Ground-Water Geology of the Bruneau–Grand View Area Owyhee County, Idaho

By R. T. LITTLETON *and* E. G. CROSTHWAITE

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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GROUND-WATER GEOLOGY OF THE BRUNEAU-GRAND VIEW AREA, OWYHEE COUNTY, IDAHO

By R. T. Littleton and E. G. Crosthwaite

ABSTRACT

The Bruneau–Grand View area is part of an artesian basin in northern Owyhee County, Idaho. The area described in this report comprises about 600 square miles, largely of undeveloped public domain, much of which is open, or may be opened, for desert-entry filing. Many irrigation-entry applications to the Federal Government are pending, and information about ground-water geology is needed by local citizens and well drillers, by Federal agencies that have custody of the land, and by local and State agencies that administer water rights. The areal geology and ground-water conditions in the Bruneau–Grand View area seemingly typify several basins in southwestern Idaho, and this study is a step toward definition and analysis of regional problems in ground-water geology and the occurrence and availability of ground water for irrigation or other large-scale uses.

Owyhee County is subdivided physiographically into a plateau area, the Owyhee uplift, and the Snake River valley. The Bruneau–Grand View area is largely within the Snake River valley. The climate is arid and irrigation is essential for stable agricultural development. Nearly all usable indigenous surface water in the area is appropriated, including freshet flow in the Bruneau River, which is used for power generation at the C. J. Strike Dam. However, with storage facilities additional land could be irrigated, and some land may be irrigated with Snake River water if suitable reclamation projects are constructed.

Sedimentary and igneous rocks exposed in the area range in age from Miocene to Recent. The igneous rocks include silicic and basic intrusive and extrusive bodies, and the sedimentary rocks are compacted stream and lake sediments. The rocks contain economically important artesian aquifers; the principal ones are volcanic rocks in which ground water is imperfectly confined beneath sediments of the Idaho formation, thus forming a leaky artesian system. The altitude of the piezometric surface of the artesian water does not exceed about 2,700 feet above mean sea level. In some areas, where the land surface is below that altitude, the artesian system discharges water through springs and seeps and locally causes waterlogging and development of alkali soil.

In chemical quality much of the water is unsuitable for irrigation and domestic use. The water contains a relatively moderate amount of dissolved solids, but the percent sodium and the concentration of fluoride are excessive for some uses. The quality of the water for irrigation ranges from excellent in the southern part of the artesian system to unsuitable in the northern part. All the artesian ground water that was sampled contained excessive amounts of fluoride.

There is a substantial supply of undeveloped artesian water in the area, but

sustained use of the water for irrigation may not be feasible unless provisions can be made for adequate soil drainage and soil amendment, because of the high percentage of sodium in the water. Detailed hydrologic and geologic study of the area should precede development.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

During early decades of the present century the Bruneau-Grand View area (fig. 12) underwent substantial irrigation development, chiefly with surface water. A small amount of ground water was used for stock and domestic supplies. The indigenous supply of surface water available for gravity irrigation is not adequate for all the arable land, and though reclamation-project proposals to impound and divert

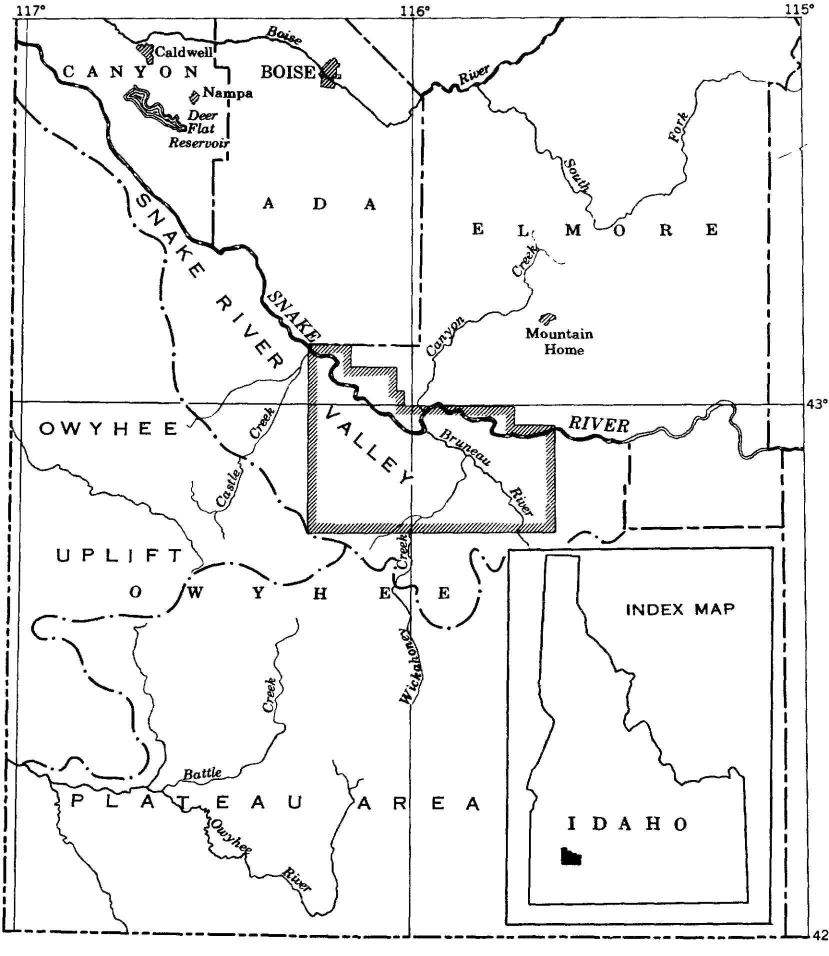

FIGURE 12.—Index map showing area covered by this report.

Snake River water to part of the area have been considered, construction has not been authorized by Congress. Accordingly, during the past 10 years ground water received increasing attention and many irrigation wells were drilled on privately owned land. Large tracts of so-called desert land in the public domain, previously used only for grazing, may be irrigable. Public demand is strong for increased openings of public land to irrigation entry under the Desert Land Act of 1877 and subsequent amendments.

According to the 1950 Census of Agriculture, the stock population of Owyhee County included 40,485 cattle valued at $4,805,840, and 70,210 sheep valued at $1, 154,020. The percentage of the county's stock population that is kept in the Bruneau–Grand View section is not known, but stockraising is an important industry in the Bruneau Valley. Where pasture land is irrigated, irrigation is an aid to stockraising. On the other hand, where grazing land is converted to raising irrigated grain and row crops, stockmen and irrigators may compete for land if irrigation farming encroaches on lowland winter range. This report may be useful to those agencies concerned with determining the most suitable long-term use of the available land and water.

The Idaho State Reclamation Engineer administers the waters of the State, and processes applications for water rights. The source, occurrence, availability, and chemical quality of ground-water supplies have great economic interest and importance to the State. They are important also to Federal agencies that are concerned with reclamation, range conservation and utilization, soil conservation, administration of public land, and making farm-home and crop loans.

In much of southern Idaho the arable land area exceeds the amount that could be irrigated with the visible supply of usable water. In order that feasible developments may proceed in an orderly manner, the State Reclamation Engineer needs information about ground-water geology and ground-water resources. The ground-water geology in several arable districts in southwestern Idaho is somewhat uniform in that the areas have similar geologic histories, contain similar geologic materials, and are related or similar in geologic structure. The Bruneau–Grand View district is representative of areas where geologically late sedimentation and volcanic activity were accompanied and followed by deforming earth movements. Study was undertaken as a step in the broader problem of deciphering regional ground-water geology and evaluating the regional ground-water resources of the southwestern part of the State. The Bruneau–Grand View area was chosen as the first unit of study because the ground-water supply there is of immediate practical concern. The report emphasizes geologic factors that affect the ground-water supply; appraisal of the ground-water resources of the area is only preliminary and qualitative. Quantitative appraisal would require additional study.

The report contains information about (1) the nature, distribution, and water-bearing characteristics of geologic materials, (2) the artesian pressure in aquifers, (3) the sources of ground-water recharge, (4) the probable ground-water potential of the Bruneau–Grand View area, and (5) the chemical quality of the ground water and its suitability for irrigation. The geologic map (pl. 6), representing about 600 square miles, was prepared in the field, using topographic maps of the Geological Survey as a base. Records of 81 artesian wells and chemical analyses of water from 24 artesian wells are included.

The work was part of the regular program of ground-water investigations in Idaho by the U. S. Geological Survey in cooperation with the State of Idaho. Cooperative ground-water investigations in Idaho by the Geological Survey are directed jointly by A. N. Sayre, chief of the Ground Water Branch of the Geological Survey, Washington, D. C., and M. R. Kulp, Idaho State Reclamation Engineer. The investigation described in the report was supervised by R. L. Nace, former district geologist, Boise, Idaho.

PREVIOUS INVESTIGATIONS

Early field investigations of the geology of the Bruneau–Grand View area were limited in scope, and the reports (Stearns, 1922; Buwalda, 1923; Piper, 1924) do not contain sufficiently detailed geologic information to disclose the effects of geologic factors on the occurrence of artesian water. A brief inspection of the geology and hydrology of part of the Bruneau–Grand View area was made by H. T. Stearns during a 3-day period in April 1922. His unpublished report contains general information about the drainage basin of Shoofly Creek and indicates generally favorable possibilities for irrigation development with artesian ground water. Buwalda's report was concerned with gas and oil possibilities. Piper's report covered the eastern part of the area and included a geologic map, records of artesian wells, and records of chemical analyses of the ground water. A geologic map of Idaho (Ross and Forrester, 1947) shows regional geologic features but does not delineate the local features.

FIELD WORK AND ACKNOWLEDGMENTS

About 600 square miles in the Bruneau–Grand View area, chiefly south of the Snake River in Tps. 3–8 S., Rs. 2–7 E., in northern Owyhee County was mapped. Small parts of adjacent townships in southern Elmore County, along the north rim of the Snake River canyon, are included in the map area. Field work was done from July 17 to November 6, 1953, and during several periods of a few days each in 1955. Eugene Shuter and G. E. Brandvold assisted with the field work.

About 60 percent of the field work was geologic study and mapping, with special attention to the principal aquifers (water-bearing materials), which are igneous rocks. The physical characteristics and field occurrences of rock units were studied, and their outcrops and structures (pl. 6) were mapped on a scale of 1: 24,000, using as a base published topographic-quadrangle sheets of the Geological Survey. The stratigraphic and structural relations of the rock units are illustrated graphically on plate 6.

Residents, well owners, and public officials supplied information about wells. The cooperation of property owners with the field party is gratefully acknowledged. Special thanks are given to Messrs. A. M. Knutson and I. E. Glineski, well drillers, who contributed some of the well logs in this report. Officials of the Idaho Power Co. furnished information about subsurface conditions disclosed by core and test drilling and provided motor-boat transportation for use in geologic mapping of the Snake River canyon above the C. J. Strike Dam. The following Geological Survey employees participated in the investigation: J. B. Reeside, Jr., D. H. Dunkle, Jean Hough, and I. G. Sohn identified fossils from the Idaho formation; R. E. Wilcox made thin-section examinations of volcanic rocks (written communication, April 17, 1954); and field conferences on stratigraphic and structural problems were held with Howard Powers and Dwight Taylor.

WELL-NUMBERING SYSTEM

The well-numbering system used in Idaho by the Geological Survey indicates the location of wells within the official rectangular subdivisions of the public lands, with reference to the Boise base line and meridian. The first two segments of a number designate the township and range. The third segment gives the section number, followed by two letters and a numeral, which indicate the quarter-section, the 40-acre tract, and the serial number of the well within the tract. Quarter sections are lettered a, b, c, and d in counterclockwise order, from the northeast quarter of each section (fig. 13). Within the quarter sections 40-acre tracts are lettered in the same manner. The digit following the letters indicates the order in which the well was visited within the 40-acre tracts. Well 7S–5E–12cd1 is in the SE¼SW¼ sec. 12, T. 7 S., R. 5 E., and is the well first visited in that tract.

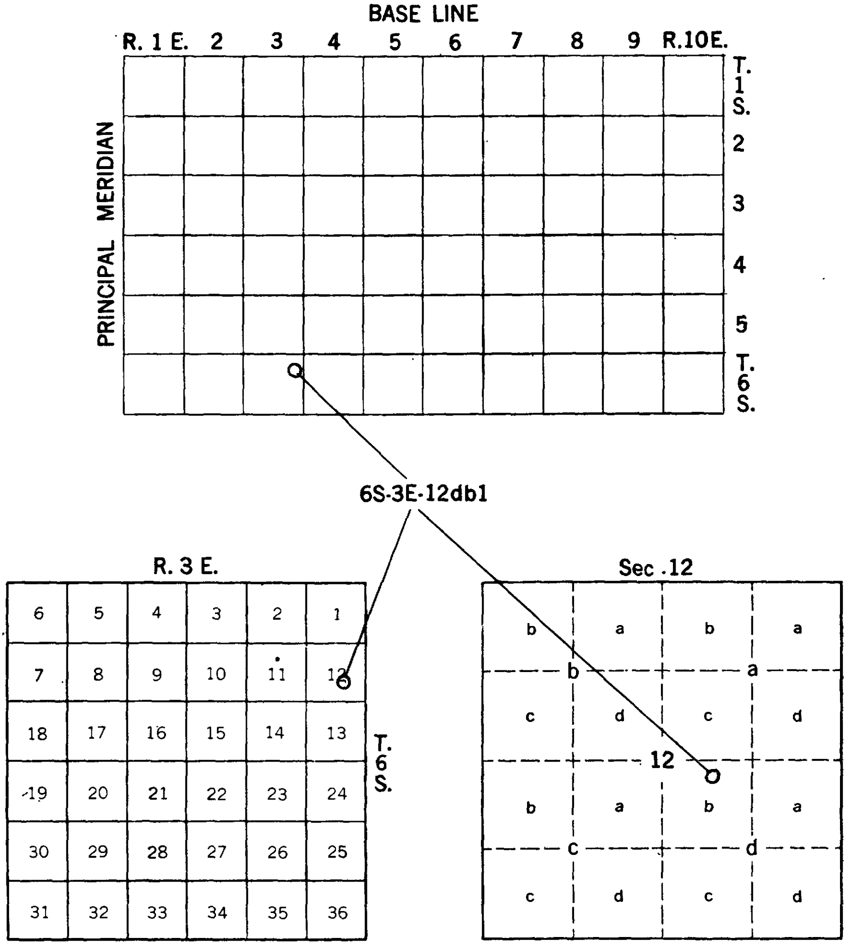

FIGURE 13.—Sketch of well-numbering system.

GEOGRAPHY

PHYSICAL SUBDIVISIONS AND LANDFORMS

Owyhee County includes about 7,650 square miles in three principal physical subdivisions—a plateau area, the Owyhee uplift, and the Snake River valley. (See fig. 12.) The Bruneau–Grand View area is almost entirely within the Snake River valley, but landforms and geologic features of adjoining areas strongly affect the occurrence and amount of water. Accordingly, the outstanding characteristics of each subdivision are described.

Plateau area.—An extensive plateau, ranging in altitude from about 3,000 to 7,000 feet above sea level, occupies the southern two-thirds of Owyhee County. The predominant surface rocks are volcanic, but alluvial and lake sediments also are widely distributed. Nearly horizontal thin sheets of resistant basalt form extensive tablelands, separated by the deep, steep-walled canyons of the principal streams. Silicic volcanic rocks generally form rolling uplands in which stream courses are deeply incised. In the southern part of the Bruneau–Grand View area the silicic rocks are displaced by a regional fault. The downthrow is on the north, where the rocks are deeply buried beneath basalt of Pliocene(?) age and sediments of the Idaho formation. Sediments exposed in the northern part of the plateau belong chiefly to the Idaho formation.

