Where the volcanic sand overlies the surface in more than mere thin patches the soil is coarse, incoherent, and of little value for agriculture.

[13] Frémont, J. C., Narrative of the exploring expedition to the Rocky Mountains in the year 1842 and to Oregon and north California in the years 1843–44, p. 164, London, 1846.

The soils of the sloping bench lands are relatively fine and calcareous, suitable in many places for dry farming and in the lower areas capable of irrigation.

WATER RESOURCES OF THE FORT HALL INDIAN RESERVATION.

By W. B. Heroy.

FIELD WORK AND ACKNOWLEDGMENTS.

In order to make this report cover with some degree of fullness the natural resources of the Fort Hall Indian Reservation the writer was requested to prepare a discussion of the water supply. Accordingly, a short period in the fall of 1914 was spent in the field in obtaining data, chiefly with reference to underground waters. The statements made regarding wells and the occurrence of ground water on the reservation rest on the information obtained at that time. (See Pl. XIII, p. 133.)

The records of stream flow have been obtained from the records of the United States Geological Survey. The discussion of water power is largely based upon an unpublished report by E. C. La Rue, hydraulic engineer of the United States Geological Survey. Data concerning the Fort Hall irrigation project were in the main obtained from a report by R. J. Ward, of the Indian Irrigation Service, which was courteously lent by W. M. Reed, chief engineer of the service.

SURFACE WATER.

SNAKE RIVER BASIN.

The Fort Hall Indian Reservation lies entirely within the area drained by Snake River and its tributaries, although the extreme south end of the reservation is but a short distance from the divide between the Snake River and Bear River basins.

Snake River forms the northwest boundary of the reservation for a distance of about 25 miles from the mouth of Blackfoot River to that of Portneuf River. Throughout this portion of its course the Snake flows in general through a broad alluvial valley, though its northwest bank is here and there bordered by cliffs which mark the easternmost extension of the Snake River lava. The channel of the river is in most places only a few feet below the level of the valley, but in some places steep gravel banks 15 feet high have been cut on the outside of bends. The gradient, which is only about 2½ feet to the mile, is not uniformly distributed, and the course of the river is broken into rapids and reaches. The large volume of water carried at ordinary stages results in a swift current over the rapids. Consequently the river is not navigable, except for small boats or canoes, and then only with the current.

In volume of flow and drainage area Snake River ranks among the great rivers of the United States. Its headwaters rise in the Continental Divide along the greater part of the east boundary of Idaho and across part of western Wyoming. Originally it was called the Lewis Fork of Columbia River, after the explorer, but it takes its present name from the Shoshones, or Snake Indians, many of whom now have their homes in the Fort Hall Reservation. The main stream, which rises in the southern part of Yellowstone National Park, flows southward through Jackson Valley in Wyoming and then turns westward into Idaho. Most of its course in eastern Idaho is through a deep canyon, from which it emerges a few miles east of Idaho Falls. Here it is joined by Henrys Fork, a large tributary which has its origin in Henrys Lake, in the extreme northeast corner of southern Idaho.

In view of the importance of Snake River to southern Idaho, both for irrigation and for power, much care has been exercised in determining the volume of water which it carries. A number of gaging stations have been established by the United States Geological Survey, in part in cooperation with the State of Idaho and with other governmental agencies, for measuring the flow of the river. One of these stations was established on June 6, 1910, in sec. 31, T. 3 S., R. 34 E. Boise meridian, about 10 miles southwest of Blackfoot and about a quarter of a mile below the mouth of Blackfoot River. The measurements at this station, which is located in part on the reservation, indicate the amount of water which enters that part of Snake River which forms the west border of the reservation. The flow of the river at this station is affected both by the irrigation diversions above and by water released from storage, so that it does not represent the normal volume of the river. The observations made at this station have been published in detail in other reports of the United States Geological Survey,[14] and only a summary of the results obtained is given here. The following table gives the flow of Snake River at this station for the period of record:

[14] U. S. Geol. Survey Water-Supply Papers 292, pp. 295–297, 1913; 312, pp. 270, 271, 1915; 332, pp. 285–287, 1916.

Monthly discharge of Snake River near Blackfoot, Idaho, for 1910–1914.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1910.				
June 6–30	17,100	3,560	8,250	409,000
July	9,510	890	3,960	243,000
August	1,050	238	469	28,800
September	1,920	1,120	1,540	91,600
The period				772,400
1910–11.				
October	2,900	1,570	2,430	149,000
November	3,780	2,900	3,410	203,000
December	3,870	2,270	3,230	199,000
January	5,870	2,140	3,250	200,000
February	7,270	2,270	3,870	215,000
March	5,620	2,200	4,000	246,000
April	9,450	3,610	4,960	295,000
May	18,800	9,170	14,800	910,000
June	32,900	14,800	25,600	1,520,000
July	21,900	1,300	9,200	566,000
August	6,860	625	3,520	216,000
September	3,700	2,520	3,150	187,000
The year	32,900	625	6,780	4,910,000
1911–12.				
October	4,120	2,680	3,650	224,000
November	4,850	2,410	3,850	229,000
December	6,690	2,410	3,900	240,000
January	5,090	3,140	3,950	243,000
February	4,040	2,820	3,420	197,000
March	3,660	2,820	3,210	197,000
April	5,320	3,140	4,240	252,000
May	24,100	5,800	13,700	842,000
June	34,000	19,400	26,600	1,580,000
July	25,500	4,000	13,000	799,000
August	12,200	2,660	7,970	490,000
September	11,300	6,260	9,170	546,000
The year	34,000	2,410	8,050	5,840,000
1912–13.				
October	7,760	6,310	6,970	429,000
November	6,860	4,870	5,840	348,000
December	5,090	3,140	3,940	242,000
January	3,790	1,920	3,110	191,000
February	3,980	2,770	3,330	185,000
March	6,230	3,610	4,190	258,000
April	17,900	6,500	10,100	601,000
May	32,400	12,400	19,500	1,200,000
June	32,400	15,300	25,000	1,490,000
July	22,000	3,890	12,500	769,000
August	12,800	2,620	5,250	323,000
September	9,000	6,100	7,710	459,000
The year	32,400	1,920	8,970	6,500,000
1913–14.				
October	6,640	5,610	6,010	370,000
November	6,360	5,370	5,710	340,000
December	5,370	2,690	4,150	255,000
January	4,800	2,930	4,060	250,000
February	4,480	2,130	3,360	187,000
March	4,280	3,700	3,960	243,000
April	16,500	3,700	9,650	574,000
May	24,400	13,200	18,000	1,110,000
June	35,500	11,600	21,100	1,260,000
July	10,800	3,170	6,360	391,000
August	5,610	2,470	3,700	228,000
September	5,980	2,850	4,360	259,000
The year	35,500	2,130	7,540	5,470,000

The next station below the Blackfoot station is at Neeley, Idaho. Portneuf River and Bannock Creek and large amounts of spring water enter Snake River between these stations. The station at Neeley, which was established March 17, 1906, is the oldest on the river, and the record which has been obtained there is of great value in the interpretation of the flow of the river and in the formulation of plans for its utilization. The hydrometric data procured at the Neeley station have been published in the water-supply papers of the United States Geological Survey.[15]

This record may be regarded as a continuation of that obtained at Montgomery's Ferry near Minidoka during the years 1895–1899 and 1901–1910. There is not much inflow and practically no diversions between those stations.

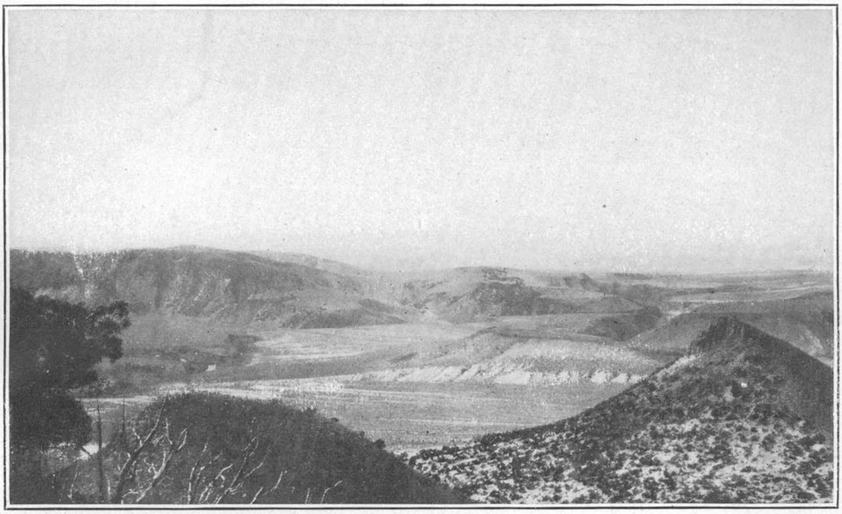
Snake River probably receives a relatively small amount of direct inflow from the Fort Hall Indian Reservation, but its tributaries, Blackfoot River, Portneuf River, and Bannock Creek, which drain most of the reservation, are important streams.

BLACKFOOT RIVER BASIN.

