Pamphlet No. 11.

STATE OF IDAHO
Chas. C. Moore, Governor

BUREAU OF MINES AND GEOLOGY
Francis A. Thomson, Secretary

GEOLOGY AND WATER RESOURCES

OF THE

BRUNEAU RIVER BASIN

OWYHEE COUNTY, IDAHO

By Arthur M. Piper

Prepared in cooperation with the
United States Geological Survey.

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GEOLOGY AND WATER RESOURCES
of the
BRUNEAU RIVER BASIN, OWYHEE COUNTY, IDAHO

By Arthur M. Piper

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INTRODUCTION.

Purpose and scope of the survey.

The report at hand presents the findings of two months of field work in the Bruneau River basin by the writer, assisted by Messrs. H. L. Powell and Rollin Farmin, during July, August, and September, 1922. The investigation was made in response to requests for information regarding the possibility of developing additional ground water for use in irrigation. It was carried out by the Idaho Bureau of Mines and Geology cooperating with the United States Geological Survey as one unit of an extensive study of the ground water resources of the State.

The survey comprised a one-week's geologic reconnaissance of the drainage area of Bruneau River within the State of Idaho, and a study in moderate detail of the geology and ground water conditions of the lower Bruneau River basin and of Little Valley. The extent of these areas is delineated under the heading Location of the area and is shown on the key map, Plate 1.

One week's time was obviously too brief for anything more than a very general reconnaissance and no attempt was made to map the entire drainage area. The conditions existing in lower Bruneau River basin and Little Valley, however, are plotted on the map (Pl. II), which accompanies this report. The base of the map was compiled from the township plats of the United States General Land Office. Detail was added in the field by compass and automobile speedometer, and by plane table triangulation and stadia traverse. The locations and elevations of the wells shown were determined by plane table stadia traverse controlled by an unsupported line of levels extended along the axes of Bruneau Valley and of Little Valley. The datum of this line of levels is a bench mark[1] established in 1911 by the General Land Office and located

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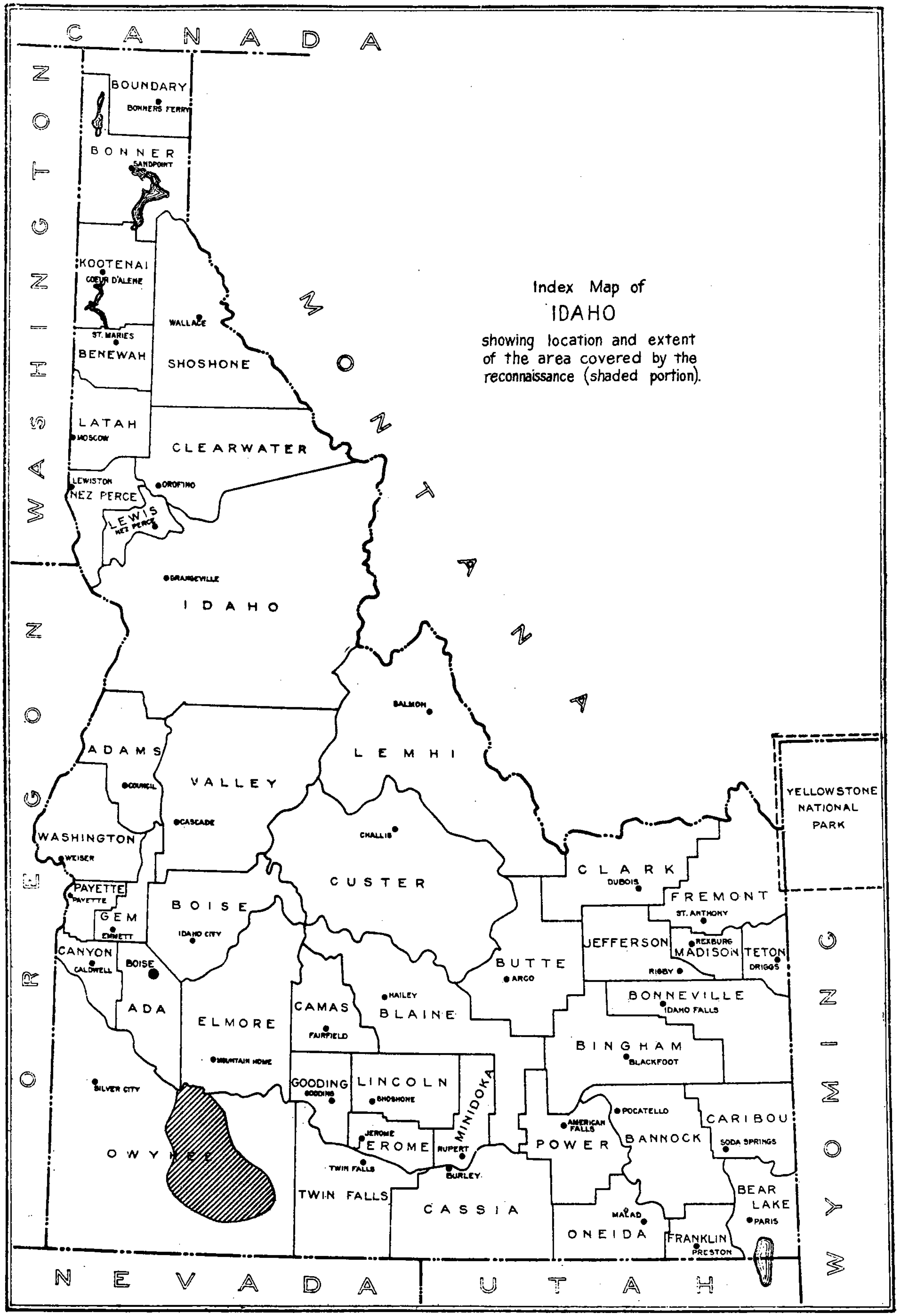
[1] Results of spirit leveling in Idaho: U. S. Geol. Survey Bull. 567, p. 100, 1915.


Index Map of
IDAHO
showing location and extent of the area covered by the reconnaissance (shaded portion).
CANADA
WASHINGTON
OREGON
MONTANA
WYOMING
NEVADA
UTAH
YELLOWSTONE NATIONAL PARK
BOUNDARY
BONNERS FERRY
BONNER
SANDPOINT
KOOTENAI
COEUR D'ALENE
WALLACE
ST. MARIES
BENEWAH
SHOSHONE
LATAH
MOSCOW
CLEARWATER
LEWISTON
NEZ PERCE
OROFINO
LEWIS
NEZ PERCE
GRANGEVILLE
IDAHO
SALMON
LEMHI
ADAMS
COUNCIL
VALLEY
CASCADE
WASHINGTON
WEISER
CHALLIS
CUSTER
CLARK
DUBOIS
FREMONT
ST. ANTHONY
PAYETTE
PAYETTE
GEM
EMMETT
BOISE
IDAHO CITY
CANYON
CALDWELL
BOISE
JEFFERSON
REXBURG
MADISON
TETON
DRIGGS
RIGBY
BUTTE
ARCO
BONNEVILLE
IDAHO FALLS
HAILEY
ADA
ELMORE
CAMAS
FAIRFIELD
BLAINE
BINGHAM
BLACKFOOT
MOUNTAIN HOME
SILVER CITY
GOODING
GOODING
LINCOLN
SHOSHONE
MINIDOKA
POCATELLO
AMERICAN FALLS
CARIBOU
JEROME
JEROME
RUPERT
POWER
BANNOCK
SODA SPRINGS
OWYHEE
TWIN FALLS
BURLEY
BEAR LAKE
TWIN FALLS
CASSIA
MALAD
PARIS
ONEIDA
FRANKLIN
PRESTON

25 feet northwest of the Hot Springs-Grasmere road in Sec. 28, T. 7 S., R. 6 E.; on Plate II, it is marked "B. M. 2903."

Previous geologic work.

This investigation has been preceded in Bruneau River basin by the work of Russell and Schrader, Federal geologists, whose published reports[2] have assisted in the preparation of this paper. The typescript report of a reconnaissance by Stearns[3], also of the staff of the United States Geological Survey, describes an area a short distance northwest of the Bruneau Basin, and has also been consulted.

GEOGRAPHY.

Location of the area.

The drainage area of Bruneau River lies in southwestern Idaho and north central Nevada, south of Snake River, of which stream it is a tributary. The area covered by reconnaissance comprises about 1650 square miles in eastern Owyhee County, Idaho; it lies between the 42d and 43d parallels of latitude and its western boundary approximately coincides with the 116th meridian of longitude. The lower Bruneau River basin, including Little Valley, has an area of about 285 square miles; of which about 18,000 acres is irrigable land. It lies south of the 43d parallel of latitude and is bounded on the west by the 116th meridian of longitude. The lower Bruneau River basin comprises the area shown on Plate II; and extent of the total area examined is indicated by the shaded area on Plate I.

Population and settlements.

The population of the Bruneau River drainage basin in 1920 was 806. The principal settlement is the village of Bruneau, in sec. 24, T. 6 S., R. 5 E. and sec. 19, T. 6 S., R. 6 E., containing a post office, bank, school, hotel, garage, several stores, and a weekly newspaper. Bruneau precinct had a population of 471. Hot Spring precinct had a population of 152 with post office, in sec. 22, T. 7 S., R. 6 E., and a school. Three Creek precinct had a population of

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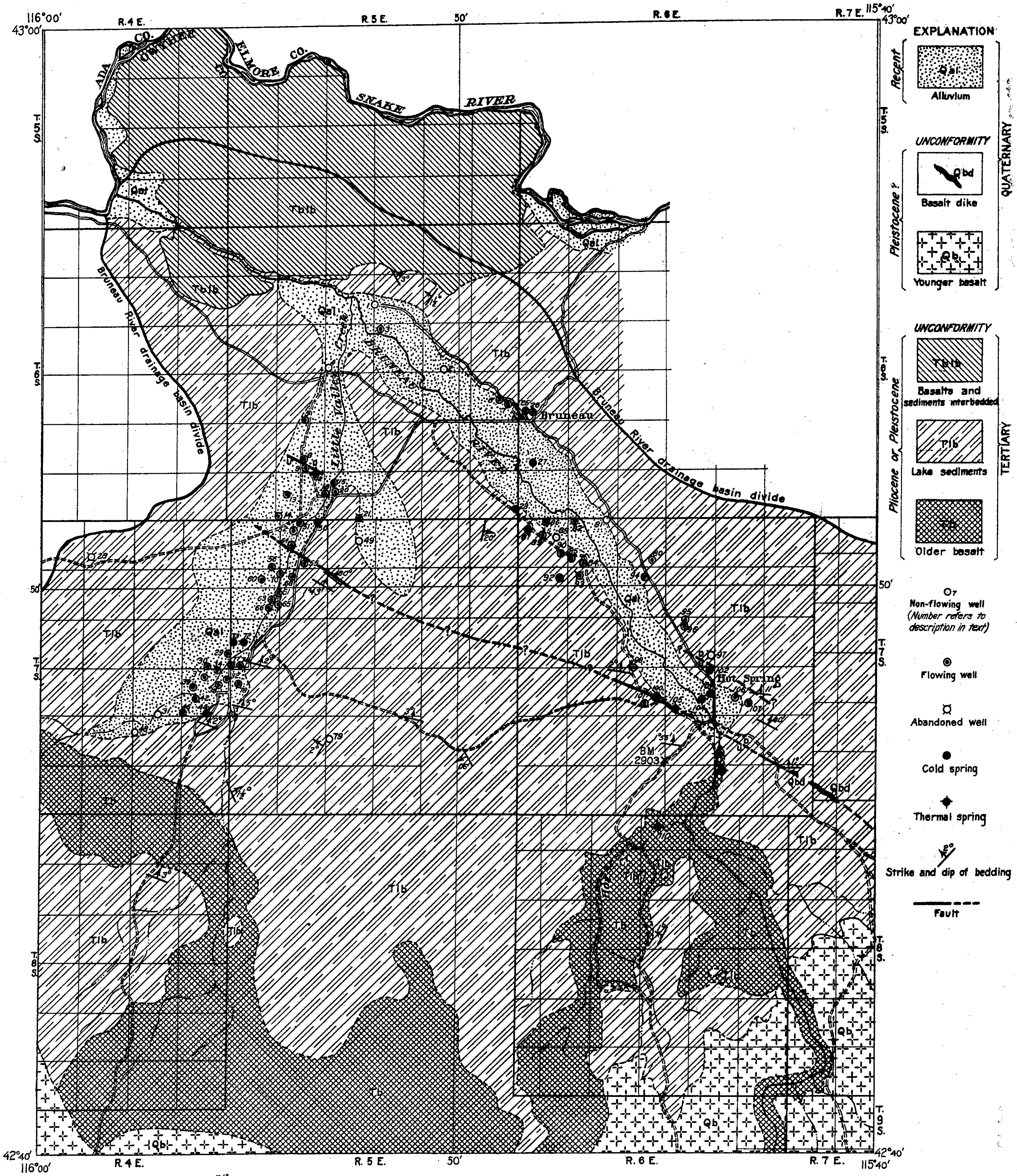
[2] Russell, I. C., Geology and water resources of the Snake River Plains of Idaho: U. S. Geol. Survey Bull. 199, 1902.
Russell, I. C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Water-supply Paper 78, 1903.

[3] Stearns, H. T., Artesian water near Grandview, Owyhee County, Idaho: 1922. (Unpublished manuscript.)



Base from U.S.G.L.O. plats and planetable traverses by A. M. Piper, H. L. Powell, and R. Farmin. Compiled at Moscow, 1922, by A. M. Piper.

TRUE NORTH — MAGNETIC NORTH — 19½°
APPROXIMATE MEAN DECLINATION 1922

1 ½ 0 1 2 3 4 5 Miles

DIAGRAM OF TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Geology by A. M. Piper. Surveyed in 1922. In cooperation with United States Geological Survey.

Geologic map of lower Bruneau River basin, Owyhee County, Idaho

106, with post office and store in T. 16 S., R. 11 E. Grasmere precinct had a population of 77 with a store in sec. 20, T. 12 S., R. 5 E. Another post office is located at Tindall in T. 13 S., R. 5 E. Other settlements, whose population is included in the precincts already described, are Wickahoney in T. 11 S., R. 4 E., Clover Flat in sec. 23, T. 11 S., R. 9 E., and Grassy Hill in T. 14 S., R. 11 E.

The industries are wholly agricultural. During the summer months alfalfa hay and grain are raised on the irrigated land along the streams, and cattle, horses, and sheep are grazed in the mountains lying south and west of the area studied. Some of the alfalfa is raised for seed and the remainder fed during the winter months to the stock that is brought down from the summer range.

Access, communication, and transportation.

No railroad traverses any portion of the Bruneau River basin, the nearest railroad station being Mountain Home, on the main line of the Oregon Short Line Railroad. An automobile stage carries mail, passengers, and express, between Mountain Home, Bruneau, and Hot Spring, daily except Sunday. From Rogerson, the terminus of a branch of the Oregon Short Line, a tri-weekly stage runs to Three Creek and Jarbidge, Nevada. A bi-weekly stage goes between Bruneau, Tindall, and Riddle, the summer route being thru Wickahoney and the winter route by Hot Spring and Grasmere; Riddle, the terminus of the route, lies west of the Bruneau drainage basin.

The one direct route of access to Bruneau from the north is the stage road from Mountain Home, bridging Snake River near the mouth of Rattlesnake Creek, and crossing the low divide into Bruneau basin; the entire distance of 25 miles is well graded and graveled. Automobile roads radiate from Bruneau to the south, southwest, and west. A graded but poorly graveled road runs due west from that town a distance of two miles, inclines to the northwest across Little Valley and onward to Snake River near the mouth of the Bruneau, thence westward along the Snake to the town of Grandview. An ungraveled stage road used during the summer months branches from this route and runs southwestward up Little Valley about 15 miles, thence southward 20 miles along the divide east of Wickahoney Creek and up the Creek to Wickahoney, thence southward and eastward 15 miles to Tindall, and 19 miles farther to Riddle. A good automobile road leads southward along the east side of Bruneau Valley to Hot Spring, a distance of 9 miles. From Hot Spring a fair road bridges Bruneau River, crosses the divide into Hot Creek, follows the bed of that stream to its head and continues southward, a total distance of 39 miles to Grasmere, thence southward about 8 miles to Tindall; this is the route followed during the winter months by the Bruneau-Tindall stage. From the bridge over Bruneau

River in sec. 28, T. 7 S., R. 6 E. another road in fair condition trends southeast and crosses the East Fork of Bruneau River at Clover Flat, 42 miles from Hot Spring; thence it leads southward and eastward on a course west of the river and parallel to it for 24 miles, re-crosses the river to the eastern side, and continues southward 7 miles to Three Creek. The latter settlement lies on the Rogerson-Jarbidge stage road 37 miles westward and southward from Rogerson and is the point of access to the Bruneau basin from the east.

Wagon roads, in varying stages of disrepair, are several. One branches from the Bruneau-Tindall stage road in sec. 33, T 6 S., R. 5 E., crosses Little Valley Creek, and courses westward over a divide into the basin of Shoofly Creek. Another leads westward from Grasmere about 8 miles, crosses Sheep Creek, and courses southward parallel to the West Fork of Bruneau River about 35 miles to Rowland, Nevada. Two others branch from the Hot Spring-Clover Flat road; one trends eastward from sec. 5, T. 8 S., R. 7 E., into the basin of Pot Hole Creek, a tributary of Snake River; the second leads southward and southeastward from sec. 8 of the same township about 17 miles and rejoins the Hot Spring road in sec. 15, T. 10 S., R. 8 E. Any of the roads may with difficulty be followed with an automobile.

Bruneau and Hot Spring have a local telephone system connecting at Mountain Home with the trunk lines of communication by telephone or telegraph. Electric power is supplied to Bruneau by a transmission line from Mountain Home.

Climate.

Within the Bruneau River basin there exist widely variant climatic conditions as a consequence of the great variation in altitude, about 8000 feet, between the summit of the mountainous headwater divide and Snake River, the master stream. In the lower basin, aridity and mild seasons are characteristic; in the headwater region, humidity and rigorous seasons prevail.