Owyhee uplift.—The Owyhee uplift is a rugged mountainous area in west-central Owyhee County, whose altitude ranges from about 3,800 to 8,400 feet above sea level. In the central part of the uplift is an eroded core of metamorphic and granitic rocks which were emplaced in Cretaceous time (Lindgren and Drake, 1904). On the flanks of the uplift younger igneous and sedimentary rocks are exposed. Structural features on the northeast flank of the uplifted area trend eastward to southeastward across the southern part of the Bruneau–Grand View area.

Much of the uplifted area is used for summer grazing. Gold and silver are mined on a small scale. Within the area is the historic town of Silver City, now a ghost town and tourist attraction.

Snake River valley.—The Snake River valley was formed by erosion of the Idaho formation and the Snake River basalt. Following the erosion, stream sediments were deposited on the valley floor. South of the river is a series of tributary valleys, dry washes, low hills, gravel terraces, and gently sloping pediments, some of which are covered by gravel. The north valley wall is a steep escarpment composed of beds of sediments and capped by resistant layers of the Snake River basalt. Locally the valley is a narrow canyon between nearly vertical walls. Altitudes in the Snake River valley and adjacent foothills range from about 2,300 to 3,800 feet above sea level. Topographic features and their altitudes in the Snake River valley are shown in profile on plate 6.

DRAINAGE

Drainage of the Bruneau–Grand View area is by perennial and intermittent streams and washes, most of which are directly tributary to the Snake River (see fig. 12). A few drainageways discharge to the Bruneau River, the largest local tributary of the Snake River. The headwaters of the Bruneau River, which include the East Fork and West Fork of the Bruneau River and the Jarbidge River, rise in the Jarbidge Mountains of Nevada, about 60 miles south of Bruneau. The streams cross the plateau area in deeply incised canyons which range in depth from 1,200 feet at the Idaho-Nevada boundary to about 800 feet below the junction of the East and West Forks (Piper, 1924, p. 11). The Bruneau River canyon is about 600 feet deep at the south boundary of the mapped area. Very little information is available about the discharge characteristics of the headwaters streams.

Jacks and Wickahoney Creeks rise on the plateau about 19 miles south of the map area. The upper reaches of these streams are perennial but only intermittent flow occurs in the map area. Little Valley Creek, which is formed by the confluence of Jacks and Wickahoney Creeks, is perennial in reaches where it receives waste water from irrigation and ground water from flowing artesian wells, seeps, and springs. Drainage in the western part of the area is principally by two intermittent streams, Shoofly and Poison Creeks. Throughout the area there are numerous ephemeral drainageways that carry only flood runoff.

CLIMATE

Only meager climatic records are available for Owyhee County, but precipitation is greater in the Owyhee uplift and on the plateau than in the Snake River valley. The average annual precipitation in the Bruneau–Grand View area as a whole probably is about 9 inches. Irrigation is necessary for most farm crops.

Precipitation and temperature in northern Owyhee County

[From records of the U. S. Weather Bureau]

Station	Altitude (feet above sea level)	Period of record	Average annual precipitation (inches)	Mean annual temperature (°F)	Length of growing season (days)
Hot Spring	2,590	1906–18	8.62	52.5	148
Grand View	2,365	[a] 1924–53	7.66	51.5	159
Silver City	6,280	1902–18	23.14	------------	------------

[a] Intermittent; 10 years of record are missing.

A weather-observation station on the plateau was established in December 1953 at Grasmere, about 35 miles south of Bruneau. Records of precipitation will aid estimation of the amount of precipitation that is available for ground-water recharge on the plateau, which contributes by underflow to ground water in the Snake River valley.

AGRICULTURE

The agricultural economy of the Bruneau–Grand View area is based chiefly on the production of livestock and hay. Alfalfa in excess of local winter needs is exported. The sparse shrubs and grasses in the area and throughout Owyhee County support extensive summer grazing.

Native vegetation in the Bruneau-Grand View area

[From records of the U. S. Bureau of Land Management]

Shrubs			Grasses		
Scientific name	Common name	Distribution	Scientific name	Common name	Distribution
Artemisia spinescens.	Bud sagebrush.	Lowland.	*Agropyron smithi.*	Bluestem wheatgrass.	Widespread.
Artemisia tridentata.	Big sagebrush.	Widespread.	*Agropyron spicatum.*	Bluebunch wheatgrass.	Uplands.
Atriplex conescens.	Fourwiug saltbush.	Lowland.	*Bromus tectorum.*	Cheatgrass.	Widespread.
Atriplex confertifolia.	Shadscale.	Widespread.	*Distichlis stricta.*	Desert saltgrass.	Alkali flats.
Atriplex matalii.	Salt sage.	Lowland.	*Elymus condensatus.*	Giant wildrye.	Widespread.
Chrysothamnus spp.	Rabbitbrush.	Widespread.	*Hordeum jubatum.*	Foxtail barley.	Do.
Erotia lanata.	Winterfat.	Do.	*Oryzopsis hymenoides.*	Indian ricegrass.	Do.
Grayia spinosa.	Spiney hopsage.	Lowland.	*Poa secunda.*	Sandberg bluegrass.	Do.
Sarcobatus vermiculatus.	Black greasewood.	Alkali flats.	*Sitanion hystrix.*	Foxtail.	Do.
			Stipa comata.	Needle-and-thread.	Uplands.

Livestock.—The livestock industry in the Bruneau Valley was begun in 1869 on the John Turner homestead. The industry expanded rapidly but early grazing was loosely managed and many hundreds of cattle ranged the broad expanse of Owyhee County throughout the year. Livestock operations flourished until the unusually severe winter of 1888–89, when cattle losses were excessive and some ranchers failed financially. Remaining ranchers improved their herds and began better range management, including winter feeding.

According to records of the Bureau of Land Management, permits for grazing on about 485,000 acres, mostly in the plateau area, have been issued to holders of irrigated hay land in the Bruneau-Grand View area. Approximately 80 percent of the Federal-owned grazing land supports about 7,920 head of cattle and 20 percent supports about 9,900 head of sheep. This distribution is based on a monthly allotment of 7 acres per head of cattle or per 5 head of sheep, for a grazing period of 7 months each year. The sparseness of the forage on the plateau makes it necessary to graze far from springs and watercourses, and stock water commonly is hauled from streams or large springs. Excessive depths to ground water, especially in elevated interstream areas, discourages the drilling of stock wells. There are, however, four stock wells on the southern edge of the so-called Owyhee desert (local name used by the stockmen) between the East and South Forks of the Owyhee River. These wells reportedly range in depth from 400 to 700 feet.

Much livestock winters in the valleys of the Snake and Bruneau Rivers and in Little Valley, which are good wintering areas because of the relatively mild winter climate and the availability of warm stock water.

Irrigation.—The principal irrigated crop in the Bruneau–Grand View area is alfalfa. Small acreages of grain and row crops also are irrigated. According to records of the State Reclamation Engineer, about 12,000 acres in the Bruneau Valley and south of the Snake River near Grand View is irrigated with surface water. Irrigation water for the Bruneau Valley is diverted from the Bruneau River by two small dams in the SW¼ sec. 26 and NW¼ sec. 35, T. 7 S., R. 6 E. Water for irrigation in the valley of the Snake River near Grand View is transmitted by three canals from the C. J. Strike Reservoir.

The last of the surface water available without surface-storage structures for irrigation in the area, exclusive of water in the Snake River, was appropriated in 1905. Since then the degree of interest in ground water for irrigation has fluctuated widely. In the early 1920's W. I. Turner obtained supplemental irrigation water by drilling wells in Little Valley and the valley of Shoofly Creek in the northern part of T. 6 S., R. 3 E. The success of flowing artesian wells touched off a minor land rush in 1922, but interest subsided within a year because the yields from some wells diminished to only a few gallons a minute within a relatively short time. In May 1951 completion of a flowing artesian well (7S–5E–7ab1, table 5) in Little Valley caused another local land boom. This well tapped volcanic rocks that underlie the Idaho formation and the initial large flow (about 3,800 gallons per minute) has been sustained. By July 7, 1954, the Bureau of Land Management had allowed, or recommended for allowance, 34 desert-land-entry filings (9,891 acres) in the Bruneau–Grand View area. Sixteen additional filings (4,817 acres) were suspended pending a field examination and report. About 3,500 acres in Bruneau, Sugar, Little, and Shoofly Creek Valleys are now irrigated with water from flowing and pumped artesian wells.

POPULATION AND TRANSPORTATION

According to the 1950 U. S. Census of Population, the population of Owyhee County was 6,307 or 655 more than in 1940. The Bruneau–Grand View area has no incorporated towns, but Bruneau precinct had a population of 479 and Grand View precinct had a population of 302.

The area is not served directly by rail; the nearest railhead is at Mountain Home on the Union Pacific Railroad. Mountain Home, the county seat of Elmore County, is 21 miles north of Bruneau on State Highway 51, and 25 miles northeast of Grand View by asphalt-surfaced county road (pl. 6). There are about 30 miles of asphalt-surfaced roads in the mapped area; other roads are graded and either gravel surfaced or unimproved.

STRATIGRAPHIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

The occurrence of ground water and the feasibility of obtaining it depend partly on geologic factors. Artesian water occurs only under specialized and distinctive geologic conditions. Accordingly, pertinent geologic factors and their influence on the occurrence and development of artesian water are reported herein.

The physical properties of individual rock units and their water-bearing characteristics are summarized on pages 158–159. Rocks of Miocene age, equivalent to the Columbia River basalt and the Payette formation, have been identified in many parts of the Snake River Plain. By inferences from the known surface distribution and structural trends of outcrops of these formations, Kirkham (1931b) postulated that they are widely present at depth beneath the plain. The formations, however, do not crop out in the Bruneau–Grand View area and they have not been recognized in the records or cuttings from drill holes. Therefore, neither of these formations are discussed here.

RHYOLITIC ROCKS

Both fine- and coarse-grained biotite-rich rhyolitic rocks were observed. Interconnecting mineralized fault zones in these rocks crop out in the southwestern part of the area. The observed field relations suggest that the rocks are similar in age and composition to rocks exposed in the Jarbidge area, Nevada (Howard Powers, personal communication, 1955). They are thought to be of Miocene age and their extrusion probably was contemporaneous with late stages of development of the Owyhee uplift. Much of this rock mass is overlain unconformably by silicic volcanic-flow rocks, by the Idaho formation, and by unconsolidated alluvial-fan deposits. Because their occurrence is not germane to the artesian ground-water problems, special study of these rocks was not made.

SILICIC VOLCANIC ROCKS

Volcanic rocks that are intermediate to high in silica content occur in flows, dikes, domes, and necks in the south-central and southwestern parts of the map area. The flow rocks locally include beds of welded tuff. All these rocks were mapped as a single unit, here called silicic volcanic rocks. These and related volcanic rocks, which crop out in a large area in southwestern Idaho and adjacent parts of Nevada and Oregon, were collectively termed the Owyhee rhyolite by Kirkham (1931a). Little of the rock is rhyolite, and the name Owyhee rhyolite has not been accepted by the Geological Survey for use in official reports. Study of thin sections from rock samples in the mapped

Summary of stratigraphic units in the Bruneau-Grand View area, Idaho

System	Series	Stratigraphic unit	Thickness (Feet)	Physical characteristics	Water-bearing characteristics
Quaternary	Recent to Pleistocene	Windblown sand and silt	0–50±	Fine-grained sand and silt in hills, mounds, and crescent-shaped dunes. Sand grains are predominantly angular.	Surficial deposits that are not permanently saturated. Too limited in areal extent to be of much importance.
		Alluvium and slope wash	0–50±	Sand, silt, and clay, and a few lenses of gravel and boulders derived from numerous sources. Commonly on and adjacent to the flood plains in stream valleys.	Contain unconfined ground water beneath the flood plains of principal streams. Locally recharged by leakage from underlying artesian aquifers. Locally waterlogged; alkali accumulation in some low-lying lands.
		Alluvial-fan deposits	0–75±	Fanglomerate, consisting of boulders, cobbles, gravel, sand, and silt at the bases of mountains. Windblown sand and silt are present at or near the toes of the fans. Lies on the irregular surface of consolidated older rocks.	No zones of permanent ground-water saturation, owing to the elevated position of the deposits. Locally, highly permeable materials absorb precipitation and may be areas of temporary saturation.
		Terrace gravel	0–60±	Cobble gravel, sand, and silt, locally containing thin caliche layers at or near the top. Locally, sand and silt overlain by windblown deposits. Mappable terrace deposits are present on high erosion surfaces of the Idaho formation and locally in the Snake River canyon.	Do.
		Pediment gravel	0–30±	Cobble gravel derived from silicic volcanic rocks. Many cobbles are tabular in form. The deposits lie on a beveled erosion surface of gently dipping beds of the Idaho formation.	Do.
Quaternary and Tertiary	Recent to Pliocene	Snake River basalt	3–250	Chiefly olivine basalt flows, light to dark gray, glassy to fine grained, dense to vesicular; pillow lava at some places, locally associated with volcanic agglomerate. Occurs as cap rock on north rim of the Snake River canyon and on buttes immediately south of the river. Occurs locally as an intracanyon basalt. Agglomerate in exhumed vent areas. Basalt dikes, chiefly fine grained, dense; some glassy and scoriaceous. Associated with ash and cinders.	Lie entirely above the regional water table, owing to occurrence at high levels in areas of much topographic relief. Contain perched water that supplies small springs issuing from the base of the basalt on the north wall of the Snake River canyon.

Tertiary	Pliocene	Idaho formation	2,800 (Maximum)	Poorly to well stratified terrestrial and lake deposits: lenticular beds of sand, sandstone, silt, and clay. Considerable ash is disseminated in the silt and clay and there are also thin layers of ash. In the lower part of the formation there are intercalated basalt layers. Locally thins to a featheredge.	Permeable beds underlying areas below an altitude of 2,700 feet generally contain water under artesian pressure. The beds are recharged by migration of water along faults from aquifers in the underlying volcanic rocks. Yields of artesian wells range from a few gallons to 1,500 gallons per minute.
	Pliocene(?)	Basalt	350	Basalt and olivine basalt, dark gray and brown, hard to soft, dense, fine to coarse textured; locally vesicular. A series of consolidated flows with interbedded lenses of red, pink, and brown tuff and tuffaceous fine-grained sediments. Exposed in the southern part of the area; dips northward and is deeply buried in the northern part of the area.	Contains water under artesian pressure in areas below an altitude of 2,700 feet. Principal aquifers are contact zones between layers of basalt and beds of tuff. Yields to artesian wells reportedly range from a few tens of gallons to 900 gallons per minute.
	Pliocene or Miocene	Silicic volcanic rocks	?	Intrusive and extrusive igneous rocks in dikes and sheets. Chiefly latite, ranging in color from light reddish brown to purple and black; glassy to fine grained and porphyritic; mostly dense.	Highly fractured rocks absorb surface water and ground-water underflow, and recharge artesian aquifers. The volcanic rocks, and possibly beds of welded tuff, are important aquifers from which large yields are obtained.
	Miocene	Rhyolitic rocks	------------	Fine- to coarse-grained extrusive rocks rich in quartz and biotite. Locally cut by mineralized fault zones.	Not important as aquifers.

area show that they are predominantly dacite and latite, (R. E. Wilcox, written communication, April 17, 1954). For convenience in reporting, the silicic volcanic rocks are here termed latite, the variety that is most common in the area. According to Ross and Forrester (1947) and Kirkham (1931a), the age of these rocks is late Miocene or early Pliocene.