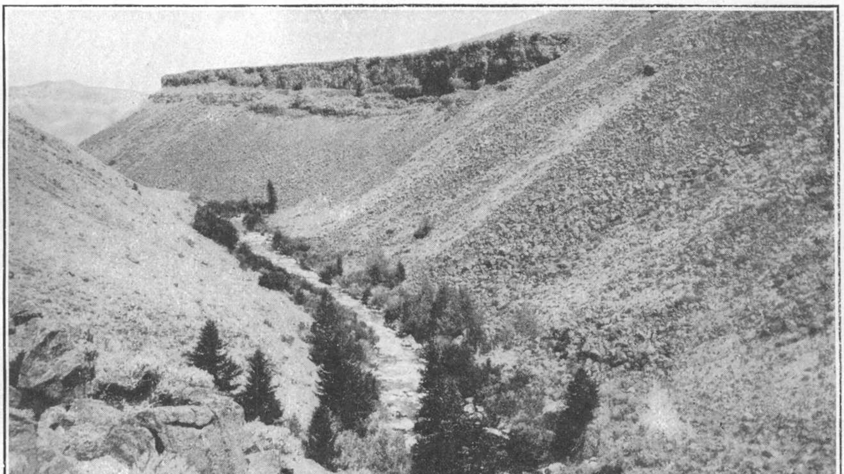
Blackfoot River forms the north boundary of the reservation from the northeast corner to its confluence with the Snake. The sources of Blackfoot River are chiefly in the Preuss Range, 40 miles east of the reservation, in a region of high relief, well forested, and yielding a high run-off. After leaving the mountains the river flows on the surface of an extensive lava plateau. This plateau extends in general from the Caribou, Preuss, and Aspen ranges on the east to the Portneuf Range on the west. It is not continuous, however, for many hills and mountains which antedate the lava sheet project through it and break up the surface of the plateau into a number of intermountain areas.

Throughout the eastern part of this lava plateau Blackfoot River flows with a gentle gradient through an open valley that is but slightly intrenched in the lava surface. In T. 5 S., R. 40 E., the river enters a canyon (Pl. XII) through which it flows for a distance of about 40 miles. The depth of the canyon is at first moderate, but it gradually increases northwestward and reaches a maximum in T. 3 S., R. 38 E. Here the black basalt walls are about 400 feet high, very steep, in fact, vertical, and in places but a few hundred feet apart. The gradient of the stream through portions of the canyon is about 100 feet to the mile, and the white and green turbulent waters of the

[15] U. S. Geol. Survey Water-Supply Papers 214, p. 76, 1907; 252, pp. 212–214, 1910; 272, pp. 255–257, 1911; 292, pp. 297–300, 1913; 312, pp. 271–273, 1915; 332, pp. 287–299, 1916; 362, pp. 269–271, 1917; 393, pp. 24–26, 1916; 413, pp. 27–28, 1918.



A. LOWER PORTION OF BLACKFOOT RIVER CANYON AND ADJACENT SNAKE RIVER VALLEY.



B. CANYON OF BLACKFOOT RIVER, SEC. 10, T. 3 S., R. 38 E., SHOWING RELATION OF CLIFFS AND TALUS SLOPES TO RIVER.

river rushing through the blackness of the canyon present an impressive picture.

After leaving the canyon in sec. 11, T. 2 S., R. 37 E., the river enters the valley of Snake River, which here flows across a broad plain that was developed in the Gibson cycle, as described by Mr. Mansfield. In an earlier cycle Blackfoot River built a large alluvial fan at the mouth of the canyon. Much of this deposit has since been removed by the stream, but the uneroded portion now forms a terrace on the north side of the river. Across the valley of Snake River the Blackfoot flows practically on the Gibson surface, and has a slight gradient. The drainage basin of Blackfoot River has an area of about 1,070 square miles.

Gaging stations for measuring the flow of Blackfoot River have been established at several points along its course. The first of these stations was established April 17, 1903, near Presto, a former post office that was located about 5 miles below the mouth of the canyon. This station was discontinued December 31, 1909. It has, however, been practically replaced by a station that was established June 26, 1909, at a more favorable location about 1½ miles above the mouth of the canyon. The measurements obtained at this station, known as "Blackfoot River near Shelley, Idaho," indicate the entire flow of the river, as there are no large tributaries below and no diversions of consequence above. The observations at the Presto station have been published in water-supply papers,[16] and only a summary of the discharge of the river as computed therefrom is given here.

Monthly discharge of Blackfoot River near Presto, Idaho, for 1904–1909.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1904.				
June	975	233	536	31,890
July	216	150	179	11,010
August	182	150	161	9,900
September	216	182	198	11,780
October	269	216	251	15,430
November	269	216	230	13,680
December 1-10	269	216	238	4,721
The period				98,410
1905.				
March 5-31	335	166	256	13,710
April	498	269	412	24,520
May	606	242	368	22,630
June	233	142	183	10,890
July	121	76	91.2	5,608
August	536	64	100	6,149
September	121	82	89.0	5,296
The period				88,000

[16] U. S. Geol. Survey Water-Supply Papers 135, p. 186, 1905; 178, p. 106, 1906; 214, p. 84, 1907; 252, p. 231, 1910; 272, p. 284, 1911.

Monthly discharge of Blackfoot River near Presto, Idaho, for 1904–1909—Contd.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1905–6.				
October	150	121	138	8,485
November	166	121	145	8,628
December	216	107	177	10,880
January			a150	9,220
February			a150	8,330
March	349		196	12,100
April	1,350	150	552	32,800
May	1,040	602	813	50,000
June	960	272	582	34,600
July	290	100	179	11,000
August	162	88	113	6,950
September	215	154	183	10,900
The year				204,000
1906–7.				
October	253	197	225	13,800
November	273		254	15,100
December			a250	15,400
January			a250	15,400
February	458		304	16,900
March	470	234	321	19,700
April	2,370	400	1,460	86,900
May	1,590	1,270	1,430	87,900
June	1,290	766	1,020	60,700
July	714	293	391	24,000
August	314	224	256	15,700
September	283	253	269	16,000
The year				387,000
1907–8.				
October	367	283	328	20,200
November	378	335	366	21,800
December	422		309	19,000
January			a250	15,400
February			a200	11,500
March	470		291	17,900
April	792	411	578	34,400
May	447	284	339	20,800
June	696	304	491	29,200
July	284	124	163	10,000
August	159	117	134	8,240
September	175	130	149	8,870
The year				217,000
1908–9.				
October	284	167	237	14,600
November	274	227	249	14,800
December	264		217	13,300
January	344	200	246	15,100
February	284	227	260	14,400
March	264	175	222	13,600
April	1,960	227	660	39,300
May	1,960	1,440	1,700	105,000
June	1,680	578	1,060	63,100
July	566	253	364	22,400
August	263	197	227	14,000
September	356	234	282	16,800
The year				346,000
1909.				
October	378	215	336	20,700
November			352	20,900
December			a500	30,700
The period				72,300

a Estimated.

The data for the station near Shelley have also been published.[17] The following table gives the discharge of the river for the period of record as computed therefrom:

Monthly discharge of Blackfoot River near Shelley, Idaho, for 1909–1914.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1909.				
June 26–30	757	586	649	6,440
July	586	308	385	23,700
August	284	241	262	16,100
September	304	248	289	17,200
October	343	304	336	20,700
November			331	19,700
The period				104,000
1910.				
April 2–30	1,100	988	1,050	60,400
May	1,060	195	588	36,200
June	236	168	214	12,700
July	165	39	89.1	5,480
August	500	107	349	21,500
September	659	148	508	30,200
The period				166,000
1910–11.				
October	109	69	85.4	5,250
November	85	63	72.9	4,340
December	111	50	73.1	4,490
January	553	50	103	6,330
February	277	35	104	5,780
March	325	35	113	6,950
April	432	138	216	12,900
May	215	135	179	11,000
June	636	130	261	15,500
July	422	123	266	16,400
August	308	130	210	12,900
September	195	96	131	7,800
The year	636	35	151	110,000
1911–12.				
October	121	69	90.8	5,580
November	83	55	65.8	3,920
December	58	45	53.1	3,260
January	97	56	76.5	4,700
February	149	70	85.8	4,940
March	114	80	90.6	5,570
April	180	93	134	7,970
May	649	160	442	27,200
June	372	177	296	17,600
July	490	309	374	23,000
August	516	418	466	28,700
September	490	110	420	25,000
The year	649	45	217	157,000
1912–13.				
October	531	320	487	29,900
November	307	85	136	8,090
December	93	65	79.5	4,890
January	74	62	67.2	4,130
February	238	61	122	6,780
March	708	203	345	21,200
April	1,280	796	1,040	61,900
May	1,200	829	990	60,900
June	1,000	582	828	49,300
July	764	661	722	44,400
August	764	684	720	44,300
September	727	637	659	39,200
The year	1,280	61	518	375,000

[17] U. S. Geol. Survey Water-Supply Papers 272, p. 282, 1911; 292, p. 333, 1913; 312, p. 300, 1915; 332, p. 321, 1916; 362, p. 307, 1917; 393, p. 57, 1916.

Monthly discharge of Blackfoot River near Shelley, Idaho, for 1909–1914—Con.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1913–14.				
October	637	133	208	12,800
November	147	126	138	8,210
December			a 158	9,720
January			a 191	11,700
February			a 142	7,890
March	319	96	235	14,400
April	764	299	544	32,400
May	796	514	589	36,200
June	897	745	807	48,000
July	745	696	722	44,400
August	702	109	559	34,400
September	672	137	544	32,400
The year	897		404	293,000

a Monthly mean estimated largely from records at station near Henry.