Climatological observations have been recorded for varying periods by the United States Weather Bureau at several stations in and near the region under discussion. The data compiled at Hot Spring, and for Silver City, in the Owyhee Mountains west of the basin, will approximate the respective normals for the lower basin and for the headwaters; they are tabulated below.

Table 1.--Average monthly and annual precipitation, in inches, at stations in or near the Bruneau River basin, Idaho.

Station	Hot Spring	Silver City
Elevation	2590 ft.	6280 ft.
years of record	1906--'18	1902--'18
January	1.04 in.	3.60 in.
February	0.87	2.85
March	.65	1.62
April	.87	1.95
May	.72	2.19
June	.89	1.70
July	.50	0.92
August	.16	.34
September	.55	.69
October	.78	1.40
November	.84	2.80
December	.75	3.80
Annual	8.62	23.14

Table 2--Average maximum, mean, and minimum monthly and annual temperatures at Hot Spring, Idaho.[a]

	Maximum	Mean	Minimum
January	57.9 F.	32.4 F.	0.6 F.
February	58.1	37.4	15.5
March	75.1	45.7	20.7
April	83.9	53.3	28.9
May	90.6	58.4	27.9
June	98.1	65.7	36.1
July	102.5	74.5	43.6
August	100.3	72.7	43.5
September	92.6	62.8	34.1
October	83.4	52.7	23.1
November	71.1	42.5	14.1
December	53.5	31.8	3.4
Annual	102.5	52.5	-3.8

[a]For the years 1909-1916.

The data from which the tabulated means were compiled do not represent a period of sufficient duration to disclose cyclic variations. The mean annual precipitation at Hot Spring is 8.62 inches and at Silver City is 23.14 inches, the marked difference resulting from the greater elevation of Silver City. At both stations the maximum monthly precipitation generally occurs in January and the minimum in August. The average annual range of temperature for the eight-year period 1909-1916, is from -3.8 F. to 102.5 F.; July is the hottest month and January or December the coldest. The extreme recorded annual range is about 115 F.

The average frost-free period at Hot Spring, based on observations extending over a twelve-year period, is 148 days; the average date of the latest killing frost in spring is May 17 and of the first in autumn is October 12. Killing frosts have occured as late as June 12 and as early as September 14, but the shortest frost-free period is 128 days. The secure growing season is long, nearly five months. The mean temperature during the period is about 65 F. These two facts unite in making the lower Bruneau River Basin well suited to the growing of crops of diverse nature.

Soil.

The flood plains of the lower Bruneau River basin and of Little Valley are mantled with a fine rich soil derived from soft sandstones and shales. When watered, the soil is very productive. Alkali concentration is low and very seldom interferes with the growing of crops. The long growing season, which has been described under the heading Climate, makes the district one of promise wherever water for irrigation is available.

Vegetation and animal life.

Bruneau River basin, within the region studied, is almost devoid of trees; cottonwoods and a very few cedars are found at places along the lower portions of the stream canyons. The flood plains of Bruneau River and of Little Valley, where not cleared, are covered with vigorous greasewood (Sarcobatus vermiculatus), with which are interspersed various small edible plants and grasses. Sagebrush (Artemisia tridentata) grows profusely over the upland areas and on the intermediate slopes. Grasses grow along the water courses and cover the beds of the "dry lakes" of the plateau. Wild rose bushes grow in the lowlands at a few localities where the moisture is sufficient; these will be discussed further under the heading Area of vegetal discharge.

With the exception of the stealthy coyote, large animals are very few. Horned toads and various lizards are frequently met on the arid plateau, and the venomous rattlesnake is still occasionally encountered. Cranes and other water birds are commonly met along the streams; the hawk, owl, and other birds of prey are equally frequent over the lower basin.

PHYSIOGRAPHY.

Drainage system.

The master stream to which Bruneau River is tributary is Snake River, which drains the whole of southern and central Idaho and flows westward in a gentle curve concave to the north 350 miles across the State. Here and there along its course the stream flows in box canyons and at the western boundary of the State it turns northward on its way to the Pacific and plunges into a canyon which attains a maximum depth, 75 miles north of Weiser, of approximately 8000 feet.

Bruneau River heads in the lofty Jarbidge and Elk mountains of northern Nevada and is separated by that range from the waters of the Great Basin which is contiguous with the Bruneau basin on the south. From their heads within Nevada, the forks converge slowly to the north, and from the junction their combined waters flow north-northwestward to Snake River, a total distance of about 105 miles.

The west or main fork of Bruneau River rises in the Jarbidge Mountains, enters Idaho from Nevada in T. 16 S., R. 7 E., and flows nearly due north a distance of 20 miles to point at which it is joined by Jarbidge River. The latter stream crosses the State line 13 miles east of the West Fork and courses 30 degrees west of north to the point of confluence. Sheep Creek, the westernmost tributary, leaves Nevada about 14 miles west of the West Fork crossing, flows northeastward and northward and joins West Fork about five miles north of the mouth of Jarbidge River. From the mouth of Sheep Creek, the West Fork follows a due northerly course about 15 miles to its confluence with the East Fork. The East Fork of Bruneau River heads against the northwestern slope of the Elk Mountains in a number of tributaries which enter Idaho in the vicinity of Three Creek, about 11 miles east of Jarbidge River. From Three Creek the stream trends slightly west of north to Clover Flat, thence northwest to th junction with the West Fork, a total distance of about 50 miles. From the junction of its two forks, the Bruneau flows north-northwestward a distance of 35 miles to Snake River; the last 30 miles of its course is shown on Plate II.

The northwestern lobe of the basin is drained by Little Valley Creek, and its two tributaries, Jacks Creek and Wickahoney Creek. These two streams head in T. 10 S., R. 2 E., flow northeasterly approximately 20 miles, and unite in Little Valley Creek. The later continues northeastward about 13 miles and empties into Bruneau River in sec. 9, T. 6 S., R. 5 E.

Topographic features.

Bruneau basin is divisible into several portions characterized by very different topographic features. Jarbidge and Elk Mountains form a lofty range culminating in a rugged crest nearly 11,000 feet above sea level. From their base a broad, nearly level piedmont plain extends northward a distance of 55 miles and slopes sharply into the basin in which the town of Bruneau is situated. Northward from Bruneau this basin converges into a narrow canyon leading to the master stream, Snake River.

<u>Jarbidge and Elk Mountains</u>.--The mountain range of which Jarbidge and Elk Mountains are the high points, extend for 50 miles across the heads of Bruneau River and marks a gentle curve concave toward the northwest. This lofty ridge lies wholly in the State of Nevada and is well described by

Schrader[4]. The mountains are of the massive rounded type carved by sub-aerial erosion in horizontally deposited volcanic rocks, in the case of the Jarbidge Mountains, and in uplifted, tilted and folded sedimentary rocks in the Elk Mountains. The topography is characterized by long, high, sometimes narrow ridges with smooth, rounded slopes, separated by deep valleys and gulches mostly V-shaped in cross-section bounded by slopes rising in places at angles of nearly 45°. These ridges trend north-northwesterly along lines controlled by fissuring and faulting and harmonize with the trend of the Great Basin topography on the south. Moderately heavy precipitation on the mountain slopes results in vigorous erosion by the streams, both headwater and lateral, and in the bold slopes and occasional escarpments of an adolescent surface.

Piedmont plain.--From the base of this mountain range a piedmont plain extends northward nearly 50 miles toward the plains of Snake River. From an elevation of nearly 6000 feet at the Idaho-Utah boundary line it descends northward in a long gentle slope to an elevation of approximately 3500 feet at the rim of the lower basin of Bruneau River, an average grade of 45 or 50 feet per mile. This slightly undulating plain is dissected by the deep V-shaped canyons, in places box-like, occupied by the roughly parallel northward-flowing branches of Bruneau River. The dissecting canyons vary in depth from 1200 feet near the State boundary line to about 800 feet north of the junction of East and West Forks. Northward from the point of junction Bruneau River flows for nearly ten miles in a very remarkable gorge known as Ninemile Canyon. This cleft is eroded to a depth of approximately 800 feet in a thick series of dense basaltic lavas, and is a classic example of a precipitous-walled box canyon. A wagon road approaches very closely to the eastern rim in sec. 31, T. 8 S. R. 7 E., as may be seen from an inspection of the map (Pl.II).

The gulches and ridges of the mountain mass to the south were in existence before the outpouring of the basaltic lavas that comprise the plain, and controlled the courses of the streams as they began their dissective work. Due both to the resistance to erosion of the basalt and to the slight precipitation in this portion of the basin, the intermittent lateral tributaries have worn only shallow channels. Only the master streams have been eroding vigorously, and that in deepening rather than widening their channels.

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[4]Schrader, F. C., A reconnaissance of the Jarbidge, Contact and Elk Mountain mining districts, Elk County, Nevada: U.S. Geol. Survey Bull. 497, pp. 21-27 and 151-152, 1912.

Schrader, F. C., The Jarbidge mining district, Nevada: U. S. Geol. Survey Bull. 741, pp. 7-12 and 78-83, 1923.

Lower Bruneau River basin.--Wherever erosion has removed the protecting basalt cap from the underlying lake sediments- a basin of relatively gentle relief is found. Such a depres- sion below the general level of the plain is that occupied by the lower reaches of Bruneau River and by Little Valley. From the rimof the piedmont plain about 12 miles south of Bruneau it extends 14 miles northward to a small lava-capped mesa which merges northward into the plains of Snake River. Alluvial plains one to two miles wide comprise the valley floors, from which low rounded hills and ridges rise in slopes only occasionally interruped by terraces of some erosion- resistant stratum. To the east and to the west the ephemeral tributary gulches terminate against slopes rising abruptly to the drainage divides. Rapid lateral erosion in the soft lake beds has reduced the surface of this basin to adolescence or early maturity. The extent of this topographic division coin- cides with the areas of alluvium and of lake sediments shown on Plate II.

Lower Canyon of Bruneau River.--Two miles north of Brun- eau the river flood plain terminates abruptly against a small lava-capped mesa separated by the canyon of Snake River from the extensive basalt-covered plain north of the latter stream. Across the southwestern lobe of this meas, Bruneau River scribes a narrow canyon about 2½ miles long and 450 feet deep, and emerges from it only 1½ miles before emptying into Snake River, at an elevation of 2440 feet.

STRATIGRAPHIC GEOLOGY.

General Character and succession of the rocks.

The rocks of the Bruneau River drainage area comprise a basement of granitic rocks, of Cretaceous or early Eocene age, intruded into a series of metamorphosed Paleozoic sediments. These rocks are unconformably overlain by three groups of Tertiary volcanic and sedimentary rocks. These several groups are separated from one another by unconform- ities and are comprised of a massive rhyolite poured out during early Miocene (?) time, a complex of rhyolite flows and tuffaceous and sedimentary rocks possibly of late Miocene age, and a third series of Pliocene sediments interbedded with basalt. This Tertiary terrane is concealed over large areas by basaltic lavas extruded during Pleistocene time and unconformable with the underlying rocks. The most youthful geologic formation is the Recent alluvium comprising the flood plains of the lower reaches of the streams.

The tilted and folded Paleozoic sediments, the Cretaceous granitic rocks, and the early Miocene (?) massive rhyolite crop out only in the mountainous province within the State of Nevada and were not examined during the course of the reconnaissance. They are, however, well described by Schrader and rocks of the same ages and of similar characteristices hav been studied by the writer in a region about 90 miles to the eastward in Goose Creek basin[6]. These two sources of information have been consulted in the preparation of the descriptions that follow.

Paleozoic rocks.

Sedimentary rocks, probably of Paleozoic age, constitute the north-south range of hills between the heads of Jarbidge River and of West Fork of Bruneau River, as well as the summits of the Elk Mountains about 10 miles eastward. In the latter area there are exposed about 1600 feet of these sediments, principally quartzite, limestone, and a considerable amount of shale and slate, although a greater thickness may exist. These rocks are similar to the sediments of ascertained age cropping out in the Great Basin to the south and described by several writers[7]. It is probable that the rocks exposed in the areas described are continuous beneath the surface and that considerable of the southern portion of Bruneau basin is underlain by Paleozoic sediments at moderate depths.

The Paleozoic sediments have been greatly disturbed and tilted by faulting and folding accompanying the intrusion of the granite. Between Jarbidge River and West Fork they dip steeply to the north about 60 ; in the Elk mountain district they have been domed up by and dip quaquaversally away from the granitic core. The dips are rather uniform and vary from 40 to 70 with a maximum on the north. Near the intruded granitic rocks contact metamorphism[8], with garnet zones in the limestones and shales, is well developed.

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[5] Schrader, F. C., A reconnaissance of the Jarbidge, Contact and Elk Mountain mining districts, Elk County, Nevada: U. S. Geol. Survey Bull. 497, pp. 27-31, 33-42, 152-154, 1912; Bull. 741, pp. 78-83, 1923.

[6] Piper, A. M., Geology and Water resources of the Goose Creek basin, Cassia County, Idaho; Idaho Bur. Mines and Geol. Bull. 6, pp. 22-27, 1923.

[7] U. S. Geol. Expl. 40th. Par. Atlas, Map IV.

Emmons, W. H., A reconnaissance of some mining camps in Elko, Lander, and Eureka Counties, Nevada; U. S. Geol. Survey Bull. 408, p. 15, 1910.

[8] Emmons, W. H., op. cit.

Cretaceous (?) granitic rock.

Erosion has here and there stripped back the broken and shattered Paleozoic sediments from the granitic intrusive upon which they rest and exposed the gray, coarsely crystalline core. From one locality specimens are identified as hornblende granite[9], from another they are termed granodiorite[10]. Within the Bruneau basin this crystalline rock crops in the Jarbidge and Charleston districts and in the central part of the Elk Mountains as an oval-shaped area about 1½ miles in length and three-fouths of a mile in width with its longitudinal axis trending slightly west of north.

The relations of similar granitic rocks to sedimentary rocks of known age in many parts of the west have led several geologists[11] to conclude that the granite patholiths of Idaho, California, and Western Nevada, with their outliers, belong to one general period of intrusion, probably within Cretaceous or early Eocene time. The granitic rocks of the Elk Mountain district are younger than the Paleozoic sediments which they intrude and older than the Tertiary (early Miocene (?)) lavas which they do not intrude. There can be little doubt that they are properly correlated with the intrusives of other areas and are, in consequence, of Cretaceous or early Eocene age.

Tertiary system.

Early Miocene (?) rhyolitic lava.--The Jarbidge Mountains are formed largely from rhyolitic lavas poured out over the eroded surface of the Paleozoic sediments in successive thick flows aggregating 6000 feet in depth. This rock is

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[9] Sweetser, N. W., Geology of the Jarbidge Mining district: Min. & Sci. Press, V. 101. No. 27, pp 871, Dec. 31, 1910.

[10] Schrader, F.C., op. cit., pp. 33 and 152.
Emmons, W. H., op. cit., pp.25.

[11] U. S. Geol. Expl. 40th Par., v. 2, p. 621, 1877.
Lindgren, Waldemar, Am. Jour. Sci., 4th ser., v. 3, p. 306, 1897.

Lindgren, Waldemar, The mining districts of the Idaho Basin and Boise Ridge, Idaho: U.S. Geol. Survey Eighteenth Ann. Rept, pt. 3, pp. 517-719, 1898.

Lindgren, Waldemar, The gold and silver veins of Silver City, Delamar and other mining districts in Idaho; U.S. Geol. Survey Twentieth Ann. Rept., pt. 3, p. 195, 1900.

Lindgren, Waldemar, A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: U.S.Geol. Survey Prof. Paper 27, p. 17-20, 1904.

Lindgren, Waldemar, U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 104), 1904.

Russell, I.C., Geology and water resources of the Snake River Plains of Idaho: U.S.Geol. Survey Bull. 199,p.39-42,1902.

Emmons, W.H., op. cit., p. 28-29.

Umpleby, J.B., Geology and ore deposits of Lemhi County, Idaho: U.S. Geol. Survey Bull. 528, p. 42-43, 1913.

exposed over an area roughly rectangular in shape about eight miles in width and trending south from the vicinity of Jarbidge at least 15 miles. No exposures north of the Idaho-Utah boundary line within the Bruneau Basin are known. The rocks are prevailingly pinkish or reddish ash-gray in color, although greens, reds, and purples are not uncommon. They are extensively fissured and fractured, in part by contraction of the mass during cooling from the fluid state but chiefly by crustal movement accompanied by normal faulting. Schrader's[12] description of the macroscopic, microscopic, and chemical characters of these rocks is very full and need not be repeated here. Subsequent to their extrusion but before the outpouring of the rhyolites of the next period of igneous activity, these massive igneous rocks were deeply eroded by subaerial agents.

Late Miocene (?) rocks.--About two miles north and six miles east of Jarbidge[13] the steeply dipping erosion surface formed on the early Miocene (?) lava plunges beneath younger rhyolite flows that form an inward-facing scarp and an outward-sloping plain extending eastward as far as Elk Mountain and merging northward with the piedmont plain already described. These rhyolites are characteristically dull reddish purple or reddish brown and homogeneous fine-grained flows, but they locally contain intercalated sheets of vesicular and glassy phases. They rest in part on the deeply eroded older rhyolite and in part on the erosion surface of the Paleozoic sediments, and attain maximum thickness exceeding 1000 feet where they have filled the depressions of this old surface. Schrader describes the rocks as very slightly disturved by folding or faulting and as having gentle quaquaversal dips away from the mountains; within the Jarbidge district he did not find them associated with Tertiary sedimentary rocks.