DIKES, DOMES, AND NECKS

Genetically related to and mapped as a part of the silicic volcanic rocks is a complex group of dikes, domes, and necks (volcanic feeders and injected masses) exposed between Jacks and Wickahoney Creeks and in a narrow belt extending southeastward about 4 miles from the junction of those streams. These rocks, here called informally the volcanic rocks on Jacks Creek, are intensely fractured and distorted. The rocks include many varieties, the most common of which are purple lithoidal felsite porphyry, jet-black obsidian porphyry, and agglomerate. Vertical intrusions, volcanic throat breccia, and agglomerate are exposed in canyon walls. According to Wilcox (written communication, April 17, 1954), the rocks of the complex were protruded coincidentally with volcanic extrusions from many vents in a large area, perhaps during a considerable span of geologic time. After a period of erosion, the rough volcanic topography was buried by basalt of Pliocene(?) age and sedimentary deposits. Later the complex was partly exhumed by erosion.

VOLCANIC FLOW ROCKS

Volcanic flow rocks having an aggregate thickness of about 425 feet crop out in an eroded fault scarp at the north boundary of the plateau area, trending about N. 60° W. across secs. 2 and 3, T. 8 S., R. 2 E., in the southwest corner of the mapped area. The rocks are extensively exposed in the plateau area, where the maximum thickness probably is several thousand feet. Thin-section study of a single purple specimen from near the base of the series in the NE¼SE¼ sec. 3, T. 8 S., R. 2 E., showed that the rock is andesine-pyroxene felsite porphyry (mineralogically, a latite) (R. E. Wilcox, written communication, April 17, 1954).

In general the rocks occur in two textural phases—purple felsite porphyry (visible crystals in a very fine-grained matrix) and black obsidian porphyry (glassy matrix). The fine-grained phase is predominant and makes up most flows. The glassy phase occurs in thin, irregular zones at the bases of flows and grades upward into the fine-grained phase. Although the thin section studied did not have a fragmental structure, this group of rocks locally may contain much welded tuff. The columnar jointing and the great areal extent of individual rock units in some outcrops are characteristic of welded-tuff blankets.

Rocks exposed in Shoofly Creek canyon, near the southeast corner of sec. 34, T. 7 S., R. 2 E., belong to a typical silicic flow which was about 50 feet thick but was small in areal extent. The rocks are broken and shattered, forming crude tabular slabs, 1–3 inches thick and a few inches to a few feet across. The rocks seem to be felsite porphyry, similar in texture to those previously described.

WATER-BEARING PROPERTIES

A complex system of fractures in the volcanic rocks on Jacks Creek renders the rocks quite permeable, so that most of the normal flow of Jacks and Wickahoney Creeks sinks into these rocks and becomes ground water. Columnar-jointed silicic flow rocks and associated beds of welded tuff seemingly are the most important aquifers in the Bruneau–Grand View area. Locally the aquifers probably are coarse-grained, unconsolidated alluvium and talus derived from the volcanic rocks on Jacks Creek that accumulated on an erosional surface of silicic volcanic rocks, the whole being now buried by younger materials.

Wells tapping these aquifers yield as much as several thousand gallons per minute by artesian flow. Well 7S–5E–7ab1 has a measured flow of 3,825 gpm (gallons per minute) derived chiefly from silicic volcanic rocks at depths of 1,510 to 1,625 feet. Only a few wells tap these rocks, and the characteristics and distribution of the aquifers are poorly known. They are known to extend beneath the surface about 5 miles northeastward from the outcrop of the volcanic rocks on Jacks Creek, and a considerable thickness of the materials may underly most of the area (pl. 6). The potential yield from these acquifers may be great but the safe perennial yield is not known.

BASALT OF PLIOCENE(?) AGE

DISTRIBUTION, CHARACTER, AND THICKNESS

A sequence of basalt flows and interbedded tuff of Pliocene(?) age is exposed in the Bruneau River canyon near Hot Spring. There the rocks dip northward about 220 feet a mile, passing beneath sediments of the Idaho formation. Near Hot Spring the rock is believed to be displaced underground by the Hot Spring fault. The rock is deeply buried in the northern part of the area. In the south-central part of the area erosion has left only isolated remnants of basalt that rest unconformably on silicic volcanic rocks.

The basalt of Pliocene(?) age is predominantly hard, dense, coarse- to fine-textured olivine basalt. Locally the basalt is vesicular or amygdaloidal, with amygdules of a white carbonate mineral. The upper part of the unit is weathered and considerably stained with limonite or coated with a green mineral that resembles, and may be, chlorite. Lenticular beds of red, pink, and brown tuffaceous material are widely distributed in the formation and their color assists correlation from well to well and between outcrop areas. The tuff interflow beds include slightly tuffaceous fine-grained sediments.

The maximum thickness of basalt in the report area is about 350 feet. Piper (1924) estimated that the thickness south of Hot Spring, beyond the map area, is about 650 feet. Drill cuttings indicate a thickness of about 319 feet in well 7S-4E-12bd1 and 303 feet in well 7S-4E-13dc1. Thus the formation thins westward and may not be present beneath the southwestern and west-central parts of the map area.

AGE AND CORRELATION

The succession of basalt and tuff interbeds is part of an extensive sequence of volcanic rocks older than the Snake River basalt. The beds that crop out in this area are on the south margin of a faulted structural depression in which they form an irregular floor beneath a considerable thickness of alluvial and lake sediments. In the vicinity of Hagerman, Idaho, 40 miles to the east, similar rocks in a similar stratigraphic position were mapped and described by Stearns, Crandall, and Steward (1938) under the name Banbury volcanics, and their geologic age was presumed to be late Pliocene. Correlation of the easterly outcrops of basalt of Pliocene(?) age in the Bruneau-Grand View area with Stearns' Banbury volcanics is suggested, but further geologic study is needed.

WATER-BEARING PROPERTIES

The basalt of Pliocene(?) age yields water copiously to flowing artesian wells and springs. Contact zones between the layers of basalt and interflow beds seemingly are highly permeable. Individual wells yield as much as 900 gpm. The aquifers are tapped by wells in Little Valley south of the Hot Spring fault, and near the Hot Spring fault in Bruneau Valley. North of the Hot Spring fault wells do not penetrate the basalt, but well 6S-5E-10dd1 may have ended on the unit at a depth of 1,667 feet. A wildcat oil-exploration test hole near the NW cor. sec. 16, T. 6 S., R. 7 E., penetrated 100 feet of basalt below a depth of about 2,550 feet. Hydrologic data from the test well are not available.

IDAHO FORMATION

DISTRIBUTION, CHARACTER, AND THICKNESS

The Idaho formation crops out or is near the surface in most of the Bruneau-Grand View area. Overlying deposits are chiefly unconsolidated gravel, sand, silt, and clay of Pleistocene and Recent age. The

Idaho formation rests unconformably on basalt of Pliocene(?) age except in the southwestern part of the area, where it lies on a very irregular, eroded surface of the silicic volcanic rocks.

The Idaho formation consists of lenses, tongues, and sheets of clay, silt, sand, and sandstone, in most of which there is an appreciable amount of volcanic ash. There are a few beds of relatively pure ash. Well records show that at least three basalt flows, averaging 30 feet in thickness, occur within the succession of sediments. A fossiliferous, porous limestone, averaging about 20 feet thick (sections A–A′ and C–C′, pl. 6), is exposed in the canyons of the Bruneau River and Hot Creek near Hot Spring, where it is mappable in an area of about 8 square miles. A deposit of channel sand and sandstone (section D–D′, pl. 6) crops out in an elongated area of about 10 square miles along Shoofly and Poison Creeks above and below their junction. Locally the sandstone is oolitic, calcareous, and fossiliferous.

Stratification in the Idaho formation ranges from distinct to poorly defined, and beds are regular to irregular. Silt and clay layers in the upper 150 feet of exposed beds are poorly stratified. Regular bedding planes in the lower part of the formation assist stratigraphic measurements but distinct marker beds that could be traced more than about 4 miles were not found. Thus it was not practicable to establish definite correlations of surface exposures with beds described in well logs.

The thickness of the Idaho formation differs greatly from place to place, owing to erosion of its upper part and to the irregular configuration of the surface on which the formation was deposited. The thickness is 210 feet in the Bruneau River canyon in sec. 2, T. 8 S., R. 6 E. In the southwestern part of the map area the thickness ranges from a featheredge to a few tens of feet, but it increases to about 2,880 feet in the northeastern part of the area.

AGE AND CORRELATION

Use of the name Idaho formation in earlier geologic literature was summarized by Kirkham (1931a, p. 201), who said—

> A series of terrestrial deposits and lake beds, in places several thousand feet thick, overlies Columbia River basalt and Owyhee rhyolite and presents a characteristic lithology and a flora and fauna of Pliocene and later age. . . . According to the original definition of Idaho formation all of the upper series [i. e., lake beds above the Columbia River basalt and "Owyhee rhyolite"] should be included in it.

The Geological Survey classifies the Idaho formation as Pliocene in age. Piper (1924) did not apply a formal stratigraphic name to the sediments here called the Idaho formation but grouped them with a succession of sedimentary and volcanic rocks of Pliocene or Pleistocene age.

Stearns, Crandall, and Steward (1938, p. 92) applied the name Hagerman lake beds to sediments in the vicinity of Hagerman, Idaho, whose lithology and stratigraphic position are similar to those of the Idaho formation. They stated that "The Hagerman lake beds of the present report are equivalent to part at least of the Idaho formation, which is more extensively exposed farther west."

Fossils from the Idaho formation in the Bruneau–Grand View area, Idaho

[Identified by J. B. Reeside, Jr., D. H. Dunkle, Jean Hough, and I. G. Sohn]

Name and type of fossil	Lithology of matrix	Locality where found	Remarks
	Invertebrates		
Pelecypoda (clams and mussels):			
Oryqoceras arcuatum	Sandstone, coarse-grained, limonitic.	SW¼ sec. 33, T. 7 S., R. 6 E.	Common in the fauna of the Idaho formation; has been assigned Pliocene age.
Pisidium sp	Limestone	NE¼NE¼ sec. 4, T. 8 S., R. 6 E.	Age is possibly Pleistocene, but it may be an unfamiliar Pliocene species in the Idaho fauna.
Unio or *Anodonta* sp	Clay, silty, ashy	SE cor., sec. 12, T. 7 S., R. 6 E.	Long-ranging fossil; no value for age determination.
Sphaerium idahoense	Sandstone, coarse-grained, limonitic.	NW¼ sec. 33, T. 7 S., R. 6 E.	Identified by previous investigators as typical of Idaho fauna and Pliocene in age.
Do	Clay, silty	SW¼ sec. 9, T. 5 S., R. 2 E.	Do.
Gastropoda (snails):			
Valvata sp	Limestone	NW¼NE¼ sec. 4, T. 8 S., R. 6 E.	Age is possibly Pleistocene, but it may be an unfamiliar Pliocene species in the Idaho fauna.
Do	Sandstone, coarse-grained, limonitic.	SW¼ sec. 33, T. 7 S., R. 6 E.	Do.
Amnicola sp	Limestone	NW¼NE¼ sec. 4, T. 8 S., R. 6 E.	Do.
Lioplax sp	do	do	Do.
Vorticifex binneyi	Clay, silty, ashy	SW¼NW¼ sec. 20, T. 7 S., R. 4 E.	Identified by previous investigators as typical of Idaho fauna and Pliocene in age.
Goniobasis taylori	Sandstone, coarse-grained, concretionary.	SE cor. sec. 25, T. 7 S., R. 5 E.	Do.
Ostracoda (crustaceans):			
Candona sp	Limestone	NW¼NE¼ sec. 4, T. 8 S., R. 6 E.	Tentative age designation, probably Pliocene.
Cypris? sp	do	do	Do.
Cypridopsis? sp	do	do	Do.
Tuberocyproides sp	do	do	Tentative age designation, Pliocene.
Ilyocypris? sp. (rare)	Clay, silty, ashy	SE cor. sec. 12, T. 7 S., R. 6 E.	Do.
	Vertebrates		
Osteichthyes (bony fish): *Rhabdofario lacustris* or *Mylocyprinus robustus*.	Sandstone, coarse-grained, concretionary.	SW cor. sec. 25, T. 7 S., R. 5 E.	Range in age from Pliocene to Recent. Unsuitable for stratigraphic correlation.
Insectivora (insectivorous mammal): *Desmana moschata*.	Clay, silty, ashy	SE cor. sec. 12, T. 7 S., R. 6 E.	Identified from teeth. Unusual in North America. Known geographic range restricted to southeastern Russia, northwestern Asia, and the Pyrenees. Similar species are known from the upper Pliocene to Pleistocene of England and Belgium.

Mammalian fossil remains from near Grand View have been described by Gazin (1934). A fossil hare, *Hypolagus furlongi*, was identified and compared with a similar species found near Hagerman, about 55 miles east of Grand View. Gazin presumed that the species from near Grand View was slightly later in time and thus inferred that the beds of the Idaho formation in this area were slightly younger than Stearns' Hagerman beds farther east. Accumulated paleontological information indicates that the beds of the Idaho formation as mapped in the Grand View–Bruneau area are of Pliocene age but may include some beds of Pleistocene age. Fossil lists show both Pliocene and Pleistocene types, with a preponderance of Pliocene.

WATER-BEARING PROPERTIES

Permeable beds of sand and sandstone in the Idaho formation yield water to wells. In general the yield of individual wells by artesian flow is small, ranging from less than 1 gpm. to 60 gpm. Several pumped wells reportedly yield 700–1,500 gpm. The wells are largely uncased and the walls are unstable. Initial yields seemingly were considerably greater than at present, but the wells have very little casing, and caving may be the cause of reduced yields.

The piezometric surface of artesian water in the Idaho formation is below an altitude of about 2,700 feet. Thick, permeable lenses of sand and ash or channel deposits of sand and sandstone are capable of yielding by artesian flow sufficient water for irrigation. In order to sustain large yields the wells must be large in diameter, fully cased, and properly screened. This type of well construction has not been practiced in the Bruneau–Grand View area, and many existing wells in the Idaho formation are inefficient.

SNAKE RIVER BASALT

The Snake River basalt of Pliocene to Recent age caps the north wall of the Snake River Canyon and the buttes immediately south of the river. The formation is a succession of basalt layers, some of which are separated by lenticular beds of red, pink, and gray tuffaceous clay. At places the basalt is mantled by loessial and alluvial clay and silt derived partly from the Idaho formation. At some places along the north wall of the Snake River valley the basalt is underlain by or includes an intercalated bed of coarse-grained tuffaceous sediments 10–40 feet thick. Basaltic lava seemingly entered the Bruneau–Grand View area from the north, spreading over the Idaho formation. The variation in aggregate thickness of the basalt, especially from north to south, is caused partly by the irregular erosion relief on the surface of the underlying Idaho formation, on which there probably was a well-developed local system of drainage toward the west and southwest. Eastward from the lower part of the C. J. Strike Reservoir, in the southern part of T. 5 S., Rs. 4–5 E., and the northern part of T. 6 S., Rs. 4–5 E., there are several flows of irregular thickness. These may be either intravalley flows now partly covered by reworked sediments derived from the Idaho formation, or they may be interbedded in the Idaho formation. The stratigraphic position of the basalt in that area was not determined because it has no bearing on the occurrence of artesian water. In the northwest corner of the map area, north of the river, an intracanyon flow forms a terrace about 200 feet below the rim of the canyon. The aggregate thickness of the Snake River basalt in the Bruneau–Grand View area ranges from less than 10 feet in the SE¼ sec. 12, T. 6 S., R. 4 E., to more than 400 feet in secs. 19 and 20, T. 5 S., R. 6 E.