A gaging station has also been established on Blackfoot River near Henry, 1 mile below the dam of the Blackfoot River reservoir of the Indian Irrigation Service and approximately 37 miles above the Shelley station. The records of the measurements made at the Henry station indicate the amount of water released from storage. This station is not located on the reservation and those interested will find the records published elsewhere.[18]

A number of small streams enter Blackfoot River between the Henry and the Shelley gaging stations. Several of these streams rise on the eastern slope of that portion of the Portneuf Range which extends northward into the reservation. The size of these tributaries may be judged from the following measurements made by E. C. La Rue, October 10–15, 1909, during the period of low flow: Deadman Creek, 0.39 second-foot; Beaver Creek, 0.86 second-foot; Wood Creek, 3.14 second-feet; Tenmile Creek, 0.43 second-foot.

Below the Shelley gaging station Garden and Lincoln creeks, which traverse the Fort Hall Indian Reservation, are tributary to Blackfoot River. Garden Creek is very small. Lincoln Creek drains an area of perhaps 40 square miles. Its flow is reported by E. C. La Rue to range from 3 to 75 second-feet. He estimated the discharge at a section half a mile above old Fort Hall to have been 3.8 second-feet on July 14, 1911. At low stages the flow of the stream sinks in the sand before reaching Blackfoot River.

During the season of 1910 a number of discharge measurements were made of the flow of Blackfoot River near its mouth, which afford an indication of the degree of utilization of the water of Blackfoot River during the irrigation season:

[18] U. S. Geol. Survey Water-Supply Papers 252, p. 231, 1910; 272, p. 279, 1911; 292, p. 331, 1913; 312, p. 298, 1915; 332, p. 318, 1916; 362, p. 305, 1917; 393, p. 55, 1916.

Discharge measurements of Blackfoot River near its mouth during the year ending Sept. 30, 1910.

[W. R. King, hydrographer.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
July 30	1.70	20.4	Aug. 17	1.50	20.7
Aug. 3	1.51	21.15	20	1.93	69.0
8	1.50	21.2	25	2.42	128.4
12	1.50	19.8			

PORTNEUF RIVER BASIN.

Portneuf River and its tributaries drain the greater part of the eastern and southern portions of the reservation.[19] The river rises on the eastern slope of the northward extension within the reservation of the Portneuf Range, and a short distance below its source it enters a fairly broad intermontane valley, through which it flows southward for about 10 miles. In the vicinity of Chesterfield, near the boundary of the reservation, this valley opens into a broad lava plain, which resembles that in the upper portion of the Blackfoot River drainage. This lava plain, called Portneuf Valley, has an average width of about 6 miles, an elevation of 5,300 to 5,500 feet, and a length of about 25 miles southeastward to Bear River.

Portneuf River flows southward along the west margin of the valley for about 8 miles and then leaves through a gap near the southwest corner. In this valley Topons Creek is tributary to Portneuf River from the west, and Eighteenmile, Moses, and Twentyfourmile creeks from the east.

After leaving Portneuf Valley the river flows southward for about 10 miles and then westward for about the same distance through a picturesque canyon cut across the Portneuf Range. In this portion of its course the Portneuf has a steep gradient and falls about 600 feet between Pebble and McCammon. Pebble Creek, Fish Creek, and Dempsey Creek are the largest tributaries, each draining a portion of the Portneuf Range. Near Dempsey a number of hot springs add materially to the flow of the river.

At McCammon Portneuf River enters Marsh Valley, a broad structural valley which lies between the Portneuf and Bannock ranges. The river takes a northward course along the east side of Marsh Valley for a distance of about 10 miles. This valley is drained chiefly by Marsh Creek, which flows northward along the center of

[19] Portneuf River is stated by Capt. Nathaniel J. Wyeth to have been named "from a man killed near it": The correspondence and journals of Capt. Nathaniel J. Wyeth, 1831–1836: Sources of Oregon History, vol. 1, pts. 3–6 incl., p. 162, Oregon Univ., Contrib. Dept. Economics and History, Eugene, Oreg., 1899.

the valley and, after paralleling Portneuf River for a considerable distance, finally joins it.

The river leaves Marsh Valley through a deep, gorgelike valley cut across the Bannock Range, flows with a moderate slope westward for about 6 miles and then turns to the northwest into a more open valley, in which lies the city of Pocatello. Rapid Creek, Indian Creek, City Creek, and Pocatello Creek are the more important tributaries in this vicinity.

Westward from Pocatello the river is intrenched in the alluvial deposits of the Gibson cycle. Its valley gradually broadens to the west and merges into the recent flood plain of Snake River, locally called the "Fort Hall bottoms." The lower 12 miles of its course is across the reservation. Across the flood plain the stream is sluggish. Near its mouth it receives a large volume of water from Ross Fork and Spring Creek.

No station for measuring the flow of Portneuf River has been maintained on the reservation. On September 8, 1910, a station was established near Pebble, in sec. 26, T. 7 S., R 38 E., on the west side of Portneuf Valley. The data obtained at this station have been published in several water-supply papers[20] and a summary of the discharge of the river at this station follows:

Monthly discharge of Portneuf River near Pebble, Idaho, for 1910–1913.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1910.				
September 8-30	43	39	39.3	1,790
October	47	47	47.0	2,890
November	66	47	51.5	3,060
December	66	39	52.6	3,230
The period				11,000
1910–11.				
October	47	47	47.0	2,890
November	66	47	51.5	3,060
December	66	39	52.6	3,230
January	624	47	99.6	6,120
February	606	56	115	6,390
March	345	56	202	12,400
April	249	117	163	9,700
May	233	165	190	11,700
June	152	73	113	6,720
July	102	45	61.1	3,760
August	56	32	42.8	2,630
September	56	39	45.7	2,720
The year	624	32	98.6	71,300
1911–12.				
October	66	47	56.8	3,490
November	76	39	55.8	3,320
December	43	39	40.4	2,480
January	52	39	45.8	2,820
February	52	46	48.8	2,810
March	72	46	54.5	3,350

[20] U. S. Geol. Survey Water-Supply Papers 292, p. 340, 1913; 312, p. 308, 1915; 332, p. 344, 1916; 362, p. 335, 1917.

Monthly discharge of Portneuf River near Pebble, Idaho, for 1910–1913—Contd.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
April	312	62	176	10,500
May	365	126	247	15,200
June	317	103	220	13,100
July	98	39	66.8	4,110
August	77	50	62.2	3,820
September	57	46	50.5	3,000
The year	365	39	93.6	68,000
1912–13.				
October	120	48	72.6	4,660
November	103	45	67	3,990
December	51	36	40	2,460
January	49	34	42.6	2,620
February	51	49	50.3	2,790
March	462	49	89.9	5,530
April	537	140	206	12,300
May	216	94	173	10,600
June	144	82	113	6,720
July	132	54	74.6	4,590
August 1–15	78	41	57.1	1,700
The period				57,800

The station near Pebble was discontinued on August 15, 1913. At the beginning of that year, however, a station was established at a point in sec. 23, T. 9 S., R. 37 E., 16 miles downstream from the Pebble station. The new station, at Topaz, is in the lower part of Portneuf Canyon and a short distance above the headgate of the main canal of the Portneuf-Marsh Valley Irrigation Co. A summary of the discharge at this station follows:

Monthly discharge of Portneuf River at Topaz, Idaho, for 1913 and 1914.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1913.				
January 12–31	163	156	161	6,350
February	211	163	184	10,200
March	679	202	269	16,500
April	902	251	412	24,500
May	449	266	380	23,400
June	247	170	196	11,700
July	285	156	189	11,600
August	186	128	150	9,220
September	170	141	157	9,340
The period				123,000
1913–14.				
October	202	163	185	11,400
November	266	194	220	13,100
December	186	170	180	11,100
January	194	170	183	11,300
February	211	170	189	10,500
March	512	202	321	19,700
April	770	346	575	34,200
May	593	413	533	32,800
June	565	285	373	22,200
July	368	266	299	18,400
August	285	178	230	14,100
September	285	163	212	12,600
The year	770	163	292	211,000

A station was also maintained on Portneuf River near Pocatello for portions of the years 1897 to 1899. A new station was established within the city limits on August 31, 1911, below all important diversions. The flow at this station indicates the approximate flow of Portneuf River at the reservation boundary 6 miles below. The complete record at this station has been published by the Survey,[21] and only a summary of the discharge is given here.

Monthly discharge of Portneuf River at Pocatello, Idaho, for 1912–1914.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1912–13.				
October	376	271	323	19,900
November	400	290	347	20,600
December	353	220	259	15,900
January			[a] 215	13,200
February	331		[a] 243	13,500
March	535	242	391	24,000
April	915	535	688	40,900
May	695	300	485	29,800
June	331	86	160	9,520
July	353	53	129	7,930
August	86	53	65.1	4,000
September	187	70	146	8,690
The year	915	53	287	208,000
1913–14.				
October	270	187	225	13,800
November	353	260	310	18,400
December	290	196	242	14,900
January	425	196	286	17,600
February	599		380	21,100
March	664	454	521	32,000
April	1,080	509	818	48,700
May	958	425	794	48,800
June	661	270	411	24,500
July	353	153	220	13,500
August	251	130	165	10,100
September	310	161	240	14,300
The year	1,080	130	384	278,000

[a] Estimated.