About one-half of a mile east of Three Creek, rhyolites very similar to those described by Schrader are associated with white, unconsolidated sediments which consist in part of volcanic ejecta. They dip 11 N. 65 W. Both the sedimentary and the igneous material exposed at this place resemble very closely in macroscopic characteristics some phases of the Tertiary sediments and intercalated rhyolite flows studied by the writer[14] in the Goose Creek basin and tentatively assigned

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[12] Schrader, F.C., op. cit., p. 38-42.
[13] Schrader, F.C., op. cit., Pl. II.
[14] Op. Cit. pp. 27-31.

to the early Miocene. It is believed, although time was not available to test this belief thoroughly in the field, that the exposures in the vicinity of Three Creek represent a westward extension of the series that is at the surface over most of the Goose Creek basin. The same rhyolite is exposed in the Canyon of the West Fork of Bruneau River near the Idaho State line and at the surface in the low ridge forming the western divide of the drainage basin in the vicinity of Wickahoney. At the latter place it dips 3 N. 30 W. Similar igneous rocks are exposed east of the Bruneau drainage area in the basin of Salmon Falls Creek, to the west in the Owyhee Mountains[15], to the north in Snake River canyon at Shoshone Falls,[16] in the high ridges north of Mountain Home[17], and elsewhere. It is probable that the greater portion of Bruneau basin north of the Idaho-Utah line is underlain by rhyolitic lavas.

Pliocene rocks.--The lower basin of Bruneau River is carved into a group of rocks, probably Pliocene in age, in part volcanic and in part sedimentary. From the economic viewpoint this group is of great importance, inasmuch as it is the storage reservoir for the artesian waters. The following table presents a composite section of the group. Three divisions of the group have been recognized and their areal extent shown on Plate II by different patterns of line shading. They are respectively designated thereon as older basalt, lake sediments, and basalts and sediments interbedded. They form basal, intermediate, and uppermost divisions, respectively, of the Pliocene group.

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[15] Lindgren, Waldemar, U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 104), 1904.
[16] King, Clarence, U. S. Geol. Expl. 40th Par., v.1, p.592-593, 1878.
[17] Russell, I.C., Geology and water resources of the Snake River plains of Idaho: U.S. Geol. Survey Bull. 199, p.42-45, 1902.

Table 3.--Composite section of the Pliocene rocks exposed in Bruneau River basin.

No.	Character of beds	Thickness Ft.
1	Basalt, dense, black, fine grained, base not exposed. This flow caps the Snake River Plains near mouth of Bruneau River; about----------------------	100
2	Volcanic tuff, white to cream-colored, top not exposed: about---------------	50
3	Basalt, black, slightly vesicular:about-	75
4	Lake sediments, semi-consolidated conglomerate of quartzite and rhyolite boulders near top, white to cream sands, shaly sands, and volcanic tuffs; sequence broken by fault; at least------	400
5	Conglomerate of sub-angular rhyolite pebbles up to 3 inches in greatest diameter, semi-consolidated--------------	1
6	Lake sediments, white to light gray and buff, sandstones and sandy shales, volcanic ash; poorly consolidated, exposures infrequent; about-------------	475
7	Conglomerate, well-rounded quartzite and rhyolite boulders up to 6 inches diameter at base, grading upward into coarse sandstone; vertebrate fossils and fossilized wood------------------	3
8	Lake sediments, semi-consolidated white, gray, and buff, sandstones and sandy shales, volcanic ash; fossilized wood in uppermost bed: about-----------------	530
9	Conglomerate, rounded quartzite pebbles about 1 inch in diameter, dark-red-brown color, invertebrate fossils and fossilized wood--------------------------	4
10	Sandstones and sandy shales, white to gray, semi-consolidated--------------	55
11	Limestone, white to gray, somewhat celluear------------------------------	15
12	Sandstones, white to buff colored, some well consolidated beds---------------	79
13	Basalt, dense, black, massive----------	101
14	Volcanic ash or tuff, white to buff, red at top----------------------------	20
15	Basalt, dense, black; massive; slightly vesicular in places-------------------	79
16	Volcanic tuff, buff colored, friable; about	40
17	Basalts and tuffs interbedded, to base of exposed section; not measured;at least--	400
	Total exposed thickness-----	2425

The basal or older basalt of the Pliocene formations comprises members 13 to 17 of the composite section (Table 3). It crops out in the valleys of Bruneau River and of Hot Creek in T. 8 S., R. 6 E., and extends westward across unsurveyed T. 8 S., R. 5 E. into T. 8 S., R. 4 E., and northwestward into T. 7 S., R. 4 E. The most complete exposure of the basal lavas is exposed in Ninemile Canyon of Bruneau River in Tps. 8 and 9 S., Rs. 6 and 7 E. The canyon at this point has cut into the lavas about 750 feet. The base of the flows is not exposed. The upper portion of the vertical section, measured from the top downward is; basalt 101 feet, tuff or volcanic ash 20 feet, basalt 79 feet, tuff approximately 40 feet. Below this horizon lie a number of unmeasured basalt flows and intercalated tuffaceous beds with a total thickness of at least 450 feet. The volcanic tuffs are in most cases excellent storage reservoirs of underground water. The individual flows vary from 50 to 100 feet in thickness, and are typically massive to semi-columnar. In the hand specimen the rock is an extremely fine grained, dense, black olivine basalt of felsitic texture.

The intermediate division of the Pliocene group lies conformably upon the basal basalts and is composed of stratified beds of sedimentary and volcanic material. Its thickness represents nearly two-thirds of the entire group and totals about 1500 feet or more. It comprises members 4 to 12 of the composite section. The beds are prevailingly white, gray, cream, or buff colored. For the most part they are poorly consolidated and friable, are easily sculptured by wind and by water, and throughout most of their extent are concealed beneath a mantle of fine light-colored debris. They are rather evenly bedded or very slightly lenticular. In members 4, 6, and 8 there exists a frequent alternation of fine-grained sandy shales with semi-consolidated sands and an occasional dense sandstone; their uniformity of color and the paucity of outcrops throughout their areal extent, make it impossible to establish readily traceable horixon markers or to determine a section in any greater detail than is tabulated. Strata of gypsum, in some instances quite pure, are locally interbedded with the friable white shales and sandstones of member No. 8 at several localities in Little Valley; their thickness varies from one to eight inches. Four members are worthy of brief individual treatment. Conglomerate No. 5, made up of sub-angular rhyolite pebbles, forms a weather resistant cap on Horse Hill, in unsurveyed secs. 35 and 36, T. 7 S., R. 5 E. and secs. 1 and 2, unsurveyed T. 8 S., R. 5 E., and has given to this summit a flat mesa-like contour. The conglomerate occupies similar positions on several other isolated elevations. The debris from this member has been scattered over large areas by running waters and may readily be mistaken for gravel formed during the present erosion cycle and transported from the distant outcrops of rhyolite near the head of the drainage basin. Conglomerate No. 7 on the other hand is formed from well-rounded boulders of quartzite, a rock that crops out only as a member of the Paleozoic sediments in the headwater region, and of rhyolite in subordinate amount. Cobbles as large as 6 inches in diameteroccur at the base of the formation and grade upward into fine pebbles at the top, the whole being enclosed in a matrix of fine quartz sand. Like the debris from conglomerate No. 5, the quartzite cobbles have been widely scattered by erosion. The base of the conglomerate and a coarse gray sand lying below it contain much fossilized wood; from the top of the formation and the overlying sands have been taken both invertebrate and vertebrate fossils. They are discussed in a following section under the heading Correlation of the Tertiary system. The formation crops out only in the vicinity of Hot Spring and of Horse Hill in T. 7 S., Rs. 5 and 6 E.; its truncated edge in each case forms a terrace. Conglomerate No. 9 differs quite markedly from the last-described formation. It is composed of well-round quartzite pebbles, rarely more than one inch in diameter and often little more than coarse sand grains, held in a matrix of iron oxides. It crops out in the basin of Hot Creek in Tps. 7 and 8 S., R. 6 E., and forms a dark red-brown capping on several small hills and terraces. It contains many small fossilized twigs and numerous casts of invertebrate fossils, which are also discussed under the heading Correlation of the Tertiary system. The vertebrate fossils and the type of fossilized wood associated with member No. 7 are, however, not found. Formation No. 11 is a fresh water limestone, white, cream, or gray in color, and in the hand specimen has a somewhat cellular structure closely resembling travertme or devitrified trachyte. It crops out in Tps. 7 and ' S., R. 6 E., about 80 feet above the uppermost of the basal basalts, and is uniform in thickness and character throughout the four or five-mile trace of its outcrop on either side of Bruneau River. Southward it had been removed by erosion before the outpouring of the Pleistocene basalts forming the piedmont plain; to the north it dips beneath the surface in sec. 26, T. 7 S., R. 6 E. near the mouth of Bruneau River canyon. This limestone is also exposed a quarter of a mile east of the Bruneau-Wickahoney stage road, in SE. $\frac{1}{4}$ sec. 5, T. 7 S., R. 5 E., dipping 75 -85 N. 30 E., and may be traced southeastward along its strike about a mile. The significance of its unusual dip is discussed under the heading Faulting.

The uppermost division of the Pliocene group comprises members 1, 2, and 3 of the composite section and is designated on the map (Pl. II) as basalts and sediments interbedded. It is exposed only in the mesa-like upland described under the caption Lower canyon of Bruneau River and lying between the lower basin of Bruneau River and the canyon of Snake River. Member 1 is a flow of black massive, semi-columnar basalt about 100 feet thick; its contact with the underlying bed of tuffaceous and sedimentary material is concealed by talus but the two have an approximate combined thickness of 200 feet.

The tuff is underlain in turn by member 3, a basalt very similar in characteristics to member 1; it has an estimated thickness of 75 feet. This division of the Pliocene group holds forth no promise as a source of undergournd water. On the north side of Snake River canyon the members of the division are repeated and form at least the greater portion of the exposed section of the beds which underlie the plains in the vicinity of Mountain Home.

Correlation of the Tertiary system.--The assignmentt of the formations exposed in the Bruneau basinto epochs of the Tertiary period is only tentative. It is based upon scanty paleontological evidence which is not wholly conclusive, and on lithologic similarity to beds of known age in other localities.

The formations heretofore described as the Pliocene grou may be assigned with some certainty. The occurrence of vertebrate and invertebrate fossils in Bruneau basin in these beds has been mentioned in the Preceding section. A collecti of invertebrate fossil specimens was made by the writer from conglomerate No. 9, in the SW. 1/4 sec. 33, T. 7 S., R. 6 E., and has been examined by Dr. W. H. Dall, geologist and paleontologist of the United States Geological Survey. Dr. Dall reports as follows:

> "The specimens consist of imperfect internal casts of freshwater shells in a matrix of coarse gravel cemented by oxide of iron, which takes very poor impressions. *** The only fossil of which even a tentative specific indentification can be hazarded is a Corbicula whcih resembles a shell described by Meek from the Miocene of Idaho, under the name of Sphaerium idahoense, but which is certainly not a Sphaerium. The other casts are of a depressed Vivipara, of the type of the Eocence V. Leai Meek and Hayden, the internal cast of what may be a Goniobasis, and - - - one which is probably that of a Lymnaea. The assemblage may be anything from late Eocene to Pliocene, but is probably Miocene if the tentative identification of the Corbicula is correct."

From an exposure of conglomerate No. 7, in The SE. 1/4 sec. 26, T. 7 S., R. 5 E., on the western slope of Horse Hill, at the head of Little Valley, vertebrate fossil remains were collected by the writer. Dr. Gidley, of the United States National Museum, studied this material and identified the following types - - - of Mylocyprinus robustus Leidy: vertebrae, upper jaws, and other skull portions; cf. Odocoileus sp.: distal end of humerus. The geologic horizon, Dr. Gidley says, is Pleistocene or possibly Pliocene. From beds of the same locality and at approximately the same horizon, Russell[18] collected vertebrae, teeth, etc. of Anchybopsis fasciolatus Cope, and vertebrae of Rhabdofario Cope.

[18]Russell, I. C., Op. cit., p. 56.

Of the latter, Dr. F. A. Lucas, paleontologist, says: "They are typical Pliocene species, such as are found in the Plioce of - - - Idaho". King[19] and Lindgren[20] collected fossils of these same genera at different localities from the Idaho formation, and classified them as Miocene or Pliocene. The group of formations described under the heading Pliocene rocks may propertly be correlated with Kings Idaho Formation. The vertebrate remains contained therein show at least the upper portion of this group is not older than Pliocene and ma be in part Pleistocene. The lower half of the group, in which were found the invertebrate remains, may be late Miocene so far as the fossil determinations are diagnostic. There is no interruption or change in the character of the beds between the upper and lower portions of the group, however, and it seems probable that the time interval of accumulation was approximately coincident with the Pliocene epoch.

The oldest rock of the Tertiary period is the massive rhyolite which forms the greater part of the Jarbidge Mounta Schrader[21] has assigned this rock to the early Miocene. Lindgren[22] assigns the rhyolite of the Silver City district to the early Eocene; this classification, however, is not in harmony with the facts that in the latter district the rhyoli is younger than granite of late Cretaceous or early Eocene a and that in the Jarbidge Mountains the granite had been expos by erosion before the outpouring of the rhyolites. The massi Jarbidge Mountain rhyolite is clearly later than early Eocene It is the writer's opinion that Schrader's classification is essentially correct.

An intermediate series between the early Miocene rhyolit below and the Pliocene group above is Schrader's "younger" rhyolite and the associated sedimentary and tuffaceous beds described under the heading Late Miocene (?) rocks. It is separated from the early Miocene and from the Pliocene by unconformities, pronounced in the first instance and slight in the latter. If the two extremes of the sequence of Tertiary rocks have been properly classified as early Miocene and as Pliocene or in part earlier, Schrader's correlation of the

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19 King, Clarence, U. S. Geol. Expl. 40th Par., v. 1, pp. 418-440, 1878.

20 Lindgren, Waldemar, The mining districts of the Idaho Basi and the Boise Ridge, Idaho: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 628, 1897.

Lindgren, Waldemar, The gold and silver veins of Silver City, Delamar, and other mining districts in Idaho: U.S. Geol. Survey Twentieth Ann. Rept., pt. 3, p. 98-99, 1900.

Lindgren, Waldemar, U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 104), 1904.

21 Schrader F, C., op. cit.

22 Lindgren, Waldemar, U.S. Geol. Survey Geol. Atlas, Silver City folio (No. 104), 1904.

Intermediate series with the Pliocene is inharmonious. In spite of the lithologic similarity between it and the Payette formation of the lithologic similarity between it and the Payette formation classified by Lindgren[22] as Eocene, and by King[23] as Pliocene, the intermediate group may be assigned only to the late Miocene epoch of the geologic time scale.

Quaternary system.

The youngest rocks in the Bruneau drainage area belong to the Quaternary period, both the Pleistocene anddRecent epochs being represented. The former epoch was characterized by the latest igneous activity and the latter by the accumulation of alluvial debris in the lower courses of the streams

Pleistocene basalt.--Ingeous activity during the Pleistocene epoch is signified by the presence of baslatic flows and at least one dike. The piedmont plain extending from the lower Bruneau basin southward to the vicinity of Three Creek, has already been described. Throughout most of its extent this plain is capped by a thin flow of black, soft, vesicular basalt resting unconformably on the Pliocene. A ngular blocks of lava lie scattered over a thin sheet of surficial soil, formed largely by weathering of the basalt in place. Near its northern extremety the flow has a thickness of about 50 feet. The long period of accumulation of the Pliocene gro manifested by the wide range of the fossil remains found therein, and the unconformity between that group and the overlaping basalt, call for the assignment of the latter to the Pleistocene epoch.

In sec. 36, T. 7 S., R. 6 E., the Pliocene sediments are cut by a basaltic dike trending S. 58 E. about 1½ miles into sec. 31, T. 7 S., R. 7 E., and secs. 5 and 6, T. 8 S., R. 7 E. Near its western end the dike varies between two and six feet in width, is dense, fine-grained, and black, and dips vertically. Several small masses of Pliocene sandstones, engulfed by the fluid lava at the time of intrusion, are now wholly surrounded by the dense solidified basalt. Farther east the dike attainssa width of about 500 feet and is accompanied by vesicular and fragmental phases of the lava. The intrusion is obviously later than the Pliocene sediments and presumably was one of the fissure vents through which was outpoured the Pleistocene basalt flow described in the preceding paragraph. The intruding lava forced its way to the surface along a plane of movement in the Pliocene rocks, and the present dike is one of the surface evidences of a deformation, which is discussed in a following section under the heading Faulting.

[23] King, Clarence, Op. cit.

Recent alluvium.--Within the lower basin the valley floors are flat, nearly level alluvial plains between one and two miles in width, made up of fine alluvial debris deposited from the streams. The areal extent of these plains is indicated on the map (Pl. II) by a distinctive symbol. The alluvial plain of Bruneau River extends northeastward from the sec. 26, T. 7 S., R. 6 E. about 13 miles to the beginning of the lower canyon in sec. 8, T. 6 S., R. 5 E. The plain of Little Valley trends somewhat east of north from sec. 27, T. 7 S., R. 4 E. nearly 10 miles and merges with the plain of Bruneau River. Sugar Valley forms a lobe of the Little Valley plain and trends northwestward from sec. 10, T. 7 S., R. 5 E. These are typical flood plains, built up by the slow accumulation of fine debris deposited from the streams during the annual spring period of high water. The material of the alluvial fill is a fine silt derived largely from the Pliocene sediments; gravel is very infrequently encountered. Even along the axes of the valleys the accumulations seldom exceed 20 feet in thickness.

STRUCTURAL GEOLOGY.

Lewis artesian basin.

Bruneau River basin occupies a portion of the southern limb of a large structural depression termed by Russell[24] the Lewis artesian basin. Russell says of this depression:

> "The rocks on each side of Snake River from near the mouth of Kinghill Creek westward to beyond the Idaho-Oregon boundary are gently inclined or dip towards the canyon of that stream from each side. The inclination of the rocks is most readily seen on the south side of Snake River; as, for example, in the highlands to the east of Bruneau River, and in the hills near the mouth of Owyhee River, where the strata rise when traced southward at the rate of perhaps 100 feet to the mile. This rise, although gentle, is sufficient to carry the strata which underlie Snake River to an elevation of more than a thousand feet above its surface in the hills and mountains of Owyhee County. On the north side of Snake River the rocks are seemingly level, but, as nearly as can be

[24] Russell, I. C., Geology and water resources of the Snake River plains of Idaho: U. S. Geol. Survey Bull. 199, pp. 178-179, 1902.