The Snake River basalt in the map area is predominantly dense black olivine basalt, commonly with the ropy surface features of pahoehoe lava. Vesicles and tension joints are typical features of the rock; vesicular zones are localized mainly near the tops and bottoms of flows. Locally, the formation is highly permeable but in this area it is not an aquifer, owing to its position above the water table.

In the southeast corner of the area a basalt dike or dikes crop out at two places. The magma rose along the Hot Spring fault and the bodies of rocks exposed at the two places probably are connected at depth. The basalt is fine grained to glassy and scoriaceous to dense. A small amount of cinders is associated with the dike rock, but basalt seemingly never was extruded from the fissure.

UNCONSOLIDATED SEDIMENTARY ROCKS

Unconsolidated silt, sand, and cobble gravel, ranging in age from late Pleistocene to Recent, indirectly influence the occurrence of artesian water because they form a permeable mantle on extensive upland areas, where they absorb precipitation and transmit water to artesian aquifers. Owing to the aridity of the climate the deposits in upland areas are not permanently saturated. Unconsolidated sediments occur on pediments, terraces, and hillsides, and in alluvial fans.

Pediment gravel.—Cobble gravel is spread thinly and uniformly over an erosional surface (pediment) that bevels gently dipping beds of the Idaho formation in the south-central part of the area. The cobbles are chiefly of latite porphyry, derived from an escarpment that faces northward at the head of the pediment. The pediment gravel forms the so-called Shoofly "desert," which extends from Jacks Creek to a short distance west of Shoofly Creek. In the northern half of T. 7 S., Rs. 3 and 4 E., there are mappable erosion remnants of these deposits. The thickness of the pediment gravel ranges from about 4 feet, immediately west of Little Valley, to about 30 feet in the vicinity of Shoofly Creek.

Terrace gravel.—Alluvial cobble gravel and sand occur at three different terrace levels along the east side of the Bruneau River, at several places adjacent to the Snake River, along Jacks and Wickahoney Creeks, and in secs. 1 and 2, T. 8 S., R. 5 E. The gravel fragments are chiefly quartzite, with subordinate amounts of silicic volcanic rocks. White and light-gray caliche locally caps the terrace deposits, and at places interstitial calcium carbonate forms hardpan in the gravel a few feet below the surface. Locally, windblown sand blankets some of the gravel and at places migrant dunes occur on the terrace deposits. The terrace deposits range in thickness from a few feet to 60 feet.

The several levels at which the terrace gravels occur mark the positions of former flood plains of the streams. Subsequent erosion left only remnants of the terraces and the derived materials are strewn widely over surfaces cut across the rocks of the Idaho formation.

Alluvial-fan deposits.—Deposits of boulder to pebble gravel and sand form alluvial fans spreading outward from mountains in the southwestern part of the area. The thickness of the deposits ranges from about 75 feet near the mountains to a featheredge at the toes of the fans. The texture of the sediments is progressively finer away from the mountains. The fans coalesce to form a piedmont alluvial plain.

The gravels contain fragments of granite and latitic and rhyolitic volcanic rocks. They lie on an irregular erosion surface on silicic volcanic rocks, rhyolitic rocks, and beds of the Idaho formation. Windblown sand and silt thinly mantle much of the piedmont alluvial plain.

Alluvium and slope wash.—Coarse alluvium occurs along the floors of principal stream valleys and is interfingered with fine-grained slope wash along hillsides. The deposits range in thickness from a featheredge to about 50 feet. The texture ranges from coarse gravel to clay and the material contains varying amounts of all the rock types discussed here. Along the Snake River, test holes sunk by the Idaho Power Co. were drilled in deposits consisting largely of basalt boulders.

The alluvium in the principal stream valleys contains unconfined ground water that may be adequate for stock wells. Vertical leakage into the alluvium from the underlying artesian aquifers has caused waterlogging and alkalinization of the soil at some places in the Bruneau and Little Valleys.

Windblown sand and silt.—The youngest deposits are windblown sand and silt which overlie all other types of rocks and sediments.

They are of mappable thickness in the northeastern part of the area. In secs. 13, 14, 23, and 24, T. 6 S., R. 6 E., the windblown deposits contain some ground water, but they are not important aquifers.

GEOLOGIC STRUCTURE

REGIONAL DIP OF BEDS

In general, beds of the Idaho formation are tilted northward, dipping 1°–8°. Locally the beds are horizontal or dip gently southward. Lack of a systematic pattern in the angle and direction of dip (pl. 6), and the lack of individual beds that are continuous over large areas, suggest that the Idaho formation was deposited in a series of small lakes, ponds, deltas, and flood plains. Many beds had original dips. Some time after deposition, the beds were tilted a few degrees northward.

The basalt of Pliocene(?) age seemingly dips northeastward. The dip was not measurable on single layers but subsurface records indicate that the unit as a whole dips about 220 feet a mile (sections A–A′ and B–B′, pl. 6).

The silicic volcanic rocks in the southwest corner of the mapped area dip about 4° SE. from the Owyhee uplift. This dip may be original, rather than diastrophic, conforming to an old topographic slope on the Owyhee uplift over which the lava flowed.

FAULTS

The principal faults and associated fractures strongly influence the occurrence of ground water because they provide avenues for downward movement of water in the areas of ground-water recharge, and for ascending movement in areas of artesian discharge. Locally there are highly permeable zones of intense fracturing adjacent to the faults. Faults are numerous throughout the area but relatively few are traceable on the surface (pl. 6). The presence of concealed faults at some places is suggested by the occurrence of artesian hot springs.

The Hot Spring fault, in the southeastern part of the area, trends N. 75° W. from near Hot Spring to beyond Little Valley. Locally, beds of the Idaho formation are displaced a few tens of feet. Narrow dikes of calcareous material and vertical cylindrical sandstone concretions are associated with the fault. Subsurface information indicates that the volcanic rocks underlying the Idaho formation are displaced as much as 400 feet. The Idaho formation seemingly was deposited after most of the fault movement occurred, so that the small displacement of beds of the Idaho formation at the surface represents only minor late movement along the older fault. Basalt was extruded along the Hot Spring fault plane in sec. 36, T. 7 S., R. 6 E., and sec. 31, T. 7 S., R. 7 E.

A fault at the southern end of Little Valley displaced beds of the Idaho formation about 20 feet; correlations based on drill cuttings from wells confirms that underlying volcanic rocks are equally displaced.

A fault-line scarp trends about N. 60° W. across secs. 2 and 3, T. 8 S., R. 2 E., in the southwest corner of the area, about a quarter of a mile southwest from the probable line of faulting. The fault itself is concealed by sediments but is believed to be part of an irregular regional belt of faults. The belt is several miles wide and trends westward to northwestward. Displacements of several hundred feet have occurred along some faults. This structural belt probably originated during uplift of the Owyhee area. The faults were largely obscured by later injection of volcanic magma and by explosive volcanism. The structural belt was further complicated by later faulting related to the so-called Snake River downwarp (Kirkham, 1931b). The silicic volcanic rocks and rhyolitic rocks were displaced several hundred feet along this belt of faulting. In the Bruneau–Grand View area the silicic rocks are deeply buried beneath younger rocks.

Faults in the Snake River canyon displace basaltic agglomerate exposed in partly exhumed volcanic vents and in landslides where the basalt slid down from the north rim of the canyon.

CENOZOIC HISTORY

The Bruneau–Grand View area is part of the southern flank of a huge structural basin, the so-called Snake River downwarp (Kirkham, 1931b), which extends across southern Idaho into southeastern Oregon (Russell, 1903). The history of the Bruneau–Grand View area is closely tied to that of the entire area of downwarp. The pre-Cenozoic history of the area occupied by the downwarp is poorly known, but the principal events of the Cenozoic era are reasonably well understood. These later events produced the principal geologic conditions that control the occurrence and movement of ground water.

TERTIARY PERIOD

In early Tertiary time the area now occupied by the Snake River downwarp was floored by impermeable ancient rocks. Southwest of the Bruneau–Grand View area there were mountains in the present position of the Owyhee uplift. Far to the north were the ancestral mountains of central Idaho. The mountains seemingly had been uplifted in Late Cretaceous time by arching of the pre-Tertiary rocks, accompanied by igneous intrusion and dynamic metamorphism. Little is known about events during Paleocene, Eocene, and Oligocene time, but these probably were epochs of extensive erosion during which pre-Tertiary sedimentary rocks were largely stripped from the mountains, exposing their cores of igneous and metamorphic rocks. In the Bruneau–Grand View area the rhyolitic rocks were emplaced in Miocene(?) time.

In late Miocene or early Pliocene time volcanic eruptions occurred along a belt of structural weakness in the south-central part of the mapped area, along the northeast margin of the Owyhee uplift. Silicic magma injected fault and fracture zones and erupted as viscous lava flows. Explosive eruptions produced volcanic ash, pumice, and welded tuff.

In early or middle Pliocene time basaltic lava erupted from vents that have not been found and spread over the eastern part of the Bruneau-Grand View area. Basaltic tuff and tuffaceous sediments were deposited also. The basalt flows may be a westward extension of the Banbury basalt of Stearns, Crandall, and Steward (1938).

Earth movements that began early in Tertiary time in the Snake River Plain continued in Pliocene time. The basalt layers in the Bruneau–Grand View area were tilted toward the north and northeast; they terminate on the west against the silicic volcanic rocks of the rugged Owyhee uplift. By late Pliocene time the Bruneau–Grand View area was on the southern flank of a newly formed structural basin and the surface of all but the southwestern part of the area was formed by a downfaulted basalt field that was dotted with both active and dormant volcanoes. Surface drainage was poor, being constantly changed by emplacement of new lava flows. Stream, lake, and windblown sediments, and local intercalated basalt layers accumulated on the older volcanic-rock surfaces in late Pliocene and early Pleistocene time. Seemingly, sedimentation first occurred on flood plains and in intermittent shallow ponds. Later, however, the area was invaded from the northwest by a large lake[1] in which a thick sequence of stratified silt, clay, and ash accumulated.

QUATERNARY PERIOD

Early in the Pleistocene epoch a well-developed drainage system was established across southwestern Idaho. The ancient lake or lakes were drained and thereafter deposition was largely alluvial. Erosion and deposition, interrupted frequently by lava eruptions, continued into Recent time, producing the modern topography.

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[1] The traditional view is that the Idaho formation is largely lake beds. Unpublished data show, however, that much, if not most, of the formation is nonlacustrine. The late Tertiary and Pleistocene history of the area is very poorly known, and future studies probably will lead to substantial revision of the traditional interpretations. Also, recent study in the authors' opinion shows that part of the Idaho formation and most of the Snake River basalt is of Pleistocene age.

Nonresistant sediments of the Idaho formation were deeply eroded. Cycles of stream cutting and deposition left terrace, pediment, and alluvial-fan deposits in many parts of the area. A late succession of basalt flows spread over the erosional surface. Continued regional downwarping probably accompanied the Pleistocene volcanism, giving gentle northward dips to the Idaho formation. Erosion of the older rocks and local deposition of alluvium and slope wash have been the principal active geologic processes during Recent time.

GROUND WATER

Ground water in the Bruneau–Grand View area occurs both under unconfined (water table) and confined (artesian) conditions. The unconfined ground water is a minor source of irrigation water and is considered only incidentally in this report, which is concerned principally with the source, occurrence, and chemical quality of the artesian water.

GENERAL ARTESIAN CONDITIONS

Artesian conditions depend upon the character of the water-bearing rock and confining beds, and their mutual stratigraphic and structural relations. In the Bruneau–Grand View area a favorable combination of geologic factors provides a recharge area and permeable aquifers in which ground water is stored and transmitted, as well as nonpermeable confining beds between which the artesian water is held under pressure. Well records show that the chief conduits are permeable zones in silicic and basic volcanic rocks. The principal confining beds are fine-grained sediments of the Idaho formation. Dense volcanic rocks confine water under artesian pressure in some places.

The maximum recorded artesian head developed in the system is sufficient to produce artesian flow at altitudes up to about 2,700 feet above mean sea level, or slightly higher. Pressure-head altitudes, interpolated from topographic maps and data on water levels in wells, range from about 2,708 feet in well 7S–5E–19ccl to 2,445 feet in well 5S–2E–2aal. The considerable drop in head downgrade from the recharge areas is caused partly by friction loss in the aquifer, but interformational leakage and discharge of artesian water from springs and wells probably are the principal causes. Owing to the lenticular form and structural displacement of the confining beds, the artesian system has many hydraulic leaks, and abrupt areal variations in pressure.

The artesian aquifers are tapped by wells only in scattered local areas (table 5) and the configuration of the artesian-pressure surface (piezometric surface) has not been determined. Moreover, many wells are not tightly cased, and, owing to interformational leakage, the pressure heads measured at the wells do not reflect true head in the aquifers. The general direction of decreasing altitude of the piezometric surface, and hence of the direction of ground-water movement, is northwestward. The average slope of the piezometric surface is about 14 feet per mile.

Precipitation, the ultimate source of practically all ground-water recharge, either enters the ground or runs off in streams. Water that enters the ground restores soil moisture and may be dissipated by evapotranspiration; excess soil water percolates downward and recharges underground reservoirs. Recharge to the artesian system in the Bruneau–Grand View area occurs both within the area and south and southeast of the area. There are two principal systems of aquifers, one of volcanic and the other of sedimentary rocks, and the two are recharged in distinctly different ways.

WATER IN VOLCANIC ROCKS

Recharge to the volcanic-rock aquifers seemingly is controlled partly by the irregular belt of faults that trends west to northwest across the south-central and southwestern parts of the area. The extensively fractured rocks in this zone are highly permeable. For example, the entire normal flow of Jacks and Wickahoney Creeks is absorbed by rocks of the complex along Jacks Creek. The amount of water thus absorbed is not known, owing to lack of streamflow data, but measurements at the upstream and downstream edges of the complex would give an approximate measure of the amount of such recharge from normal flow.

The silicic volcanic rocks are not artesian aquifers in the plateau area or in the Owyhee uplift, but they transmit ground water into the artesian aquifers. The zone of fault contact between the volcanic rocks that underlie the Bruneau–Grand View area and those south of the fault zone contains unconfined water that enters the volcanic artesian system and moves northward. Recharge to the artesian system occurs largely along that boundary.

In the southwestern part of the area, infiltration of surface water from Shoofly and Poison Creeks is a source of recharge. These streams were observed to lose much of their water as they pass over the contacts between the Idaho formation and underlying extrusive igneous rocks.

WATER IN THE IDAHO FORMATION

Permeable beds in the Idaho formation are recharged partly by leakage from underlying volcanic-rock aquifers. Artesian water ascends along fault zones, leaks upward through imperfectly confining beds, and migrates laterally through irregularly interlocking lenses of permeable sand. Faults in the southeastern part of the area are the principal vertical avenues of upward movement of ground water (sections A–A′ and B–B′, pl. 6). Considerable recharge to the Idaho formation probably occurs where the sedimentary beds overlap older volcanic rock. Water moving through fractures in the volcanic rock, and through the basal conglomerate or breccia at the contact, finds its way into permeable confined aquifers in the Idaho formation.

DISCHARGE OF GROUND WATER

In the Bruneau–Grand View area ground water is discharged artificially through wells and naturally through springs and seeps and by evapotranspiration. The amount of water discharged by evapotranspiration is not known but probably is substantial because extensive nonirrigated lowland areas contain alkaline and saline soil. Much of the evaporated water probably is from unconfined aquifers, but these in turn receive water by upward leakage from artesian aquifers. Wherever the soil is poorly drained and the ground surface is lower than the piezometric surface, alkali accumulation occurs as a result of evaporation of artesian water leaking upward.

