Water-Supply and Irrigation Paper No. 78

Series { B, Descriptive Geology, 29
0, Underground Waters, 20

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

PRELIMINARY REPORT

ON

ARTESIAN BASINS

IN

SOUTHWESTERN IDAHO AND SOUTHEASTERN OREGON

BY

ISRAEL C. RUSSELL

WASHINGTON
GOVERNMENT PRINTING OFFICE
1903

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

The publications of the United States Geological Survey consist of (1) Annual Reports; (2) Monographs; (3) Professional Papers; (4) Bulletins; (5) Mineral Resources; (6) Water-Supply and Irrigation Papers; (7) Topography Atlas of the United States, folios and separate sheets thereof; (8) Geologic Atlas of United States, folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

The Bulletins, Professional Papers, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. Complete lists of papers relating to water supply and allied subjects follow. (B=Bulletin, PP=Professional Paper, WS=Water-Supply Paper.)

SERIES I—IRRIGATION.

WS 2. Irrigation near Phoenix, Ariz., by A. P. Davis. 1897. 98 pp., 31 pls. and maps.
WS 5. Irrigation practice on the Great Plains, by E. B. Cowgill. 1897. 39 pp., 11 pls.
WS 9. Irrigation near Greeley, Colo., by David Boyd. 1897. 90 pp., 21 pls.
WS 10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker. 1898. 51 pp., 11 pls.
WS 13. Irrigation systems in Texas, by W. F. Hutson. 1898. 68 pp., 10 pls.
WS 17. Irrigation near Bakersfield, Cal., by C. E. Grunsky. 1898. 96 pp., 16 pls.
WS 18. Irrigation near Fresno, Cal., by C. E. Grunsky. 1898. 94 pp., 14 pls.
WS 19. Irrigation near Merced, Cal., by C. E. Grunsky. 1899. 59 pp., 11 pls.
WS 23. Water-right problems of Bighorn Mountains, by Elwood Mead. 1899. 62 pp., 7 pls.
WS 32. Water resources of Porto Rico, by H. M. Wilson. 1899. 48 pp., 17 pls. and maps.
WS 43. Conveyance of water in irrigation canals, flumes, and pipes, by Samuel Fortier. 1901. 86 pp., 15 pls.
WS 70. Geology and water resources of the Patrick and Goshen Hole quadrangles, Wyoming, by G. I. Adams. 1902. 50 pp., 11 pls.
WS 71. Irrigation systems of Texas, by T. U. Taylor. 1902. 137 pp., 9 pls.
WS 74. Water resources of the State of Colorado, by A. L. Fellows. 1900. 151 pp., 14 pls.

The following papers also relate especially to irrigation: Irrigation in India, by H. M. Wilson, in Twelfth Annual, Part II; two papers on irrigation engineering, by H. M. Wilson, in Thirteenth Annual, Part III.

SERIES J—WATER STORAGE.

WS 33. Storage of water on Gila River, Arizona, by J. B. Lippincott. 1900. 98 pp., 33 pls.
WS 40. The Austin dam, by Thomas U. Taylor. 1900. 51 pp., 16 pls.
WS 45. Water storage on Cache Creek, California, by A. E. Chandler. 1901. 48 pp., 10 pls.
WS 46. Physical characteristics of Kern River, California, by F. H. Olmsted, and Reconnaissance of Yuba River, California, by Marsden Manson. 1901. 57 pp., 8 pls.
WS 58. Storage of water on Kings River, California, by John B. Lippincott. 1902. 100 pp., 32 pls.
WS 68. Water storage in Truckee Basin, California-Nevada, by L. H. Taylor. 1902. 90 pp., 8 pls.
WS 73. Water storage on Salt River, Arizona, by A. P. Davis. 1902. 54 pp., 25 pls.

The following paper also should be noted under this heading: Reservoirs for irrigation, by J. D. Schuyler, in Eighteenth Annual, Part IV.

SERIES K—PUMPING WATER.

WS 1. Pumping water for irrigation, by Herbert M. Wilson. 1896. 57 pp., 9 pls.
WS 8. Windmills for irrigation, by E. C. Murphy. 1897. 49 pp., 8 pls.
WS 14. New tests of certain pumps and water lifts used in irrigation, by Ozni P. Hood. 1898. 91 pp., 1 pl.
WS 20. Experiments with windmills, by T. O. Perry. 1899. 97 pp., 12 pls.
WS 29. Wells and windmills in Nebraska, by E. H. Barbour. 1899. 85 pp., 27 pls.
WS 41. The windmill; its efficiency and economic use, Part I, by E. C. Murphy. 1901. 72 pp., 14 pls.
WS 42. The windmill, Part II (continuation of No. 41). 1901. 73-147 pp., 15-16 pls.

(Continued on third page of cover.)

Water-Supply and Irrigation Paper No. 78

Series { B, Descriptive Geology, 29
0, Underground Waters, 20

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

PRELIMINARY REPORT

ON

ARTESIAN BASINS

IN

SOUTHWESTERN IDAHO AND SOUTHEASTERN OREGON

BY

ISRAEL C. RUSSELL

WASHINGTON
GOVERNMENT PRINTING OFFICE
1903

CONTENTS.

	Page.
Letter of transmittal	7
Introduction	9
Conditions on which the flow of artesian wells depend	10
Surface indications of the presence of subsurface water under pressure	14
Rocks of the region examined	16
Sedimentary rocks	16
Igneous rocks	18
Volcanic rocks	18
Plutonic or deep-seated igneous rocks	21
Geological structure	22
Artesian basins	24
Lewis artesian basin	24
Springs	26
Mountain Home	26
Boise	27
Salmon River	27
Little Valley	27
Bruneau Valley	27
Walters Butte	27
Enterprise	27
Sands	27
Owyhee Canyon	28
Vale	28
Westfall	28
Beulah	29
Drilled wells	29
Boise	29
Bruneau Valley	30
Little Valley	31
Guffey	32
Central	32
Enterprise	33
Ontario	34
Vale	34
Summary	34
Eastward extension	37
Otis artesian basin	37
Harney artesian basin	38
Springs	39
Burns	39
Little Sage Hen Valley	39
Silver Lake	39
Harney Lake	39
Malheur Lake	39
Summary	39

	Page.
Artesian basins—Continued.	
Harney artesian basin—Continued.	
Drilled wells	40
Harney	40
Burns	41
Summary	41
Whitehorse artesian basin	43
Artesian wells in alluvial deposits	44
Size of drill holes, the casing of wells, etc	45
Preservation of well records	46
Laws	47
Literature	50
Index	53

ILLUSTRATIONS.

		Page.
PLATE	I. Map showing position of area under discussion	9
	II. Sketch map of portions of Oregon and Idaho, showing artesian basins	16
FIG.	1. Cross section of two dishes with sand between	11
	2. Ideal cross section of a typical artesian basin charged with water from above	11
	3. Ideal cross section of an artesian basin charged with water from below	13

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., December 2, 1902.

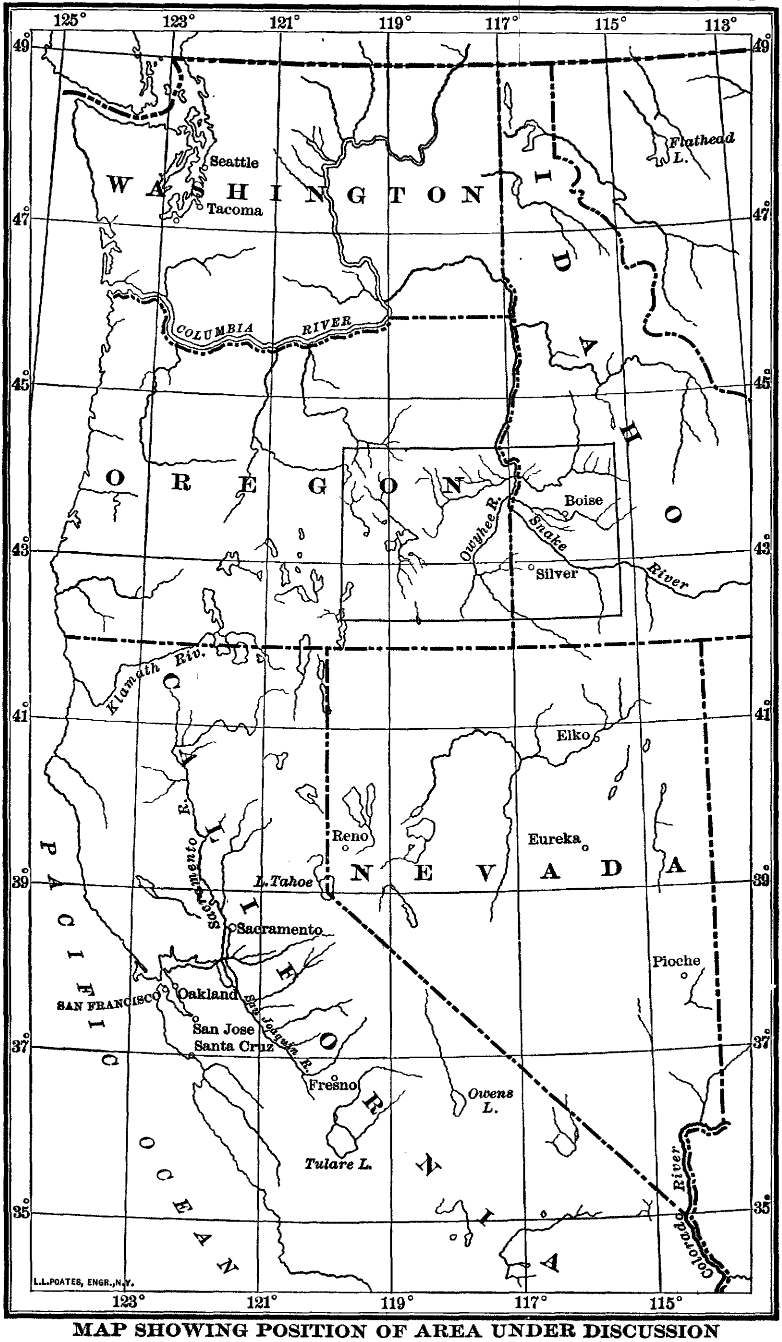
SIR: I have the honor to transmit herewith a manuscript prepared by Prof. Israel C. Russell, and to request that it be printed as one of the series of Water-Supply and Irrigation Papers. The paper relates to work carried on by Professor Russell during the summers of 1901 and 1902, and contains a description of the geologic structure of southwestern Idaho and southeastern Oregon, with special reference to the occurrence of underground waters. The artesian basins are described as far as these are known, and facts are assembled as to the probabilities of obtaining deep or flowing wells.