Russell, I.C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: U.S. Geol. Survey Water-supply Paper 78, pp. 24-25, 1903.

judged, rise gradually to meet the mountains of older rock to the north of Mountain Home, Boise, etc. The inclinations of the rocks just referred to show that they have been bent into a broad trough-shaped depression the longer axis of which bears about northwest and southeast, and is followed by the canyon of Snake River in a general way from Glenns Ferry to the Idaho-Oregon boundary. In certain localities, however, the axis of the fold is a mile or two north of the river."

Structure of Pliocene rocks.

The circulation of underground water in the Bruneau drainage area is controlled by the structure of the Pliocene rocks in other words, by the manner in which tose beds slope and are bent or broken.

Folding.--The preceding quotation from Russell has described the master structural feature of the region, a warping or bending of the layers of rock into a trough-shaped depression. It must be borne in mind that this trough is extremely flat, being about 50 miles wide and perhaps 3000 feet deep. The Bliocene rocks of the Bruneau basin dip, or slope, gently to the northward and eastward and comprise a portion of the southern slope of this depression. The beds are very slightly undulatory here and lie horizontal there, but the general dip is persistently about 1½ N. 10 E. The uniformity and direction of this dip is well shown in the low ridges flanking the plains of Bruneau River and of Little Valley. Several buff and brown colored beds, when observed from a distance, stand out from the mass of the formation and are seen to slope northward and successively plunge beneath the surface of the ground. It may also be seen that the dip of the beds is quite independent of the slope and shape of the surface.

Faulting.--The continuity of the Pliocene rocks is interrupted by normal faults crossing the lower basin of Bruneau River and bearing N. 65 W. to N. 70 W. One such fault, or plane of movement, strikes northwestward alongside the basalt dike described under the heading Pleistocene basalt, crosses Bruneau River in sec. 26, T. 7S., R. 6 E., and Little Valley Creek in sec. 5, T. 7 S., R. 5 E.. Its course is shown on the map (Pl. II). Three thermal or warm springs in the plain of Bruneau River lie on or near the trace of the fault, and displacements of the strata occur in sec. 21, T. 7 S., R. 6 E. The steeply dipping bed of limestone in secs. 5 and 8, T. 7 S., R. 5 E., described under the caption Pliocene rocks is believed to be associated with this fault, but alluvial debris masks the other beds and prevents definite analysis of the structure. The fault trace across Little Valley is defined by the records of drilled wells. Between Little Valley and Bruneau River it is inferred from topographic forms. The plane of the fault is approximately vertical where it is exposed at the surface east of Bruneau River. The rocks lying north of the fault have been dropped about 350 feet in relation to those on the south side.

A second fault about $1\frac{1}{2}$ or 2 miles north of the one just described is disclosed by the records of wells drilled east of Bruneau River in secs. 15 and 23, T. 7 S., R. 6 E., and in Little Valley in sec. 29, T. 6 S., R. 5 E. Surface evidences of faulting are not at all conclusive, and the trace of the fault has not been shown in whole on Plate II. The fault plane probably dips steeply or is vertical, as in the case of the first-mentioned parallel structure, and the rocks north of the plane of movement have been thrown down in relation to those lying to the south. The throw of the fault, as estimated from well records, is approximately 400 feet.

The basalts that form the upland between the lower basin of Bruneau River and Snake River, described under the headings Lower canyon of Bruneau River and Pliocene rocks, do not seem to continue southeastward at their proper horixon. If this is true, the southward-facing rim of the mesa may represent a slightly eroded fault scarp and the upland itself may be yet another downfaulted block. No solution for this question was sought in the field as the structural relations are largely concealed by debris and the answer, if found, would have no direct bearing on the problem at hand.

In several outcrops of the Pliocene sediments in the lower basin, there may be seen planes of movement along which the displacement has been from a few inches to one foot. In each case the strike is west or slightly north of west and the dip nearly vertical.

Epochs of deformation.--The folding and faulting of the Pliocene rocks represent two distinct epochs of deformation. The folding represents the earlier deformation and probably took place during late Pliocene time or at the close of that epoch. Displacement along the normal faults followed the folding but preceded the outpouring of the Pleistocene basalts, if the correlation with the Pleistocene of the basalt dike already described is correct. This second epoch of deformation must, therefore, have occurred in early Pleistocene time.

GEOLOGIC HISTORY.

The geologic history of the Bruneau drainage area may be reconstructed with some certainty from late Cretaceous time to the present. During the late part of the Cretaceous period or possibly in the early Eocene epoch the Paleozoic sedimentary rocks which covered this portion of southwestern Idaho were intruded by granitic rocks, and were thereby updomed and extensively faulted in two regions--one covering most of central Idaho, the other forming a broad belt bearing east and west along the Idaho-Nevada boundary. The intrusion was followed by an erosion interval of such duration that the sediments were stripped back and the granite exposed over much of the central Idaho region and here and there along the Idaho Nevada line. This interval extended well into early Tertiary time and at its close the surface was one whose relief was probably little greater than that of today and one characterized by rounded mountain masses. The next period of accumulation was the outpouring of rhyolitic lavas during early Miocene time, probably through fissures opened along the axis of the earlier uplift. The outpouring continued until the accumulated flows had formed a huge elongated dome trending east and west and had a total thickness of 6000 feet. Subsequently these rhyolites were fissured by contraction of the cooling mass and by normal faulting accompanying the formation of the Great Basin Mountain ranges. Sub-aerial erosion cut deeply into the dome during the remainder of early Miocene time. During late Miocene time the valley to the north of the elevated area became covered with an extensive lake, named Lake Payette by Lindgren, in which were accumulated stratified deposits of sedimentary and volcanic debris; these strata have a thickness of more than 700 feet in the Goose Creek basin[25]. Igneous activity again showed itself in the extrusion of the rhyolite flows intercalated with sedimentary and tuffaceous strata in the Goose Creek basin and of the "younger rhyolites" of the Bruneau area. Lake Payette dwindled greatly in extent and in some areas no accumulations of stratified material separated the lava flows. This period of volcanism was followed by a short interval of erosion and by slight uptilting of the strata accompanied by little or no faulting.

Close on the heels of this brief interval came a renewal of volcanic accumulation in the outpouring of the basal basalts of the Pliocene series in the early part of that epoch. Flows followed one another at short intervals, separated in some cases by the accumulation of thin beds of tuff, until a total thickness exceeding 650 feet had been accumulated. A new inland body of water, Lake Idaho, was born on the infant basalt plain and the accumulation of sedimentary beds began, first of sands and sandy shales, then of limestone as clear-water conditions were attained. Subsequent shoaling of the lake resulted in the deposition, as the water level fluctuated, of the thick series of sandstones, sandy shales, and conglomerates that has been described. The occurrence of fossilized wood in the conglomerates, and of fossilized fragments of wood rounded before silicification, as though by pounding on a beach, show that the lake was at times little more than a mud flat. In late Pliocene time a final shoaling of the waters and a deposition of coarse gravel was followed by the accumulation of the basalt flows and the separating tuffaceous bed that form the uppermost division of the Pliocene.

[25]Piper, A. M., Op. Cit., p. 28.

Down-warping and erosion of the series progressed into early Pleistocene time. Normal faulting, perhaps late in the early part of the Pleistocene epoch, increased the stream gradients and accelerated erosion. The sedimentray members of the Pliocene group were stripped from the southern portion of the region and the streams became securely entrenched in courses muh the same as those they now occupy.

Over the basal basalts of the Pliocene, exposed by erosion, was poured out the thin flow of Pleistocene basalt, the last igneous activity within the Bruneau drainage area. Slight uptilting of the rocks subsequently reaccelerated erosion, the canyons of the forks of Bruneau River were incised into the basal Pliocene basalts, and tributaries eroding laterally in the soft lake sediments scopped out the lowerbasin of the Bruneau. The lesser precipitation of the present has made erosion less active, but it is even now slowly cutting the valleys to grade and removing the accumulated alluvial debris from their lower reaches.

SURFACE WATER RESOURCES.

The agricultural resources of the Bruneau River basin are measured by the water supply, for precipitation during the growing season is slight and crops can be raised only by irrigation. Both surface waters and ground waters have been utilized for this purpose, but the former are by far the more important of the two.

General surface water conditions.

The irrigable land of the lower Bruneau basin comprises the plains of Bruneau River and of Little Valley Creek; its extent corresponds with the area shown on the map (Pl. II) as alluvium. Development of the land has depended upon the quantity of water available for irrigation, chiefly from surface waters.

Perennial streams.--That portion of the Bruneau drainage area lying in Nevada and extending northward into Idaho about 10 miles from the interstate boundary is drained wholly by perennial streams heading on the slopes of Jarbidge and Elk Mountains. The area of this part of the drainage is approximately 1220 square miles. Marys Creek, Sheep Creek, West Fork, and Jarbidge Rivers are the heads of the West Fork of Bruneau River; Big Flat, Cherry, Three, and Deadwood Creeks, unite and from the East Fork. The run-off from these mountain headwater basins is characterized by a flood period, generally in April and May, during which the melting snows feed into the streams fully 65 per cent of the total annual flow. During the month of June the run-off falls rapidly, then more and more slowly as the discharge cycle approaches the minimum in September, and prusues its slow six-months' climb toward the next flood-season peak.

In the region north of the headwater drainage, only East and West Forks and Bruneau River flow perennially, with the exception of Little Valley Creek and its tributaries, Jacks and Wickahoney creeks. Little Valley Creek heads on the piedmont plain and drains an area of 530 square miles in the northwestern lobe of the Bruneau basin. Before 1915, only the heads of the creeks were perennial and, except for flood discharge, the waters rarely reached beyond the head of Little Valley in T. 7 S., R. 4 E. During the past few years, however, increasing quantities of water have been used for irrigation on the valley plain and sufficient seepage has reached the creek to maintain a small flow of water throughout the dry summer months. As a perennial stream, Little Valley Creek is newly born.

Intermittent drainage.--The lower basin and the piedmont plain extending northward from the headwaters are drained into the major perennial stream, Bruneau River, by numerous short tributaries, either intermittent or ephemeral. Their flow is at its maximum in February or March, a month or more before the flood run-off from the mountainous headwater region, has in most cases ceased by the end of May, is revived by the increased precipitation of early autumn, and suddenly accelerated as the rising temperatures and rain of early spring melt the snow from the piedmont plateau. The area drained by these intermittent and ephemeral streams has a total of 1490 square miles.

Stream flow records.

The United States Geological Survey has maintained stream gaging stations on many of the creeks and streams of Bruneau Basin for varying intervals between 1909 and 1916. The accumulated data is summarized in Tables 4, 5, and 6, compiled from more detailed tabulations contained in publications[26] of the Federal Survey.

Relation of run-off to topography and climate.

The water carried by streams, termed run-Off, orginates as rain or snow precipitated upon the surface of the land. The rainfall, or the snowfall after it has melted, suffers a primary division by immediate run-off into the streams, and by absorption into the soil. Of the water absorbed into the soil a part seeps into the streams and becines added to the run-off another portion is discharged into the atmosphere in the form of water vapor, and the remainder is stored beneath the surfac as underground water. This sub-surface or ground water, as it is termed, will be discussed at some length in a following section.

26U.S. Geol. Survey Water-supply Papers 272, 292, 312, 332-B, 362-B, 393, 413, and 443.

TABLE 4

Monthly discharge measured in acre-feet of Bruneau River
(From United States Geological Survey Publications)

	Near Grandview, Idaho (1)								Near Hot Springs, Idaho (2)						
	1908-09	1909-10	1910-11	1911-12	1912-13	1913-14	1914-15	1915-16	1908-09	1909-10	1910-11	1911-12	1912-13	1913-14	1914-15
October	---	6,760	6,080	1,990	4,840a	7,440	6,950	4,080	---	7,190	5,550	5,150	9,980	8,300	8,920
November	---	12,700	8,210	5,560	---	9,220	7,260	7,560	---	14,800	6,900	6,190	12,700	9,760	6,780
December	---	12,400	11,000	7,130	10,500	8,060	5,400	10,400	---	13,900	8,240	5,890	7,810	7,010	5,280
January	---	18,300	11,500	9,280	9,780	14,900	5,320	11,800	---	18,600	8,240	7,130	9,960	16,400	6,890
February	---	18,800	26,200	8,630	10,700	15,100	9,390	17,100	---	19,200	21,700	9,380	8,890	13,700	7,500
March	---	129,000	62,700	13,800	20,600	52,900	15,900	44,500	---	117,000	46,200	13,100	16,800	50,800	4,220c
April	---	103,000	44,200	45,500	54,700	75,000	22,900	68,400	---	78,600	44,600	53,400	61,300	82,100	---
May	76,200	91,000	59,200	125,000	55,000	89,800	39,900	71,900	---	83,600	57,700	130,000	65,800	96,500	---
June	80,300	31,800	58,300	116,000	47,000	50,400	39,600	59,000	---	32,500	64,300	117,000	55,500	59,100	---
July	17,800	7,620	9,900	21,500	12,500	10,500	5,160	17,100	27,300b	8,240	16,000	31,200	20,700	18,600	---
August	2,450	1,800	1,730	3,800	2,570	984	627	609	6,460	4,110	5,060	13,200	9,960	6,330	---
September	5,800	4,180	167	3,180	2,980	2,760	1,200	726	7,260	3,870	3,870	7,020	6,490	5,330	---
The Year		437,400	299,000	361,000		337,000	160,000	313,000		401,600	288,000	399,000	286,000	374,000	

(1) Station is located in Sec. 1, T. 6 S., R. 4 E., about one-fourth mile below the Grandview Irrigation District diversion dam. Records not seriously affected by ice.

(a) October 1-20 only.

(2) Station is located in Sec. 34, T. 7 S., R. 6 E., below all important tributaries except Little Valley Creek. Buckaroo Ditch diverts about one mile below Station. Records not affected by ice.

(b) July 3-31 only.

(c) March 1-15 only. Station discontinued March 15, 1915.

TABLE 5

Monthly discharge measured in acre-feet of East Fork of Bruneau River and its Tributaries
(From United States Geological Survey Publications)

	East Fork near Hot Spring, Idaho (1)						Cherry Creek near Three Creek, Idaho (2)			Deadwood Creek near Three Creek, Idaho (3)			Big Flat Creek near Three Creek, Idaho (4)			Three Creek near Three Creek, Idaho (5)		
	1909-10	1910-11	1911-12	1912-13	1913-14	1914-15	1912-13	1913-14	1915-16	1912-13	1913-14	1915-16	1912-13	1913-14	1915-16	1912-13	1913-14	1915-16
October	---	341	322	1,180	598	793	---	1	---	---	22	---	---	376	---	---	168	---
November	---	448	494	1,350	684	756	---	21	---	49 e	49	---	381 g	336	---	175 g	176	---
December	---	585	492	1,230	500	---	9	6	---	34	40	---	419	280	---	184	161	---
January	---	2,360	965	922	2,320	---	6	28	---	24	50	---	326	320	---	138	165	---
February	---	1,390	1,190	1,530	3,490	1,640	21	63	8 c	22	149	---	292	338	43 h	146	277	58 h
March	---	8,360	1,090	3,310	5,090	1,290	196	491	264	89	386	---	548	1,070	713	652	922	781
April	---	3,260	5,000	7,500	5,610	--- b	1,400	904	249	588	613	374	3,060	3,200	1,680	2,250	1,760	774
May	---	5,100	13,500	7,930	9,720	---	781	1,030	231	799	1,070	363	3,840	5,560	2,900	1,830	2,670	762
June	---	3,770	12,000	5,950	4,220	---	424	258	85 d	455	453	158 d	3,050	2,180	1,940 i	946	809	512 i
July	---	719	2,270	2,950	1,340	---	83	---	---	44	38 f	---	1,090	---	---	303	---	---
August	58 a	92	1,150	898	488	---	24	---	---	33	---	---	603	---	---	182	---	---
September	102	106	851	549	451	---	8	---	---	0	---	---	387	---	---	147	---	---
The Year		26,500	39,300	35,300	34,500													

(1) Station is located in Sec. 15, T. 10 S. R. 8 E., about 8 miles above junction with West Fork, about 22 miles southeast of Hot Spring. Winter flow seriously affected by ice.
(a) August 13-31 only.
(b) Station discontinued April 3, 1915.

(2) Station is located in Sec. 32,T.15 S. R.11 E. about 1½ miles west of the Three Creek store. Winter flow affected by ice.
(3) Station is located in Sec. 19, T.15 S.,R.12 E., about 5½ miles southeast of Three Creek post office. Winter flow slightly affected by ice.
(c) February 24-29 only.
(d) Station discontinued June 30, 1916.
(e) November 10-30 only.
(f) July 1-23 only.

(4) Station is located approximately in Sec. 7,T.16 S., R.11 E., about 4 miles southwest of the Three Creek store. Records not seriously affected by ice. Called <u>East Fork of Bruneau River</u> in U.S.Geol. Survey publications.
(5) Station is located in Sec.27,T.15 S. R. 11 E., about 1½ miles north of Three Creek post office. Winter flow affected by ice.
(g) November 9-30 only.
(h) February 24-29 only.
(i) Station discontinued June 30, 1916.