SPRINGS

Various springs in the Bruneau and Little Valleys are alined along a major fault in the vicinity of Hot Spring. These springs were discussed by Piper (1924, p. 35–38), whose description is not repeated here. The largest group of springs is Hot Creek Springs in sec. 3, T. 8 S., R. 6 E. (pl. 6), which rise along the bedding contact of basalt and weathered tuff. The aggregate measured discharge from three openings was 1,780 gpm in September 1922 (Piper, 1924, p. 37). In September 1954 the aggregate measured discharge over a Cippoletti weir was 2,200 gpm. So far as these data show, withdrawal of water from artesian wells in the Bruneau-Grand View area has not decreased the discharge from the springs. The yield of the springs, however, probably should be measured periodically, because a persistent decline in yield would indicate approaching full development or overdevelopment of the artesian basin.

$\frac{1780}{4488}$ = 4 c[illegible] (Hot [illegible])

The gross discharge from all seeps and springs in the Hot Spring area has not been determined, but the springs probably contribute a large percentage of the flow of the Bruneau River downstream from the springs area. Short-term stream-gaging records for the Bruneau River indicate that gains to the river from spring discharge partly offset consumptive use of water along the stream and on irrigated valley land.

The amount of spring discharge in Little Valley is not known.

WELLS

Artesian irrigation wells discharge a substantial amount of ground water, chiefly by free flow. A few wells are pumped and there are a moderate number of small flowing domestic and stock wells. The discharge rates of flowing wells range from 0.5 to 3,800 gpm. An estimate of the total amount of water discharged by artesian wells in the Bruneau-Grand View area, based on estimated, reported, and measured discharges from 70 of the 81 wells that were canvassed, is 20,500 acre-feet yearly. These wells probably account for about nine-tenths of the artesian water withdrawal in the area, and the total withdrawal therefore is estimated at 22,500 acre-feet. Much of the water is not beneficially used because most of the wells flow throughout the year. Of the 70 artesian wells considered in the above estimate, 7 are nonflowing and 14 are capped during the nonirrigation season. For the purpose of estimating yearly discharge, the 21 nonflowing and capped wells were assumed to discharge during a period of 100 days each year at the rates shown in table 5.

The estimated yearly discharge of 22,500 acre-feet in 1954 was more than three times the amount discharged in 1922, which was about 7,100 acre-feet (Piper, 1924, p. 46). The increase in discharge was from a relatively few wells, drilled since 1922, that penetrate highly permeable zones in the volcanic-rock aquifers and have high discharge rates. The relative importance of the volcanic-rock aquifers is even greater than the discharge figures indicate, because many of the older wells have caved and their discharges were substantially less in 1954 than in 1922. A few additional highly productive wells would increase the total discharge greatly, and the maximum perennial yield of the artesian system could be developed by means of relatively few new wells.

QUALITY OF THE GROUND WATER

The utility of the artesian water in the Bruneau-Grand View area for domestic use, municipal supply, and irrigation is limited by its chemical quality. These limitations are outlined herein accordance with standards of the U. S. Public Health Service (1946) and the U. S. Department of Agriculture (Richards and others, 1954; Wilcox, 1948). Laboratory analyses (table 1) show that the water characteristically contains a moderate amount of dissolved solids, a high concentration of silica, a high percent sodium, and an excessive concentration of fluoride. The analyses are summarized in table 2 and are illustrated graphically in figure 14.

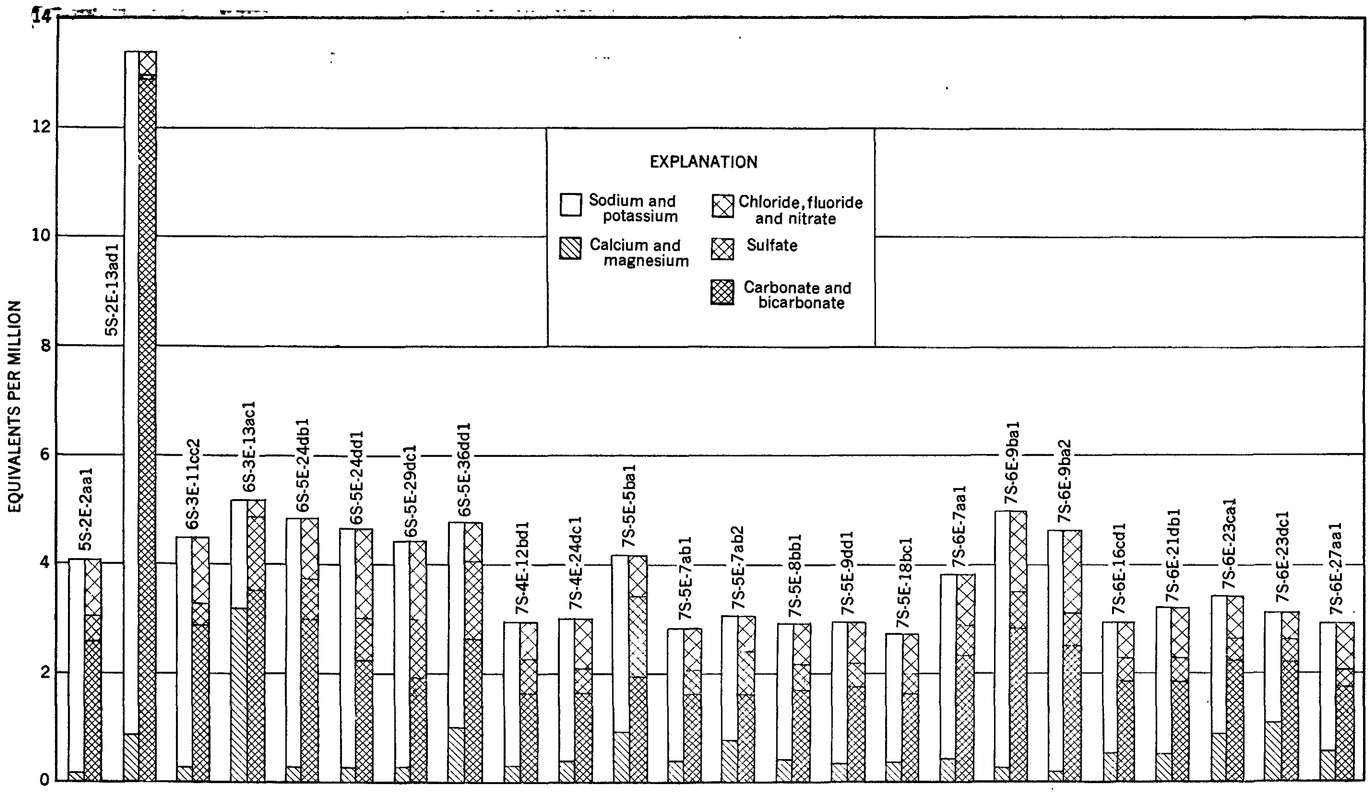

FIGURE 14.—Chemical composition of artesian water in the Bruneau–Grand View area, Idaho.

TABLE 1.—*Chemical analyses of artesian water in the Bruneau–Grand View area, Idaho*

[Chemical constituents in parts per million. Analyses by U. S. Geological Survey]

Well No.	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids		Hardness as $CaCO_3$	Percent sodium	Specific conductance (in micromhos at 25°C)	pH
																Parts per million	Tons per acre-ft				
5S-2E-2aa1	Nov. 24, 1953	126	81	0.02	2.4	0.5	91	1.0	104	37	22	12	14.0	0.4	0.85	291	0.395	8	95	395	9.4
-13ad1	do	80	98	.22	13	2.7	278	28	710	39	1.9	12	1.2	.8	.76	825	1.121	44	88	1,260	8.8
6S-3E-11cc2	do	94	110	------	3.2	1.2	98		128	24	19	16	14	1.6	------	329	.447	13	94	419	9.0
-13ac1	do	64	40	.00	56	4.7	42	6.3	215	------	65	10	.9	1.3	.05	334	.454	159	35	485	7.5
6S-5E-24db1	Nov. 23, 1953	77	90	------	4.4	.9	104		185	------	35	13	12	3.6	------	356	.484	15	94	505	8.3
	Aug. 15, 1922	92	87	.10	6.0	1.6	105		185	0	32	12	------	------	------	379	.515	22	91	----------	----
-24dd1	Nov. 23, 1953	94	77	.00	3.6	.5	100	3.1	141	------	38	12	24	2.9	.28	321	.436	11	94	455	7.9
-29dc1	Nov. 24, 1953	94	103	------	4.8	.2	97		118	------	52	17	18	.6	------	336	.457	13	94	425	7.8
	Aug. 1, 1922	90	84	.10	13	.9	91		149	0	73	15	------	------	------	375	.510	36	85	----------	----
-36dd1	Nov. 24, 1953	71	82	------	19	.5	87		160	------	69	13	6.0	2.2	------	341	.463	49	79	460	8.2
	Aug. 15, 1922	71	71	.05	26	.9	75		161	0	63	13	------	------	------	343	.466	69	70	----------	----
7S-4E-12bd1	Nov. 23, 1953	92	94	.01	6.0	.2	54	10	106	------	30	9.0	7.0	.6	.15	264	.359	16	80	289	7.5
-24dc1	Nov. 23, 1953	99	84	------	6.7	.3	60		102	------	22	11	10	.8	------	222	.302	18	88	271	8.0
	Aug. 7, 1922	99	92	.16	8.8	1.6	52		102	0	16	8.0	------	------	------	245	.333	29	80	----------	----
7S-5E-5ba2	Nov. 24, 1953	59	59	------	16	1.8	75		123	------	68	12	7.0	4.0	------	282	.383	47	78	402	7.2
	Aug. 1, 1922	60	63	.20	21	2.0	75		132	0	82	11	------	------	------	328	.446	61	73	----------	----
-7ab1	Nov. 23, 1953	102	88	.06	6.7	1.2	52	7.5	100	------	20	9.0	10	.7	.01	240	.326	22	78	286	7.0
-7ab2	Nov. 24, 1953	73	78	------	7.1	4.8	53		100	------	39	10	6.0	.8	------	228	.310	37	75	290	7.8
	Aug. 2, 1922	73	80	.60	7.6	.4	52		100	0	31	10	------	------	------	244	.332	21	85	----------	----
-8bb1	Nov. 24, 1953	73	70	------	7.9	.3	58		105	------	23	10	8.0	1.2	------	216	.294	21	86	274	7.3
-9dd1	do	92	82	.02	5.2	.7	57	7.0	115	------	20	7.0	10	1.0	.12	279	.379	16	83	290	7.8
-18bc1	do	92	90	.32	6.4	.4	50	8.3	108	------	18	8.0	9.0	.8	.08	294	.400	18	79	271	8.2
7S-6E-7aa1	Nov. 24, 1953	90	116	------	5.6	2.1	78		59	41	26	12	12	.1	------	299	.406	23	88	337	9.4
	Aug. 15, 1922	91	96	.08	7.4	1.0	69		56	34	22	11	------	------	------	282	.383	23	87	----------	----
-9ba1	Nov. 23, 1953	120	118	------	4.0	1.4	109		127	25	31	12	22	.2	------	370	.503	16	94	461	9.1
	Aug. 9, 1922	122	94	------	5.4	1.6	91		154	0	29	10	------	------	------	352	.478	20	91	----------	----
-9ba2	Nov. 23, 1953	120	99	.04	2.4	1.4	100	2.9	111	24	30	10	24	.5	.19	271	.368	12	93	449	9.2
-16cd1	Nov. 23, 1953	100	80	------	10	.9	55		117	------	20	9.0	7.0	1.6	------	222	.302	29	81	282	7.6
	Aug. 11, 1922	100	74	.05	10	1.0	51		112	0	23	9.0	------	.5	------	245	.333	29	79	----------	----
-21db1	Nov. 23, 1953	104	86	------	7.9	1.4	63		114	------	21	10	12	.8	------	236	.321	25	84	302	8.2
	Aug. 11, 1922	106	74	.04	7.2	1.0	54		100	0	20	13	------	------	------	238	.323	22	84	----------	----
-23ca1	Nov. 23, 1953	115	94	------	14	2.1	58		122	8	21	11	7.0	1.6	------	261	.355	44	74	311	8.6
	Aug. 11, 1922	115	88	.22	15	2.2	48		120	7.2	21	8.0	------	------	------	256	.348	47	69	----------	----
-23dc1	Nov. 23, 1953	105	86	------	17	3.1	47		137	------	19	9.0	4.0	1.9	------	234	.318	55	65	286	8.2
	Aug. 11, 1922	110	92	------	16	2.6	48		132	0	15	9.0	------	.95	------	254	.345	51	67	----------	----
-27aa1	Nov. 23, 1953	117	75	.00	9.1	1.2	51	6.1	110	------	17	9.0	10	1.3	.21	237	.322	28	76	287	7.2

TABLE 2.—*Range in chemical constituents in artesian water in the Bruneau–Grand view area*

[Chemical constituents in parts per million]

Constituent or property	Maximum	Minimum
Silica (SiO_2)	118	40
Iron (Fe)	.60	.00
Calcium (Ca)	56	2.4
Magnesium (Mg)	4.8	.2
Sodium (Na)	278	42
Potassium (K)	28	1.0
Sodium and potassium (calculated as Na)	109	47
Bicarbonate (HCO_3)	710	56
Carbonate (CO_3)	41	0
Sulfate (SO_4)	82	1.9
Chloride (Cl)	17	7.0
Fluoride (F)	24	.9
Nitrate (NO_3)	4.0	.1
Boron (B)	.85	.01
Dissolved solids:		
Parts per million	825	216
Tons per acre-foot	1.12	.294
Hardness as $CaCO_3$	159	8
Percent sodium	95	35
Specific conductance (in micromhos at 25° C)	1,260	271
pH	9.4	7.0
Temperature (° F)	126	59

SUITABILITY OF THE WATER FOR DOMESTIC USE

According to standards of the U. S. Public Health Service (1946) and the Idaho Department of Public Health (1953), the artesian water in the Bruneau–Grand View area is mostly unsuitable for human consumption, owing to the excessive amount of fluoride. The average fluoride content of water from all sources sampled was 10.6 ppm (parts per million). Drinking water in which the concentration of fluoride exceeds 1 or 2 ppm is associated with or causes mottling of the enamel of human teeth, a condition that develops if excessive fluoride is ingested by children during calcification and formation of the teeth (Dean, 1936). Most of the artesian water therefore is highly unsuitable as drinking water for children. Methods are available to treat water for the removal of fluoride, but discussion of those methods is beyond the scope of this report.

Samples of the public water supply of the village of Bruneau, obtained from well 6S–5E–24dd1, contained 24 ppm of fluoride on November 24, 1953, and 30 ppm on August 5, 1954. The two analyses indicate that the fluoride content of the Bruneau water supply is higher than that of any other public water supply in Idaho. Residents of Bruneau report that the water is unsatisfactory also because it has an unsavory taste and leaves a residue in cooking vessels. Some residents haul water more than 20 miles, from Mountain Home, to avoid domestic use of local artesian water.

SUITABILITY OF THE WATER FOR IRRIGATION

The suitability of a water supply for irrigation depends partly on the character of the soil to which it is to be applied. Aside from soil character, the suitability of water is determined by four principal chemical factors in the water: (1) the concentration of dissolved solids, (2) the percent sodium, (3) the residual sodium carbonate, and (4) the concentration of boron. The boron content in the artesian water in the Bruneau–Grand View area is less than 1 ppm. The water, therefore, is of class 1 for boron-tolerant crops, such as alfalfa (Richards and others, 1954, p. 81). Boron is not discussed further in this report.