At Wade's ranch, 11 miles northeast of American Falls and a short distance west of the reservation boundary, a station was established on Portneuf River on July 30, 1910, and maintained during that season. The gage is nailed to a pole of the right-hand bent of the highway bridge over the river on the road from American Falls to Horse Island. The measuring station is located 300 feet above the bridge. Measurements are made from a rowboat.

Measurements at this station indicate the flow of Portneuf River below the mouth of Spring Creek and Ross Fork and above the mouth of Bannock Creek. Ross Channel of Snake River, which branches from the main channel at the head of Horse Island, enters the Portneuf a short distance above the station, and the discharge through this channel must accordingly be deducted from the measurements at the gaging station to give the net flow of Portneuf River.

[21] U. S. Geol. Survey Water-Supply Papers 362, p. 99, 1917; 393, p. 81, 1916.

This station was established in cooperation with the United States Reclamation Service, in order to afford an indication of the amount of water contributed to Snake River from this source during the irrigation season. As the record of this station has not been published elsewhere, it is given here in full.

Discharge measurements of Portneuf River near Wade's ranch during the year ending Sept. 30, 1910.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Second-feet.*
July 30	H. L. Stoner	5.50	1,516.2
Aug. 9	Stoner and Crandall	5.50	1,443.8
21	....do	5.56	1,523.8
28	H. L. Stoner	5.50	1,573.6

Daily gage height, in feet, of Portneuf River near Wade's ranch for the year ending Sept. 30, 1910.

Day.	July.	Aug.	Sept.	Day.	July.	Aug.	Sept.
1		5.5	5.6	16		5.5	5.7
2		5.5	5.6	17		5.5	5.72
3		5.5	5.6	18		5.55	
4		5.5	5.6	19		5.58	
5		5.5	5.6	20		5.58	
6		5.5	5.6	21		5.55	
7		5.5	5.6	22		5.57	
8		5.5	5.6	23		5.57	
9		5.5	5.62	24		5.58	
10		5.5	5.62	25		5.59	
11		5.5	5.62	26		5.6	
12		5.5	5.62	27		5.6	
13		5.5	5.64	28		5.6	
14		5.5	5.68	29		5.6	
15		5.5	5.7	30		5.6	
				31	5.5	5.6	

The flow of Ross Channel was measured by Messrs. Stoner and Crandall on August 9, 1910, at the ford between the reservation and Horse Island and found to be 2.8 second-feet. The flow through this channel during July and August, 1910, was constant.

The discharge measurement of August 9 should be given preference over that of July 30 because of better soundings. It appears, then, that the discharge of Portneuf River ranged during the period of measurement from 1,440 to about 1,700 second-feet.

The important tributaries of Portneuf River within the reservation are Ross Fork, Spring Creek, and Michaud Creek. Ross Fork is formed by the junction of two principal forks which rise on the west slope of the Portneuf Range. It has a westward course, at first through a broad valley that is eroded in the older rocks of the eastern part of the reservation and farther to the west across the broad terrace of the Gibson cycle. Toward the west edge of the terrace the stream flows through a narrow valley, which it has cut in its descent to the level of the Snake River bottoms. After leaving the terrace it flows into Portneuf River.

No gaging station has been established on Ross Fork. A measurement by E. C. La Rue, on July 18, 1911, indicated a flow of 10.3 second-feet on the North Fork of Ross Fork. The minimum flow is somewhat less and may in some years be as low as 6 second-feet.

Clear Creek flows into Ross Fork a short distance above its mouth and contributes by far the larger part of its volume. This stream rises near the east margin of the Fort Hall bottoms and follows quite closely the base of the Gibson terrace. The stream is fed by springs which rise in places throughout the bottoms. No measurements of its flow are recorded, but it appears to discharge several hundred second-feet.

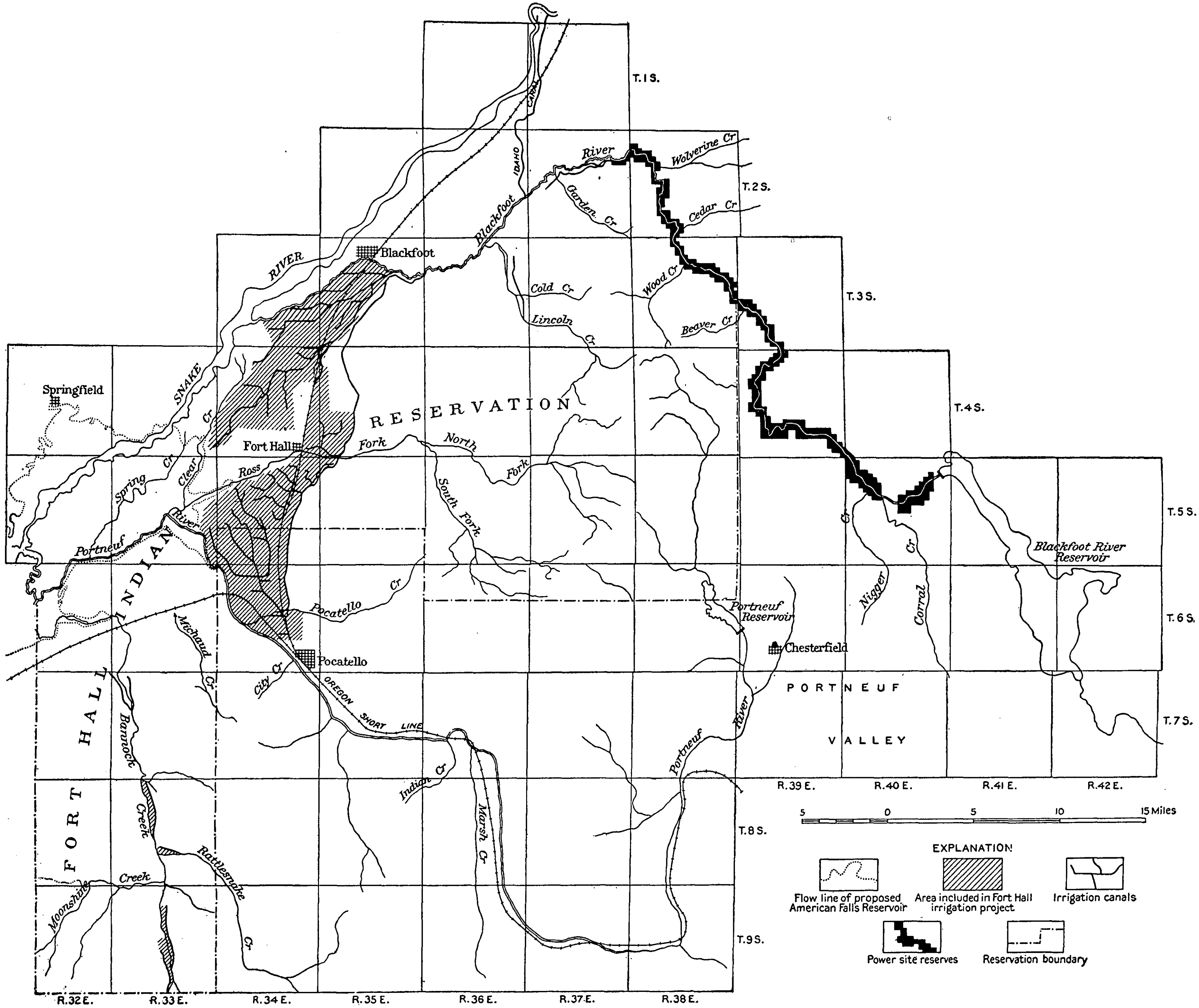
Spring Creek also heads in large springs, which rise near the north end of the Fort Hall bottoms. It flows parallel to Snake River through practically the entire extent of the bottoms and unites with the Portneuf a few miles above its mouth. The stream is remarkable for the large flow which it receives from underground sources, measurements of discharge indicating an average minimum of about 1,500 second-feet. The slope of the stream is but 2 or 3 feet to the mile. The water is beautifully clear, and in most lights has a pronounced blue color.

BANNOCK CREEK BASIN.

Bannock Creek has its source in Arbon Valley about 15 miles south of the reservation boundary. For over 30 miles it follows a generally northward course through a broad valley which lies between the Bannock Range on the east and the Rock Creek Mountains on the west and enters the Portneuf a short distance above the mouth. Its larger tributaries are Knox, Moonshine, and Starlight creeks from the west and Rattlesnake Creek from the east. The following miscellaneous discharge measurements have been made at different points in the drainage basin by engineers of the Indian Irrigation Service and of the Geological Survey:

Miscellaneous measurements in Bannock Creek basin.

Date.	Stream.	Locality.	Discharge.
1909.			*Sec.-ft.*
Sept. 26	West Branch of Bannock Creek	SE. ¼ sec. 34, T. 9 S., R. 33 E.	3.7
26	East Branch of Bannock Creek	do	24.7
27	Bannock Creek	T. 9 S., R. 33 E., sec. 27, south line	37.8
27	do	Sec. 34, T. 8 S., R. 33 E., below mouth of Moonshine Creek.	35.5
27	Rattlesnake Creek	NE. ¼ sec. 28, T. 8 S., R. 33 E.	9.3
27	Bannock Creek	Above mouth of Rattlesnake Creek	40
27	do	Below mouth of Rattlesnake Creek	51.2
1910.			
Aug. 9	do	1 mile below Horse Island	32.68
21	do	do	33.11
28	Tributary of Bannock Creek	Short distance from mouth	2.03



MAP OF FORT HALL INDIAN RESERVATION AND VICINITY, ILLUSTRATING WATER RESOURCES.