TABLE 6

Monthly discharge measured in acre-feet of West Fork of Bruneau River and its tributaries
(From United States Geological Survey Publications)

	West Fork of Bruneau River — 20 miles South of Tindall (1) 1909-10	1910-11	1911-12	1912-13	Near Rowland, Nevada (2) 1913-14	1914-15	1915-16	Marys Creek — At Tindall, Idaho (3) 1909-10	1910-11	1911-12	1912-13	Near Owyhee, Nev. (4) 1913-14	1914-15	Sheep Creek near Tindall (5) 1910-11	1911-12	1912-13	Louse Creek near Wickahoney (6) 1910-11
October	---	2,060	1,620	---	1,820	1,840	1,190	---	42	44	109	---	430	---	254	713	---
November	---	1,480	2,230	---	2,420	1,440	1,460	---	314	162	2760	---	38 g	---	302	898	---
December	---	1,960	2,150	---	1,510	904	1,480	---	713	155	290	162 f	---	248 i	254	372	---
January	---	4,110	1,880	---	2,560	1,260	1,230	---	1,960	156	256	357	---	2,210	331	208	---
February	---	6,330	2,430	---	2,800	1,600	2,860	---	1,340	1,450	217	327	---	2,630	1,110	317	245
March	---	11,400	3,570	---	15,500	4,710	15,600	---	5,400	947	2,600	1,780	772 h	9,470	1,890	2,710	688 k
April	---	15,300	21,100	---	39,600	11,100	38,300	---	4,920	6,250	4,400	4,690	2,270	9,820	8,980	7,020	271 l
May	---	18,100	36,800 b	6,480c	25,400	11,300	24,500	---	2,870	13,800	1,690	3,500	2,180	8,360	21,900	6,520	81
June	---	13,700	---	12,100	13,000	8,630	13,900	---	1,080	5,550	547	1,210	750	4,270	11,800	3,540	32
July	---	2,160	---	3,940	2,610	1,790	3,780	---	31	161	55	323	335	750	1,470	1,130	---
August	444 a	836	---	2,040	848	646	1,020	---	0	53	23 e	188	179	105	268	228	---
September	970	607	---	1,550	922	720	898	61 d	0	4	---	278	106	48	299	--- j	---
The Year		78,000			109,000	45,900	106,000		18,670	28,700					48,900		

(1) Station is located in Sec.30, T.14S, R. 7 E., above East Fork of Bruneau and Jarbidge Rivers and Louse, Marys and Sheep Creek.
(2) Station is located in Sec.29, T. 47 N. R.56 E., Mount Diablo meridian, 1½ miles above Rowland and about 4 miles south of Idaho - Nevada boundary. Records not seriously affected by ice.
(a) August 18-31 only.
(b) May 1-23 only. Station discontinued May 23, 1912.
(d) May 19-31 only.

(3) Station is located in Sec.28, T.13 S. R. 5 E., about three fourths of a mile above Rattlesnake Creek and one mile below two ditches diverting about 9 second feet. Records not affected by ice to any great extent.
(4) Station is located in Sec.19, T.15 S., R.15 E., 7 miles north of Idaho - Nevada line. Records affected by ice. Drainage area 27 square miles.
(d) September 16-30 only.
(e) Station discontinued August 31, 1913
(f) December 11-31 only.
(g) November 1-5 only.
(h) March 22-31 only.

(5) Station is located in Sec. 5, T.15 S., R.6 E., 12 miles south of Tindall post office.
(6) Station is located approximately in unsurveyed T. 12 S. R.6 E., on the Hot Spring - Grasmere road, 27 miles from Hot Spring, and about 15 miles east of Wickahoney.
(i) December 18-31 only.
(j) Station discontinued September 2,1913.
(k) March 1-10 only.
(l) April 5-30 only.

The approximate precipitation, in inches and in equivalent in acre-feet, is calculated on the supposition that precipitation over the headwater region is atleast as great as at Silver City City at an elevation of 6280 feet, and that between Hot Spring and the headwaters the precipitation increases in porportion to the rise in elevation. The run-off from the headwater streams is approximated by extending available stream-flow data with the assumption that equal areas within this topographic province discharge equal amounts of water. Discharge measurements of Little Valley Creek are not available, but the net run-off from lower Bruneau basin, including Little Valley, may be ascertained from the difference between the sum of diversions plus the discharge of Bruneau River below the Grandview dam and the discharge at Hot Spring. All run-off data are the average of measurements for the two seasons 1912-13 and 1913-14, so that comparability is attained even though the record is too short to yield an approximation of the normals for the region. The table shows that the precentages of run-off for the headwaters and for the piedmont plain are approximately the same, though the amounts of run-off differ greatly; but that the percentage for the lower basin and Little Valley Creek is much less.

Utilization of surface water.

The surface water supply of the Bruneau basin is diverted for use in irrigation by two organizations--the Buckaroo Ditch Company, a corporation having its principal place of business at Bruneau, and the Grandview Irrigation District, a quazi-municipal corporation with headquarters at Grandview, Idaho. The Buckaroo Ditch Company operates a diversion dam in sec. 25, T. 7 S., R. 6 E., near Hot Spring, and serves approximately 4200 acres of the bottom lands of Bruneau River by two ditches following the edges of the plain on either side of the river. The Grandview corporation diverts water from Bruneau River in sec. 1, T. 6 S., R. 4 E. and serves a district of 7000 acres of which 6000 is under cultivation, in the vicinity of Grandview. Gaging stations were maintained by the United States Geological Survey during the period 1912-1915 on the ditches operated by these corporations; the data of quantities diverted are summarized in the following table compiled from the more detailed records published[27] by the Federal Survey.

[27] U. S. Geol. Survey Water-Supply papers, 332-B, 362-B, and 393, and 413.

Table 8.--Monthly diversions from Bruneau River.
(From United States Geological Survey publications.)

	Acre-feet.						
	Buckaroo	ditch at Hot Spring[1]		Grandview canal near Grandview[2].			
	1911-12	1912-13	1913-14	1911-12	1912-13	1913-14	1914-1
October	--------	978	744	--------	1,620	2,390	3,980
November	--------	958	522	--------	d	803	1,780
December	--------	713	122	--------	d	430	1,110
January	--------	214	151	--------	d	430	1,110
February	--------	0	115	--------	d	389	1,000
March	--------	719	39	--------	d	139	500
April	244[a]	496	1,260	1,420[c]	4,050	5,950	5,120
May	2,930	2,670	2,790	5,270	6,010	7,750	4,450
June	2,550	1,950	236[b]	5,320	6,370	6,600	5,940
July	953	1,600	--------	6,820	8,360	6,070	6,330
August	1,170	1,490	--------	4,980	4,890	4,290	1,770
September	1,110	1,270	--------	2,680	3,550	2,730	--------
The Year	--------	13,100	--------	--------	34,850	38,000	--------

[1]Station is located in Sec. 22, T. 7 S., R. 6 E., at bridge across the canal, above all laterals.
[2]Station is located in sec. 35, T. 5 S., R. 4 E., about one mile below the Grandview Irrigation District diversion dam, below two small laterals.
[a]April 25-30 only.
[b]June 1-3 only. Station discontinued June 3, 1914.
[c]April 11-30 only.
[d]Canal dry except for small quantity of water for stock.
[e]August 1-2 only. Station discontinued August 20, 1915.

Neither the Buckaroo Ditch Company nor the Grandview Irrigation District have storage reservoirs and the flood discharge of the stream during the spring months overflows the bottom lands of the lower basin and wastes into Snake River over the spillway of the Grandview diversion dam. Even after the peak of the flood discharge, which generally occurs during May, a considerable quantity of water passes the two diversions. The magnitude of this waste is summarized in the following table, computed from the data of Table. 8.

Table 9.--Average monthly waste[1] over spillway of Grandview Irrigation District dam.
(From United States Geological Survey publications)

Month	Acre-feet
October	5,610
November	8,420
December	9,270
January	17,500
February	15,100
March	48,500
April	59,100
May	76,000
June	60,300
July	12,800
August	1,820
September	2,620
Total	317,000

[1]For the years 1909-1916.

The amount of water diverted by the Buckaroo Ditch Company during the low-water months of July, August, and September is not adequate to the needs of the area it serves. It is quite practicable to remedy this condition by a more efficient use of the available surface water supply. The remedy may be gained firstly by improvement of the ditch system distributing the water so as to minimize losses by evaporation and seepage, secondly by cooperation with the Grandview Irrigation District in adjusting diversions so that no water is wasted over the spillway of the Grandview dam, and thirdly by provision of a small storage capacity above the Buckaroo diversion so that the normal flow of the river during this three-months' period may be equalized. Such development promises greater returns and should have precedence over the drilling of additional artesian wells.

BRUNEAU ARTESIAN SLOPE.

Natural discharge of ground water.

Ground water is returned to the surface within the Bruneau basin directly by the discharge of springs and indirectly by evaporation from the leaves of distinctive types of vegetation whose roots feed on ground water.

Areas of vegetal discharge.--In the greasewood-studded plain of Little Valley there is an oval shaped area covered with vigorous rabbit brush, wild rose brush, and various wild grasses. All these types of vegetation indicate ground water at a depth of only a very few feet whereas greasewood sends its roots 12 to 20 feet or more in search of water. The longitudinal axis of this area is about three-quarters of a mile in length and thrends approximately S. 70° W. from the NW. 1/4 sec. % into the E. 1/2 sec. 6, T. 7 S., R. 5 E.; the transverse dimension is equal to one half of the longitudinal. Another area covered by a growth of similar vegetation supported by ground water at shallow depth lies near the head of Sugar Valley and is approximately centered about the corner separating secs. 9, 10, 15, and 16, also of T. 7 S., R. 5 E. Its diameter is roughly half a mile. The trace of one of the normal faults traversing the Pliocene series bisects the first of these areas and in projection passes close to the second. It is highly probable that ground water finds an avenue of upward percolation in the crushed rocks of the fault plane and by it comes near enough to the surface to support the vegetal types that feed on permanent ground water.

Cold Spring.--One spring, known as Cold Spring, in lower Bruneau basin discharges small amount of water whose temperature approximates the mean annual temperature of the region. Cold Spring, No. 50[a], is located on the NE. 1/4 sec. 5, T. 7 S., R. 5 E., on the eastern side of Little Vallgy, about 100 feet west of the Bruneau-Riddle stage road, at an elevation of 2259 feet above see level. A well was bored in the spring opening with improvised tools by Frank M. Purjue about the year 1900 to a depth reported as 120 feet, and cased at the top with wooden casing, but is now caved to the surface. A few gallons per minute of water with a temperature of 57.8° F. escape from the orifice. The alluvial valley plain conceals the underlying rock structure that causes the discharge at this point.

Thermal springs.--Several springs within lower Bruneau basin and many others in the stream canyons of the piedmont plain discharge thermal ground water.

Rosebrier Spring, No. 12, is located in the NE. 1/4 sec. 32, T. 6 S., R. 5 E., in the alluvial plain of Little Valley Creek at an elevation of 2530 feet. A well was bored in the opening of this spring, also by Mr. Purjue, to a reported depth of 130 feet, and cased to a depth of 20 feet with wooden casing, but is now caved to within 3 feet of the surface. The spring discharges a few gallons per minute of water with a temperature of 68.2° F. AA low mound of soil, about 50 yards in diameter, covered with wild rose brush and rank greasewood has developed close to the spring. The Structure of the underlying rocks is concealed by the alluvial valley fill, but the spring is close to the trace of one of the faults described under the heading Faulting and probably is fed by water ascending the fault plain.

Spring No. 44 is located near the head of Little Valley in thethe SE. 1/4 sec. 24, T. 7 S., R. 4 E. on land owned by J.B. Conner, and about 150 feet north of the western branch of the Bruneau-Riddle road. The spring originally flowed 2 or 3 miner's inches (25 gallons per minute) at an elevation of 2693 feet but the discharge was increased to 15 miner's inches (135 gallons per minute) by five 2-inch wells about 40 feet deep drilled in the spring opening by Mr. Conner during 1596 and subsequent years. The combined discharge of the enlarged spring and ofanearby well has a temperature of 99° F.

[a]Numbers refer to the corresponding locations on Plate II.

Spring No. 100 is located on the western side of Bruneau Valley in the SE. $\frac{1}{4}$ sec. 21, T. 7 S., R. 6 E., on land owned by Arthur Pence, Jr. but formerly held by W. N. Roberson. The spring discharges about 3 miner's inches (25 gallons per minute) of water with a temperature of 104 F. at 2618 feet elevation. It is reported that no decrease in flow resulted from the sinking of nearby artesian wells. The rock structure is concealed by a cover of hill wash, but the spring lies on a projected fault trace. It is probably a fissure spring.

Spring No. 104 lies in the plain of Bruneau Valley about 200 yards east of the stream in the SE. $\frac{1}{4}$ sec. 22, T. 7 S., R. 6 E., on land owned by Arthur Pence, Sr. Thermal Waters with a temperature of 114 F., accompanied by occasional small bubbles of gas, rise from an irregular area of one acre in the river flood plain at an altitude of 2584 feet. The measured[28] discharge was 2.35 second-feet, equivalent to 118 miner's inches, or 1,060 gallons per minute, in September, 1922. One of the openings has been enlarged to form a pool about 6 by 8 feet by 5 feet deep and enclosed by a small bath-house. The spring is about a third of a mile north of the projected trace of a fault from which it may derive its water supply.

Spring No. 105 lies at the base of the slope forming the western limit of the plain of Bruneau River on the land owned by Arthur Pence, Jr., in the SW. $\frac{1}{4}$ sec. 22, T. 7 S., R. 6 E. Approximately 4 miner's inches (35 gallons per minute) of water are discharged from a single opening 2609 feet above sea level. The temperature is 111 F. The rock structure is masked by hill wash but the spring lies close to the fault trace passing through No. 100 and, like the latter, is probably a fissure spring.

Hot Creek Spring, No. 110, is located on public land in Lot 3, sec. 3, T. 8 S., R. 6 E. Water issures at an altitude of 2667 feet from many openings in the top of a bed of tuff (formation No. 16 of the composite section, Table 3) below basalt. Of the temperatures at the several discharges openings the maximum is 98.5 F. and the minimum 94. F.; the stream of combined discharges has a temperature of 98. F. The measured discharge during September, 1922, was 3.96 second-feet or 198 miner's inches (1,780 gallons per minute.) No faulting of the rock strata occurs and the spring is undoubtedly of the canyon type in which a sloping water-bearing bed is truncated by a canyon.

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28 "Measured" discharges of springs and wells are current meter determinations made by A. G. Fiedler of the United States Geol. Survey.

All of these thermal springs were visited by Russel during this study of the area in 1901 and are mentioned in his report.[29]

Many thermal springs in addition to those described occur in the canyon of Bruneau River south of Hot Spring but most of them were not visited by the writer. Several openings in the river bed, which are submerged during the flood season, discharge ground waters with a temperature of 105 F. in the SW. 1/4 sec. 29, T. 8 S., R. 6 E. about 100 yards below the Buckaroo diversion dam. A large warm spring is located on the east bank of Bruneau River approximately in the NW. 1/4 sec. 35, T. 7 S., R. 6 E. Several with temperatures about 100 F. are situated on the ranch of B. T. Rovertson in Bruneau River canyon below the mouth of H t Creek in lot 1, sec. 3, T. 8 S., R. 6 E. Mr. Rovertson reports that the San Francisco earthquake of 1906 was felt in the Bruneau basin and that immediately thereafter the springs on and near his ranch were muddy for a week or more, the flow was increased in some, and one small spring was newly born at the time. Mr. Rovertson also reports that as one proceeds upstream from his ranch hot springs are frequently met for the space of two or three miles, that above is a reach of several miles in which none are found, and that still farther above they are again abundant. The tuff bed serving as aquifer to Hot Creek Spring is at the surface at Robertson's ranch and for some distance upstream. It is probable that the reach of the river characterized by an absence of springs is coincident with extent of the outcrop of the underlying basalt and that the appearance at the surface of the next underlying permeable bed is marked by a renewal of the phenomenon of thermal water discharge. Several large thermal springs also occur farther to the south and west near the headwaters of the drainage basin but none of them was visited by the writer.

The geologic significance of the temperature of the thermal ground water is treated under the headings Temperature of the water and Circulation of ground water and source of pressure. The quality of the waters from several of the thermal springs is discussed under the heading Quality of the water.

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[29] Russell, I. C., Op. cit., pp. 167 and 175.

Existing artesian wells.

Well records.--Carefully kept, accurate records of the formations and aquifers pierced by the drill and of fluctuations of the flow are not available for all the wells that have been sunk in the development of the artesian waters of the lower Bruneau Basin. The data that are available from drillers notebooks, from the memories of drillers or of owners, and from the results of field examinations by the writer are summarized in Table 10. An effort has been made to correlate the aquifers of the individual wells with the formations of the Pliocene rocks described in Table 3. This effort has met withindifferent success due in part to inadequate descriptions of the sequence of formatons penetrated by the drill and in part, especially in the head of Little Valley, to widespread gaps in the chain of available records. The tabulated records of flow are the result of approximate measurements by the writer and in a few instances, noted in Table 10, of current meter measurements by Mr. Fiedler of the United States Geological Survey.

History of Past development.--The development of the underground waters of the lower Bruneau basin dates back to the year 1896 and has been characterized by a period of slow exploration and a subsequent burst of enthusiastic expansion. During 1896 two wells, Nos. 1 and 2 of the tabulated well records, were bored with 2-inch tools for the purpose of developing a water supply for domestic use; neither of these wells overflow3d at the surface. In 1896 also Mr. J. B. Conner sank the first of the series of five 2-inch auger holes in the opening of the thermal spring located on his ranch near the head of Little Valley. The discharge of the spring was materially increased thereby. The first flowing well was drilled in 1898 to a depth of 730 feet on land owned at that time by B. Whitson in Bruneau River valley; this well, No. 80 of Table 10, discharged about 150 gallons per minute on bench land about 40 feet above the axis of the valley and proved the existence of artesian conditions. The following year, 1899, wells Nos. 108 and 109 were bored near Hot Spring by Arthur Pence, Sr., with a 2-inch hand auger to depths of 362 and 242 feet respectively. No. 108 was drilled on the top of a small knoll and failed to flow; No. 109, on the other hand, was drilled at a point of lower surface elevation and discharged a small amount of water. About 1900 well No. 99 was drilled on land then owned by W. N. Roberson. During this period between 1898 and 1900 several flowing wells were drilled with a 2 1/2 inch bit near the head of Little Valley. Russell[30] mentions the wells in Bruneau Valley and five well that had been drilled in Little Valley prior to 1901, but fails to locate them specifically. Two of these are wells Nos. 36 and 73 but the other three were not recovered during 1922 by the writer. During the period from 1901 to 1912 exploratory drilling proceeded slowly until in 1912 there were 15 to 20 flowing wells in Bruneau River valley and Little Valley northward from their heads to the

[30]Russell, I.C., Op. cit., pp. 174-176.