The information has particular value at this time, when great interest is being displayed in the reclamation of the arid lands. All facts which assist in procuring water are eagerly sought, and the data collected by Professor Russell are particularly important in the development of a large extent of vacant public land.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.



MAP SHOWING POSITION OF AREA UNDER DISCUSSION

Scale

100 50 0 100 200 300 miles

PRELIMINARY REPORT ON ARTESIAN BASINS IN SOUTHWESTERN IDAHO AND SOUTHEASTERN OREGON.

By ISRAEL C. RUSSELL.

INTRODUCTION.

During the summer of 1901 I made a geological reconnaissance in southern Idaho which covered, in a general way, the region embraced in the Snake River Plains from the boundary between Ada and Elmore counties eastward to Blackfoot.[a] The studies thus begun were continued in the summer of 1902, when parts of Canyon and Owyhee counties, Idaho, and of Malheur and Harney counties, Oreg., were examined. The route traversed during the second reconnaissance followed Snake River from Guffey northwestward to the mouth of Owyhee River, in Idaho, and thence through Vale, Westfall, Beulah, Drewsey, Harney, Burns, Narrows, Diamond, Smith, Mule, Alvord Valley, Jordan Valley, etc., in Oregon, to Rockville, on the west border of Owyhee County, Idaho. From Rockville the return to Boise was by way of Caldwell and Nampa. The route followed was chosen for the purpose of passing through the greatest number of valleys where artesian conditions might most reasonably be expected to exist and where the largest areas of good land are available for agriculture.

Each of the journeys referred to above was a rapid reconnaissance, having for its principal object the discovery of localities where flowing water can be obtained by drilling wells. In addition to gathering facts bearing on the question of an artesian water supply, as much attention as the time available would permit was given to the study of the general geology of the country traversed, the surface water supply, soil conditions, etc. The results of my examinations may, then, be divided into two parts—namely, that pertaining directly to artesian basins and that relating to geological history, topographical development, etc. As the search for artesian basins, especially during the journey made in 1902, was far more successful than I had hoped, it

[a] A report on this reconnaissance, entitled Geology and Water Resources of the Snake River Plains of Idaho, has been published as Bulletin No. 199 by the United States Geological Survey. A copy of this report may be had without charge by applying to the Director of the United States Geological Survey, Washington, D. C.

seems advisable to present a preliminary report, with the view of giving early information concerning the artesian basins to the people living in the region examined and later to prepare a more definite record of the geological and geographical facts observed.

During the reconnaissance of 1901 it was found that the geological conditions in the Snake River Canyon from near Glenns Ferry westward to the boundary between Elmore and Ada counties and in Bruneau and Little valleys are such that a surface flow of water can reasonably be expected where the surface elevation is not too great if wells are drilled to the proper depth. The artesian basin crossed by the portion of Snake River just mentioned was for convenience named the Lewis artesian basin, but its extension west of the boundary between Elmore and Ada counties was not examined. The western portion of the basin was made the first subject of study during the following field season, and, as will be stated later, it was found to reach westward to beyond the Idaho-Oregon boundary.

The reconnaissance in southeastern Oregon showed that if wells are properly drilled, a surface flow of water may reasonably be expected in at least three separate valleys in addition to the basin which is crossed by Snake River. These are Otis Valley, situated about 6 miles north of Drewsey; the broad valley in which Malheur and Harney lakes are situated, known in part as Harney Valley; and Whitehorse Valley, situated about 10 miles east of the higher portion of Stein Mountain. The basins in which these valleys are situated will be termed in this report the Otis artesian basin, the Harney artesian basin, and the Whitehorse artesian basin, respectively.

Before presenting the facts which are the basis of the conclusion that in each of the basins just named a surface flow of water can be had by drilling, it will, I think, be of assistance to review briefly the leading conditions governing the flow of artesian wells.

CONDITIONS ON WHICH THE FLOW OF ARTESIAN WELLS DEPENDS.

The term artesian well, as commonly employed, signifies a well which overflows upon the surface. The leading conditions favoring the rise and overflow of water from wells may perhaps be best indicated by describing the essential features of a typical artesian basin of the simplest character.

In what is properly termed an artesian basin, the layers of rock are bent downward, so as to resemble a pile of shallow plate-shaped dishes, placed one within another. One or more of the beds of rock is porous and allows water, supplied by rain on its upturned and exposed margin, to percolate into it. Above and below the water-charged layer are close-textured beds, like clay, which prevent the escape of the water in the bed between them. The leading conditions which characterize artesian basins will be reproduced on a small scale if one pan is placed within another, and the two are separated by a layer of sand, and the spaces between the sand grains are filled with water. If a hole is drilled in the bottom of the uppermost pan, water will rise from below and overflow until the level of the water in each pan is the same. This is illustrated by the following cross section (fig. 1), which represents two pans, with a layer of sand between them, as they would appear if cut across and one-half removed. The pans in such an experiment represent the compact or impervious layers, and the sand the porous or pervious bed, in an artesian basin.

FIG. 1.—Cross section of two dishes with layer of sand between; to illustrate the leading essential features of an artesian basin.

In the following diagram (fig. 2) an ideal cross section is presented through an artesian basin which may be assumed to be 50 or more miles in diameter. The rocks are in layers or strata, and their combined thickness, we will assume, is 1,000 feet. A cross section taken in any direction through the pile of saucer-shaped beds (as is the case with the experiment with the pans referred to above) would be essentially the same. In the diagram (fig. 2) B and C represent compact and impervious beds, such as clay or shale; and A represents a porous bed, such as sand, open-textured sandstone, or fissured and broken rock. The beds, it will be noted, are depressed in their central parts, but about their edges come to the surface. Under these conditions water falling as rain on the exposed margin of the pervious bed and the water from streams, etc., would percolate into it until it was water filled. If, now, a hole drilled in the central part of the

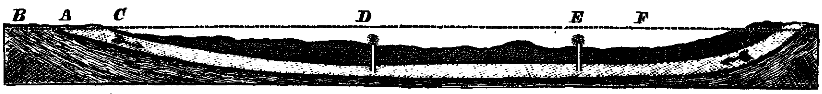


FIG. 2.—Ideal section illustrating the chief conditions requisite to artesian wells.

basin, as at D or E, reaches the pervious bed the pressure of water at a higher level will cause the water in the well to rise and overflow at the surface, and a flowing artesian well will result.

If, in the case just cited, no additional water should come to the exposed margin of the pervious bed, the well drilled at D or E would decrease in volume and finally cease to flow when the water in the porous bed, or so-called reservoir, was lowered so as to be on a level with the surface at the localities referred to. If, on the other hand, rain falls on the exposed margin of the pervious layer, or streams bring water to it, a continuous discharge from the well would result; as will be seen, one well in an artesian basin might be conspicuously successful, while many wells might permit of such a freedom of escape of the water in a pervious bed as to practically ruin all of them.

In the illustration just presented, but one pervious bed was considered. In nature several such beds may be present in a single artesian basin, and several wells, drilled to different depths, might be successful, each well being supplied by a different pervious bed.

The height to which the water will rise above the surface opening of an artesian well depends on the height of the water in the raised border of the water-charged bed from which it derives its supply. For example, in fig. 2 the lowest point in the rim of the water-charged bed is at A, and if the pipe in the well drilled at D or E be carried up into the air and the end not closed, the water will rise in it until it reaches the level of A. The height to which the water will rise in an open tube attached to the surface opening of an artesian well is termed the artesian head. At all points within an artesian basin below the level of the artesian head water may be expected to rise to the surface and overflow when a well is drilled and properly cased. But if the surface of the ground is above the horizon of the outcrop of water-bearing bed, the pressure on the water will not be sufficient to force it to the surface, even if a drill hole is put down and properly cased. The height of the surface within an artesian basin may thus furnish the controlling condition on which success in searching for artesian water would depend. For this reason the pioneer well in an artesian basin should evidently be drilled at the lowest available locality in order to determine the artesian head. In making this test the bottom of the casing in the well should be just above the water-bearing stratum and securely packed on the outside so as to prevent leakage. If a well has a surface flow the height to which the water will rise above the ground may be learned by attaching a flexible hose pipe, or, in fact, any kind of a tube, to the upper end of the casing of the well and carrying it up a ladder or trestle until the water stands at the upper end, but does not overflow.[a] When two or more water-charged layers are present in an artesian basin, wells obtaining water from different layers may have different artesian heads.

Another necessary surface condition in reference to most artesian basins is that the margins of the porous beds shall rise to the surface and be exposed, so as to become charged with water from rain, melting snow, streams, etc. The amount of precipitation is also an important factor, especially in reference to the number of wells that may advantageously be put down in an artesian basin; but even in regions having an arid climate the porous beds beneath the surface so situated as to receive water at their edges, and from which its escape is prevented, will be found to be water charged.

As the pervious beds in an artesian basin commonly descend to a

[a] Practical suggestions in this connection are presented in the papers No. 3 and No. 4 in the list at the end of this report.

considerable depth below the earth's surface, the water which escapes from them when drill holes are put down is usually warmer than the water in neighboring dug wells. The reason for this is that the temperature of the earth increases with depth below its surface, as is discussed below. The temperature of water in a pervious bed is therefore regulated by the depth of the bed below the surface, and several flowing wells drilled in the central part of a basin should yield water with essentially the same temperature.

In the case of artesian basins generally, the water supply is furnished by rain and streams and enters the pervious beds at their outcrops—that is, the water descends into the pervious beds from above. There are instances, however, in which the water rises from below. If a basin exists, as already explained, water may be supplied to the pervious beds either by the upward leakage of a lower pervious bed, or, as is illustrated in the following diagram, by fissures in the rocks beneath.

The water which rises through deep fissures in the earth's crust is commonly hot, and when it appears at the surface forms hot springs. In a case like that illustrated by fig. 3 the pervious bed is charged by

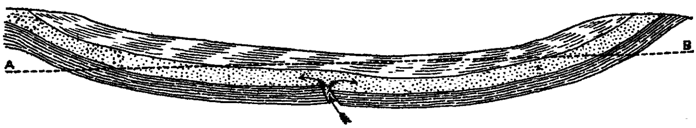


FIG. 3.—Ideal section of an artesian basin charged with water rising from below through a fissure.

water rising through the rocks beneath it, and artesian wells supplied by it would have a higher temperature than under normal conditions would be expected from their depth. More than this, several wells drilled in the central portion of a basin which is supplied in the manner just explained might vary greatly in temperature according to their distance from the subterranean source of supply, although deriving their water from the same pervious bed. The artesian head in the case just cited would depend on the height of the water stored in the pervious bed, but could not exceed the pressure on the incoming water from a deep source. Where there is a subterranean source of water supply for an artesian basin there is probably always an additional supply coming from above, so that both the pressure and temperature of the water obtained by drilling will be regulated by an adjustment between these two leading conditions.