The discharge measurements made in August, 1910, were obtained at a point about 600 feet above the highway bridge on the road from American Falls to Horse Island, a short distance west of the reservation boundary. The total discharge of Bannock Creek into Portneuf River is obtained by adding to the discharge at this station that of the small tributary given in the above table. The total flow of Bannock Creek at the mouth thus appears to have been about 35 second-feet during July and August, 1910.

GROUND WATER.

Consideration of the ground-water supply of the Fort Hall Indian Reservation is divided naturally into a discussion of conditions in the eastern and southern mountain and valley regions and in the alluvial plains of the Snake River valley. (See Pl. XIII.)

OCCURRENCE IN THE MOUNTAINOUS AREAS.

But a short time was devoted to studying in the field the occurrence of ground water in the more mountainous areas. Numerous springs and small streams make these portions of the reservation generally well watered. The faulting and flexuring of the rocks, described by Mr. Mansfield, which have resulted in the discontinuity of water-bearing beds, have apparently caused complex ground-water conditions. Circulation of ground water is doubtless largely influenced by lines of fracture, and the return of ground water to the surface along fault lines appears to explain the location of some of the mountain springs.

In the narrow valleys which head between the mountain spurs small amounts of ground water may be stored in narrow belts of alluvium along the streams. In the larger valleys, like those of the upper Portneuf River, of Ross Fork, and of Bannock Creek, no difficulty will generally arise in obtaining water for domestic use from shallow wells in the valley fill. Two wells, both shallow, are reported in Bannock Valley, one on the allotment of Francis Mosho and one at the reservation farm in the S. ½ NE. ¼ sec. 32, T. 7 S., R. 33 E., occupied by Jesse White. A well drilled to a depth of 76 feet on the reservation farm in Ross Fork valley, in the SW. ¼ SW. ¼ sec. 31, T. 4 S., R. 36 E., passed through 20 feet of alluvium and then entered rock. The water level was not ascertained but is reported to be less than 10 feet from the bottom. The well is said to have cost $210.

OCCURRENCE IN SNAKE RIVER VALLEY.

Ground-water conditions in the valley of Snake River are of greater economic importance than in the areas just discussed for the reason that surface-water supplies are less abundant.

The terrace of the Gibson cycle averages 6 to 8 miles in width across the Fort Hall Indian Reservation and north of Blackfoot River extends as a broad plain to Idaho Falls and beyond. Southwestward it narrows abruptly and disappears as a conspicuous topographic feature in the vicinity of American Falls. Throughout the reservation the west boundary of the terrace, a steep bluff that forms an abrupt descent to the Snake River bottoms, is usually sharply defined. In the northwestern part of T. 4 S., R. 34 E., just south of Big Butte, the height of the bluff is only about 15 feet, but it gradually increases southward and near Cedar Butte in the northeastern part of T. 4 S., R. 33 E., is about 60 feet. The terrace is dissected by the valleys of Ross Fork and Portneuf River, more deeply by the latter. South of the Portneuf, however, it continues with only minor irregularities to the west boundary of the reservation.

So far as observed, only sands and gravels are exposed in the margin of the terrace facing Snake River, although some of the wells drilled in the eastern part of the terrace are reported to have penetrated lava strata. The sands and gravels that compose the terrace appear to have a slight dip in the direction of Snake River, owing presumably to conditions of sedimentation rather than to subsequent tilting. They represent débris brought from areas of high relief and deposited at a time when the base-level of the region was perhaps 100 feet higher than at present.

On the west side of Snake River, opposite the reservation, is a terrace which corresponds in elevation to that of the Gibson cycle on the reservation. Its eastern margin is largely made up of exposures of Snake River lava. No corresponding lava outcrops appear on the reservation side. As there is no evidence of faulting or other disturbance the conclusion is probably justified that the uppermost sheet of the Snake River lava has never extended much farther east than the west bank of the river. The Gibson terrace thus appears to be the remnant of a deposit of alluvial material which originally extended westward across the present Snake River bottoms and met the eastern margin of the lava.

Either through change in base-level or through headward erosion the Snake River later began downcutting. Its course was such that the entrenching was done in the alluvium and not in the lava, and in consequence the river was able to accomplish rapid work in clearing out a valley at a level below the Gibson terrace. The river has now removed about one-third of the alluvium deposited against the eastern margin of the lava during the Gibson cycle. On its right bank most of the alluvium has been eroded. Remnants may, however, be observed at intervals along the road from American Falls to Blackfoot.

The alluvium of the Gibson terrace has a texture favorable for carrying water. The gravels are coarse and have large interstices, and it is probable that this influences the depth to the water table under most of the terrace, the gravels providing a ready exit for the ground water in the direction of Snake River. The location of the water table with relation to the surface of this terrace is indicated by the following data relating to wells:

Wells on the Gibson terrace.

No.	Owner.	Location.	Depth of well.	Depth to water level.
			Feet.	*Feet.*
1	George W. Tenday	E. ½ SE. ¼ SE. ¼ sec. 36, T. 3 S., R. 34 E	48	44
2	Ralph Dixie	Lot 5, SE ¼ NE. ¼ sec. 9, T. 3 S., R. 35 E	67	*a* 47
3	Charley Diggie	E. ½ NW. ¼ SW. ¼ sec. 10, T. 3 S., R. 35 E	47	40±
4	Peter Jim	S. ½ SW. ¼ SE. ¼ sec. 10, T. 3 S., R. 35 E	....	....
5	Jones Johnson	W. ½ NW. ¼ NE. ¼ sec. 17, T. 3 S., R. 35 E	38	34
6	....do	....do	50	41
7	Jimmie Smart	E. ½ NE. ¼ NW. ¼ sec. 19, T. 3 S., R. 35 E	31	22
8	Tea Pokibro	W. ½ NE. ¼ NW. ¼ sec. 22, T. 3 S., R. 35 E	50+	....
9	Captain Willie	E. ½ NW. ¼ NE. ¼ sec. 29, T. 3 S., R. 35 E	51	41
10	Presbyterian Mission	SW. ¼ SE. ¼ sec. 29, T. 3 S., R. 35 E	84	40
11	Billy George	E. ½ NW. ¼ NW. ¼ sec. 32, T. 3 S., R. 35 E	80±	40±
12	William Penn	E. ½ SE. ¼ NE. ¼ sec. 1, T. 4 S., R. 34 E	50±	44
13	Frank Trouchart	E. ½ NE. ¼ NW. ¼ sec. 3, T. 4 S., R. 34 E	....	....
14	Dick Burns	N. ½ SE. ¼ sec. 26, T. 4 S., R. 34 E	30	20
15	Tom Madzeweyu	SW. ¼ NE. ¼ sec. 35, T. 4 S., R. 34 E	....	13
16	Agency	NW. ¼ SW. ¼ sec. 36, T. 4 S., R. 34 E	108	50±
17	Mary M. Hutchinson	E. ½ SE. ¼ NW. ¼ sec. 36, T. 4 S., R. 34 E	76	55±
18	Oregon Short Line R. R.	NW. ¼ SW. ¼ sec. 36, T. 4 S., R. 34 E	147	....
19	Agency	....do	115±	....
20	....do	....do	125±	....
21	Episcopal Mission School	SW. ¼ SE. ¼ sec. 36, T. 4 S., R. 34 E	100+	....
22	Agency Farm	SW. ¼ NW. ¼ sec. 36, T. 4 S., R. 35 E	83	54
23	Hiram Faulkner	W. ½ SE. ¼ NE. ¼ sec. 29, T. 4 S., R. 35 E	*b* 102	82
24	M. Y. LeSieur	W. ½ NE. ¼ NE. ¼ sec. 2, T. 5 S., R. 34 E	56	36±
25	Shorty George	N. ½ NE. ¼ NE. ¼ sec. 11, T. 5 S., R. 34 E	41	35
26	Jessie P. Blakesley	N. ½ NE. ¼ SE. ¼ sec. 11, T. 5 S., R. 34 E	86	66±
27	Mamie Nahsie	SW. ¼ SE. ¼ SW. ¼ sec. 14, T. 5 S., R. 34 E	....	58
28	Rose Brady	W. ½ SE. ¼ SE. ¼ sec. 16, T. 5 S., R. 34 E	38	30±
29	Johnny Book	E. ½ SW. ¼ SW. ¼ sec. 17, T. 5 S., R. 34 E	....	28
30	Earl E. Cutler	W. ½ NW. ¼ SE. ¼ sec. 22, T. 5 S., R. 34 E	*c* 50	42
31	Ida Browning	W. ½ NE. ¼ SW. ¼ sec. 23, T. 5 S., R. 34 E	70	64
32	Ed Lavata	NE. ¼ sec. 1, T. 5 S., R. 35 E	100±	38
33	Reservation School	NW. ¼ SW. ¼ sec. 1, T. 5 S., R. 35 E	175	80
34	Charles Faulkner	NW. ¼ SE. ¼ sec. 1, T. 5 S., R. 35 E	220	23

a Yields 100 gallons a minute to pump without much lowering of water level.
b First water struck at 20 feet.
c Pumped by gasoline.