TABLE 10

Records of Drilled Wells in the lower Bruneau Basin

No.	Location	Owner or Lessee	Year	Elev. Feet	Depth Feet	Casing Dia. In.	Casing Depth Feet	Flow G.M.	Head Ft.	Temp. °F.	Use	Aquifers Description	Aquifers Depth Feet	Aquifers Formation(1)	Remarks
	T.6 S. R.5 E.														
1	NE¼SE¼ Sec. 9	J.S. Black	1896	---	267	2	---	None	-2	59	Dom.	---	---	4	
2	SE¼SW¼ Sec.14	A.W. Newkirk	1896	2469	500	2	---	None	-4	56	Dom.St.	---	---	4	
3	NW¼NW¼ Sec.15	Edward Ruud	1918	2443	412	4	0-20	1	---	64	Dom.	Gray Sand	410-412	4 ?	Seasonal variation of flow; maximum of 10 G.M. in winter, minimum about 1 G.M.
4	SW¼SW¼ Sec.16	O. Eide	1913	2470	440	4	---	None	0	61	Dom.	Sand above rock	440	6 ?	Sometimes flows very slightly during the winter.
5	SW¼SE¼ Sec.20	Mohawker	1912	2529	1002	4	0-27	Small(2)	--	74	Irr.	Black sand Sand	260 980-990	5 ? 6 ?	Original flow reported as 40 G.M. In 1922 well was caved within 235 feet of surface.
6	NW¼SE¼ Sec.24	G.S. Craig	---	2538	1325	6 4	0-30 30-270	Small	---	61	None	Sand below rock Sand	938-948 1190	8 ? 8 ?	In 1922 well was caved within 340 feet of surface.
7	SE¼SE¼ Sec.24	W.I. Turner	1912	2542	1170	3	0-500	10	6	92	Dom.	Sand below rock	964-1170	8 ?	Capping rock is thought to be formation No.7.
8	SW¼SE¼ Sec.29	David Kenison	1920	2539	1000	2	---	1	---	76	Irr.	Black Sand Sand	260 830	? ?	Original flow reported as 10 or 15 G.M.
9	SW¼SE¼ Sec.29	David Kenison	1915	2541	1173	4	0-20	10	---	90	St.Irr.	Black sand Black sand Gray sand	160 560 954-1110	5 ? 6 ? 8 ?	
10	SW¼SE¼ Sec.29	David Kenison	---	2539	300	4	---	Small	---	68	Dom.	Black sand	260	?	Not shown on Plate II; located under porch of Mr.Kenison's ranch house and 195 ft.S.46°E. from well No. 9.
11	SW¼SE¼ Sec.29	David Kenison	1913	2544	1122	3	0-20	None	-3	--	---	Black sand Gray sand Gray sand Gray sand	180 260 830 1080	5 ? 6 ? 8 ? 8 ?	Not shown in Plate II; located 620 ft. S.89°W. from house. Well flowed when first completed; in 1922 it was caved within 200 ft. of the surface.
13	SE¼NW¼ Sec.32	Cato	1916	2561	900	4	---	.3	---	70	---	Sand	900	8 ?	Depth in 1922,measured with sounding line, 680 feet.
14	SW¼SW¼ Sec.32	Al Bowman	1916	2565	1113	6	0-21	---	---	--	Irr.	Black Sand Sand	220 735	5 ? 8 ?	Flowed slightly when completed. The well was dynamited at a depth of 800 ft. and pumped at rate of 150 G.M. steadily for a month by pump in pit 16 ft. below surface. Now wholly caved.
15	NW¼NW¼ Sec.33	S. J. Hay	---	2531	530	4	---	52	---	62	Irr.	---	---	6 ?	
16	SW¼NW¼ Sec.33	S. J. Hay	1915	2537	590	4	0-20	24	---	67	Irr.	Gray sand Gray sand	115-118 590	4 ? 6 ?	
17	SW¼NW¼ Sec.33	S. J. Hay	---	2541	575	4	---	6	---	61	Irr.	Black Sand	150	5 ?	Not shown on Plate II; located 240 ft. N.50 W. from well No. 16. To be drilled deeper.
18	SW¼NW¼ Sec.33	S. J. Hay	---	2538	580	4	---	25	---	65	Dom.Irr.	Black sand White sand	160 580	5 ? 6 ?	Not shown on Plate II; located 690 ft. S.62°W. from well No. 20.
19	SW¼NW¼ Sec.33	S. J. Hay	1913	2537	802	6	0-20	22	---	69	Dom.St. Irr.	Black Sand Gray sand Gray sand	160 600-605 780-785	5 ? 7 ? 8 ?	Not shown on Plate II; located 520 feet S.66°W. from well No. 20.
20	SW¼NW¼ Sec.33	S. J. Hay	1913	2542	546	4	---	14	---	69	Irr.	Black sand Gray sand	120 160	? ?	Sand caved at depth of 160 ft. and well abandoned for time, then re-drilled to greater depth; record of redrilling not available

(1) Formation refers to the composite section, Table 3, and defines the approximate horizon of the aquifer.
(2) Small flows are less than one gallon per minute.

TABLE 10 - Cont'd.

Records of Drilled Wells in the lower Bruneau Basin

No.	Location	Owner or Lessee	Year	Elev. Feet	Depth Feet	Casing Dia. In.	Casing Depth Feet	Flow G.M.	Head Feet	Temp. °F.	Use	Aquifers Description	Aquifers Depth Feet	Aquifers Formation	Remarks
21	SW¼SE¼ Sec.33	Will Coberly	---	2567	1020			None	---	---	Irr.	Black sand Black sand and river gravel Blue sand	130 160 215	4 5 6	Originally flowed 65 G.M. reported by Mr.Coberly. Well is now caved, casing pulled and abandoned.
22	SW¼SE¼ Sec.33	Will Coberly	---	2568	200	4	---	None	-3	---	---	---	---	-	Not shown on Plate II; located 300 ft. east of well No. 21. Originally flowed, first flowing water being struck at a depth of 70 ft. In 1922 the well was caved within 80 feet of the surface.
23	SE¼SE¼ Sec.36	Z.P.Pinkstom	---	2532	400	4	---	54	---	71	Irr.	---	---	-	
24	SE¼SE¼ Sec.36	Z.P.Pinkston	---	2532	375	4	---	45	---	71	Dom.Irr.				Not shown on Plate II; located 310 ft. S.45°E.from well No.23. No seasonal fluctuation or steady decrease of flow has been noted by Mrs.Pinkston.
	T.6 S., R.6 E.														
25	SW¼SW¼ Sec.19	Bruneau town	1913	2551	976	4½	0-610	45	42	99	Dom.Irr.	Sand	960	8	Rock stratum from 940 to 943 ft. from surface is thought to be formation No. 7. Original flow reported as 180 G.M.
26	SW¼SW¼ Sec.19	H.D.Lawson	1913	2591	800	4	---	5	---	92	Dom.	---	800	8 ?	Original flow reported as 135 G.M.
27	SE¼SW¼ Sec.30	Jack Turner	1912	2509	320	3	0-300	.2	---	68	Dom.St.	Sand	180	6 ?	
	T.7 S., R.4 E.														
28	SW¼SW¼ Sec. 3	Stradley	---	2820	646	4	0-162	None	---	--	---	---	---	-	In 1922 casing had been pulled, well was caved and abandoned.
29	NE¼SE¼ Sec.13	Fet. Black	---	2654	---	6	---	5	---	78	Dom.	---	---	-	
30	SW¼SE¼ Sec.13	Kern	1914	2676	410	4	---	39	---	86	---	Tuff in basalt	400-410	13 ?	Original flow reported 90 G.M.
31	SW¼SE¼ Sec.23	O.R. Lawson	1915	2725	620	6	---	None	-15	--	Irr.	---	---	--	Well is 6 inch diameter for 344 ft. from surface and 4 inch diameter from that point to the bottom.
32	NE¼NE¼ Sec.24	Ira Purjue	1916	2678	---	6	---	82	---	82	Dom.St.Irr.	---			
33	NE¼NE¼ Sec.24	Ira Purjue	1921	2678	413	4	---	52	---	91	Irr.	Tuff below basalt	---	--	Not shown on Plate II; located 175 ft. west of well No. 32.
34	NE¼NE¼ Sec.24	Ira Purjue	---	2673	---	6	---	90 a	---	96	Irr.	---	---	--	
35	NW¼NE¼ Sec.24	W. T. McGinnes	---	2693	---	4	---	3	---	75	St.Irr.	---	---	--	Not shown on Plate II; located 360 feet S. 23°E. from well No. 37
36	NW¼NE¼ Sec.24	W. T. McGinnes	---	2691	---	2	---	Small	---	72	Dom. St.	---	---	--	Not shown on Plate II; located by door of Mr. McGinnes' ranch house.

(a) Flows with the superior letter "a" represent current meter measurements by Mr. A. G. Fiedler, United States Geological Survey.

TABLE 10 - Cont'd

Records of Drilled Wells in the lower Bruneau Basin.

No.	Location	Owner or Lessee	Year	Elev. Feet	Depth Feet	Casing Dia. In.	Casing Depth Feet	Flow G.M.	Head Feet	Temp °F.	Use	Aquifers Description	Aquifers Depth Feet	Aquifers Formation	Remarks
37	NE¼NW¼ Sec.24	W.T. McGinnes	---	2691	---	6	---	49	---	78	St. Irr.	---	---	--	
38	SE¼NE¼ Sec.24	Ira Purjue	---	2687	---	6	---	65	---	77	Irr.	---	---	--	
39	SE¼NW¼ Sec.24	W.T. McGinnes	---	2697	520	8	---	300 a	---	100	Irr.	Tuff below basalt	500 ?	?	
40	SE¼NW¼ Sec.24	W.T. McGinnes	---	2696	300	5	---	10	---	90	Irr.	---	---	--	Not shown on Plate II; located 310 feet S.20°E. from well No. 39.
41	SE¼NW¼ Sec.24	W.T. McGinnes	---	2695	---	4	0-400 ?	70	---	98	Irr.	---	---	--	Not shown on Plate II; located 340 feet S.13°E. from well No. 39.
42	NE¼SW¼ Sec.24	Frank Purjue	1920	2697	485	6 4	0-20 310-326	75	---	96	Dom.St.Irr.	Tuff below basalt ?	390-450	?	6 inch diameter to depth of 310 ft., 4 inch diameter from that point to the bottom.
43	SW¼SE¼ Sec.24	J. B. Conner	---	2702	417	6	0-21	110 a	6	99	Irr.	Sand below basalt Sand below basalt	186 332	? ?	Not shown on Plate II; located 300 feet N.35°E. from well No. 44
44	SW¼SE¼ Sec.24	J. B. Conner	1907	2701	200	6	---	40	---	99	---	---	---	--	Shown on Plate II as thermal spring; well is located 50 ft. north of the spring.
45	SW¼SE¼ Sec.24	J. B. Connor	---	2704	310	6	---	20	---	100	Irr.	Below basalt	---	--	Not shown on Plate II; located 260 feet N.40°E. from well No. 44.
46	SW¼SW¼ Sec.24	Frank Purjue	1921	2709	385	4	0-150	20	---	95	Irr.				
47	NE¼NW¼ Sec.26	J. A. Carlberg	---	2727	120	6	0-43	None	-14	60	Dom.St.	Sand	85	?	Not shown on Plate II; located 400 feet S.21°W. from well No. 31.
48	SW¼NW¼ Sec.26	Tate	---	2745	355	6	---	None	-6	---	Dom.Irr.	---	---	--	Well is in basalt between 40 and 355 feet from the surface.
	T. 7 S., R. 5 E														
49	SE¼NE¼ Sec.4	F. E. Adams	---	2571	70	4	---	None	-19	---	Irr.		70	4	Well drilled in bottom of sump 8 feet square and 38 feet deep. When first completed the well was pumped at the rate of 225 G.M. for 12 hour periods without appreciable draw-down; wells No. 21 and 22 ceased flowing while the pumping was going on.
51	NE¼NW¼ Sec.5	Dave Kenison	1920	2565	906	4	0-33	15	---	60	Irr.	Hard gray sandstone	190	5 ?	
52	NE¼NW¼ Sec.5	Dave Kenison	1916	2566	920	4	0-24	65	---	77	Irr.	Gray sand Caving gray sand	120 920	4 ? 8 ?	Original flow reported as 180 G.M.
53	NE¼NW¼ Sec.5	Dave Kenison	1921	2566	920	4	---	70	---	79	Irr.	Gray sand Caving gray sand	120 920	4 ? 8 ?	Not shown on Plate II; located 165 feet S.15°W. of well No. 52
54	NW¼SW¼ Sec.5	Dave Kenison	1918	2570	645	4	0-20	40	---	75	Irr.	Gray sand Caving gray sand	230-232 645	6 ? 8 ?	

TABLE 10 - Cont'd

Records of Drilled Wells in the lower Bruneau Basin

No.	Location	Owner or Lessee	Year	Elev. Feet	Depth Feet	Casing Dia. In.	Casing Depth Feet	Flow G.M.	Head Ft.	Temp. °F.	Use	Aquifers Description	Aquifers Depth Feet	Aquifers Formation	Remarks
55	SW¼SE¼ Sec.5	Albert Harley	1921	2626	810	4	0-24	40	15	92	Irr.	Hard black sand	800-810	?	
56	SE¼SE¼ Sec.6	Leonard Lawson	1921	2591	540	4	---	15	--	70	Irr.	Several sands	126-525	6?	In 1922 the well was filled to within 270 feet of the surface as measured with sounding line.
57	NE¼NE¼ Sec.7	Carl Johnson	1921	2599	---	4	---	65	--	78	Irr	---	---	--	Not shown on Plate II; located 1470 feet S. 25 E. from well No. 56.
58	NE¼NE¼ Sec.7	Carl Johnson	1920	2599	---	4	---	20	--	74	Irr	---	---	--	Reported that the subsequent drilling of wells Nos. 57 and 59 reduced the flow about 25 per cent. Not shown on Plate II; located 1380 feet S. 16°E. from well No.56.
59	NE¼NE¼ Sec.7	Carl Johnson	1921	2598	---	4	---	60	--	77	Irr.	---	---	--	Not shown on Plate II; located 1200 ft. S.18°E from well No.56.
60	NW¼NE¼ Sec.7	Carl Johnson	1910	2607	500	4	0-300 ?	--	--	73	St. Irr.	---	---	--	Well measured but 370 ft. in 1922.
61	SE¼NE¼ Sec.7	Albert Harley	1921	2606	460	4	0-20	25	--	80	Irr.	Vesicular lava above dense phase	460	?	
62	SE¼NE¼ Sec.7	W. V. Turner	1917	2604	---	4	0-22	20	--	78	Irr.	---	---	--	Not shown on Plate II; located 600 ft. N.57°W. from well No. 61.
63	NE¼SE¼ Sec.7	W. V. Turner	1917	2607	688	4	0-22	120	--	88	Irr.	Sand Sand Sand below rock	130-190 490-525 590-610	 8 ?	It is reported that the original flow was reduced about 80 G.M. when wells Nos. 66 and 67 were drilled subsequently.
64	NE¼SE¼ Sec.7	W. V. Turner	1920	2612	480	4	0-20	5	--	74	Dom.	---	---	--	Not shown on Plate II; located 240 feet N.25°W from well No. 66.
65	NE¼SE¼ Sec.7	W. V. Turner	1920	2617	720	6	---	75	--	90	St. Irr.	---	---	--	Encountered same formations and aquifers as well No. 66.
66	NE¼SE¼ Sec.7	W. V. Turner	1920	2614	1134	8 4	--- -680	215 a	16	92	Dom. Irr	Sand Tuff and sand below basalt	675 1067-1134	? 17 ?	Diameter of well at bottom is 2½ inches.
67	NE¼SE¼ Sec.7	W. V. Turner	1920	2613	710	6	0-20	130 a	7	88	St. Irr.	Fine black sand Red sand Yellow sand above soft lava	409-410 448-450 641-675	? ? ?	Not shown on Plate II; located 90 feet S.85°W. from well No. 66.
68	NW¼NW¼ Sec.8	Albert Harley	1915	2645	710	4	0-20	30	--	81	St.Irr.	Tuff or sand overlain and underlain by rock	---	?	Original flow reported as 60 G.M.
69	NW¼NW¼ Sec.8	Albert Harley	1912	2594	580	4	0-140	40	--	73	Dom.Irr.	Several sands	---	--	Not shown on Plate II; located 520 ft. S.77°W. from well No. 68. Original flow reported as 90 G.M.
70	NW¼NW¼ Sec.8	Albert Harley	1918	2595	566	4	0-22	40	--	71	Irr.	Sand Sand Gray sand above rock	220-235 525-527 540-546	8 ? 8 ? 8 ?	
71	NW¼NW¼ Sec.8	Albert Harley	1920	2596	530	4	0-20	45	--	75	Irr.	Gray sand	524-530	8 ?	Not shown on Plate II; located 390 ft. south of well No. 70. No diminution in flow between 1920 and 1922.
72	SE¼NW¼ Sec.18	Fet Black	1908	2650	350	4	0-50	--	--	--	Irr.	Sand above rock	350	?	
73	SW¼NW¼ Sec.18	Fet Black	---	2649	---	2	---	Small	--	65	---	---	---	--	
74	SE¼SW¼ Sec.18	Will Coberly	1920	2660	290	6	---	80	--	--	St. Irr.	Sand or tuff below rock	280	?	