There are other conditions than those just considered which permit a surface flow of water when wells are drilled, but so far as the artesian basins to be described later are concerned, it is unnecessary to consider them at this time.

Even when a well-defined artesian basin is present there may be qualifying or adverse conditions which will prevent a surface flow of water where one might reasonably be expected. These "accidents," as they may perhaps be termed, are caused by the fact that sheets of rock which are open textured, and consequently pervious, in one portion may become close textured and practically impervious in another portion. Also, an impervious bed may be fractured so as to allow the water to escape. In Idaho and Oregon the rocks which are bent so as to form basins are at times traversed by dikes; that is, more or less vertical sheets of rock formed by molten material forced upward into fissures from deep within the earth's crust, and cooling and hardening. There are still other locally adverse circumstances which may exist in even the best-defined artesian basins. These and other questions bearing on the success or failure of artesian wells have been discussed by several writers, and for a more complete and critical presentation of the subject than it is desirable to attempt at this time the reader is referred to the publications mentioned at the end of this report.

SURFACE INDICATIONS OF THE PRESENCE OF SUBSURFACE WATER UNDER PRESSURE.

The presence of artesian conditions is most frequently inferred from the structure of a basin, but confirmation of the supposition that water under pressure exists below the surface may frequently be had from the occurrence of warm springs. Such springs may also furnish evidence in reference to the depth to which a well should be drilled in order to penetrate the water-charged stratum.

The water which occurs in artesian basins has descended from the surface, and as the temperature of the earth increases with depth, the deeper the water has penetrated the rocks the higher will be its temperature. The increase in the temperature of the earth below a depth of about 50 feet in temperate regions is in general about 1° F. for each 60 feet, but there is considerable evidence for concluding that the rate of increase in southern Idaho and the adjacent part of Oregon is approximately 1° F. for each 45 feet in depth.[a] In temperate latitudes the increase in the temperature of the earth should be reckoned from a depth of 50 feet below the earth's surface, because the seasonal changes in temperature extend to that depth. At the horizon referred to there is a constant temperature which agrees with the mean annual temperature of the locality chosen. In the portions of Idaho and Oregon under consideration the mean annual temperature is approximately 50° F. In tropical countries the depth to which seasonal changes of temperature extend is less and in arctic regions much greater than that just stated. If, for example, a spring in the region referred to has a temperature of 65° F., or 15° above the temperature

[a] The facts on which this conclusion is based are recorded in Bull. U. S. Geol. Survey No. 199, 1902, pp. 173-174.

of the stratum of no seasonal variation, it would be safe to conclude that the water rises from a depth of at least 675 feet below that stratum or 725 feet below the surface. As the freedom of escape of the waters of springs is usually obstructed, some allowance must be made for its cooling as it rises, so that in the same case just cited 725 feet would indicate the minimum depth to which a drill hole would have to be extended with the hope of penetrating rocks in which water existed under sufficient pressure to cause it to rise to the surface.

In artesian basins there are apt to be localities where there is an escape of the water to the surface, so as to form springs. In such instances the springs usually flow throughout the year without appreciable changes in volume or in temperature, and the water is above the mean annual temperature of the locality where it reaches the surface. Where the structure of the rocks suggests that an artesian basin is present, the occurrence of warm springs within the basin is an assurance that water is present under sufficient pressure to force it to the surface in case wells are drilled. The warm springs referred to may be termed natural artesian wells, and their temperature indicates the depth of the water-charged bed below the surface, and the elevation of the locality where they occur gives a minimum measure of the height of the artesian head.

While warm springs (or those ranging in temperature from about 60° to 100° F.) situated within a region which has the structural features of an artesian basin may be taken as evidence of the presence of a water-charged layer which would supply flowing wells, a hot spring (or one having a temperature of more than 100°) is not so favorable an indication. Hot springs ordinarily rise from such a depth that even if they come from a well-defined water-charged layer it would be impracticable for most purposes for which artesian water is used to reach it by drilling. Although the conditions which lead to the occurrence of hot springs are not well understood, owing to the depth from which their waters rise, there are reasons for believing that they are frequently supplied by fissures that penetrate deep into the earth. The irregularities of fissures are such as to preclude prediction as to where they occur. In the case of every hot spring, however, there is a chance that if a well is drilled near it, even to a moderate depth, a flow of water will be secured, but in such instances the flow of water obtained should be classed as a "developed spring" rather than an artesian well. The fact, however, as previously explained, that water rising from a depth through fissures may charge the pervious beds in an artesian basin renders it evident that both warm and hot springs demand careful study in conducting a search for artesian water.

ROCKS OF THE REGION EXAMINED.

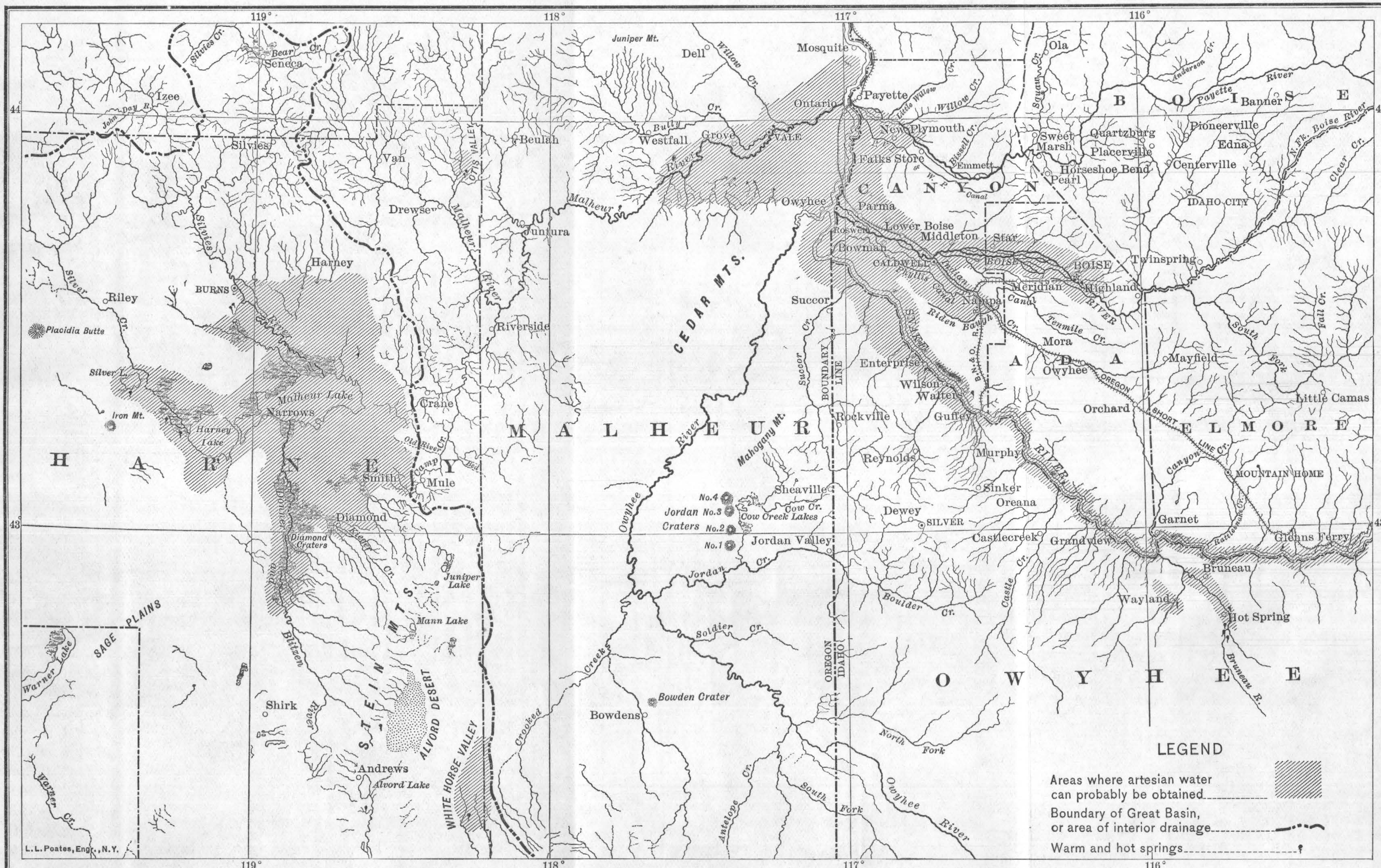
A classification of the most common rocks of southwestern Idaho and southeastern Oregon, sufficiently accurate for the present purpose, is as follows:

- Sedimentary rocks: Conglomerate, sandstone (in part hardened so as to form quartzite), shale, clay, sand, and gravel, together with beds of volanic dust and volcanic gravel or lapilli.
- Igneous rocks:
  - Volcanic rocks:
    - Lava flows: Basalt. Rhyolite.
    - Fragments blown out of volcanoes: Basalticlapilli. Rhyolitic dust and tuff. (Also mentioned above as forming sedimentary beds.)
  - Plutonic rocks: The molten material like that extruded from volcanoes at the earth's surface, but which cooled below the surface in fissures, etc.

SEDIMENTARY ROCKS.

The stratified rocks of the region examined, or those composed of fragments of older rocks which have been spread out in layers or strata by the waters of lakes and streams, comprise conglomerate or pudding stone; sandstones; soft, highly calcareous, usually nearly white shales; loose gravel, sand, white volcanic dust; and dark, usually yellowish, volcanic gravel or lapilli. These beds were, for the most part, deposited in lakes during Tertiary time.

Examples of the conglomerate and sandstones referred to may be seen in the hills near where the Owyhee joins Snake River, in the isolated hills near Vale, and in the conspicuous bluffs to the southeast of Malheur and Harney lakes, as well as many other localities. These rocks are usually dark yellow, but occasionally, as near Narrows, are nearly white, and in some instances are sufficiently compact to be used for building stone. Associated with the layers of consolidated pebbles and sand just referred to, and having a wide extent in both Idaho and Oregon, are soft, unconsolidated light-colored shales and marls, and thick beds of nearly white sand and light-colored clay. Beds of this general nature, aggregating more than 1,000 feet in thickness, underlie Snake River Valley between Glenns Ferry and Weiser, and form the conspicuous white bluff along each side of that stream. Similar beds occur also in the lower portion of the valley of Malheur River and beneath the rim rocks of the canyons on the west slope of Stein Mountain. Light colored, and in part greenish shales, outcrop on the west side of Alvord Valley, where they pass beneath the sheets of basalt forming the bold eastern face of Stein Mountain. Fine exposures of rain-sculptured lacustral sediments, usually of a peculiar light-greenish tint, occur on the borders of Owyhee River near the mouth of Jordan Creek. Similar beds are present also in the



SKETCH MAP OF PORTIONS OF OREGON AND IDAHO SHOWING, APPROXIMATELY, ARTESIAN AREAS

Scale

0 5 10 20 30 40 miles

mountains of Owyhee County, Idaho, and are an extension southward of the thick sediments exposed along Snake River. This same formation extends northward from Snake River and is exposed near Boise, and in the valley of Payette River. From its abundant outcrops along the last-named stream, it has been termed the Payette formation by Waldemar Lindgren.[a]

While the Payette formation has a wide extent in Oregon, and possibly reaches to John Day River, where other similar beds outcrop, it is not positive that all the exposures of similar material as far south as Harney and Silver lakes were deposited in the same lake basin. The lacustral sediments beneath the basalt of Stein Mountain have a thickness of fully 1,000 feet, and, as now seems probable, are older than the Payette formation.