SPECIFIC CONDUCTANCE

The electrical conductivity of water is an approximate indication of its mineral content. Specific conductance, the reciprocal of the electrical resistivity of water, is expressed in micromhos per centimeter ($K \times 10^6$ at 25°C). The U. S. Department of Agriculture (Richards and others, 1954) recognizes four classes of water on the basis of electrical conductivity. The classes are those having low, medium, high, and very high salinity. The dividing points between classes are 250, 750, and 2,250 micromhos. Except for the water from well 5S–2E–13ad1, which has high salinity, all of the artesian waters that were sampled have medium salinity.

PERCENT SODIUM

Two methods for evaluating the suitability of water for irrigation in which the concentration of sodium is an important factor have been used by the Department of Agriculture. The first method relates the percent sodium to the dissolved solids, the latter being expressed as electrical conductivity (Wilcox, 1948). A later method (Richards and others, 1954) is based on the sodium-adsorption ratio which is related to the extent the soil will adsorb sodium, and to the dissolved solids in terms of electrical conductivity. The percent sodium and the sodium-adsorption ratios of samples that were analyzed are listed in table 3.

The percent sodium is determined mathematically by the formula

$$\text{Percent Na} = \frac{Na^{+} \times 100}{Ca^{++} + Mg^{++} + Na^{+} + K^{+}}$$

in which the concentrations of sodium, calcium, magnesium, and potassium are expressed in equivalents per million (epm). The quality of the water then is shown graphically by plotting the percent sodium as one ordinate and the specific conductance as the other (Wilcox method). The results for artesian water in the Bruneau–Grand View area and their classification are shown in figure 15. According to the

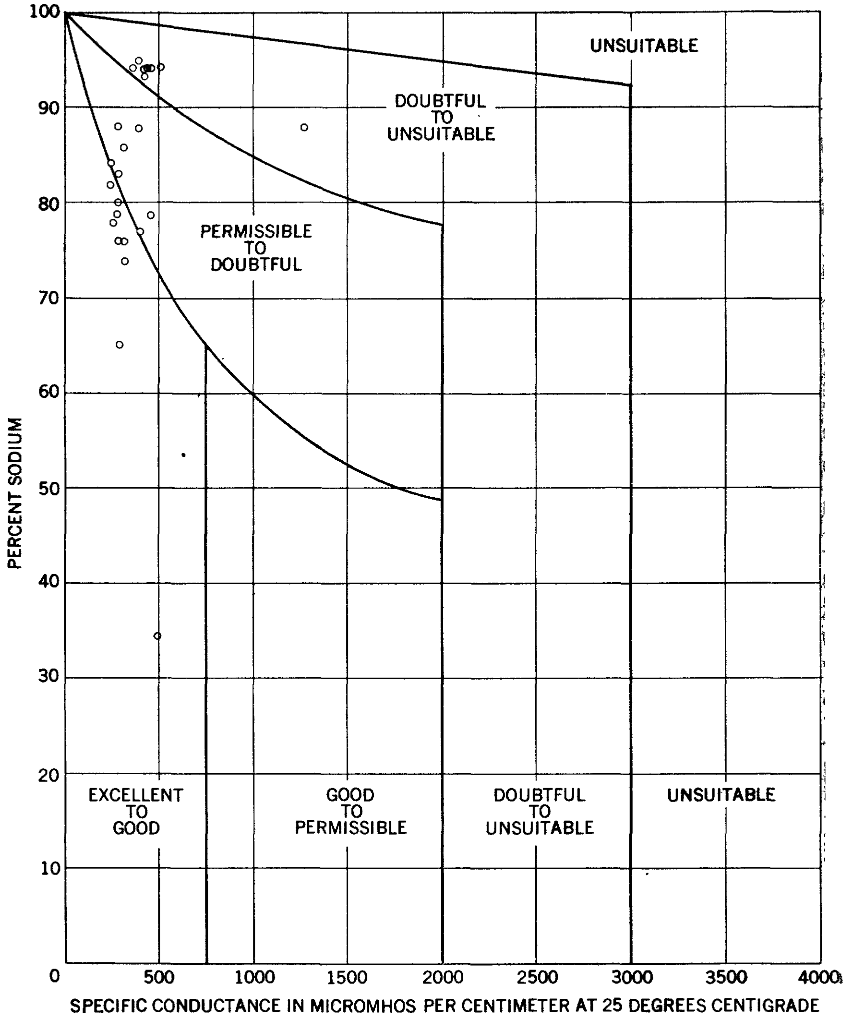

FIGURE 15.—Classification of artesian water in the Bruneau–Grand View area for irrigation (Wilcox method).

Wilcox method the water from 8 wells is doubtful to unsuitable in quality, that from 7 wells is permissible to doubtful, and that from 9 wells is excellent to good.

The U. S. Salinity Laboratory (Richards and others, 1954) has proposed the use of the sodium-adsorption ratio (SAR) for appraising the potential sodium hazard in water for irrigation. The sodium-adsorption ratio is defined by the equation

$$SAR=\frac{Na^{+}}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}}$$

in which the concentrations of sodium, calcium, and magnesium are expressed in equivalents per million (epm). Water is divided into four sodium-hazard classes by the SAR method: low (S1), medium (S2), high (S3), and very high (S4). For waters in which the specific conductance is 250 micromhos, the dividing points for the classes are at SAR values of 8, 15, and 22. The SAR method effectively expresses the adaptability of irrigation water to specific soil types. Detailed treatment is not attempted here because classification of the soils in the Bruneau–Grand View area has not been made and their study is beyond the scope of this report.

RESIDUAL SODIUM CARBONATE

In addition to the unfavorable sodium ratios, the amount of residual sodium carbonate in the artesian water is significant. The residual sodium carbonate is conveniently determined by the equation

$$RSC = (HCO^{-} + CO_3^{--}) - (Ca^{++} + Mg^{++})$$

The amounts of residual sodium carbonate, in millequivalents per liter, in the waters sampled are shown in table 3. The approximate values also can be determined graphically from figure 14.

TABLE 3.—*Classification and suitability of the artesian water for irrigation*

[Determined by method of Richards and others, 1954. Classes: S1, low-sodium hazard; S2, medium-sodium hazard; S3, high-sodium hazard; S4, very high sodium hazard. All samples collected in November 1953]

Well No.	Percent sodium	Sodium-adsorption ratio		Residual sodium carbonate	
		Ratio	Class	Milliequivalents per liter	Suitability
5S-2E-2aa1	95	14	S2	2.78	Unsuitable.
-13ad1	88	18	S4	12.07	Do.
6S-3E-11cc2	94	12	S2	2.64	Do.
-13ac1	35	1.4	S1	0.34	Probably safe.
6S-5E-24db1	94	12	S2	2.74	Unsuitable.
-24dd1	94	13	S2	2.09	Marginal.
-29dc1	94	12	S2	1.68	Do.
-36dd1	79	5.4	S1	1.63	Do.
7S-4E-12bd1	80	5.9	S1	1.42	Do.
-24dc1	88	6.1	S1	1.31	Do.
7S-5E-5ba2	78	4.7	S1	1.07	Probably safe.
-7ab1	78	4.9	S1	1.21	Do.
-7ab2	75	3.8	S1	0.89	Do.
-8bb1	86	5.5	S1	1.30	Marginal.
-9dd1	83	6.2	S1	1.53	Do.
-18bc1	79	5.1	S1	1.42	Do.
7S-6E-7aa1	88	7.2	S1	1.88	Do.
-9ba1	94	12	S2	2.59	Unsuitable.
-9ba2	93	13	S2	2.38	Marginal.
-16cd1	81	4.5	S1	1.34	Do.
-21db1	84	5.4	S1	1.36	Do.
-23ca1	74	3.8	S1	1.39	Do.
-23dc1	65	2.8	S1	1.14	Probably safe.
-27aa1	76	4.2	S1	1.25	Marginal.

The following statement (Richards and others, 1954, p. 81), outlines the method of determining the suitability of water for irrigation according to the amount of residual carbonate:

Water with more than 2.5 meq/l [milliequivalents per liter] residual sodium carbonate are not suitable for irrigation purposes. Waters containing 1.25 to 2.5 meq/l are marginal and those containing less than 1.25 meq/l are probably safe.

SUMMARY

Chemical analyses of artesian water in the Bruneau-Grand View area show moderate to high percentages of sodium, commonly high sodium-adsorption ratios, and generally large amounts of residual sodium carbonate. Therefore the sodium hazard to poorly drained irrigated soil is generally high.

Table 3 and figure 15 show that the artesian water ranges in quality from "probably safe" to "unsuitable" for irrigation. In general the water is marginal in quality. Water from most of the wells could be used for irrigation for an indefinite period of time on well-drained soils, with good irrigation practices. Soils formed on coarse-grained pediment or terrace deposits are well suited to irrigation because of their good drainage. Coarse-grained materials at shallow depths provide natural subsurface drainage and reduce substantially the hazard of alkali accumulation. Application of excessive amounts of the artesian water to fine-grained impermeable residual and transported soils that rest on relatively impermeable bedrock or subsoil would cause waterlogging and alkali accumulation. For some of the poorly drained soils the water might be suitable if applied sparingly. The data suggest that careful study of soils in the Bruneau-Grand View area should precede large-scale application of artesian water for irrigation.

GEOLOGIC FACTORS IN THE QUALITY OF THE WATER

The chemical quality of the artesian water is related directly to geologic factors in the subterranean environment through which the water passes. Three outstanding chemical characteristics of the water are the large amount of silica in relation to the dissolved solids, the high percentage of sodium, and the high concentration of fluoride.

The average amount of silica in solution is about 30 percent of the dissolved solids in the artesian ground water, ranging from a high of 39 percent in water from volcanic rocks to a low of 12 percent in water from the Idaho formation. The reason for this is that warm alkaline water percolating through the silicic volcanic rocks in the recharge area and underlying the artesian basin tends to acquire a high concentration of silica. The silica content of the volcanic rocks through which the water moves is shown by a chemical analysis of a representative silicic volcanic rock from the area (table 4).

TABLE 4.—*Chemical composition of silicic volcanic rock (latite) from sec. 21, T. 10 S., R. 13 E., near Castleford crossing, Twin Falls County, Idaho*

[Analysis by the U. S. Geological Survey]

Constituent	Percent of total	Constituent	Percent of total
SiO_2	68.29	H_2O	2.34
Al_2O_3	13.25	TiO_2	.71
Fe_2O_3	1.62	P_2O_5	.17
FeO	2.41	Cl	.02
MgO	.82	F	.09
CaO	2.17	MnO	.07
Na_2O	2.79	BaO	.07
K_2O	4.92	Total	99.74

The average percent sodium in the artesian water is 82.3. With one exception, analyses show that water produced from the Idaho formation has a higher percent sodium than water from the volcanic rocks. The exception is well 6S–3E–13ac1, which taps water in shallow stringers of sandstone to which recharge is from overlying saturated alluvium.

The principal sources of the sodium seemingly are the minerals in the Idaho formation and in tuffaceous sediments interbedded with the volcanic rocks. The sediments contain substantial amounts of devitrified volcanic ash and bentonitic clay, which contain appreciable amounts of soluble sodium and potassium minerals but only small amounts of soluble calcium and magnesium minerals. The most favorable sodium ratios occur in the southeastern part of the area, near Hot Spring. There the volcanic rocks are nearer to the surface and there is rapid upward percolation of artesian water along fault planes before it has had much contact with sodium-bearing rocks or sediments.

The concentrations of fluoride in the artesian water of the Bruneau-Grand View area are higher than is common in natural waters of the Pacific Northwest. According to Swenson (1954), the Bruneau-Grand View area is one of two northwestern areas where excessive amounts of fluoride have been found in ground water; the other area is the Rogue River valley in southwestern Oregon, where high-fluoride water occurs in certain sedimentary formations.

The fluoride in the water presumably is derived from silicic volcanic rocks or the Idaho formation. The amount of fluoride in basalt is relatively small, and elsewhere in Idaho ground water derived from basalt contains very little fluoride. The high proportion of sodium to calcium in the water may be related to the high fluoride concentration, owing to the high solubility of sodium fluoride and the low solubility of calcium fluoride.

TEMPERATURE

The temperature of artesian water in the Bruneau–Grand View area ranges from 59° to 126°F. (table 5), which is above normal for its depth of occurrence. (See Collins, 1925, p. 101.) Water from the volcanic rocks is generally warmer than that from the Idaho formation, ranging in temperature from 92° to 126°F. Water from the Idaho formation ranges in temperature from 59° to 108°F. Water temperatures less than 70° were observed in wells that tap both shallow unconfined water and artesian water.

The observed water temperatures do not vary systematically with well depths, and therefore evidence of a uniform thermal gradient in the Bruneau–Grand View area is lacking. The average temperature of water from depths between 350 and 1,745 feet is about 97°F. Piper (1924, p. 52) discussed three factors that might cause the high temperatures: (1) residual heat of volcanism and dying phases of volcanism at depth beneath the area, (2) mechanical heat of friction from recent earth movements, and (3) migration of warm water from depths at which the observed temperatures are normal. He suggested that the last cause seemed most plausible for this area. The present investigation did not reveal any new data on the cause of the high water temperatures. Systematic distribution of water temperature, either with depth or with location, may actually prevail. Many wells, however, are defective in construction, allowing migration and mixing of water from various aquifers, and disrupting whatever nautral pattern may once have existed.

ARTESIAN-WATER POTENTIAL

Conditions that favor further artesian-water development in the Bruneau–Grand View area include the following: (1) Extensive and highly permeable volcanic-rock aquifers; (2) a source of substantial recharge and ground-water underflow; (3) a reservoir that obviously could yield more water yearly than is now being withdrawn for beneficial use; (4) availability for desert land entry of undeveloped public land.

An estimate of the perennial yield of the artesian basin cannot be made at this time and would require intensive study. The estimated discharge from existing artesian wells is about 22,500 acre-feet yearly (see p. 174). Records of water levels and artesian pressure in the basin, nevertheless, do not disclose appreciable decline of the artesian head.

A small percentage of the existing wells discharge a relatively large percentage of the total water withdrawn. Thus, a small number of highly productive new wells might greatly increase the volume of yearly water withdrawals. Therefore, it should not be inferred from this report that the basin could safely and economically supply a large number of additional irrigation wells.

There are numerous natural leaks and avenues of water migration in the artesian aquifers. Many uncased and defective wells allow additional leakage and migration. Properly constructed artesian wells in the Bruneau–Grand View area would be tightly cased, with screens or perforated casing in producing zones where necessary. Flowing wells that are satisfactorily cased can be shut in when not in use, without causing excessive subsurface leakage or migration of water unless they tap two or more producing zones between which there is a marked differential in head. In order to conserve the artesian supply for beneficial use, flowing wells should be so constructed that they can be shut in when water is not needed.

The most unfavorable aspect of artesian-water development in the area is the generally poor chemical quality of the water. The average suitability of the water for irrigation is marginal, owing to the high percent sodium.

SUGGESTIONS FOR FURTHER STUDY

The geologic and hydrologic features of the Bruneau–Grand View area are complex and the safe water yield could be determined only by further study and systematic observations while development proceeded. As new wells are brought into production, water levels and artesian pressures are bound to decline, but such decline alone is not necessarily proof of overdevelopment. In a natural regime, discharge from the basin would be equal to recharge, the aquifers being essentially in equilibrium. In an artificially altered regime, discharge would continue to equal recharge so long as the perennial yield was not exceeded. The water discharged from wells is salvaged water that otherwise would be discharged elsewhere, because lowering the head reduces natural discharge. In practice, feasible development is less than the full ground-water yield of the basin because not all natural discharge can be stopped, and water levels might decline below the economical pumping lift. Thus, two factors are involved in the concept of "safe perennial yield," one being the amount of water available and the other being the amount that is economically recoverable.