The evidence bearing on the quantity of water which can be obtained from the underflow in this area is meager. The well which supplies the railroad water tank at Ross Fork is pumped at the rate of 24 gallons a minute, and it is said that continuous pumping lowers the water surface in the well appreciably. The agency is supplied from a well pumped by an automatically controlled electric motor. The supply has proved ample for all purposes, including fire protection. The well owned by Ralph Dixie is reported to have yielded under test 100 gallons a minute without greatly lowering the water surface.

There is considerable seasonal fluctuation in the water level. The water table is lowest early in the spring and highest early in the fall, a difference in level of 3 or 4 feet being reported in some wells. The cause of this fluctuation is apparently the application of water to the irrigated lands, the water standing highest soon after the period of maximum irrigation.

Data are not available to indicate whether irrigation has affected the water level in this area. The establishment of bench marks at wells within the limits of the irrigation project and the taking of occasional readings of the depth to water is desirable, in order that if the rise of the water table under the irrigated area should prove to be progressive measures might be taken to prevent the eventual water-logging of the irrigated lands. The coarseness of the terrace alluvium is a factor of safety in this regard, because it will result in rapid movement of the ground water toward the river. With reasonable care in the use of water for irrigation it should be possible to avoid any serious difficulty from water logging.

The Fort Hall bottoms, the broad level plain which borders Snake River and which belongs to the Spring Creek cycle of erosion, begins as a narrow flat just west of Big Butte. It widens greatly in a short distance southward and attains a maximum width of about 5 miles near the junction of Ross Fork with Portneuf River. The plain slopes to the southwest at about the same gradient as that of Snake River itself, which is somewhat more than 2 feet per mile. The relief on the plain is slight; the streams which cross it, Spring and Clear creeks, flow practically on its surface; and the gravel banks along Snake River have a maximum height of only about 15 feet above the low-water stage of the river. Near Snake River the plain is cut up by high-water channels.

Cut banks along the river and placer miners' test pits indicate that the flat is immediately underlain by a deposit of coarse stream gravel, which in many places still has the form of old river bars. This deposit of gravel has, over a large area of the plain, been covered by a rich soil, which generally ranges in depth from 2 to 6 feet. Much of the area is covered by a luxuriant growth of wild grasses. The hay forms an important resource of the reservation, providing winter feed for the herds of the Indians. Portions of the plain, especially along the river, are covered with a growth of cottonwood and other deciduous trees. Other portions are swampy and under present conditions valueless except as they provide a feeding ground for large numbers of water fowl.

The water table is generally very near the surface. Places where it is more than 10 feet below the surface are exceptional, and its average depth is probably less than 5 feet. The surface soil of much of the plain thus obtains through capillarity sufficient moisture to produce the hay crop. Between Spring Creek and the river there is, however, a tract where the water table is apparently too far below the surface to support a heavy growth of grass. This tract might be irrigated to advantage.

The most remarkable ground-water feature in this region is the presence of numerous large springs throughout the Fort Hall bottoms. (See pp. 19, 132, 136.) These springs contribute the large volume of 1,400 second-feet to the flow of Portneuf River. This flow is remarkably constant, varying but little throughout the year and apparently not fluctuating from one season to another. Both Clear Creek and Spring Creek obtain practically all their flow from underground sources, as the area of their drainage basins is insignificant.

Clear Creek follows the edge of the bluff at the western border of the Gibson terrace. The springs which form it are individually small, but the flow probably aggregates 100 second-feet by the time it unites with Ross Fork. These springs do not seem to come out from beneath the terrace but rise from the midst of the plain without apparent relation to topographic features. Spring Creek has its source in a very large spring or group of springs near the south base of Big Butte, a prominent hill near the northwest corner of the reservation, and directly at the foot of the bluff that forms the margin of the narrow remnant of the Gibson terrace which fringes the south slope of the butte. Here a large volume of beautifully clear water wells up in a pool about 50 feet in diameter and flows southward through a marsh. At the bridge on the road from Fort Hall to Tilden Bridge Spring Creek is a deep, swift stream with a volume of perhaps 500 second-feet. Clear Creek practically parallels Snake River throughout the length of the bottoms.

These springs have great economic importance, for they contribute a large volume of water to Snake River at all seasons and furnish a constant supply for the irrigation of the lands around Twin Falls, even when the Snake goes dry at Blackfoot, as it has been known to do in very dry years. Considerable interest has thus been aroused in their origin, and several alternative hypotheses have been suggested to account for them. Their origin is thus attributed to (1) the reappearance of water lost into the underflow by seepage from Blackfoot River; (2) by seepage from Portneuf River; (3) by seepage from Snake River; (4) ground water which has accumulated in the gravels that underlie the Gibson terrace; (5) ground water which has been collected under the Snake River plain to the northwest and which has traveled southeastward along strata interbedded with or underlying the Snake River lava.

In considering the possibility that the water of these springs comes from Blackfoot River, reference must be made to the records of discharge of Blackfoot River which have been cited. It is at once apparent from an examination of the records obtained at the gaging station near Shelley, above all large diversions, that only in occasional months of high yield is the discharge of Blackfoot River as large as the flow of these springs, whereas the mean discharge of the river is in most years only about 10 per cent of the discharge of the springs. Practically the entire flow of Blackfoot River during the summer is diverted and used for irrigation, and the flow in the channel of the river below the head gate of the reservation canal is usually very small.

Investigations have been made by the United States Geological Survey at the request of the Indian Irrigation Service to determine the amount of water lost by seepage from Blackfoot River between the reservoir and the canal head gate. The results of the investigation made in 1909, which covered 42 miles of the river between Rockyford and Presto, indicated a gain of 1.10 second-feet in that distance, making allowance for all tributaries and diversions.[22] The other investigations, in November, 1912, and June, 1913, covered the portion of the river between the gaging station near Shelley, a short distance below Presto, and the head gate of the reservation canal. These investigations showed that no appreciable loss or gain in the flow occurs between these points except as the flow is increased or diminished, respectively, by surface tributaries or diversions. It may therefore be concluded that but little water passes into the underflow from the channel of Blackfoot River and that the volume of the flow of the river is entirely inadequate to feed these springs were it all to pass underground.

Portneuf River, because of large diversions for irrigation and the small volume of flow as compared with the springs, also appears inadequate as a source of supply. Furthermore, the springs are so situated topographically with relation to the river that it is difficult to understand how they can be in any way related.

Another explanation of the flow of the springs is that they represent the reappearance of the water of Snake River which has passed underground at points farther up the stream, perhaps in the irrigated district north of Blackfoot. There are, however, certain facts which are difficult to reconcile with this hypothesis. The springs show no tendency to fluctuate in volume, as would be expected if they were directly related to the flow of the river. Records of stream discharge show that even in the periods of maximum flood on Snake River there is no corresponding increase in the flow of the springs. Even

[22] U. S. Geol. Survey Water-Supply Paper 272, pp. 286–288, 1911.

in seasons when Snake River goes dry at Blackfoot the flow of the springs is practically undiminished.

The springs on the reservation are, however, not the only springs which add to the flow of Snake River between the mouth of Blackfoot River and American Falls. In the vicinity of Tilden and Springfield, on the west side of Snake River, there are a number of large springs which flow out of the Snake River lava, and some of them rise at a considerable elevation above the river. One of these, Donaldson's Spring, rises well toward the top of the lava terrace on the west side of the river at an elevation of about 60 feet above the river. The total volume of the springs on the west side of the river is, however, only a fraction of the total flow of the springs on the reservation.

If this water is derived from Snake River it must have entered the underflow a long distance upstream, for the slope of the river for a number of miles above the springs is small. Allowance must also be made for the difference in head produced by the friction of the water in passing through the rocks. When both these factors are considered it is difficult to see how the water of Donaldson's and other springs west of the river is derived from it.

The topographic relations of the springs on the east side of the river do not conclusively eliminate Snake River as the source of the water. Although perhaps none of the springs are less than 5 feet and some are fully 20 feet above the river, their similarity to springs west of the river makes it improbable that they have an essentially different origin. The fact that it is difficult to show that the springs on the west side have any definite connection with Snake River lends additional weight to the belief that the springs on the east side do not come from that source.

It is apparent that the 100 square miles of drainage area of the Gibson terrace is entirely inadequate to collect the large amount of water which the springs discharge. It is possible that the underflow from the terrace may contribute slightly to the discharge of these springs, but the aggregate from these sources constitutes in all probability but a small addition to their flow.

The hypothesis that the water comes from underneath the Snake River plain to the northwest and has a common origin with the water which flows from the springs on the west side of the river has much in its favor. The lava plains to the west of Snake River which have no surface drainage cover a very large area, 40 to 50 miles in width, that extends from far up the Snake River valley southward and westward across the State. The region that may be regarded as a possible catchment basin for these springs has an area of perhaps 3,000 square miles. It receives an average annual precipitation of 10 inches or more. Because of the extremely rough and broken character of the surface the proportion of the precipitation which enters the lava is doubtless high. To produce a continuous discharge of 1,400 second-feet approximately 1,000,000 acre-feet would have to enter the underflow annually, an amount equivalent to a depth of 6.3 inches on this area. It is well known that Big Lost and Little Lost rivers, which sink on the northwest side of the lava plains, contribute large amounts of water to the lavas. When all these factors are considered it appears that the underflow from this lava area is competent to account for the greater part if not all of the flow of these springs. The flow derived from such a source would be practically constant in volume and subject only to slight annual or seasonal changes.