Interbedded with the sandstone, shale, etc., of the formations just mentioned, and frequently forming a considerable and at times seemingly the major part of their thickness, are beds of exceedingly fine, white volcanic dust. This dust was blown out of volcanoes during violent eruptions, and falling in lakes, or being washed into them by streams, became interbedded with other sediments or intimately commingled with them. Pure white, stratified volcanic dust, from 10 to 20 feet or more thick, may be seen in the hills on the lower course of Owyhee River, a few miles south of Owyhee. It is also splendidly exposed near Beulah. Outcrops of material of the same nature, conspicuous on account of their whiteness, occur beneath the rim rock near Diamond, in the borders of the small valleys in the northern portion of Owyhee County, Idaho, as well as at a large number of localities in the bluffs bordering Snake River.

An interesting fact in connection with the stratified beds briefly described above is that they contain the bones of animals which are now extinct, but which lived in large numbers in and about the ancient lakes in which the sand, clay, volcanic dust, and other material now exposed and eroded into hills and valleys was deposited. Throughout these same beds, but most abundantly in the thinly laminated white silts and beds of fine volcanic dust, occur fossil leaves, and less commonly the fruits of plants. These plant remains differ from the vegetation living on the earth to-day, and reveal the nature of the luxuriant forests that flourished in the now arid portions of the far West during the Tertiary period of geological history. The fossil bones and impressions of leaves and fruits referred to, and also the shells of fresh-water mollusks frequently associated with them, are of great scientific interest, as they furnish evidence in regard to past climatic changes and the gradual evolution of life on the earth, and enable geologists to determine the age of the beds in which they occur.

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 632-634; Twentieth Ann. Rept., Pt. III, pp. 93-99; Geologic Folio No. 45

The sedimentary beds to which attention has just been directed are in many instances open-textured and of such a nature that water will readily percolate through them, while in other instances they are of the consistency of clay and tend to retain water in the porous beds, if any is present, between them. These conditions indicate that wherever the sedimentary beds have been bent or displaced from their original horizontal position so as to form basins, there is a probability that flowing water may be obtained by drilling wells.

It is reasonable to assume that quartzite or granite is present beneath the Payette formation and associated volcanic rocks, throughout the Snake River Valley. The quartzite is usually a yellowish-white and excessively hard rock, and was orginally a sandstone, but has been altered or metamorphosed, so that the separate grains of quartz sand are no longer distinguishable. The granite is composed principally of conspicuous crystals of quartz, feldspar, and mica, as may be seen in the extensive outcrops in the mountains to the north of Boise, and is of deep-seated igneous origin. When either of these formations is encountered in drilling, the hope of obtaining flowing water by continuing to a greater depth had best be abandoned.

IGNEOUS ROCKS.

VOLCANIC ROCKS.

The rocks which came from volcanoes are by far the most conspicuous of any of the formations in southwest Idaho and the adjacent part of Oregon, and are no doubt of greater extent and thickness than the associated sedimentary beds. They may, with sufficient accuracy, be classified as basalt and rhyolite, but a critical study will no doubt show that what is here termed rhyolite in reality includes several rock species.

Both the basalt and the rhyolite present two conspicuously different phases, due to the manner in which the material composing them was spread out on the earth's surface. These rocks while molten were in part extruded by volcanoes so as to form sheets, which in many instances flowed far and wide over the surface of the land before cooling. In other instances the lava, while yet in the craters from which it came, cooled sufficiently to become rigid and was shattered by steam explosions, and the fragments thus produced were blown into the air and widely distributed through the action of the wind, etc., as sheets of volcanic dust, volcanic gravel, or lapilli and angular fragments, frequently of considerable size. The basalt was spread over the surface of the land, mostly in a molten and even highly fluid condition, and the beds of fragmental material produced were relatively small. The rhyolite, to a great extent, was shattered at the time it was erupted, and the resulting beds of fragments were probably of greater extent and thickness than the sheets of the same material which were spread out as lava flows. This difference in the behavior of the volcanoes from which the comparatively fusible basalt was erupted and of the volcanoes from which the more refractory rhyolite was discharged is of much significance in reference to the nature of volcanoes, but can not be discussed at this time.

The basalt is a black, compact rock, but is frequently cellular and even scoriaceous on account of the presence in it of steam cavities, and in many localities is columnar. In the region under review it occurs in widely extended sheets, which in general vary in thickness from about 20 to 80 feet. Fine examples occur all along Snake River, but more especially on the northern side of its canyon, in the canyon of Bruneau River, and in the hills and mountains of Malheur and Harney counties, Oreg. The finest exposure of basalt in the region visited by me in 1902, if not the most remarkable in the world, is to be seen in Stein Mountain. The eastern slope of that splendid mountain is composed of the broken and eroded edges of sheets of basalt, which dip westward at an angle of 3° to 4° at the crest of the uplift, but flatten rapidly when traced westward, and present an aggregate thickness of not less than 5,000 feet. Between the sheets of basalt, as observed in at least eighteen instances, there are beds of coarse sandstone, varying in thickness from a few inches to 6 feet. Where the beds of sandstone occur the sheets of basalt are in general about 60 feet thick. From this and other similar evidence the total number of lava flows which occur at the locality referred to is estimated at between 80 and 100.

The widely extended sheets of basalt just referred to, like the sedimentary beds with which they are intimately associated—the sheets of basalt and the beds of sandstone, shale, clay, etc., in many instances alternating one with the other—are of ancient date, and belong principally to the Tertiary division of geological history.

Volcanic eruptions have occurred, however, at intervals from the time the oldest sheets of basalt were poured out in a molten condition down to almost the present day. Recent volcanoes, which discharged great quantities of basaltic lava in the condition both of lava sheets and of angular fragments, occur at three localities in southeastern Oregon. One of these is situated a few miles west of Diamond, Harney County, where there are craters that are built in part of scoria, lapilli, etc., and in part of lava sheets, and are surrounded by extensive lava flows. This group of small volcanoes may with propriety be named the Diamond craters. About 6 miles northeast of the former Bowdens post-office, in Malheur County, and approximately 18 miles south of Owyhee River where Jordan Creek joins it, there is an isolated crater of recent date, built almost entirely of congealed lava, which cooled about the opening in the earth from which it rose. About this Bowden crater, as it may be termed, is a recent lava flow which came from it and spread over at least 150 square miles of country. The most instructive as well as the latest of the three recent eruptions referred to occurs in the east-central part of Malheur County from 15 to 20 miles west of Jordan Valley, and the hills it built are here named the Jordan craters. The Cow Creek lakes owe their existence to the obstruction to the drainage caused by the extensive sheet of fresh black lava which came from the most northerly and most recent of Jordan craters. The rocks extruded from these recent volcanoes were spread over the surface both as lava flows and as sheets and piles of fragments, and serve in a most instructive manner to illustrate the mode of origin of the more ancient and far more extensive accumulation of similar rock.

The rhyolite, like the basalt, occurs both as massive sheets, which were poured out from volcanoes in a molten condition, and fragmental deposits, which also form well-defined beds. Of the beds originating in these two ways, the sheets of angular fragments, now in many instances firmly cemented and forming a rhyolitic tuff, are far more numerous and more extensive than the associated rhyolitic lava beds. The deposits of white volcanic dust described above as forming a part of the sedimentary formations are composed of the finest of the fragments blown into the air by the volcanoes from which came the material now forming the sheets of rhyolite and of rhyolitic tuff.

The compact, massive rhyolite is lighter colored than basalt, and in Idaho and Oregon is usually purplish on fresh surfaces, but weathers to a rich brown or red. It contains conspicuous crystals and grains of quartz, feldspar, and other minerals, and hence usually appears spotted. Frequently the crystals and grains referred to exhibit an arrangement such as would be produced by a flowing motion in the glassy base in which they are embedded.

The rhyolitic tuff is composed of angular fragments of the rock just described, which in most instances are firmly cemented so as to form sheets that are nearly, if not fully, as resistant to atmospheric conditions as the similar material which cooled from fusion without being shattered, as may frequently be seen in the rim rock on the sides of canyons and valleys.

Extensive exposures of rhyolite and of rhyolitic tuff occur in the mountains on the northeast side of Harney Valley, sometimes termed the Crow Creek Mountains. The conspicuous rim rocks on each side of Rattlesnake Creek, near Harney, are of rhyolitic tuff, while certain of the beds, usually cavernous on the weathered outcrops lower down in the walls of the same canyon, are of rhyolite which has a peculiar concentric or spherulitic structure. Again, in the bluffs of Silvies River, to the west of Burns, the edges of a thick sheet of compact tuff are well exposed, and similar rock has a wide distribution in the forest-covered mountains in which Silvies River rises. Other exposures of tuff and of compact rhyolite occur about Silver Lake, at Iron Mountain, and in the Mahogany Mountains. The conspicuous rim rocks in the vicinity of Diamond are composed of tuff, and similar rock has a wide distribution in the hills near Smith and Mule.

An interesting fact in connection with the sheets of rhyolite and of rhyolitic tuff in southeastern Oregon is that they are younger than most of the basalt of the same region and overlie it. There have been eruptions of basalt, also, since the youngest observed sheet of rhyolite and of rhyolitic tuff was spread out.

The rhyolitic tuff is in many instances highly porous and permits the free percolation of water through it, but in other instances it is firmly cemented and probably nearly impervious. The compact rhyolite is to be classed, in most instances, as an impervious rock, although its weathered outcrops are at times conspicuously cellular. The presence of sheets of these rocks in an artesian basin, together with sheets of basalt and stratified sandstone, shales, clay, sand, etc., would tend to increase the variety among the strata, and in a general way, at least, be favorable to the storage of water under pressure.

PLUTONIC OR DEEP-SEATED IGNEOUS ROCKS.

The molten magmas which rise in volcanoes and in part overflow, so as to form lava sheets, also, in part, cool below the surface in the conduits of volcanoes and in fissures. Many distinctive features in the rocks produced from the same molten magma arise in this way, which it is unnecessary to consider at this time.