The information gained by this and earlier investigations suggests that additional artesian-water development is feasible, but further and more detailed study is needed to assist orderly and reasonable development. Study would include, but not be limited to, (1) complete inventory of existing wells and springs; (2) systematic collection of discharge records for wells and springs and computation of the total yearly volume of withdrawals; (3) operation of a network of observation wells; (4) mapping of piezometric surfaces; (5) study of leakage and migration of artesian water; (6) aquifer tests permitting calculation of hydraulic coefficients of aquifers; (7) collection, compilation, and study of surface-water records for the Bruneau River system; and (8) comprehensive investigation of the chemical quality of the artesian waters. Concurrently, appropriate agencies should make systematic soil studies of potentially irrigable land.

RECORDS OF ARTESIAN WELLS

The 81 artesian wells listed in table 5 include most of the wells that have large yields. Their aggregate discharge probably accounts for about nine-tenths of the total yearly withdrawal from artesian wells in the area. Wells are used for irrigation, stock, and domestic supplies. One well (7S–6E–27aa1) supplies water to Valley Plunge, a public bathing facility at Hot Spring. Many small wells supply water for yard and garden watering and some groups of small wells supply farm-irrigation water. The well depths shown in the table are those reported to the authors, but many wells have caved and the depth from which they obtain water is not known.

TABLE 5.—*Records of artesian wells in the Bruneau–Grand View area*

Use of well: D, domestic; De, destroyed; I, irrigation; O, observation; PS, public supply; S, stock; U, unused.

Aquifer: Ti, Idaho formation; Tb, Basalt of Pliocene(?) age; Tsv, Silicic volcanic rocks.

Distance to water level: r, reported.

Yield: e, estimated; r, reported; m, measured. All yields are by artesian flow except where noted by asterisk (*).

Remarks: C, well for which chemical analysis of water is given in table 1; L, log included at end of report.

Well No.	Owner	Year drilled	Depth of well (feet below land surface)	Casing		Use of well	Aquifer	Temperature (°F)	Measuring point		Distance to water level above (+) or below (−) land surface (feet)	Date of measurement	Yield (gallons per minute)	Remarks
				Diameter (inches)	Depth (feet)				Description	Distance above or below (−) land surface (feet)				
5S-2E- 2aa1	Oscar Field		1,745(?)	2	1,745(?)	D,I,O	Tb(?)	126	Tap	4.0	+116.0	Oct. 28, 1953	^{r}72	C.
-13ad1	Emory Ratliff and associates.	1923	1,748	6	126	S,O	Ti	80	Top of stock tank	2.5	+6.8	Jan. 8, 1954	^{e}5	C, L.
5S-3E-15cb1	L. A. Hoalst	1941	1,620	6	32	D	Tb(?)						^{e}5	L.
-18ca1	Verna Weaver			3		S	Ti	71	Top of casing	.0	+2.8	Aug. 18, 1953	^{e}.5	Water contains gas.
-20bb1	W. G. Burghart			4		S	Ti		Top of discharge pipe.	2.6	+7.1	do	^{e}5	
-22aa1	C. E. Wilson	1915	1,300	4	60(?)	D,S	Ti	88						
-25bb1	A. L. Beach			4		U	Ti	65	Land surface	.0			^{e}<1	
6S-3E- 4ab1	Bessie Whitson		1,400	4			Ti	93	Top of casing	.3	+3.3	Aug. 18, 1953	^{e}3	
- 4bc1	W. A. Thurber		1,400	4		I	Ti	98	Top of elbow	1.0	+5.1	do	^{e}20	
- 5ad1	do			4		S	Ti	98					^{e}10	
- 9aa1	Bessie Whitson		1,400	4		I	Ti		Top of casing	.0	+10.1	Aug. 18, 1953	^{e}20	
- 9aa2	do		1,400	4		I	Ti	98	do	.0	+13.1	do	^{e}30	
-10bb1	do		1,400			I	Ti	93	do	.0	+2.7	do	^{e}15	
-11ca1	Smith and Hinton			6		U	Ti	92	do	.0	+10.8	do	^{e}5	
-11cb1	do		1,500	6		D	Ti(?)	89					^{e}10	
-11cc2	do	1923	1,423	6	32	I	Ti	94					^{e}20	C, L; original flow 240 gpm.
-12db1	do		90	4		D(?)	Ti		Top of casing	1.0	−8.28	Aug. 18, 1953		
-13ab1	do		1,350+	4		S,I	Ti(?)	101	do	1.0	+27.7	do	^{e}50	
-13ac1	do	1922	396	8	36	I	Ti	64	Elbow of discharge pipe.	−1.0			^{e}*500	C.
-13ad1	do			6		I	Ti(?)	98	Bottom of elbow	2.0	+10.0	Aug. 17, 1953	^{e}15	
-13ad2	do	1922		6		I	Ti(?)	90	Top of casing	−1.5	+7.9	Aug. 18, 1953	^{e}15	
-13bc1	do		290	6		U	Ti		Lower lip of discharge pipe.	−.5	−26.8	Aug. 17, 1953		
-13bd1	do	1933	460	8-6-4	419	I	Ti	62					^{e}*700	
-14bb1	do	1923	1,250	6	426	De	Ti							L.

-14bb2	do	1923	1,501	4	------	U	Ti	------	Top of casing	.8	−11.8	Oct. 7, 1953	------	Caved at 47 feet.
-14bc1	do	1923	1,341	6	373	O	Ti	85	do	−2.0	+5.9	Aug. 18, 1953	^{e} 3	L.
-14bd1	do	1953	300	20–16	287	I	Ti	68	------	------	------	------	^{r} *1,620	
6S–4E–15bd1	U. S. Government	------	500+	2	------	S	Ti(?)	67	Top of casing	−.5	+1.7	Aug. 17, 1953	^{e} 1	
-25bb1	Garry Kohring	1953	1,750	16–12	290	------	Ti	------	------	------	------	------	------	L; well unfinished.
6S–5E–10dd1	Errol F. Black	1923	1,667	6–4	78	S	Ti	103	Top of casing	1.0	+3.7	Aug. 11, 1953	^{e} 5	L; original flow 150 gpm.
-16cc1	Idaho Power Co.	------	412	6	412	------	Ti	------	do	.0	−4.8	Aug. 13, 1953	------	
-22db1	Milford Vaught	1930	165	8	------	S	Ti	------	do	1.5	−2.6	Aug. 11, 1953	------	
-24bc1	George Hutchinson	1926	1,095	6–4	76	D, S, O	Ti	84	Top of discharge pipe	.9	+33.4	Oct. 19, 1953	^{e} 20	L; original flow 70 gpm.
-24ca1	George Craig	1913	1,325	6–4	430	D, S	Ti	104	Top of casing	−4.8	−30.6	Oct. 14, 1953	------	
-24db1	W. I. Turner	1912	1,170	3	500	D	Ti	92	------	------	------	------	------	C; original flow 72 gpm.
-24dd1	Bruneau Village	1913	976	6–4	620	PS	Ti	94	------	------	------	------	^{e} 25	C; original flow 200 gpm.
-29dc1	Perle Davis and Sons.	1924	1,560	4	20	S	Ti	94	------	------	------	------	^{e} 3	C, L; original flow 40 gpm.
-33bc1	Frank Faria	------	700	4	------	U	Ti	------	Top of casing	.3	+3.1	Aug. 11, 1953	^{e} 5	
-36dd1	Angel Eridosa	------	375	4	------	D, S	Ti	71	------	------	------	------	^{e} 5	C.
6S–6E–19cc1	A. C. Mackley	1926	913	6–4	277	I, D	Ti	104	Top of bathtub	1.5	+19.0	Jan. 8, 1954	^{e} 15	L; original flow 300 gpm.
-30bb1	Richard Benham	1926	844	6–4	368	D, S	Ti	------	------	------	------	------	^{e} 5	
-30cc1	Turner estate	------	790	------	------	D, S	Ti	66	Concrete walk	.0	+6.0	July 28, 1953	^{e} 5	
-32bd1	Albert Black	1951	1,402	8	850	U	Ti	65	Top of casing	1.0	+54.7	do	^{r} 27	L.
7S–4E–12bd1	Frank Faria	1954	1,105	14–8	675	I	Tb	108	------	------	------	------	^{m} 1,400	C (sample depth 755 feet); L.
-13dc1	Lauri Lahtinen	1954	1,000	12	194	I	Tb and Tsv	103	------	------	------	------	^{e} 1,000	L.
-24bd1	J. E. Sullivan	------	750	8	24	I	Tb	101	------	------	------	------	^{r} 900	
-24dc1	A. M. Glidden	1917	417	6	23	S, I	Tb	99	------	------	------	------	^{e} 60	C.
7S–5E– 4ac1	James Agenbroad and Sons.	1949	1,100	16–6	700	I	Ti	60	------	------	------	------	^{e} *1,500	
- 5ba1	Perle Davis and Sons.	1916	920	4	------	I	Ti	75	Top of casing	−.3	+8.8	Aug. 12, 1953	^{e} 15	Caved at 131 feet
- 5ba2	do	1920	906	4	33	U	Ti	59	do	.6	+.6	Nov. 24, 1953	^{e} 1	C.
- 7ab1	James Agenbroad and Sons.	1951	1,625	16	60	I, S	Tb and Tsv	100	------	------	------	------	^{r} 4,000	C.
- 7ab2	Carl Johnson	1910	370	4	300	U	Ti	73	------	------	------	------	^{e} 2	C.
- 7da1	Grant Deming	1920	1,134	8–4	680	D, S, I	Tb	97	------	------	------	------	^{m} 215	Discharge meassured in 1922.
- 7bd1	do	1920	720	4	20	S, I	Ti	88	Top of casing	.5	+8.1	Aug. 12, 1953	^{m} 130	Discharge measured in 1922.
- 8bb1	Albert Harley	1912	580	4	180	D	Ti(?)	73	------	------	------	------	^{e} 10	C.
7S–5E–8bc1	Ruby Harley	1928	600	4	------	I	Ti and Tb	85	Top of casing	.0	+30.4	Aug. 12, 1953	^{e} 100	
9dd1	James Agenbroad and Sons.	1952	1,700	20	------	I	Tb and Tsv(?)	92	------	------	------	------	^{e} 200	
18bc1	Albert Black	1951	517	14	------	I, O	Tb	92	Top of discharge pipe	3.6	------	------	^{e} 750	L.

TABLE 5.—*Records of artesian wells in the Bruneau–Grand View area*—Continued

Well No.	Owner	Year drilled	Depth of well (feet below land surface)	Casing		Use of well	Aquifer	Temperature (°F)	Measuring point		Distance to water level above (+) or below (−) land surface (feet)	Date of measurement	Yield (gallons per minute)	Remarks
				Diameter (inches)	Depth (feet)				Description	Distance above or below (−) land surface (feet)				
7S–5E–18cc1	Lauri Lahtinen			2		I	Ti	88	Top of starter pipe	.5	+13.0	Aug. 12, 1953	^{e} 30	
19cc1	Edward Underdahl	1950	760	12	300	I, O	Tb and Tsv(?)	96	Top of casing	2.0	−10.3	Aug. 12, 1953	^{r} *1,170	L.
28ac1	Fred King	1950	1,003	16–12	236	I	Tb and Tsv	92	Land surface	.0	^{r} −103	May 13, 1953	^{r} *1,400	L.
7S–6E– 4ca1	Errol F. Black		1,040	5		U	Ti	80	Top of elbow	.8	+4.5	July 28, 1953	^{e} 10	
4dc1	do	1921	680	6–4	186	I	Ti(?)	108	do	1.0	+27.1	July 28, 1953	^{e} 200	
6ba1	J. E. Turner		400	4		D, S	Ti	69	Top of casing	.5	+22.3	July 31, 1953	^{r} 135	
6ba2	do	1953	330	10	40	S, I	Ti	60					^{e} 30	
7aa1	do	1915	1,086	6–4	342	S	Ti	90					^{e} 20	
9ba1	Errol F. Black	1912	910	5		S, I	?	123	Top of elbow	2.0	+39.6	July 28, 1953	^{e} 270	
9ba2	do	1936	960	8	80	I, O	?	122	do	1.5	+39.7	July 28, 1953	^{e} 630	
15ba1	U. S. Government	1914	910	6	65	U	Ti		Top of casing	1.0	−25.7	July 29, 1953		L; original flow 50 gpm.
16cd1	H. L. Bean	1917	353	8	80	S, I	Ti and Tb(?)	100					^{e} 35	Original flow 90 gpm.
18bb1	Dillard Sawyers	1953	1,480	12–10	376	I	Ti	81	Land surface	.0	^{r} −65	1953	^{r} *720	
21db1	Stacio Okimeka	1918	611	8	177	I	Tb	104					^{m} 765	Discharge measured in 1922.
22aa1	George Pinkston	1950	580	8	80	I	Tb	116	Top of discharge pipe	3.0	+34.2	July 29, 1953	^{r} 900	
23ca1	Angel Bilbao	1914	900	6	40	I	Tb	115	Top of elbow	7.0	+27.3	July 29, 1953	^{r} 360	
23ca2	do	1935	485	6	120	I	Tb	114	do	4.5	+49.7	July 29, 1953	^{r} 225	
23cc1	Boni Bilbao	1930	460	6	107	I	Tb	106	do	4.0	+29.6	July 30, 1953	^{r} 495	
23dc1	Angel Bilbao	1922	1,220	6	365	D, S, I	Tb	105	do	−18.0	+0.8	July 29, 1953	^{r} 630	
26ac1	Michael Zuvizarretta.	1950	355	6	125	I	Tb	94	Top of discharge pipe	2.0	+17.0	July 30, 1953	^{r} 630	
26ba1	Boni Bilbao	1927	365	6	107	I	Tb	102	Top of elbow	3.5	+54.3	July 30, 1953	^{r} 684	
27aa1	Mrs. Eva Bertschy	1937	350	10		D, S, I	Tb	117	Land surface	.0	+88.9	July 30, 1953	^{r} 765	
27ad1	Angel Eridosa		400	6		D, S, I	Tb	111	Top of elbow	2.0	+46.4	July 31, 1953	^{r} 400	

LOGS OF WELLS

The well logs on the following pages were obtained from drillers, well owners, and files of the State Department of Reclamation and the Geological Survey. The writers identified the stratigraphic units and the original-source terminology was modified for uniformity and clarity.