A difficulty arises, however, in explaining how the water may have been carried eastward under the present channel of the river. As has been previously stated, the western bank of Snake River, throughout practically all that portion opposite the Fort Hall Indian Reservation, is formed by the exposed edge of the uppermost sheet or sheets of the Snake River lava. The river itself flows on a gravel bottom throughout this stretch, and as far as known no lava is exposed in its bed or in the entire plain adjacent to the river. At American Falls, 12 miles southwest, the river drops over the edge of a lower lava sheet, which is exposed on both sides of the river for some distance downstream from the falls. Northward this lava does not appear at the surface. If, however, this lava sheet, which might reasonably be expected to extend a considerable distance northward from American Falls, should project farther to the east than the overlying exposed sheets it may pass concealed under the bed of Snake River and underlie in part the Fort Hall bottoms. Water might then be carried either through the fissures of this lava sheet or through underlying alluvial deposits entirely under the bed of Snake River to the contact of the eastern margin of the lava with the terrace gravels and then follow this contact to the surface. Whatever may be the exact course of this water underground, it appears more reasonable to ascribe these springs to a deep underground source than to explain their origin in the other ways that have been suggested.

UTILIZATION OF WATER.

DOMESTIC USE.

The mountainous portions of the reservation contain abundant supplies of water, which are available for domestic use and for watering stock. It is improbable that the future needs of the reservation will require any extensive development of water for these uses in the more rugged areas. Similarly water can readily be obtained in the Snake River bottoms either from streams or springs or from shallow wells.

On the Gibson terrace permanent and pure water supplies for ranches can generally be obtained by wells that range in depth from 50 to 100 feet. Wells are easily dug, but on account of the looseness of the gravels lining will ordinarily be required to prevent caving. Because of the porosity of the soil, drilled wells carefully cased are preferable to open wells as less likely to become contaminated from surface drainage.

The supply for the agency buildings at Fort Hall is obtained from a well pumped by an electric motor. The railroad water tank at Ross Fork is supplied by a steam pump which has a capacity of 28 gallons a minute.

IRRIGATION.

The principal irrigated areas on the reservation are in the valley of Bannock Creek and on the Gibson terrace, the Fort Hall irrigation project covering nearly all of that part of the terrace between Blackfoot River and Pocatello. The irrigated areas are indicated on the accompanying map.

Bannock Valley.—The ditches which divert from Bannock Creek are all small and each covers not more than three or four Indian ranches. The highest of these ditches diverts from the West Fork south of the reservation boundary and follows the west bank for about 3 miles. A second ditch diverts from the east bank in the NE. ¼ SW. ¼ sec. 22, T. 9 S., R. 33 E., and extends northward about 2 miles. Other ditches divert from Moonshine and Rattlesnake creeks. The largest ditch in the valley has its head gate in the SW. ¼ SE. ¼ sec. 21, T. 8 S., R. 33 E., and covers lands on the east side of the creek for a distance of about 4 miles.

The waters of Bannock Creek were adjudicated by a decree of the United States district court dated April 9, 1907. The Indians of Fort Hall Reservation were awarded a prior right to 16¼ second-feet of water from Bannock Creek, dating from April 1, 1887. Settlers on public lands on the head of Bannock Creek south of the reservation boundary were awarded junior rights, aggregating 19.6 second-feet.

The water right awarded to the Indians has not been extensively utilized, whereas the amount awarded the settlers has been largely put to beneficial use.

Fort Hall irrigation project.—The Fort Hall irrigation project contemplates the ultimate irrigation of 50,000 acres that lie principally on the Gibson terrace in the western part of the reservation. Of this area 38,000 acres are situated within the reservation and

12,000 acres lie south of the reservation boundary in the ceded area near Pocatello.

The project depends for its water supply on Blackfoot and Snake rivers. The waters of Blackfoot River have been appropriated under the laws of the State of Idaho. Applications were filed with the State engineer on September 3, 1907, for permits to appropriate the flow of Blackfoot River for storage in the Blackfoot River reservoir. These permits contemplated the impounding in the reservoir of 200,000 acre-feet annually, an amount approximately equivalent to a continuous flow of 280 second-feet.

By a decree of the district court the Fort Hall irrigation project was also allotted 600 second-feet from Snake River, with a priority dating from December 14, 1891. The water used under this decree is diverted from Snake River in sec. 31, T. 1 N., R. 37 E., near the village of Shelley and carried southward through the Idaho Canal to Blackfoot River. The point of discharge is in sec. 24, T. 2 S., R. 36 E., a few miles above the head gates of the project canals. The Idaho Canal is about 12 miles in length and was constructed with a capacity of 600 second-feet. Its principal use is as a feeder for this project, although large amounts of water wasted from irrigated lands in the vicinity of Blackfoot are carried through it.

The construction of the dam for the Blackfoot River reservoir was commenced in the summer of 1908. The dam (Pl. I, *B*) is situated in the NE. ¼ sec. 12, T. 5 S., R. 40 E., about 50 miles southeast of the city of Blackfoot. It is 40 feet in height above the bed of the river, 120 feet long at the bottom, and 250 feet long on the crest. It is a combined rock-fill and hydraulic-fill structure, with a concrete core wall, and the reservoir side is paved to prevent erosion. The outlet is through a tunnel at the south end of the dam, 200 feet long, which is lined with concrete and has a cross section of 90 square feet. The spillway is excavated in rock at the north end of the dam and has a width of 50 feet. The reservoir is about 17 miles in length and over 5 miles in maximum width, with an area of 15,000 acres and a capacity of 200,000 acre-feet. On June 30, 1916, it contained approximately 132,000 acre-feet of stored water.

The water released from storage is carried in the channel of Blackfoot River a distance of about 50 miles to the head gates of the two main canals of the project. The upper canal, which heads about 2 miles east of Blackfoot, was designed to carry 400 second-feet and to irrigate 30,000 acres. The heading is a rock-fill dam, in which are placed six concrete head gates. The canal follows the foothills on the east side of the project, extending in a southerly direction nearly to Pocatello. Ross Fork is crossed by a concrete siphon 133 feet long. A high area, situated principally on ceded lands south of the reservation, is reached by a concrete siphon 4,500 feet long, which has a capacity of 200 second-feet. The lower canal covers about 20,000 acres between Blackfoot River and Ross Fork. It heads about a mile below the upper canal and has a capacity of about 250 second-feet. Its length is 10.5 miles.

As by far the greater part of the irrigable lands of the project is held by Indians, many of whom were not accustomed to irrigation farming, the agricultural development of the area has not been especially rapid. In the season of 1915, 18,542 acres were irrigated, of which 9,005 acres were in the ceded area; 7,447 acres were irrigated by the 209 Indian farmers on the project. Approximately 91,000 acre-feet of water was diverted from Blackfoot River in 1915, giving a duty of nearly 5 acre-feet at the point of diversion.

As the project is further developed and new lands are brought under cultivation the total amount of water required will necessarily increase, although after the soil is saturated the duty should be higher. It is probable that the project will ultimately require the diversion from Blackfoot River of 200,000 acre-feet annually. The length of the irrigation season is about 180 days from April 20 to October 10. In 1915 the percentage diversions by months were approximately as follows: April, 6; May, 14; June, 18; July, 29; August, 17; September, 11; and October, 5.

Portneuf project.—The portion of the Gibson terrace that lies on the south side of Portneuf River and extends toward American Falls is an area of excellent agricultural land which would become highly productive with irrigation. Approximately 40,000 acres of this land could be irrigated by a canal that would divert water from Portneuf River in T. 7 S., R. 35 E., about 10 miles southeast of Pocatello. The location of the canal follows the south bank of the river for a distance of about 16 miles before any irrigable lands are reached. An alternative plan of irrigation involves pumping from the Portneuf about 4 miles northeast of Pocatello. Under either plan the flow of Portneuf River during the irrigation season would have to be largely increased by providing additional storage in the upper drainage basin of that stream or by the diversion into the Portneuf of additional water from an adjacent drainage basin.

Fort Hall bottoms.—In the event that the American Falls reservoir is not constructed the irrigation of a portion of the Fort Hall bottoms by the diversion of the waters of Spring Creek appears possible. Surveys which would demonstrate the feasibility of such a plan have not been undertaken. The sheltered situation of the lands of the Fort Hall bottoms below the general level of the plains on either side gives them a somewhat more favorable climate which might be well adapted to growing the hardier fruits.

WATER POWER.

The water powers of the Fort Hall Indian Reservation are undeveloped, and their utilization, when it is accomplished, must be coordinated with the higher use of water for irrigation. The location of power plants and the amount of power which can be obtained are thus to a high degree dependent on the course of future irrigation development, some of the possibilities of which have been discussed.

Snake River.—The fall of Snake River along the western boundary of the reservation is but little more than 2 feet to the mile. No concentrations of fall which would afford opportunity for power development and no feasible dam sites occur along this portion of its course. At American Falls, 7 miles west of the reservation, a feasible dam site exists in secs. 19 and 20, T. 7 S., R. 31 E. A dam at this site with a height of 90 feet would create a reservoir with an estimated capacity of 3,036,000 acre-feet of water. The area overflowed would be approximately 70,000 acres, of which about 30,000 acres are within the reservation, the remainder being mainly private holdings.