Both the basalt and the rhyolite, which occur in extensive sheets in Idaho and Oregon, came to the surface through openings, as fissures, for example, and below the present surface it is to be expected that there were many fissures in which molten rock has cooled, so as to form what are termed dikes. A few dikes were observed in the bold eastern face of Stein Mountain, and indicate that others may be present elsewhere. The dikes referred to are nearly vertical, vary in width 20 to 60 feet, and are horizontally columnar. As is well known, dikes have frequently led to the hardening of the walls of the fissures they occupy and for this and other reasons their presence in an artesian basin might introduce serious difficulties in the way of obtaining flowing wells. If in drilling a well, the locality chosen should chance to be directly above a dike, it is probable that the well would be a failure, even if the usually compact and hard rock of the dike could be penetrated. Where the country rock is concealed beneath deep sheets of soil, alluvial deposits, etc., it is frequently impossible to detect the presence of dikes in the rocks beneath the surface covering, unless they are encountered in drilling or making other excavations. So far as can now be judged, however, the dikes in the artesian basins described in this report are not numerous, and the chances of striking them in drilling are small. A greater danger lies in the fact that they may cut a pervious bed so as to prevent the percolation of water through it.

GEOLOGICAL STRUCTURE.

By geological structure is understood in part the positions occupied by stratified or bedded rocks in the earth's crust. For example, sandstone, shale, etc., originally laid down in horizontal sheets, are now found in many instances to be inclined or folded, and often occupy a vertical position.

The rocks, both sedimentary and volcanic, which underlie southwestern Idaho and southeastern Oregon, were at the time of their formation spread out in nearly horizontal layers, but subsequently they have been depressed in one locality and raised in another, and in certain instances crushed together so as to form great upward and downward folds. In other localities they have been broken along nearly vertical planes, and a portion of the strata on one side of the break has been upraised or depressed in reference to corresponding strata on the opposite side; that is, the beds have been faulted. Examples of gentle tilting of previously horizontal sheets of rocks throughout great areas are furnished in the broad Snake River Plains between Glenns Ferry and Owyhee. To the north of Snake River the rocks are now gently inclined upward to the north, but south of the river the same beds rise when followed southward, and in the Owyhee Mountains the strata are more than a thousand feet above the position they occupy beneath Snake River. This uptilting of stratified beds is well displayed in the hills near the point where Snake River first crosses the Idaho-Oregon boundary. These remnants of formerly much more extensive strata indicate not only the way in which once horizontal beds have been tilted, but bear evidence as to the great amount of denudation that has occurred throughout an extensive region.

Broad and comparatively gentle elevations and depressions of once horizontally stratified rocks occur also in other portions of the region examined; as, for example, in the neighborhood of Harney and Burns. The rocks beneath the extensive valley in which Malheur and Harney lakes are situated slope upward in the hills and mountains about the borders of the basin, as is well shown in the walls of the canyons on the west side of Stein Mountain, in the Crow Creek Mountains, on the border of the canyon of Rattlesnake River, in the hills west of Burns, and several other localities. In general, all about the Harney basin, as it is convenient to term the great depression in which Malheur and Harney lakes are situated, as well as in the country draining to them, the rocks are upraised. This basin, however, is not a simple saucer-shaped depression, but has irregularities, and is due to the association of several areas in which upheavals or depressions have occurred.

The broad, gentle undulations in the rocks just referred to, which in some instances have horizonital axes measuring a hundred or more miles, are promising structural features in reference to the hope of obtaining an artesian-water supply.

Of smaller size than the broad and usually somewhat indefinite swells and depressions referred to above are upward folds, or anticlines, and downward folds, or synclines. These are similar in shape and in the manner in which they are produced to the folds or corrugations that may be made by pushing one side of a pile of rugs toward its center; or, on a still smaller scale, by forcing together the sides of a pile of newspapers so as to compress them into folds. In the region under consideration there are several examples of such folds; but, as is commonly the case on all land areas, the relief produced in the manner referred to has been greatly modified by erosion. The upward folds particularly have been cut away, leaving for the most part only their basement portions.

A striking illustration of a great upward bend, involving bedded lava sheets having an aggregate thickness of fully 5,000 feet and a great but unknown thickness of stratified sedimentary deposits as well, is furnished by the north portion of Stein Mountain and the several parallel nearly north-south ridges to the east of it and north of Alvord Desert. The larger features of this rugged belt of country are due to the erosion of a great anticlinal fold, the longer axis of which trends about northeast and southwest. The hard layer of compact basalt in the truncated remnant of the fold now forms the sharp crested ridges to the east of Juniper and Mann lakes, which have a gentle surface slope on one side and a steep escarpment on the other.

A characteristic example of a broad downward fold or syncline may be seen from the summit of Stein Mountain on looking toward the southwest over the region drained by Donner and Blitzen River. The longer axis of this basin trends in a north-south direction and is inclined downward, or pitches, to the north.

Accompanying the bending of rocks so as to form corrugations, breaks sometimes occur, and the edges of the broken layers on the sides of the fracture are upheaved or depressed with reference to each other. In this and yet other ways what are termed "faults" are produced.

When the rocks have been broken and displaced or faulted, the conditions are not favorable for obtaining artesian water. Even if an artesian basin is present, the impervious beds, which would otherwise confine water under pressure, may be broken and permit the water to escape. In this connection it is to be noticed that hot springs are frequently situated on fault lines. In the case of the Stein Mountain fault, a spring with several surface openings having temperatures ranging from 168° to 177° F. occurs on the southwest side of Alvord Desert.

It is principally from the study of the structure of the rocks in any region that the presence of artesian basins is to be determined. The reason why structure may be considered as the controlling condition in this connection is because the other necessary conditions, such as the presence of pervious and impervious layers in a series of stratified rocks, the presence of water in pervious beds, etc., are of common occurrence; while the requisite conditions for storing water beneath the earth's surface and under pressure are much less frequent, and it is these conditions which are dependent principally on the positions which the rocks occupy—that is, the geological structure. When a saucer-shaped basin is present, the chances are that the other necessary conditions will also exist.

ARTESIAN BASINS.

The four principal areas in southwest Idaho and southeast Oregon in which artesian water has already been discovered, or in which convincing evidence is found that it may be obtained, have already been referred to under the names of the Lewis, Otis, Harney, and Whitehorse artesian basins. Such facts as have been learned concerning each of these basins as are thought to be of immediate value to persons interested in the development of their artesian conditions are here presented.

LEWIS ARTESIAN BASIN.

The portion of this artesian basin in which flowing water may be obtained is situated along Snake River between Glenns Ferry and Weiser, and might with propriety have been named after it, except for the possibility that other artesian basins may be discovered in the extensive region it drains. Lewis, the less frequently used but more appropriate name of the Snake River, has therefore been selected as a convenient term by which to designate the artesian basin under consideration.

The rocks on each side of Snake or Lewis River from near the mouth of Kinghill Creek westward to beyond the Idaho-Oregon boundary are gently inclined or dip toward the canyon of that stream from each side. The inclination of the rocks is most readily seen on the south side of Snake River; as, for example, in the highlands to the east of Bruneau River, and in the hills near the mouth of Owyhee River, where the strata rise when traced southward at the rate of perhaps 100 feet to the mile. This rise, although gentle, is sufficient to carry the strata which underlie Snake River to an elevation of more than a thousand feet above its surface in the hills and mountains of Owyhee County. On the north side of Snake River the rocks are seemingly level, but, as nearly as can be judged, rise gradually to meet the mountains of older rock to the north of Mountain Home, Boise, etc. The inclinations of the rocks just referred to show that they have been bent into a broad trough-shaped depression, the longer axis of which bears about northwest and southeast, and is followed by the canyon of Snake River in a general way from Glenns Ferry to the Idaho-Oregon boundary. In certain localities, however, the axis of the fold is a mile or two north of the river.

On reaching Snake River, in 1901, I observed the general features pertaining to the dip of the rocks just referred to, and at once recognized the possibility of the presence of an artesian basin. Other conditions confirming the truth of this inference, such as the presence of warm and hot springs, were soon discovered, and the fact was learned that several successful artesian wells had already been drilled in Bruneau and Little valleys, thus demonstrating that water under pressure exists below the surface. In 1902 the portion of Snake River Valley lying west of the region traversed the previous year was examined, and the structural basin referred to was found to extend beyond the Idaho-Oregon boundary and to include a wide extent of territory in Oregon.

The eastern end of the Lewis artesian basin is for convenience considered to be near the eastern boundaries of Elmore and Owyhee counties, principally for the reasons that this is the eastern limit in the canyon of Snake River where land suitable for irrigation occurs below the artesian head of the basin as at present known, and also because sufficient study has not as yet been given to the region east of the counties mentioned to justify me in expressing an opinion in reference to the actual eastern extension of the basin in question.

The margin of the Lewis artesian basin can not yet be actually mapped, but within it is included, in a general way, the Snake River Plains in Elmore, Ada, and Canyon counties, and the country in Owyhee County which is drained by northward-flowing streams. In Oregon its boundary is still less definitely known, but it includes the greater part of the northern third of Malheur County. The position of the actual boundary of the basin, or the line from which the rocks begin to slope toward a central axis, is of much less practical moment, however, than the boundary of the country below the artesian head.

As will be stated below, the artesian head of the Lewis artesian basin has not been accurately determined, but provisionally it is taken at 2,500 feet above sea level. This is certainly a safe assumption, as flowing wells now discharge this water at that level, and others, as determined by a less accurate method of measurement, namely, the aneroid barometer, overflow at 2,700 feet above the sea. This indefiniteness is due to the fact that none of the wells in the basin are properly cased, and it was impracticable with the means at my disposal to make definite measurement of the water pressure. However, the area throughout the greater part of the Snake River Canyon or Valley, which is between an elevation of 2,500 and 2,700 feet, is comparatively small, and the extent of territory below the former level is probably more than sufficient to utilize all the artesian water that can be had within its boundary.

The tracing of the territory below the known artesian head in the portion of the Lewis artesian basin which is situated in Idaho is a simple matter, as most of it has been surveyed and accurate contour maps are available. The maps referred to are published by the United States Geological Survey, and comprise the following sheets of the topographic atlas of the United States: Mountain Home, Bisuka, Boise, Silver City, Nampa, and Weiser.[a] By consulting these maps it will be seen that a large extent of territory adjacent to Snake and Boise rivers lies below the 2,500-foot contour. Practically all of the flat land favorable for agriculture adjacent to Snake River, between Glenns Ferry and the mouth of Boise River, lies below the horizon referred to. That is, the 2,500-foot contour marks, in general, the beginning of the abrupt slopes which rise from the flat lands bordering the river to the margin of the plateau above. In the region referred to, where the surface is less than 2,500 feet above the sea, wells put down to the requisite depth, which will be discussed later, should yield flowing water. A considerable extent of country about Nampa and Caldwell, much of the valley of Boise River, and of the Snake River Valley between the mouths of the Boise and Weiser, are also below the 2,500-foot contour, and so far as can now be judged, wells put down in this region should also yield an artesian flow.