Log of wells

	Thickness (feet)	Depth (feet)
5S-2E-13ad1		
[Emory Ratliff and Associates. Driller's log from files of Geological Survey]		
Recent alluvium and slope wash:		
Soil, light-colored, soft	20	20
Sand, red, soft	40	60
Idaho formation:		
Clay, soft, yellow ("chalk rock" of driller)	30	90
Gravel, hard, coarse-grained dark	33	123
Shale, sticky, soft, blue; sparsely interbedded with thin layers of sand a few inches thick containing gas and water	1,617	1,740
Basalt of Pliocene(?) age:		
Lava, hard black (basalt?)	8	1,748
5S-3E-15cb1		
[L. A. Hoalst. Log from owner Oct. 7, 1953. Hole plugged at 1,620 feet; driller could not go deeper]		
Recent alluvium and slope wash:		
Sand and gravel; contains water	32	32
Idaho formation:		
Shale, blue and gray, interbedded with thin layers of sand (reached water and combustible gas at 1,100 feet)	1,068	1,100
Shale, interbedded with 2 very hard strata	520	1,620
6S-3E-11cc2		
[Smith and Hinton. Driller's log from files of owners]		
Recent alluvium and slope wash:		
Soil, light-color, soft	9	9
Gravel, hard, dark	12	21
Idaho formation:		
Clay, soft, yellow	6	27
Shale, hard, blue; interbedded with thin layers of sand	399	426
Sand, soft, gray; cemented in lower 6 feet; 50 gpm of water	22	448
Sand, gray; with interbedded shale; 90 gpm of water	284	732
Shale, hard, blue; interbedded with thin layers of sand a few inches thick; slight increase in water from each sand layer	346	1,078
Sand, soft, black; 45 gpm of water	26	1,104
Shale, hard, blue	26	1,130
Sand, black; becomes white in lower 69 feet; 45 gpm of water	78	1,208
Shale, hard, blue	137	1,345
Sand, hard, green	30	1,375
Shale, hard, green	18	1,393
Sand, soft, green	30	1,423
6S-3E-14bb1		
[Smith and Hinton. Driller's log from files of owners]		
Recent alluvium and slope wash:		
Soil, soft, light-colored	15	15
Gravel, hard, dark	9	24
Idaho formation:		
Clay, soft, yellow	2	26
Shale, soft, blue; interbedded with thin layers of sand containing small amounts of water	228	254
Sand, soft, caving, gray; capped by 4-inch "flinty" white rock; 200 gpm of water	154	408
Shale, hard, tough, blue; interbedded sparsely with thin beds of sand containing small amount of water	582	990
Sand, shale, black and blue in alternate 3- to 4-foot beds; 190 gpm of water	60	1,050
Sand, soft, white to dark; 150 gpm of water	70	1,120
Shale, hard, blue	120	1,240
Sand, green; caving; 50 gpm of water	10	1,250

Log of wells—Continued

	Thickness (feet)	Depth (feet)
6S-3E-14bd1		
[Smith and Hinton. Driller's log, obtained from owner Oct. 12, 1953]		
Recent alluvium and slope wash:		
Soil, sandy and gravelly	26	26
Idaho formation:		
Shale, blue	241	267
Sand, fine-grained, gray	18	285
Shale	2	287
Sand, loose, caving	13	300
6S-4E-25bb1		
[Garry Kohring. Log obtained from I. E. Glineski Aug. 23, 1953]		
Idaho formation:		
Clay, yellow; grades downward to bluish gray	80	80
Sand, very fine grained ("quicksand" of driller)	10	90
Clay, sticky, carbonaceous in part, blue; interbedded sparsely with 5-foot beds of sand and silt	1,660	1,750
6S-5E-10dd1		
[Errol F. Black. Driller's log from files of Geological Survey]		
Recent alluvium and slope wash:		
Soil, soft, light-colored	10	10
Idaho formation:		
Clay, soft, yellow	49	59
Shale, soft, blue	496	555
Sandstone, soft, gray	20	575
Shale, soft, blue	10	585
Sandstone, soft, gray	40	625
Shale, hard, blue	181	806
Rock, hard, gray	2	808
Shale, hard, blue; sandy in lower part	97	905
Rock, white- to cream-colored; 1-foot "limestone" at base (probably ash bed cemented at base)	4	909
Sand, hard to soft, gray; 40 gpm of water	211	1,120
Shale, hard, brown	45	1,165
Sandstone, hard, gray	15	1,180
Shale, hard and tough, brown	477	1,657
Sandstone, hard, gray; 100 gpm of water	10	1,667
Basalt of Pliocene(?) age:		
Rock, hard	------------	1,667
6S-5E-24bc1		
[George Hutchinson. Driller's log from files of Geological Survey]		
Recent alluvium and slope wash:		
Soil, soft, light-colored	8	8
Gravel, light-colored	10	18
Idaho formation:		
Clay, soft, yellow	15	33
Shale, soft, blue	395	428
Sand, fine-grained, blue	87	515
Shale, hard, blue; 2-foot layer of sticky clay at base	106	621
Rock, hard, gray	18	639
Rock, hard, black; (lava, with 2-foot interflow bed at 653)	18	657
Sandstone, soft, black; water	1	658
Shale, soft, blue	8	666
Rock, soft, black	12	678
Shale, soft, blue	2	680
Rock, hard, black (lava); 30 gpm of water; quit flowing after 2 weeks	42	722
Rock, soft, black	12	734
Shale, hard, blue	98	832
Rock, hard, black	8	840
Shale, hard, blue	205	1,045
Not recorded	50	1,095

Log of wells—Continued

	Thickness (feet)	Depth (feet)
6S–5E–29dc1		
[Perle Davis and Sons. Driller's log from files of Geological Survey]		
Recent alluvium and slope wash:		
Soil, soft, light-colored	10	10
Gravel, hard, dark	4	14
Idaho formation:		
Clay, soft, yellow	5	19
Shale, soft, blue; interbedded with layers of sand a few feet thick; sand contains water	935	954
Sand, soft, fine-grained, gray; water	6	960
Shale, soft, blue	150	1,110
Sand, soft, fine-grained, gray	10	1,120
Shale, soft, blue	40	1,160
Sand, gray	3	1,163
Shale, hard, blue with thin layers of sand; sandy shale from 1,330 to 1,398 feet	235	1,398
Sand, hard, white	10	1,408
Sand and shale, hard, blue	11	1,419
Sand, hard, white; thin black sand layer at top; water	32	1,451
Shale, hard, blue	63	1,514
Sandstone, hard, gray; water	46	1,560
6S–6E–19cc1		
[A. C. Mackley. Driller's log from files of Geological Survey]		
Recent alluvium and slope wash:		
Soil, soft, light-colored	13	13
Gravel, hard, light-colored	8	21
Idaho formation:		
Clay, yellow	64	85
Shale, soft, blue; harder downward	425	510
Sandstone, gray	90	600
Shale, blue; contains 2 thin beds of gray sand; water in lower sand at 820 feet	228	828
Rock, hard, black (lava?)	22	850
Shale, blue (lower 9 feet called "rock, blue, soft")	17	867
Rock, soft to hard, black; 50 gpm of water	13	880
Sandstone, soft, fine- to coarse-grained, gray; lower 3 feet noncemented	33	913
6S–6E–32bd1		
[Albert Black. Log obtained from I. E. Glineski July 28, 1953]		
Recent alluvium and slope wash:		
Soil	9	9
Sand, some gravel	78	87
Idaho formation:		
Clay, sticky, blue	653	740
Rock, soft, black	1	741
Clay, blue	199	940
Shale, broken, blue; small flow of water	8	948
Clay, sticky, brown	112	1,060
Lava, black	6	1,066
Clay, sticky, brown; sandy in lower part	336	1,402
6S–7E–16bb1		
[State of Idaho; oil-exploration test. Driller's log from records of the Idaho Bureau of Mines and Geology]		
Idaho formation:		
Shale and clay	71	71
Clay, sand, and shale	266	337
Shale and clay	541	878
Shale and sand	1,092	1,970
Shale and rock	145	2,115
Shale	225	2,340
Not recorded	20	2,360
Sand, volcanic	40	2,400
Sand and clay, brown; ashy in part; sand partly sedimentary and partly volcanic	153	2,553
Basalt of Pliocene(?) age:		
Lava (apparently basalt(?)). (Top of basalt is indefinite, reported by Petroleum Information, Inc., Denver, Colo., to be 2,550)	100	2,653

Log of wells—Continued

7S-4E-12bd1

[Frank Faria. Log obtained from J. J. DeCourcey, driller, Jan. 8, 1954. Log from 669 to 1,105 feet compiled by the writers, based on study of drill cuttings and information obtained from driller. Thicknesses of individual rock units approximate; depths recorded based largely on depths from which cuttings were recovered]

	Thickness (feet)	Depth (feet)
Recent alluvium and slope wash:		
Soil	16	16
Soil and sand	14	30
Idaho formation:		
Shale, blue	15	45
Sand	15	60
Shale, hard	83	143
Sand	27	170
Shale, sandy in lower part	210	380
Rock, black (basalt)	30	410
Sand, green and brown	41	451
Rock, black (basalt)	33	484
Shale and sand, brown	71	555
Gravel and sand	5	560
Clay, bentonitic	109	669
Basalt of Pliocene (?) age:		
Basalt, dense, medium-grained, black and dark gray; somewhat weathered; sample contains sand and silt cavings	44	713
Tuff, clayey, ashey red, tan, pink	17	730
Basalt, vesicular, black and dark gray; contains secondary pyrite and coatings of green clay; vitreous in part	20	750
Missing, (driller reported basalt, altered, 750–762)	10	760
Clay, soft, sandy, dark-tan, with angular fragments of quartz, basalt, and olivine (?)	25	785
Basalt, vesicular, hard, gray; interbedded red tuff; tuff is soft; consists predominantly of ash, partly altered to clay and stained with hematite	15	800
Basalt, hard, dense-black; contains vein calcite, white, crystalline	10	810
Tuff, brown, tan; bentonitic(?) in part; ashy	45	855
Basalt, hard, dense-black	23	878
Missing	2	880
Sand(?), tan; cuttings very fine, brought to surface by flow of water; consist predominantly of angular grains of quartz. Flow of water increased 25 inches	40	920
Missing	40	960
Basalt, dark-gray; layers of light-gray bentonite and red tuff	15	975
Clay, tuffaceous tan and brown	13	988
Silicic volcanic rocks:		
Bentonite, white, mottled with faint pink, green and yellow; soft; sample contains large fragments of porphyritic black volcanic glass	2	990
Obsidian, black; contains phenocrysts of glassy feldspar	70	1,060
Latite, porphyritic tan; sample contains black volcanic glass; water flow increased to reported maximum of 200 inches	45	1,105

7S-4E-13dc1

[Lauri Lahtinen. Log obtained from G. I. Glineski Jan. 16, 1954. Log from 210 to 900 feet compiled by writers, based on examination of drill-cuttings and information obtained from driller. Thicknesses of individual rock units approximate; depths recorded are based largely on depths from which cuttings were recovered]

	Thickness (feet)	Depth (feet)
Recent alluvium and slope wash:		
Soil	18	18
Boulders and gravel	8	26
Idaho formation:		
Clay, sticky, blue	165	191
Rock and layers of clay	9	200
Clay, light-tan to yellow ("chalk" of driller)	10	210
Gravel, fine-grained, and sand, olive-drab, dirty, clayey; sand consists chiefly of quartz and glassy feldspar with some angular and subrounded fragments of basalt	45	255
Basalt, dark-gray to black; fragments stained with limonite and coated with fine-grained sand and silt	13	268
Sand, coarse-grained, olive-drab; contains rounded to angular fragments of quartz and basalt	22	290
Missing	25	315
Clay, light-tan; sandy, with angular fragments of basalt; sample contains 30–40 percent of coarse-grained sand	20	335
Clay, light-tan; very finely sandy	25	360
Clay, light-tan to dark-tan; very finely sandy to tuffaceous	20	380
Missing	38	418
Sand, very fine grained, angular, light-tan; tuffaceous; contains several varieties of quartz, glassy feldspar, and muscovite	4	422

Log of wells—Continued

	Thickness (feet)	Depth (feet)
7S-4E-13dc1—Continued		
Basalt of Pliocene(?) age:		
Basalt, aphanitic to diabasic black; somewhat weathered; contains accessory olivine and needle-like crystals of feldspar	20	442
Olivine basalt, dark-greenish-brown and black, dense; weathered; sample is very finely pulverized	8	450
Sand, speckled light-tan and black, medium- to coarse-grained; contains rounded grains of clear glass, basalt and amygdaloidal basalt, fragments of tuffaceous clay, and several varieties of quartz	23	473
Basalt, red and brown; a few fragments are sparsely vesicular; vesicles lined with quartz; sample contains fragments of black basalt	7	480
Basalt and olivine-basalt, black, with slight greenish-brown shade; diabasic; contains large crystals of olivine	55	535
Basalt and basaltic gravel; gravel consists almost entirely of rounded fragments of basalt	23	558
Olivine basalt, black to greenish shade; somewhat weathered; sample contains small amount of green clay	10	568
Basalt, dense-black and brownish-black; contains olivine; vesicular; vesicle walls lined with quartz	52	620
Basalt (as above); sample contains yellow clay with basalt grains and fragments of maroon, red, and pink tuff	20	640
Sand, somewhat ashy black and tan; numerous fragments of red and pink tuff (interval poorly sampled)	85	725
Silicic volcanic rocks:		
Obsidian, black; sample contains numerous fragments of clear, waxey glass (interval poorly sampled)	71	796
Obsidian, black; some partly crystalline glass, dimly lavendar in color; sample contains cavings	39	835
Latite, porphyritic, vesicular purple; some fragments have a secondary coating of drusy quartz	30	865
Latite, porphyritic purple, with short, tabular crystals of feldspar. Samples contaminated with other rock materials from above, including fragments of vesicular obsidian, the vesicles walls of which are etched to a light gray color	35	900
No samples	100	1,000
7S-5E-18bc1		
[Albert Black. Log obtained from I. E. Glineski Nov. 2, 1953]		
Recent alluvium and slope wash:		
Sand, gravelly	12	12
Gravel	25	37
Idaho formation:		
Clay, yellow; hard and soft layers	243	280
Basalt	16	296
Clay, sandy, soft, yellow	164	460
Gravel, coarse-grained, clean	10	470
Basalt of pliocene(?) age:		
Lava, soft, decomposed (basalt)	25	495
Lava, hard	22	517
7S-5E-19cc1		
[Edward Underdahl. Driller's log, obtained from owner Aug. 12, 1953]		
Recent alluvium and slope wash:		
Silt, sand and gravel	56	56
Idaho formation:		
Lava, black (basalt)	18	74
Clay and gravel	108	182
Lava, black	12	194
Clay and fine rock	115	309
Rock, soft, brown	38	347
Basalt of Pliocene(?) age:		
Lava, black	83	430
Rock, brown; not hard	41	471
Lava, black; hard and soft layers; some interbedded blue clay	125	596
Rock, red and brown; locally clayey; contains some water	44	640
Rock, hard, red; crevice at 702 produced much of water	65	705
Rock, hard, red; tools sticking; no cuttings	15	720
Silicic volcanic rocks:		
"Rhyolite," hard red (latite)	40	760

Log of wells—Continued

	Thickness (feet)	Depth (feet)
7S–5E–28ac1		
[Fred King. Driller's log, obtained from owner Aug. 12, 1953]		
Idaho formation:		
"Chalk rock"	110	110
Sand(?); water at 120 feet	126	236
Lava, black	8	244
Clay, sticky, gray	80	324
Lava, black	9	333
Clay, sticky	17	350
Gravel, cemented	7	357
Clay, sticky	33	390
Sand(?)	12	402
Lava, black	28	430
Clay, sticky	47	477
Basalt of Pliocene(?) age:		
Lava, hard, black	20	497
Lava, hard, red(?)	26	523
Lava, black, with interbedded soft, red rock	227	750
Lava, red	13	763
Red sticky formation	15	778
Black sandy formation, loose	28	806
Silicic volcanic rock(?):		
Lava, black (black volcanic glass?)	39	845
Rock, reddish-brown	49	894
Rock, very hard, red	2	896
Conglomerate; broken rock; sand; clay; water	94	990
Rock, black, hard	13	1,003
7S–6E–15ba1		
[U. S. Government. Driller's log from files of Geological Survey]		
Terrace gravel:		
Soil, soft, light-colored	20	20
Gravel, hard, dark	44	64
Idaho formation:		
Shale, soft, blue; a few thin layers of sand	96	160
Sand, soft, firm, gray	15	175
Shale, soft, blue; harder with depth; interbedded sparsely with layers of resistant rock a few inches thick	552	727
Sand, soft, coarse, gray; 10 gpm of water	13	740
Shale, hard, blue	110	850
Sand, soft, gray; 10 gpm of water	10	860
Shale, hard, blue	17	877
Sand, soft, gray; 20 gpm of water	8	885
Shale, hard, blue	17	902
Rock, hard, black (lava)	8	910

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