This reservoir site is one of the principal features of the Bruneau extension irrigation project, by which it is proposed to irrigate a large tract of arid land that lies on the south side of Snake River between Salmon Falls Creek and Bruneau River. The water impounded in the American Falls reservoir would be released as required and permitted to flow down the channel of Snake River to Milner dam, the present diversion point of the Twin Falls irrigation systems. From the Milner dam the water would be conducted about 60 miles through the main canal to Salmon Falls Creek, beyond which the irrigable lands of the project are situated.

The flow of Snake River is in normal years greatest during May, June, and July, and in many years half of the annual discharge has occurred during those months. The normal flow up to the middle of July is thus largely in excess of the established demands for irrigation. After that time the flow decreases rapidly and becomes insufficient to supply all the lands dependent on the river. In consequence it is necessary to supply this deficiency by the storage of water during the early part of the irrigation season for release during the period of shortage. The United States Reclamation Service has constructed two reservoirs for this purpose, one at Jackson Lake, in northwestern Wyoming, the other, Lake Walcott, about 30 miles southwest of American Falls, Idaho. These reservoirs by no means impound all the surplus waters of Snake River, and it has been estimated that on the average about 1,400,000 acre-feet passes down Snake River during the irrigation season unutilized. In addition the normal flow during the nonirrigation season in an average year is about 2,500,000 acre-feet, which makes a total of nearly

4,000,000 acre-feet now undiverted. In storing and making available most of this surplus flow the American Falls reservoir would serve an important function in the conservation of the flow of Snake River.

The construction of the reservoir and the attendant irrigation project is, however, a very large financial undertaking. The construction of the dam alone will require an outlay of several million dollars. It is probable that considerable time will elapse before the financing of the project can be accomplished. The magnitude of the project may even be so great as to make it unattractive to private capital and construction may have to await action by the Government.

Aside from its value for irrigation the American Falls reservoir would have an important effect on the development of water power on Snake River between American Falls and the Milner dam. Three power plants are now in operation in that portion of the river, two at American Falls and one at the Minidoka dam of the Reclamation Service, and there is a good water-power site about 6 miles below American Falls. The storage of water in the American Falls reservoir for irrigation use would tend to concentrate the flow of Snake River in the irrigation season and would consequently reduce the flow and the power output during the winter. Very large amounts of power would, however, be made available for irrigation pumping and the flow during the irrigation season would be so regulated as to permit more nearly complete utilization for power during that period than is now possible. The release from storage during the winter of 1,000 second-feet would, however, provide a large power output during that period, and it is possible that water so released could be impounded in reservoirs below the power plants and thus conserved for irrigation during the following season.

If the American Falls reservoir were developed it would overflow a large area of bottom lands adjacent to the river, and the shore of the reservoir would be approximately indicated by the 4,400-foot contour line. The Indians would thus be deprived of a peculiarly valuable part of the reservation. After the development of the Fort Hall project, however, the Indians will be less dependent on the bottom lands for winter feed for their cattle, and a few years hence the reservoir might be constructed without serious disturbance of the economic relations of the Indians.

Blackfoot River.—If considered as a source of water power, the portion of Blackfoot River which forms the north boundary of the Fort Hall Reservation is divisible into three portions, as follows: (1) From its intersection with the east boundary of the reservation on the line between Rs. 38 and 39 E. to the mouth of the canyon near the east line of sec. 11, T. 2 S., R. 37 E.; (2) from the mouth of the canyon to the upper diversion dam of the Fort Hall project; (3) from the upper diversion dam to the mouth.

The upper section is approximately 12 miles long. The total fall through this distance is about 800 feet, an average of approximately 67 feet to the mile. The existing surveys are not sufficiently detailed to show the distribution of this fall, but in some portions it appears to be fully 100 feet to the mile. Throughout this portion of its course the river flows through a deep narrow canyon, the rim of which is generally formed by a lava flow and the lower slopes by the talus from the lava cliffs. A view of the lower portion of the canyon showing its relation to Snake River valley is shown in Plate XII, *A*.

The second section is about 14 miles long. The total fall of the river is about 200 feet, or 15 feet per mile, and is quite uniformly distributed. The stream is bordered by agricultural lands throughout this stretch.

In the 10 miles that comprise the third section of the river the fall is small, only about 5 feet per mile. The banks are low and in many places are formed by sand bars and dunes.

The flow of Blackfoot River before it was regulated for irrigation by the construction of the Blackfoot River reservoir and the construction of diversion canals, ranged from a maximum of perhaps 2,500 second-feet early in the spring to a minimum of about 65 second-feet late in the summer. The minimum winter flow appears to have been about 100 second-feet. As regulated for irrigation, however, the regimen of the stream is materially changed. During the winter the flow of the river is greatly reduced by the impounding of water in the reservoir, but about 10 second-feet has been permitted to pass the dam during this period in order to save the fish in the river. The winter flow between the reservoir and the mouth of Sand Creek is thus confined to the small quantity permitted to pass the dam and the inflow of tributaries below the reservoir. Measurements of the flow of Corral and Grove creeks, which enter the river between the dam and the east line of the reservation, indicate that the minimum flow at the east line of the reservation will be approximately 30 second-feet. Wolverine Creek is fed by springs and has a minimum flow of about 13 second-feet. Cedar Creek and other small tributaries contribute about the same amount, so that the total flow at the mouth of the canyon will, under regulation for irrigation, be about 60 second-feet from the middle of October till the later part of March.

In the irrigation season the flow will correspond approximately to the irrigation demand, reaching a maximum of about 1,000 second-feet in July and averaging about 600 second-feet from about the first of May to the first of October. Below the outlet of the Idaho canal and above the head gate of the irrigation project the flow during the irrigation season may be further increased by the water brought through the canal from Snake River. The diversion of water at the head gate of the project will greatly reduce the flow below that point. Under present conditions the flow of Blackfoot River below the diversion point is as low as 50 second-feet during the irrigation season, and with the more complete development of the project it is probable that the summer flow will become negligible.

When the data above given relative to the discharge, slope, and topography of the river are considered together it becomes apparent that in the lower section of the river, below the head gates of the project, the development of water power is impracticable. In the middle section the character of the valley is such as to make the construction of dams impracticable, for a relatively low dam would cause the flooding of large areas of agricultural land. Such a dam would give opportunity for the development of only a small amount of power and the unit cost would be prohibitive.

In the upper section, however, in the canyon, certain conditions are somewhat more favorable to the development of power. Throughout the canyon the topography favors the construction of dams, the walls being in places nearly vertical (Pl. XII, *B*). At the mouth of the canyon a dam 100 feet in height would, according to La Rue, have a length of approximately 250 feet on the bottom and 350 feet on the top. Nothing is known, however, of the possibility of obtaining good foundations at this and at other similar sites through the canyon. With an effective head of 90 feet approximately 5,000 continuous horsepower can be developed at this site for about six months in the year and about 500 continuous horsepower during the remainder of the year. If a market could be developed for irrigation pumping or the plant were interconnected with other plants, it is probable that development at this site would prove feasible.

The lands adjacent to this portion of Blackfoot River have been reserved for the purpose of retaining control of the development of water power. The Secretary of the Interior is, however, authorized to give permission for such development on terms which he may regard as protecting the public interests.

Bannock Creek.—In its upper portion Bannock Creek has a rapid fall. The flow of the creek is well sustained throughout the summer, and late in the fall its total discharge is over 30 second-feet. As this flow is largely derived from springs it probably is not greatly reduced during the winter, although no winter measurements are available.

The most practicable plan of power development appears to be by conduit. If the water were diverted in the southern part of T. 9 S., R. 33 E., at an elevation of 5,015 feet and carried northward along the east side of the valley a distance of about 10 miles, a head of about 320 feet could be obtained at a power house located in sec. 22, T. 8 S., R. 33 E. The flow of the east and west forks of Bannock Creek, augmented by that of Rattlesnake, would probably warrant a conduit capacity of 35 second-feet. About 875 horsepower could be developed at a cost which preliminary estimates indicate would be very reasonable. This power development can be accomplished practically without interference with the development of irrigation in the Bannock Valley.

Below the point of return of this proposed power development the flow of the creek is largely diverted during the summer for irrigation. The slope is also much less, so that the lower portion of the creek affords no sites for power development.

Portneuf River.—In the upper portion of its course Portneuf River flows through a broad, marshy valley, with a slight fall. The discharge is small, and no feasible power sites are recognized in this portion of the river. After leaving Portneuf Valley the river has in many places a steady gradient and affords opportunity for the development of power, but none of these sites are within the reservation.

The lower portion of the river, west of Pocatello, has only a slight fall. The normal flow during the irrigation season is largely diverted for irrigation, and, as the Chesterfield reservoir of the Portneuf-Marsh Valley Irrigation Co. stores much of the winter flow the possibility of developing power on the lower portion of Portneuf River is unattractive.

Ross Fork.—On the North Fork of Ross Fork there is a small power site, where it is reported that a head of 284 feet can be obtained in a stretch along the stream of about 2 miles. The available flow is probably about 10 second-feet, except in times of extreme low water, and approximately 260 horsepower can be developed on the wheel shaft. This site has been considered by the Indian Service as a source of power for the buildings of the reservation headquarters. The lands which will be required for this development have been reserved.

Lincoln Creek.—Except in its headwaters, Lincoln Creek has only a moderate fall. The low-water flow is about 3 second-feet and sinks before it reaches Blackfoot River. The power possibilities of this stream are therefore unimportant.

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