There are no good maps of the region in Oregon embraced within the Lewis artesian basin, and it is impracticable to state at present where the plane of the assumed artesian head, 2,500 feet above the sea, intersects the surface. Much of the nearly level land that is otherwise favorable for agriculture adjacent to the west side of Snake River from where it first crosses the Idaho-Oregon boundary northward to the vicinity of Weiser, and an extensive tract in the lower 25 miles of the valley of Malheur River are certainly within the limit referred to, and careful tests of the artesian conditions should be made. A rough estimate of the extent of agricultural land in Idaho and Oregon that is within the Lewis artesian basin and below its known artesian head shows it to be not less than 1,000 square miles.

As the conclusions just presented will no doubt be considered too sanguine by many persons, I desire to indicate briefly the evidence, other than the geological structure, on which they are based, and at the same time to furnish data which will assist in the more complete development of the artesian conditions.

SPRINGS.

Within the Lewis artesian basin there are a number of warm and hot springs, which show that water under pressure exists below the surface.

Mountain Home.—About 3 miles east of Rattlesnake Creek, at the locality where "Old" Mountain Home was located, there is a fine spring, or group of springs, with a maximum temperature of 167° F.

[a] These maps, on a scale of about 2 miles to 1 inch, with a contour interval of 100 feet, each sheet including about 850 square miles, can be purchased of the United States Geological Survey for 5 cents each.

The surface level is about 3,550 feet. The water is of good quality, but is not now utilized except in a small way for bathing. No attempt has been made to develop the spring by boring, although good land occurs near at hand on which any water that might be obtained could be used for irrigating.

Boise.—Springs issue from sandstone of the Payette formation, 4½ miles east of Boise, at an elevation of about 2,750 feet. The water has a faint smell of sulphureted hydrogen, contains a small amount of mineral matter in solution, and varies in temperature from 125° F. to near the boiling point.

Salmon River.—A small spring on the left bank of Snake River, about 4 miles above the mouth of Salmon River, Cassia County, has a temperature of 131° F. Another hot spring occurs in the canyon of Salmon River, about 5 miles above its mouth.

Little Valley.—Near the head of Little Valley, Owyhee County, there are several warm springs and one small hot spring, temperature 101° F., which is now partially developed by drilling wells near it to a depth of 40 feet.

Bruneau Valley.—Near Hot Spring post-office there are several copious springs, with a temperature of 109° F. One of these has been developed by drilling a well near it to a depth of 240 feet. The well furnishes 7 gallons of water per minute.[a]

Walters Butte.—A copious spring about 1 mile west of Walters Butte, Canyon County, where the elevation is 2,340 feet, has a temperature of 67° F. This spring is very likely due to the leakage from water-bearing strata, and suggests that wells put down in its vicinity to a depth of about 350 or 400 feet would yield a surface flow of water. Near Walters Butte there is an area of about 4 square miles of favorable land that lies below the known artesian head of the basin in which it is situated.

Enterprise.—On the south side of Snake River, at Enterprise, Owyhee County, there is a spring issuing at an elevation of 2,220 feet, with a temperature of 128° F., which discharges approximately 7 cubic feet of water per second and is now utilized for bathing and for irrigating about 10 acres of land. The water rises where there is a thickness of nearly 1,000 feet of soft lake sediment (Payette formation) and, as its temperature indicates, comes from a depth of approximately 4,500 feet.

Sands.—From 2 to 3 miles west of Sands, in Owyhee County, and near the point where Poison Creek descends through a deep cleft in the upland and enters Snake River Valley, there are copious springs, with a temperature of about 100° F., which are used for irrigation. These springs rise where the surface level is approximately 2,450 feet, and may reasonably be supposed to be supplied by the leakage of porous

[a]Concerning the five localities mentioned above additional information is presented in Bull. U. S. Geol. Survey No. 199.

beds in the Payette formation. They occur within the Lewis artesian basin, nearly up to the known artesian head of that basin, and are a favorable indication that wells drilled in their vicinity to a depth of approximately 1,000 feet would prove successful, but from other evidence it is to be presumed that flowing water might be expected on drilling to a less depth. To the north of the conspicuous line of bluffs trending northwest and southeast and passing Sands on the south is a large tract of good land, embracing in fact something like 100 square miles, which is below the level of the springs just referred to, and where one is justified in assuming that artesian water can be had.

Owyhee Canyon.—In the canyon of the Owyhee, about 6 miles south of Owyhee post-office, there is a copious hot spring, which issues from openings in volcanic rock and has a temperature of about 115° F. But little irrigable land occurs near this spring, and for this reason an attempt to develop it and concentrate its flow would at present not be warranted.

Vale.—At Vale, on the east border of Malheur River, there is a spring with a temperature of 198½° F. Near at hand a well put down to a depth of 140 feet yields a strong flow of water with the same temperature. These springs are in a broad region underlain by the Payette formation, but it is presumed, are supplied by fissures. These springs rise at the west base of a prominent hill, composed in part of cemented gravel, and the manner in which they are depositing mineral matter suggests that the pebbles and sand in the hill were cemented by the same process. Other similar hills or buttes are situated a mile or two northward, and another is a conspicuous object about 5 miles farther north. Each of these exceptional features in the topography of the valley is due to the resistance offered to erosion by the hard beds they contain, and suggest that in each case hot springs rising through the Payette formation have led to a local hardening of its more porous strata and, in consequence, their preservation as erosion progressed. This suggestion was not tested by examining each of the hills referred to, but may be of interest to students of geology who visit them in the future, and in addition may be found to explain the manner in which hot springs sometimes occur in artesian basins, but do not appear to have any connection with neighboring artesian wells.

Westfall.—On the stage road between Vale and Westfall, in sec. 9, T. 18 S., R. 43 E., there is a spring with a temperature of 168° F. at an elevation by aneroid barometer of 2,400 feet. This discharges by estimate about 2 miners' (California) inches, or 100 cubic inches per second, but the total flow from the several small openings is probably greater than this. The waters have a slight odor of sulphureted hydrogen, and are depositing lime in the form of cellular calcareous tufa. The water is used for bathing, and in part is conducted to a house through a pipe and used for cooking, etc. A small spring near at hand, supplied by percolation from the alluvial material in the bed of Bully Creek, has a temperature of 54° F.

The hot spring just mentioned is within the territory included in the Lewis artesian basin, and, judging from the approximate measures available, is below the artesian head of that basin, but owing to the high temperature of its waters and the consequent depth from which they rise, and the nature of the rocks in the vicinity, little if any significance in reference to the probability of obtaining artesian water in its neighborhood can be attached to it.

Beulah.—Small springs in the valley of Warm Creek, near Beulah, have a temperature of 185° F.

DRILLED WELLS.

In the portion of the Lewis artesian basin examined by me in 1901 it was found that several moderately deep borings had already been put down, several of which yielded a surface flow of water. Some account of the borings referred to was presented in my report for the year named,[a] but for the purpose of bringing together all the available evidence furnished by borings concerning water pressure, etc., within the Lewis artesian basin a brief account of those previously described is here inserted.

Boise.—To the north and east of Boise and within 2 miles of the city several flowing wells have been obtained by drilling in the Payette formation, and the water they supply is now utilized for city purposes. Boise is fortunate in possessing both cold and hot artesian wells. The following facts concerning them are compiled from a report on the geology of the Boise region of Waldemar Lindgren.[b]

The several cold artesian wells at Boise (temperature about 55° F.) are situated in the gulches north of the city and at an elevation of about 2,750 feet. They vary in depth from 400 to 609 feet, but since this information was obtained some of them have been deepened. The materials passed through in Hulls Gulch are sand and sandstone, 200 feet, and clayey beds, 200 feet, below which water was obtained. In the deepest well there are below the clay 40 feet of sand, 20 feet of clay, and 46 feet of solid basalt, below which clay occurs again. These wells yield from 40 to 250 gallons per minute, and their combined flow is stated to be about 670 gallons per minute. The water is stored in a covered reservoir and from there conducted into the city water mains.

Two wells drilled on the Davis ranch, in the next gulch north of Hulls Gulch, to a depth of 150 feet yield 40 gallons of water per

---

[a] Bull. U. S. Geol. Survey No. 199.

[b] Geologic Atlas U. S., folio 45, Boise, Idaho; published by the U. S. Geol. Survey and sold for 25 cents per copy.

minute. A well drilled to a depth of 400 feet in a ravine south of Hulls Gulch passed through clay and failed to reach water under pressure.

The hot artesian wells at Boise are situated two miles southeast of the city. Three of these, the water of which is piped to the city and extensively used for heating, baths, etc., have depths of 394, 404, and 455 feet. The character of the rocks penetrated is not definitely recorded, but it is stated that the drill, after passing through sandstone, penetrated several sheets of basalt, below which occurred red volcanic tuff or fragmental volcanic rock more or less thoroughly cemented and containing much black sand. The combined discharge of the three wells is 550 gallons a minute. The water is slightly charged with mineral matter in solution (about 300 parts in 1,000,000) and has a temperature of 170° F. The surface elevation is nearly 2,800 feet, and the water is under sufficient pressure to cause it to rise in a tube open at the top about 50 feet above the surface, or to an elevation of 2,850 feet above the sea. Several wells have been drilled on the United States military reservation a mile east of Boise, at least two of which discharge warm water. Their depths are 450 and 482 feet. The surface elevation is 2,850 feet. From the first mentioned a small flow of water with a temperature of from 75° to 140° F., increasing with depth, was obtained. The second gave a flow of about 35 gallons per minute, the water having a temperature of 90° F. These wells are located near a small tepid spring, and penetrated first 130 to 160 feet of sandstone, then 72 to 116 feet of hard, black lava (basalt), below which occurs a series 200 to 250 feet thick of clays and red basaltic tuff rich in magnetite (black sand) and sometimes containing also iron pyrites.

Other artesian wells in the neighborhood of Boise are briefly described in the Boise folio referred to above.

Both the cold and the hot artesian wells near Boise are in the Payette formation and associated and interbedded sheets of basalt which underlie the Snake River Plains. These same beds outcrop on the border of Snake River Canyon, and south of Snake River rise to an elevation of 4,000 feet or more in the Owyhee Mountains. These facts, together with the geographical position of the wells and the elevation at which they are located—that is, about 2,850 feet—render it at least possible that they belong to the Lewis artesian basin.

Bruneau Valley.—In the upper portion of Bruneau Valley there are three flowing wells, each 2½ inches in diameter, which, together with the numerous hot springs of the same region briefly described above, show that an abundance of water exists at a moderate depth and under sufficient pressure to cause it to rise to the surface if openings are provided.