TABLE 10 - Cont'd

Records of Drilled Wells in the lower Bruneau Basin

No.	Location	Owner or Lessee	Year	Elev. Feet	Depth Feet	Casing Dia. In.	Casing Depth Feet	Flow G.M.	Head Feet	Temp. °F.	Use	Aquifers Description	Aquifers Depth Feet	Formation	Remarks
75	SE¼SW¼ Sec.18	Will Coberly	1918	2664	400	6	0-45	55	---	88	St. Irr.	Below lava	240	?	Not shown on Plate II; located 180 feet south of well No. 74.
76	SW¼SW¼ Sec.18	Fet Black	---	2664	280	6	---	20	---	85	Irr.	---	---	?	Not shown on Plate II; located 630 feet S.73 W. of well No. 74.
77	SW¼SW¼ Sec.18	Fet Black	---	2666	325	4	---	Small	---	87	Irr.	Tuff or sand below lava	325	?	
78	SW¼NW¼ Sec.19	Jim Albert	1921	2687	300	6	---	5	---	82	---	---	---	--	
79	NW¼NW¼ Sec.28	W. I. Turner	1913	2844	435	4½	---	None	-20	--	---	---	---	--	
	T. 7 S., R. 6 E.														
80	SW¼SE¼ Sec. 4	Albert Harris	1898	2602	730	4	---	115	---	93	Irr.	---	---	--	Flow was about 150 G.M. in 1901 when visited by I. C. Russell.
81	NE¼NE¼ Sec. 5	A. J. Harley	1904	2544	500	3	0-300	None	-22	60	Dom.	---	---	--	
82	NW¼NW¼ Sec. 5	W. I. Turner	1917	2515	487	6 4	0-22 22-300	65	---	76	Dom. St. Irr.	Sand	460	8	
83	NW¼NW¼ Sec. 5	W. T. Turner	---	2515	180	4	0-21	None	-3 ?	52	Dom.	Gray sand	180	6	Not shown on Plate II; located 50 feet S.E. of well No. 82.
84	SE¼SW¼ Sec. 5	Angus MacDonald	---	2549	307	4	0-85	None	-6	58	Dom.St.	Black sand	90	6	
85	SW¼SW¼ Sec. 5	Joe Hawes	1918	2560	---	4	---	None	-15	58	Dom.	---	---	--	
86	NW¼NE¼ Sec. 6	Tay Hawes	1913	2523	265	4	0-20	1	---	62	Dom.	Several sands	119-265	6 ?	
87	NE¼NW¼ Sec. 6	Tay Hawes	---	2539	---	4	---	Small	---	68	Dom.	Black sand	220	6 ?	
88	SE¼NE¼ Sec. 6	W. I. Turner	---	2520	80	4	---	None	0	57	Dom.	Black sand Gray sand	54 80	4 ? 4 ?	Water stands at ground level.
89	SW¼NE¼ Sec. 6	Tay Hawes	1916	2534	400	4	0-43	65	---	70	Irr.	Black sand	220	6 ?	
90	NE¼SE¼ Sec. 6	W. I. Turner	1916	2540	230	4	0-22	1	---	66	---	Black sand	170	6 ?	
91	SE¼SE¼ Sec. 6	W. I. Turner	1915	2588	800	4	0-243	None	---	--	---	---	---	--	Not shown on Plate II; located 720 feet S. 73°W. from well No. 90.
92	SE¼NE¼ Sec. 7	Joe Hawes	1915	2587	1086	6 4	0-22 22-342	10	---	91	Irr.	Sand	1035-1036	8?	Discharges about 2½ feet above ground. Flow is about 25 G.M. when discharge occurs at ground level.

TABLE 10 - Cont'd

Records of Drilled Wells in the lower Bruneau Basin

No.	Location	Owner or Lessee	Year	Elev. Feet	Depth Feet	Casing Dia. In.	Casing Depth Feet	Flow G.M.	Head Feet	Temp °F.	Use	Aquifers Description	Aquifers Depth Feet	Aquifers Formation	Remarks
93	NW¼NW¼ Sec. 8	Joe Hawes	1915	2600	987	4	---	None	--	---	---				Dry hole
94	NW¼NE¼ Sec. 9	Bob Adams	1915	2589	910	6	0-42	165 a		122	Irr.	Sand Sand Sand Porous rock at bottom	628 806 880 910	8 ? 8 ? 8 ? ?	Reported that flow increased 50 G.M. while the well was being drilled the last inch; well does not go through this aquifer in the bottom of the hole.
95	NE¼NW¼ Sec.15	Sam Noble	1914	2666	910	6	0-65	15	---	118	Dom.Irr.	Sand Sand	727 877-887	8 ? 8 ?	Original flow reported as 40 G.M.
96	NE¼NW¼ Sec.15	Sam Noble	1917	2676	1105	6	0-70	10	---	127	---	---	---	--	
97	SE¼SE¼ Sec.15	Frank Trammel	1920	2646	750	10	0-200	None	---	---	---	---	---	--	Dry hole
98	NE¼NW¼ Sec.21	John Pinkston	1917	2606	353	8	0- 80	90	---	100	Irr.	River gravel	350-353	9	
99	NE¼SE¼ SEc. 21	Arthur Pence,Jr.	---	2618	240	2	---	5	---	104	Dom.	Black sand	236-237	7 ?	Not shown on Plate II; located adjacent to thermal spring No. 100.
101	SW¼SE¼ Sec.21	Arthur Pence,Jr.	1918	2639	611	8	0-177	765 a	61	106	Irr.	Tuff below basalt	589-611	16?	
102	NE¼NE¼ Sec.22	Frank Trammel	1919	2642	600	6	---	125	---	116	Dom.St.Irr.	Sand or tuff above basalt	405	12 ?	
103	NE¼SE¼ Sec.22	Arthur Pence,Sr.	1903	2592	240	2	---	2	---	100	Dom.	Sharp white sand	240	8 ?	No dimunition of flow has been noted by Mr. Pence.
106	NW¼SE¼ Sec.23	Grover Pence	1916	2670	725	6	---	160	---	115	Dom.Irr.	Red tuff below basalt	725	16 ?	
107	SE¼SE¼ Sec.23	Grover Pence	1922	2710	1220	6	0-365	190	2	110	Irr.	Red tuff below basalt Red tuff	650 1020	14 ? 16 ?	Artesian head of 650 foot aquifer was-15 feet; the 1020 foot aquifer increases the head 17 feet making the net head 2 feet at the top of the casing.
108	SE¼SE¼ Sec.23	Grover Pence	1899	2703	362	2	---	None	-21	---	---	---	---	--	Not shown on Plate II; located 150 feet south of well No. 107.
109	SE¼SW¼ Sec.23	Grover Pence	1899	2649	242	2	0-100	5	---	118	Irr.	Sand	242	8 ?	Not shown on Plate II; located 650 feet S. 55°W. from well No. 106. Original flow reported as 13 G.M. by Mr. Pence.

latitude of Bruneau town. In 1913 there began a rising wave of enthusiastic drilling for flowing artesian waters to irrigate lands above the Buckaroo ditch in Bruneau Valley and the lands in Little Valley for which there is little or no surface water supply. Impetus was added during 1915 and 1917 by the bringing in of several wells flowing 100 gallons or more per minute from deeper aquifers than those previously tested, and drilling proceeded until in 1922 more than a hundred wells had been drilled. The aggreate discharge of all flowing wells in 1922 was 4400 gallons per minute, or nearly 10 second-feet.

The following generalizations characterize the past developemnt.

1. Many closely spaced wells of small diameter, in cases 4-inch, have been drilled.
2. In most of the wells only the surface alluvial deposits have been supported by casing.
3. In every well the artesian head increases as deeper and deeper aquifers are penetrated.

The flow of many of the older wells drilled in the Bruneau basin has suffered a relatively large decrease. Very few measurements have been made of the orginal discharge of any well, the estimates were usually over-optimistic, and the ... apparent decrease is to a considerable degree a difference between estimate and measurement. Very few of the wells have been tightly cased between the surface and the aquifer. Under such conditions the poorly consolidated Pliocene "blue shales" through which the well has been drilled, slowly disintegrate or soften until the walls of the hole can support themselves no longer. Caving of the rocks results and the well becomes clogged with debris. The pressure of the artesian water is expended wholly or in part in forcing a passage through the debris and the flow of the well decreases or ceases. Well No. 5, for example, was drilled to a depth of 1002 feet, was cased only for 27 feet from the surface, and its flow had decreased from a reported original discharge in 1912 of 40 gallons per minute to one gallon per minute or less in 1922. Other similar instances are noted in Table 10. Those wells which have been more properly cased have not suffered such large decreases.

Aquifers and confining beds.--The structure of the lower Bruneau basin is an artesian slope whose aquifers and confining beds are members of the series of Pliocene rocks dipping uniformly northward (about $1\frac{1}{2}$ N. 10 E.) from the rim of the piedmont plain and plunging successively beneath the surface. The continuity of the aquifers, however, is interruped by the two normal faults described under the caption Faulting.

In Bruneau Valley the sequence of aquifers may be correlated with the tabulated composite section of the Pliocene rocks (Table 3) with a reasonable degree of accuracy. Tuff beds, numbered 14 and 16 in the tabulated section, yield large flows in several wells and in each case the overlying stratum of basalt acts as a confining bed. Within formations 4, 6, and 8 there exists a frequent alternation of sands or slightly consolidated sandstones with fine shaly snadstones or shales and each of the sands stores water under artesian pressure below the confining shaly beds. The sands are somewhat lenticular and vary laterally in texture and porosity; a bed that yields water freely in one well may differ in thickness in another well and yield but little water. In at least one instance the upper portion of a thick, structureless bed of fine sand acts as a confining bed to the lower portion by virtue of the friction retarding upward percolation. In many wells one or more aquifers known as "black sand" are penetrated. They are in some cases but a few inches thick, are not of great lateral extent, and possibly represent lenses of volcanic lapilli intercalated in the sediments. In one case the well driller's log reports the occurrence of river gravel with the black sand. This association and the horizon at which the aquifer occurs in this and inother wells favor the correlation, at least in some instances, of the "black sand" with conglomerate No. 5 of the composite section.

In Little Valley, however, the correlation cannot be satisfactorily made. Records of formations penetrated are lacking for most of the wells near the head of the valley, and it is impossible to trace the continuity of the aquifers or to assign them to definite horizons in the Pliocene section. The aquifers in the portion of the valley north of the mor southerly of the two normal faults already described, are accurately traceable and may be assigned to horizons of the Pliocene series without serious error.

The basal basalts of the Pliocene series and the intercalated beds of tuff, which serve as aquifers to the larger wells near the heads of the two valleys, have not been reached by the drill at any point within T. 6 S., R. 5 E. or, in Bruneau Valley, at any point less than three miles south of Bruneau. The northward extent of these aquifers and the flows that might be obtained from them in the northern parts of the valleys are unknown. Formations 4, 6, and 8 of the tabulated composite section have been penetrated at many points in the two valleys.

Artesian head.--The artesian head, or the pressure of the water at the point of discharge of the well, was determined for wells Nos. 7, 25, 43, 55, 66, 67, 101, and 107. The corresponding static levels, equal to the sum of the artesian head and the altitude at the mouth of the well, are tabulated below.

Table 11.--Artesian head and static level for some wells in Bruneau basin.

Well No.	Elev. Feet.	Head Feet.	Static level feet
7	2542	6	2548
25	2551	42	2593
43	2702	6	2708
55	2626	15	2641
66	2614	16	2630
67	2613	7	2620
101	2639	61	2700
107	2710	2	2712

Wells Nos. 43 and 101, located near the heads of Little Valley and of Bruneau Valley respectively, penetrate approximately the same aquifer and have about the same static level. Well No. 67, about 2½ miles north of No. 43, penetrate the same aquifer but its static level is 90 feet lower. Well No. 55 is situated about 1½ miles north of Well No. 67. It is fed by an aquifer above the one tapped by wells Nos. 43 and 67, yet its static level is about 20 feet higher than that of No. 67. The static level of Well No. 35, in the town of Bruneau, is about 50 feet lower than that of No. 55. Well No. 7 is about half a mile nearly west from No. 25 and taps approximately the same aquifer; its static level is, however, 45 feet lower. This difference may be due to the fact that well No. 7 is of small diameter, is not fully cased, and may be caved and partly clogged. These facts indicate that the elevation to which water will rise from a given aquifer varies irregularly. This irregular variation of the pressure of the water within the aquifers is reflected at the surface in the wide variations in flow of adjacent wells.

Quality of the water.

Chemical analyses have been made by H. B. Riffenburg in the Water Resources laboratory of the United States Geological Survey of samples collected from 23 of the wells and springs within the lower Bruneau basin. The results of these analyses, character of the waters in the form adoped by Palmer[31], and their values for irrigation as classed by

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[31] Palmer, Chase, The geochemical interpretation of water analyses: U.S. Geol. Survey Bull. 479, 1911.

TABLE 12

Quality of waters from some wells and springs in Bruneau River Basin

Base analyses	Well No.3 Pts/mill	Well No.7 Pts/mill	Well No.9 Pts/mill	Well No.24 Pts/mill	Well No.25 Pts/mill	Well No.35 Pts/mill	Well No. 39 Pts/mill	Well No. 43 Pts/mill	Spring No.44 Pts/mill	Well No.51 Pts/mill	Well No.55 Pts/mill	Well No.60 Pts/mill
Sodium and potassium, (Na+K)	141	105	91	75	93	50	56	52	52	75	52	52
Calcium (Ca)	14	6.0	13	26	4.4	9.6	9.6	8.8	4.6	21	8.0	7.6
Magnesium (Mg)	1.7	1.6	0.9	0.9	0.9	1.8	1.9	1.6	0.6	2.0	1.8	0.4
Sulphate (SO_4)	21	32	73	63	38	17	19	16	17	82	23	31
Chloride (Cl)	16	12	15	13	11	10	7.0	8.0	8.0	11	9.0	10
Nitrate (NO_3)	1.0	Trace	Trace	Trace	Trace	Trace	Trace	Trace	.50	Trace	Trace	Trace
Carbonate (CO_3)	0	0	0	0	0	0	0	0	.0	0	0	0
Bicarbonate (HCO_3)	373	185	149	161	137	98	105	102	107	132	112	100
Iron (Fe)	0.18	0.10	.10	.05	.05	Trace	0.10	0.16	.17	0.20	Trace	.60
Silica (SiO_2)	76	87	84	71	61	83	99	92	90	63	84	80
Organic matter	10	8.6	7.4	7.6	6.8	6.0	27	6.0	3.5	5.4	7.2	4.0
Hardness as $CaCO_3$ calculated	42	22	36	69	15	31	32	29	14	61	27	21
Total dissolved solids at 180°C	472	379	375	343	320	231	271	245	249	328	241	244

Reacting Values	Mg/li	%	Mg/li	%	Mg/li	%	Mg/li	%	Mg/li	%	Mg/li	%	Mg/li	%	Mg/li	%	Mg/li	%	Mg/li	%	Mg/li	%	Mg/li	%
r (Na+K)	6.134	43.86	4.568	50.55	3.959	43.66	3.263	36.45	4.046	52.63	2.175	43.11	2.436	45.24	2.262	44.66	2.262	46.31	3.263	37.70	2.262	42.07	8.262	43.16
r Ca	0.699	4.99	.299	3.31	.649	7.16	1.297	14.49	.220	2.86	.479	9.49	.479	8.89	.439	8.67	.230	4.71	1.048	12.11	.399	7.42	.379	7.23
r Mg	.140	1.00	.132	1.46	.074	.82	.074	.83	.074	.96	.148	2.93	.156	2.90	.132	2.61	.049	1.00	.164	1.89	.148	2.75	.033	.63
r SO_4	.437	3.12	.666	7.37	1.518	16.74	1.310	14.64	.790	10.28	.354	7.02	.395	7.34	.333	6.57	.354	7.25	1.706	19.71	.478	8.89	.645	12.31
r Cl	.451	3.22	.338	3.74	.423	4.67	.367	4.10	.310	4.03	.282	5.59	.197	3.66	.226	4.46	.226	4.63	.310	3.58	.254	4.72	.282	5.38
r NO_3	.016	.11	Trace		Trace		Trace		Trace		Trace		Trace		Trace		.008	.16	Trace		Trace		Trace	
r CO_3	.000	.00	.000	.00	.000	.00	.000	.00	.000	.00	.000	.00	.000	.00	.000	.00	.000	.00	.000	.00	.000	.00	.000	.00
r HCO_3	6.117	43.71	3.034	33.57	2.444	26.95	2.640	29.49	2.247	29.23	1.607	31.85	1.722	31.98	1.673	33.03	1.755	35.93	2.165	25.01	1.837	34.16	1.640	31.29
Alkalies	6.134	43.86	4.568	50.55	3.959	43.66	3.263	36.45	4.046	52.63	2.175	43.11	2.436	45.24	2.262	44.66	2.262	46.31	3.263	37.70	2.262	42.07	2.262	43.16
Earths	.839	5.99	.431	4.77	.723	7.98	1.371	15.32	.294	3.82	.627	12.42	.635	11.79	.571	11.28	.279	5.71	1.212	14.00	.547	10.17	.412	7.86
Strong Acids	.904	6.45	1.004	11.11	1.941	21.41	1.677	18.74	1.100	14.31	.636	12.61	.592	11.00	.559	11.03	.588	12.04	2.016	23.59	.732	13.61	.927	17.69
Weak Acids	6.117	43.71	3.034	33.57	2.444	26.95	2.640	29.49	2.247	29.23	1.607	31.85	1.722	31.98	1.673	33.03	1.755	35.93	2.165	25.01	1.837	34.16	1.640	31.29

Properties	%	%	%	%	%	%	%	%	%	%	%	%
Primary salinity	12.90	22.22	42.82	37.48	28.62	25.22	22.00	22.06	24.08	47.18	27.22	35.38
Secondary salinity	.00	.00	.00	.00	.00	0.00	.00	.00	.00	.00	.00	.00
Primary alkalinity	74.82	78.88	44.50	35.42	76.64	61.00	68.48	67.26	68.54	28.11	56.92	50.94
Secondary alkalinity	11.98	9.54	15.96	30.64	7.64	24.84	23.58	22.56	11.42	28.00	20.34	15.72
Irrigation Value												
Alkali coefficient	5.2	7.6	12.1	15.2	9.1	16.8	14.5	15.6	15.7	18.3	16.9	18.7
Class	Poor	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Good	Fair	Good