On W. N. Roberson's ranch, about 2 miles north of Hot Spring post-office and on the west side of the valley, a drilled well having a depth of 240 feet delivers about 7 gallons of water per minute, having a temperature of 109° F. This well is within a few feet of a large hot spring having the same temperature, the flow of which was not diminished when the well was drilled. The elevation of the surface at this point, by aneroid, is 2,750 feet. The section passed through, as reported from memory by Mr. Roberson, is as follows:

Section at Roberson's ranch.

	Feet.	Inches.
Light-colored sandy clay (Payette formation)	236	
Granular black layer, like basalt (volcanic lapilli)		10
Blue clay (Payette formation)	4	
Black lava	Several inches.	
Total depth, approximately	240	

The water is used for household purposes and for irrigation.

Nearly opposite the well just described, on the east side of the valley and at an elevation approximately 50 feet higher, a well drilled to a depth of 230 feet, on land belonging to Mr. A. H. Pence, gave a small surface flow.

On B. Whitson's ranch, on the eastern side of the valley, about 3 miles north of the two wells just mentioned, where the surface elevation is by aneroid 2,750 feet, a well 700 feet deep discharges about one-third cubic foot of water per second. The temperature is reported to be 90° F.

These three wells derive their water from different depths, and seem to indicate that water under pressure exists in at least three disconnected pervious layers, or else that a source of supply more deeply seated than has been reached by any of the drill holes yet made charges porous beds above it through fissures. The abundance of hot springs in the same vicinity apparently favors the latter hypothesis.

Little Valley.—Near the head of Little Valley, 9 miles west of Bruneau, there are five flowing wells, which range in depth from 150 to 215 feet, each drilled with a 2½-inch bit and poorly cased. The water is of good quality and has a temperature of about 67° F. The flow varies somewhat with seasonal changes, being greatest in winter and spring and least in summer and fall. In most of these wells the pipes have become clogged and the discharge is small. One of the stronger of the wells delivers in August a gallon of water in seven minutes, and is said to discharge about a gallon per minute in winter. Neighboring springs have various temperatures, ranging from 56° to 59° F.

These shallow wells, some of which began to flow when a depth of 60 to 70 feet was reached, are in a broad, deeply filled alluvial valley and evidently depend for their water supply on an alternation of pervious and impervious beds in the alluvial deposits. The source of the water for the several cold springs is no doubt the creeks which flow from the mountains to the south, but the wells must be supplied from a deeper source.

Little Valley is situated within the Lewis artesian basin and is lower than the flowing wells near Hot Spring post-office, in Bruneau Valley, but the wells referred to above do not furnish a test of what may be termed the true artesian condition. Near the wells just described, but nearer the head of Little Valley, there is a small hot spring which rises through soft, white lake beds, and which has a temperature of 101° F. Five drill holes, put down to a depth of 40 feet in the immediate vicinity of this spring, resulted in a marked increase in the outflow. The discharge is now about one-half cubic foot per second. The wells are not cased, and there is reason to believe that larger holes, with proper casing, would lead to a greater discharge.

Guffey.—In the small valley cut by Dry Creek, about 1½ miles southwest of Guffey, Owyhee County, a well drilled to a depth of 568 feet, but not completed when examined (July 12, 1902), passes through 30 feet of loose surface gravel and then about 538 feet of soft light-covered strata belonging to the Payette formation, containing three seams of hard material, and reached a hard rock, perhaps quartzite, which checked the drill. The well is 3 inches in diameter. A surface flow was obtained from a depth of 160 feet, and an additional flow at 416 feet. The discharge is nearly 1 cubic foot of water per minute; temperature 76½° F. The well is not cased below a depth of 38 feet. Elevation at surface 2,375 feet, or about 160 feet above the adjacent portion of Snake River.

In a small gulch at Guffey and about 120 feet above Snake River, a well bored with a 1½-inch hand auger to a depth of 30 feet through light-colored beds, probably shale of the Payette formation, at first discharged about 1 gallon of water per minute, but has since ceased to flow.

Central.—Near Central (Barnard Ferry), in the Snake River Canyon, and from 7 to 9 miles northwest of Guffey, four artesian wells have been drilled. All of them are situated near the bottom of the valley, and within a distance of 1½ miles of Central, toward the southeast, where the elevation is approximately 2,300 feet. The records of these wells are as follows:

On the land of Alfred Cox a 3-inch well completed in June, 1902, has a depth of about 1,033 feet. It is cased from surface to a depth of 39 feet and discharges by estimate one-half gallon of water per second; temperature 100° F. Flowing water was first reached at a depth of 600 feet, and the delivery at the surface steadily increased as long as drilling was continued. The water brings sand and gravel to the surface with it. The contract price of the well was 25 cents per foot, the owner furnishing wood and water for the engine used in drilling. The casing used was also provided by the owner of the land and cost about 50 cents per foot.

About one-half mile west of the Cox well a boring approximately 1,000 deep was put down in 1901, which failed to reach water under sufficient pressure to force it to the surface. No other record in reference to this boring has been obtained.

On the farm of P. B. Smith, adjacent to the land of Mr. Cox, and about 1¼ miles southeast of Central, an artesian well drilled in 1901 has a depth of 940 feet, is 3 inches in diameter, is cased to a depth of 30 feet, and discharges about one-third of a gallon of water per second; temperature 98° F. Water which rose to the surface was first reached at a depth of 550 feet. At 700 feet a seam of black sand, etc., was penetrated and the flow of water increased. At the bottom of the well the drill dropped about 3 feet, having reached a stratum of sand and gravel, from which the main supply of water is derived. The well discharges sand and gravel. Cost about 25 cents per foot.

On the land of Mr. Barnard, about one-half mile southeast of Central, a well drilled in 1901 has a depth of about 1,035 feet, is 3 inches in diameter, cased for a short distance at the top, and discharges, by estimate, 1 gallon of water per second, with a temperature of 106° F. At Mr. Barnard's home, in Central, a well drilled in 1901 to a depth of 720 feet, delivers about three-fourths of a gallon of water per second, not measured, with a temperature of 99 or 100° F.

The four wells near Central just referred to were all drilled in the unconsolidated lacustral deposits, mostly sandy clays and soft shales of the Payette formation. A notable fact in connection with them is that no sheets of basalt were encountered. The water from each of the wells is used for irrigation.

Enterprise.—About 3½ miles down Snake River from Central or Barnard Ferry is the post-office known as Enterprise, situated near Warm Spring Ferry. Within a radius of about 1¼ miles of Enterprise and to the southeast there are 4 artesian wells.

At the home of George Newell there are 2 flowing wells, one with a depth of 340 feet, cased with 2½-inch pipe, temperature of 87° F., and the other 385 feet deep, 6 inches in diameter; temperature 90° F. The surface elevation is about 2,300 feet. The flow of water from the larger well, particularly, is strong, but on account of leakage about the pipe could not be measured. An estimate places the combined flow from the two wells at about 1 gallon per second. The water is used for irrigation. About 1½ miles southwest of Mr. Newell's home, where the elevation is 2,500 feet, a well drilled in 1901 to a depth of 165 feet, diameter 10 inches, discharges, by estimate, about 2 gallons of water per second; temperature 87° F. The water is used for irrigation. This well was begun in igneous rock, probably rhyolite, but at a depth of a few feet entered clay, and below the clay several changes in the nature of the material occurred, but an accurate record has not been preserved. Near where the well was drilled there is a small spring of warm water. Approximately one-half mile west of Mr. Newell's ranch, on land reported to belong to Mr. Shirley, a well was drilled in 1891 to a depth of about 580 feet.

The four wells just referred to, with the exception of the 10-inch well, were drilled in the light-colored sedimentary beds of the Payette formation and, like those near Central, have surprisingly high temperatures for their depth. They are within a distance of 1½ miles of the copious hot spring at Enterprise, which has a temperature of 128° F., and, as it seems justifiable to assume, derive a part of their water at least from that or some other similar source.

Ontario.—The records of two drill holes made at Ontario, Oreg., are as follows:

A well owned by the city of Ontario, incomplete in October, 1902, has, as I am informed by Mr. A. L. Sproul, of Ontario, a depth of 1,025 feet, is 4 inches in diameter, and reached water at 195 feet, which rose to within 6 feet of the surface. The material passed through is sand and gravel to a depth of 35 feet and the remainder blue clay. The water is charged with gas, which, when properly confined, burns constantly. Cost of the well, $750.

The well just described is situated where the surface elevation is between 2,100 and 2,200 feet, or well below the artesian head of the Lewis artesian basin. The well is not cased, and the rise of the water to within 6 feet of the surface makes it probable that if proper tests of the water pressure should be made it would be found that a surface flow could be had by putting in proper casing.

The second well at Ontario, owned by A. F. Boyer, completed September, 1902, 3 inches in diameter, has a depth of 215 feet; water rose and overflowed. Gas is discharged with the water. Material passed through: Soil, 10 feet; gravel, 20 feet, and the balance shale. Cost, $100.

Vale.—A flowing well at Vale, Oreg., drilled near a hot spring to a depth of 140 feet, as already stated, discharges a strong flow of water so long as the casing is not obstructed by mineral matter deposited from it, and has a temperature of 198½° F. This well may be considered as a developed hot spring and has but little significance in reference to the artesian water supply of the basin in which it is located.

Summary.—The artesian wells near Guffey, Central, and Enterprise collectively present certain interesting facts. They are located essentially on a line extending northwest and southeast and measuring about 11½ miles. At the west end of the line is the hot spring at Enterprise. The depth of the wells and their temperatures are as follows, beginning at Guffey and approaching Enterprise:

Depth and temperature of wells at Guffey, Central, and Enterprise.

Locality.	Distance from Enterprise hot spring.	Depth.	Temperature.	Temperature gradient.
	Miles.	*Feet.*	*Degrees F.*	
Guffey	11½	538	76½	18.42
Central	5	1,033	100	19.66
Do	4½	940	98	18.54
Do	3¾	1,035	106	17.57
Do	3½	720	100	13.40
Enterprise	1	340	87	7.83
Do	1	385	90	8.37
Do	1½	165	87	3.10
Enterprise hot spring			128	

The temperature gradient, it will be remembered, is obtained by dividing the depth of a well below the stratum of no seasonal variation in temperature, assumed as 50 feet, by the number of degrees the temperature of the water discharged exceeds the temperature of the stratum of no seasonal variation, assumed to be 50° F. The temperature gradient, then, shows the depth in feet for each increase of 1 degree in temperature.