TABLE 12 - Cont'd

Quality of waters from some wells and springs in Bruneau River Basin

Base Analyses	Well No.66 Pts/mill	Well No.67 Pts/mill	Well No.92 Pts/mill	Well No.94 Pts/mill	Well No.95 Pts/mill	Well No.98 Pts/mill	Well No.101 Pts/mill	Spring No.104 Pts/mill	Well No.106 Pts/mill	Well No.107 Pts/mill	Spring No.110 Pts/mill
Sodium and potassium, (Na+K)	49	49	69	91	79	51	54	48	48	48	58
Calcium (Ca)	4.4	5.6	7.4	5.4	1.6	10	7.2	10	15	16	5.0
Magnesium (Mg)	0.9	0.7	1.0	1.6	1.6	1.0	1.0	1.9	2.2	2.6	1.0
Sulphate (SO_4)	21	19	22	29	25	23	20	18	21	15	21
Chloride (Cl)	9.0	10	11	10	14	9.0	13	7.0	8.0	9.0	10
Nitrate (NO_3)	.25	.50	Trace	Trace	Trace	0.50	Trace	Trace	Trace	0.95	Trace
Carbonate (CO_3)	14	14	34	0	34	0	0	14	7.2	0	24
Bicarbonate (HCO_3)	76	76	56	154	59	12	100	85	120	132	66
Iron (Fe)	.20	.18	.08	Trace	.08	.05	0.04	0.05	0.22	Trace	.11
Silica (SiO_2)	89	86	96	94	79	74	74	78	88	92	78
Organic matter	5.5	6.5	9.0	10	9.6	8.4	5.6	10	7.0	5.0	6.0
Hardness as $CaCO_3$ calculated	15	17	23	20	11	29	22	33	47	51	17
Total dissolved solids at 180°C	238	237	282	352	310	245	238	243	256	254	248

Reacting Values	Well No.66 Mg/li	%	Well No.67 Mg/li	%	Well No.92 Mg/li	%	Well No.94 Mg/li	%	Well No.95 Mg/li	%	Well No.98 Mg/li	%	Well No.101 Mg/li	%	Spring No.104 Mg/li	%	Well No.106 Mg/li	%	Well No.107 Mg/li	%	Spring No.110 Mg/li	%
r (Na+K)	2.132	44.11	2.132	43.81	3.001	47.87	3.959	50.95	3.437	51.57	2.219	41.27	2.349	45.06	2.088	40.36	2.088	35.46	2.088	35.72	2.523	46.24
r Ca	.220	4.55	.279	5.73	.369	5.88	.269	3.46	.080	1.20	.499	9.28	.359	6.89	.499	9.64	.749	12.72	.798	13.65	.250	4.58
r Mg	.074	1.53	.058	1.19	.082	1.31	.132	1.70	.132	1.98	.082	1.53	.082	1.57	.156	3.01	.181	3.07	.214	3.66	.082	1.50
r SO_4	.437	9.04	.395	8.12	.458	7.30	.603	7.76	.520	7.80	.478	8.89	.416	7.98	.374	7.23	.437	7.42	.312	5.34	.437	8.01
r Cl	.254	5.26	.282	5.80	.310	4.94	.282	3.63	.395	5.93	.254	4.72	.367	7.04	.197	3.81	.226	3.84	.254	4.34	.282	5.17
r NO_3	.004	.08	.008	.16	Trace		Trace		Trace		.008	0.15	Trace		Trace		Trace		.015	0.26	Trace	
r CO_3	.466	9.64	.466	9.58	1.133	18.07	.000	.00	1.133	17.00	.000	.00	.000	.00	.466	9.01	.240	4.07	.000	.00	.800	14.66
r HCO_3	1.246	25.78	1.246	25.61	.918	14.64	2.526	32.50	.968	14.52	1.837	34.16	1.640	31.46	1.394	26.94	1.968	33.42	2.165	37.03	1.082	19.83
Alkalies	2.132	44.11	2.132	43.81	3.001	47.87	3.959	50.95	3.437	51.57	2.219	41.27	2.349	45.06	2.088	40.36	2.088	35.46	2.088	35.72	2.523	46.24
Earths	.294	6.08	.337	6.92	.451	7.19	.401	5.16	.212	3.18	.581	10.81	.441	8.46	.655	12.65	.930	15.79	1.012	17.31	.332	6.08
Strong Acids	.695	14.38	.685	14.08	.768	12.24	.885	11.39	,915	13.73	.740	13.76	.783	15.02	.571	11.04	.663	11.26	.581	9.94	.719	13.18
Weak Acids	1.712	35.42	1.712	35.19	2.051	32.71	2.526	32.50	2.101	29.52	1.837	34.16	1.640	31.46	1.860	35.95	2.208	37.49	2.165	37.03	1.882	34.49
Properties	%		%		%		%		%		%		%		%		%		%		%	
Primary salinity	28.76		28.16		24.48		22.78		27.46		27.52		30.04		22.08		22.52		19.88		26.36	
Secondary salinity	.00		.00		.00		.00		.00		.00		.00		.00		.00		.00		.00	
Primary alkalinity	59.46		59.46		71.26		79.12		75.68		55.02		60.08		58.64		48.40		51.56		66.12	
Secondary alkalinity	12.16		13.84		14.38		10.32		6.36		21.62		16.92		25.30		31.58		34.62		12.16	
Irrigation Value																						
Alkali coefficient	17.9		17.6		11.8		8.8		10.4		17.3		16.1		17.4		18.2		17.2		14.5	
Class	Fair		Fair		Fair		Fair		Fair		Fair		Fair		Fair		Good		Fair		Fair	

Stabler[32], are grouped on the preceding pages in table 12.

The waters in each case have considerable primary salinity, the property due to the presence of sodium and potassium salts of the strong acids, are high in primary alkalinity, the property caused by alkaline carbonates and alkaline bicarbonates Na_2CO_3 and $Na HCO_3$, and have some secondary alkalinity due to the presence of alkaline earth bicarbonates $Ca(HCO_3)2$ and $Mg(HCO_3)2$, The waters may all be classed as primary alkaline waters, a type commonly associated with the crystalline igneous rocks. The irrigation value is expressed in terms of the alkali coefficient, equal to that depth of water in inches which on evaporation would leave a residue of toxic salts in sufficient quantity to harm vegetation. The waters are also classed as good, fair, or poor for irrigation. The waters from wells Nos. 51, 60, 106 are good, those from wells Nos. 24, 35, 39, 43, 44, 55, 66, 67, 98, 101, 107, and from springs Nos. 104 and 110 are fair but are close to the arbitrary dividing line between the two classes. It is very improbable that any of these waters would ever cause trouble when used for irrigation. The waters from wells Nos.9, 25, 92, 94, and 95 are only fair and might in time injure crops by accumulation of alkali. Water from well No. 7 is slightly above the class division line but that from No. 3 isbelow the line in the poor class. Neither of these waters is quite satisfactory for irrigation although the character of the soil may delay the accumulation of alkali in quantities sufficient to be troublesome. It is worthy of note that all of the waters whose irrigation value is questionable are from aquifers within the intermediate sedimentary division of the Pliocene rocks, and that all of the waters obtained from aquifers intercalated in the basal basalts are very satisfactory for irrigation. The ground waters leach additional quantities of mineral substances from the intermediate aquifers and become more concentrated in alkaline bicarbonates.

Temperature of the water.

The temperatures of the waters from the wells and springs of Bruneau basin are recorded in Table 10, and vary from a minimum of 52° F. in Well No. 83 to a maximum of 127°°F. in Well No 96. The shallower wells drilled along the valley axis discharge waters varying between 52° F. and 60° F., the waters from wells tapping the deeper aquifers and from some shallow wells drilled near the thermal springs are from 92° F. to 127° F., and wells reaching the intermediate aquifers discharge waters of intermediate temperatures.

[32] Stabler, H., Some stream waters of the western United States, with chapters on sediment carried by the Rio Grande and the industrial application of water analyses: U.S. Geol. Survey Water-Supply Paper 274, pp. 177-180, 1911.

It is ordinarily the case below the horizon of no seasonal variation that the temperature of the rocks and their contained water rises with increased depth at the rate of 1 F. for each 50 or 60 feet. The temperature at the horizon of no seasonal variation is approximately equal to the mean annual surface temperature, which is about 52 F. at Hot Spring, according to records of the United States Weather Bureau. If the normal sub-surface temperature gradient were applicable in the Bruneau basin the water encountered at the base of well No. 96 should have a temperature of about 75 F. rather than 127 F. The actual temperature is about 50 F. above the normal in this well. Other wells reaching the deepest aquifers have water temperatures from 20 to 50 EE above the normal that would be expected. Three possible explanations of the abnormal water temperature may be offered---expiring volcanism, mechanical heating by recent earth movements, and migration from depths at which the observed temperatures are normal. Heating of the waters through contact with partially cooled igneous rocks is not a tenable explanation, inasmuch as the volcanism of the region has been restricted to thin, rapidly cooled surface flows. Mechanical heating may be possible, but if it were the true explanation, superheated ground water should be more plentiful in the other similarly faulted regions. The condition that probably exists is that the ground water has migrated upward from a depth at which the observed temperature is normal, and is held in an aquifer far above its normal horizon.

The minimum observed temperatures presumably represent water that has been absorbed into the outcrops of the northward-dipping sediments intermediate in the Pliocene series, and has percolated down the dip of the permeable beds. Its course has not carried this water far below the horizon of no seasonal variation and it has not become heated. The intermediate temperatures undoubtedly represent thermal ground water that has migrated upward and become diluted with cooler waters moving downward from the surface.

Circulation of ground water and source of pressure.

The thermal water stored in the aquifers of the Bruneau artesian slope is fed into Pliocene rocks from below through concealed conduits. The tuff beds intercalated in the basal Pliocene basalts yield a large amount of thermal water to the wells of the lower Bruneau basin. From these same beds, along their outcrops south of the basin, many thermal springs issue. The outcrops of the aquifers constitute a zone of ground-water discharge rather than of intake. The usual condition of ground water being absorbed at the outcrop of the uptilted edge of the aquifer and percolating down the dip into the artesian basin is, therefore, not the condition existing in the Bruneau artesian slope. The water is absorbed at elevated outcrops remote from the basin, perhaps in the bordering mountainous divides, descends along favorable channels to a considerable depth below the surface, and is charged into the basal Pliocene aquifers by upward percolation along open fissures or joint planes. The basalts serving as capping rocks to these basal aquifers are undoubtedly broken by joints and fissures through which upward percolation may continue into the aquifers of the intermediate sedimentary division of the Pliocene series.

The pressure of the water confined within the aquifers is due to the hydrostatic head of the water column standing in the channels joining the remote intake area with the basal Pliocene aquifers. A considerable part of the pressure is expended in overcoming the frictional resistance of the channels and aquifers, and other modifying factors may further reduce the potential artesian head.

Further development of the artesain supply.

Areas within which flowing wells may be expected.--Flowing artesian wells may be obtained from the aquifers of the basal Pliocene at any point within the area shown on the map (Pl. II) as alluvium and in Bruneau Valley over a large part of the terrace bordering the eastern side of the valley. This terrace is bounded on the east side by a line through wells Nos. 80 and 95 and extends northward from sec. 22 into secs. 4 and 5, T. 7 S., R. 6 E. The aquifers within the intermediate sedimentary group will yield flowing water throughout the alluvial plain of Bruneau Valley, and near the axis of Little Valley. Flowing wells are not to be expected within the lower Bruneau basin at any points other than those herein mentioned.

The artesian head of wells drilled to the basal aquifers will be small at all points on the terrace land in Bruneau Valley or along the flanks of Little Valley and large flows are not to be expected within either of these areas. Furthermore, it has been shown under the caption Artesian head, that the pressure of the water within the aquifers varies irregularly and that this variation will be reflected at the surface by differences of flow between neighboring wells.

Depth of the aquifers--Any further development of the artesian supply should be of the aquifers intercalated in the basal basalts of the Pliocene series. The uppermost of these, formation No. 14 of the composite Pliocene sections (Table 3), should be entered at a depth of about 1300 feet in sec. 5, T. 7 S., R. 6 E., and at a depth of 1750 feet near Bruneau. In Little Valley this aquifer should occur at a depth of about 1600 feet in sec. 32, T. 6 S., R. 5 E., and 2000 feet or more beneath the surface in sec. 20 of the same township. The next underlying aquifer, No. 16 of the tabulated section, should be entered about 100 feet below No. 14. The quoted depths are approximate only and are based on a projection of the known dip of the beds at the surface, on incomplete well records, and on the analysis of the fault structure described under the heading Faulting. Until the positions of these aquifers and their artesian heads are known for the indicated localities north of the faults, the proper development can only be suggested and the hazards of drilling will be great.

Need of casing.--Every well put down in the future should be tightly cased with proper casing from the surface to the aquifer. If the aquifer is of such character that caving is likely, it should be supported by perforated casing, by the introduction of gravel, or both. The slow disintegration of the Pliocene rocks under the action of water and the resultant caving of the walls of the hole have been described under the caption History of past development. Moreover, a considerable lateral leakage into permeable beds above the aquifer may take place from an uncased well and may cause a considerable loss of pressure and consequently of flow. Only by properly casing the well may caving and sub-surface leakage be prevented and the artesian head and flow protected against decrease. Each well should also be provided with a valve or other capping device by which the discharge can be fully controlled. A flow of one or two gallons per minute is sufficient for the use of stock or to prevent freezing or silting up of the well, and during the non-irrigation period the discharge of each well should be limited to that amount. An artesian supply is by no means inexhaustible. To allow artesian waters to flow without beneficial use or to allow them to escape below the surface through incomplete casings is to commit an economic waste of a valuable natural resource.

Amount of the artesian supply.--Under the conditions of structure and of ground water circulation that exist in the Bruneau artesian slope it is impossible to measure the amount of the artesian supply by any practicable method. The amount of water to be obtained, however, will probably be limited by the cost of development rather than by the magnitude of the supply. It will undoubtedly be sufficient to cause a material addition to the irrigation supply, particularly if the wells are properly cased. The major part of the water discharged from the flowing wells would doubtless be permanently lost to the basin by deep percolation northward if the wells were not drilled. On the other hand a slight amount of the water discharged from artesian wells would otherwise reach the streams through springs and seeps.

Some decline in the flow of the wells is to be expected, especially if a large number are drilled, but there will always be a considerable aggregate flow and there is no reason to believe that the supply ever be permanently exhausted. Inorder that proper care may be exercised against an undue decline, a careful record of the character, thickness, and depth of each rock formation penetrated, of the height to which water rises from each aquifer as it is tapped, of the flow from each aquifer and of the amount and type of casing and mode of setting should be made and preserved for each well. In addition a weir, or other devide for measuring the discharge accurately, should be installed, and provision should be made for readily measuring the artesian head. Periodic readings of the flow and of the head of each well should be made and recoreded with the other well data.

Mode of development.--It cannot be too strongly urged tha the further development of the Bruneau artesian sloep should be carried out by cooperative organizations of the land owners of Bruneau and Little Valleys. Such organizations can achieve economics of testing, development, distribution, and conservation that are impossible for individual acting separately. Moreover, it is an undeniable fact that ill-advised development and untimely depletion of the supply will jeopardize the ultimate return of the money invested in any project of irrigation from artesian wells. A few large, carefully cased wells should be put down at separated points rather than many small, closely-spaced holes. Each well should be drilled at the lowest point on the surface from which the water may be distributed to beneficial use, in order that the maximum of artesian head and of flow may be gained. A well drilled in proximity to another syould be cased through the aquifer feeding the first well and continued to a deeper reservoir in order that the two may not interfere. When further drilling fails to increase appreciable the total flow, or results in a great diminution of the artesian head over the basin, the limit of practicable development will have been reached.

The most promising area for development is the alluvial plain of Bruneau Valley, However, the hazards of drilling on an untested faulted artesian slope are large and the artesian head cannot be predicted with certainty. A hole should, therefore, be put down to test the aquifers of the basal Pliocene at some point between Bruneau and sec. 5 T. 7 S., R. 6 E. It should be put down with the best of skill and care on the part of the driller to determine by one hole the possibilities of the northward extension of the deep aquifers. If the results of this deep test are favorable, a series of wells should be put down close to the river at intervals of at least one mile until the limits of feasible development are determined. A cooporative arrangement should be made with the Grandview Irrigation District for the flow of these wells to be diverted into the river during the irrigation season in exchange for an equivalent additional diversion at the Buckaroo dam. By such a development the maximum artesian flow may be coupled with the most efficient distribution through existing canals and ditches.

The winning of increased artesian supplies in Little Valley does not promise to be as feasible as in Bruneau Valley. A deep test should be drilled near the northern end of the valley and expansion should be based on the results of this test. Wells of large diameter should be drilled and their flows distributed in cooperation. In order that the water may be beneficially distributed the wells must be drilled at points somewhat higher than the valley axis. The depth to the aquifers will probably be greater and the artesian head lower than in Bruneau Valley, so that the cost of development will be porportionately higher. On account of the smaller artesian head the search for water along the flanks of the valley should be delayed until the lower lands of the valley axis have been fully supplied.

Subordinate in promise to both these areas is the development of the terrace lands on the east side of Bruneau Valley. The artesian head will be very low and in some parts, which cannot be definitely bounded, nor flowing wells can be obtained. The relative cost of development will be high, probably prohibitively so, and the hazards of drilling great.

The situation may be briefly summarized as follows: a further increase of the irrigation supply from flowing artesian wells in Bruneau and Little Valleys is quite practicable. The artesian head is not, however, great enough to yield flowing wells at points high above the valley axis, and the complete watering of the land already in cultivation is to be sought rather than the opening of large additional tracts. A conservative development of the underground waters is recommended.