As is indicated in the above table, the temperature gradient in the region considered increases in a conspicuous manner as the distance from the Enterprise hot spring decreases. An exceptional increase, however, is seen in the case of the last well mentioned in the table, which, as noted above, is near a small tepid spring, and no doubt for this reason shows a more rapid increase of temperature with depth than any of the others. Not considering the well just referred to, the temperature gradient increases as the Enterprise hot spring is approached, but the rate of increase can not be accurately determined from the data available, since the wells are not cased and are not supplied from the same stratum.

The facts just presented seem to indicate that the porous beds in the Payette formation in the vicinity of Enterprise are supplied in part at least from the hot spring at that place. A legitimate conclusion seems to be that the rocks beneath the Payette formation are fissured and that hot water rising through the fissure has charged the porous beds above. Whether there is a deep artesian basin beneath the Payette formation or not there are no data for judging. In general, however, hot springs rise through deep fissures and are probably in most cases not an indication of the presence of a true artesian basin. As has already been stated, the Lewis artesian basin was formed by a bending of the rocks after the Payette beds were laid down, and this bending no doubt affected a great thickness of the earth's crust below the beds now forming the surface. For this reason it is possible that a true artesian basin exists, the porous beds of which are depressed in the vicinity of Snake River to a depth of 4,000 or 5,000 feet.

In addition to the supply of water reaching the Payette beds from below, the shape of the basin and the fact that the beds composing it outcrop in the hills and mountains bordering the Snake River Plains on the north and south make it evident that additional water may reach the central part of the basin by descending from the surface.

The most logical conclusion to be drawn from all the evidence presented in reference to the probability of obtaining water in the Lewis artesian basin seems to be that flowing water may be expected when a well is so drilled as to penetrate deeply or pass through the Payette formation at any locality within its borders where the surface elevation is less than 2,500 feet. As already stated, 2,500 feet is the minimum measure of the artesian head, as shown by existing wells, but the true artesian head may considerably exceed this amount.

The wells in Bruneau Valley, as shown by an unsatisfactory method, namely, aneroid barometer measurements, have an altitude of 2,700 feet; and the artesian head at Boise is about 2,850 feet. It is not safe at present, however, to accept any measurement of the artesian head in excess of 2,500 feet, and until more wells are drilled all attempts to obtain flowing water should be confined to localities below that horizon. It chances that nearly all the good land along Snake River and in the lower portions of Malheur Valley and much of that in Boise Valley are below 2,500 feet. Abundant localities for developing the Lewis artesian basin are thus available and should be tested before attempts are made to obtain artesian wells on the uplands.

The wells drilled in Snake River Valley at Central, Enterprise, Ontario, and other places passed through soft strata and did not show the presence of beds of basalt or other hard rock in the Payette formation. It is probable that only soft beds will be encountered in drilling to a depth of about 1,000 or 1,200 feet in the portion of Snake River Valley between Guffey and Weiser, but no positive assurance that such will be found to be the case can at present be given.

As may be judged from the facts above presented in reference to the occurrence of hot springs near the artesian well now flowing, the most favorable localities for drilling additional wells may be assumed to be near where warm or hot springs rise through the Payette formation. A qualification of this statement is suggested, however, by the fact that the hot spring at Vale is depositing mineral matter in the beds it passes through in rising toward the surface, and presumably in this way forms for itself a conduit which prevents its water from spreading laterally. This exceptional condition is also indicated by the exceptionally high temperature of the spring referred to. In choosing a location for a well, therefore, it would be best, at least until more facts are gathered in this connection, to avoid the proximity of a hot spring that is depositing calcareous silica, tufa, gypsum, etc. The most favorable locality, so far as I can now judge, for continuing the development of the Lewis artesian basin is in the extensive flat in the Snake River Valley to the north of Sands.

EASTWARD EXTENSION.

On a preceding page it was stated that the Lewis artesian basin begins on the east near the mouth of Kinghill Creek, that limit being chosen mainly for the reason that but little land suitable for irrigation exists in the canyon of Snake River above the locality mentioned. The upraised rim of the basin extends farther east, however, but what its limits are is as yet unknown.

In my report on the geology and water resources of the Snake River Plains [a] some facts concerning artesian wells in and about the Rock Creek Hills were presented. It now seems not improbable that these wells are in reality situated in the Lewis artesian basin, and it may perhaps be shown by future investigations that the wonderful springs in Snake River Canyon, between Bliss on the west and the neighborhood of the mouth of Salmon River on the east, may be due to the escape of artesian water from the same basin. While there are no newly acquired facts to report concerning the region just referred to, lying south of Shoshone Falls, the study of the Lewis artesian basin certainly indicates that the probability of success in case wells are drilled there is greater than seemed evident when the report on the explorations was made by me in 1901.

OTIS ARTESIAN BASIN.

Otis Valley is situated on a creek of the same name in the extreme northeast portion of Harney County, Oreg., about 6 miles northeast of Drewsey. The valley has a flat bottom, measuring by estimate 5 by 6 miles in diameter, and contains a considerable amount of good land. About 1,900 acres are now under irrigation. The valley is underlain by sedimentary beds consisting largely of white volcanic dust, presumably belonging to the Payette formation. The bordering uplands are composed in part and perhaps principally of basalt, but the sedimentary beds and layers of volcanic dust which occur beneath the valley have also been bent upward in its elevated rim. The dip of the beds about the east side of the valley is west or toward its center at a low angle, and on the south side, as is revealed in the hills at Drewsey, the dip is northward. My examination was not so complete as I desired, but I think was sufficient to show that the valley is a structural basin, on the west side of which there is perhaps a break

[a] Bull. U. S. Geol. Survey No. 199, 1902.

or fault. The structure is such as to suggest the presence of an artesian basin, and in addition copious warm springs on its eastern side show that water under pressure exists below the surface. To term the region in which Otis Valley is located an artesian basin, however, will be justified only when the presence of water under sufficient pressure to force it to the surface is demonstrated, but the conditions observed seem to warrant a careful test by drilling. The pioneer well should be put down on the east side of the valley, a short distance to the west of the warm springs referred to. The area of the land below the level of the artesian head suggested by the elevation at which the warm springs come to the surface is about 10 or 15 square miles.

HARNEY ARTESIAN BASIN.

The region embraced within what is here termed the Harney artesian basin is so great that I could not in the time available examine it with the care it deserves, but I crossed it and visited various commanding summits so as to see more or less thoroughly its entire extent. The area embraced in the outer rim of the basin includes in a general way the region drained by streams which during the rainy season flow to Malheur and Harney lakes, and includes perhaps two-thirds of Harney County, Oreg. The principal streams referred to are Silvies River, which flows southward past Burns and enters Malheur Lake from the north, and Donner and Blitzen River, which rises on Stein Mountain, flows northward, and also enters Malheur Lake. The distance between the sources of these two streams is about 135 miles in a straight line. The breadth of the outer rim of the basin in an eastwest diameter is somewhat indefinite, but measures approximately 50 miles.

The outer rim of the Harney artesian basin is sharply limited on the southeast from near Andrews northeast to beyond Juniper Lake, a distance of 50 or 60 miles, by the east base of Stein Mountain. Its eastern border is in the Crow Creek Hills, and from these it passes northward and curves about the head branches of Silvies River, and then, bending southward, passes to the west of Silver Lake, Iron Mountain, and south of Harney Lake to the source of Donner and Blitzen River. The border is well defined, except in the broad region, with comparatively mild relief to the southwest of Silver and Harney lakes, where the strata are in general nearly flat. The basin is not a single saucer-shaped depression, but consists of at least two troughs or synclines, one in the region drained by Silvies River and the other on the west side of Stein Mountain and drained by Donner and Blitzen River. There are, besides, other folds and irregularities which it is not necessary to describe at this time.

The statements just given indicate that the Harney artesian basin has a structure such as is favorable for the accumulation of water in any porous beds which may be present, but before it is decisively pronounced an artesian basin other evidence should be obtained.

SPRINGS.

There are several warm and hot springs in the broad, generally flat region about Malheur and Harney lakes, but only a few of these were visited by the writer.

Burns.—On the border of Harney Valley, beginning about 3 miles southwest of Burns, a number of springs come to the surface at the base of a cliff of basaltic agglomerate. These have a temperature of from 75° to 80° F. The surface elevation is about 4,100 feet by aneroid, or the same as the general level of the broad, flat lands flooring the valley to the south of Harney and Burns. These springs are of considerable volume, and, as I have been informed, flow throughout the year without sensible variations either in volume or temperature. The water is drunk by stock, but is not used for irrigation except so far as the raising of wild hay is concerned.

Little Sage Hen Valley.—A number of springs come to the surface in the flat, alluvial lands forming the bottom of Little Sage Hen Valley, and, spreading over the land, serve to irrigate extensive natural meadows. Their temperature is in general 63° to 64° F.

Silver Lake.—On the west side of Silver Lake, and along Silver Creek, between it and Harney Lake, there are several warm and hot springs, flowing only during the rainy season, the waters of which serve to naturally irrigate the adjacent lands. The valley of Silver Creek is a broad, flat, swampy meadow, on which great quantities of wild hay are cut every year.

Harney Lake.—To the southeast of Harney Lake and about one-half mile from its shore, there is a spring of clear, tasteless water, with a temperature of from 145° to 150° F. The volume is by estimate about 6 gallons per second. An attempt to utilize the water for irrigation has been abandoned. The spring is situated near the south base of a bold hill, composed mainly of sandstone, and rises through soft, usually white, lacustral sediments resembling the Payette formation.

Malheur Lake.—In the bed of Malheur Lake, near its southern end, and exposed in summer when the lake is low, there are small springs with a temperature of 64° F. Copious hot springs occur near the eastern end of the lake and at a distance of 4 or 5 miles from the bold bordering uplands of the valley, but these were not visited by me.

Summary.—All of the springs enumerated above present the usual characteristics of warm and hot springs, and furnish evidence that water under pressure exists below the surface. They are widely separated, and in all instances except, perhaps, at the locality near Burns, rise through the soft beds which floor the Harney basin. Their high temperature in several instances indicates that the water rises from a considerable depth, but not from a depth greater than that to which the beds in the basal portion of the basin are depressed. In this connection I may state that the lacustral sediments exposed beneath 4,500 feet of basalt on the west side of Stein Mountain dip westward at an angle of 3° or 4°, their inclination gradually decreasing, however, with distance from the outcrop, and it is reasonable to assume that they pass under Harney Valley at a depth of certainly 6,000, and probably of 10,000 or more feet. Similar evidence of the great thickness of the strata which are deformed so as to make the Harney artesian basin is furnished in the portion of its upraised rim that forms the mountains to the west of Harney and Burns. Porous beds at any such depth as that just considered, however, are, for practical purposes, beyond the reach of the drill; but as the heated water, in several instances, rises to the surface through the strata forming the upper portion of the great series of rocks involved in the deformation of the basin, and through sedimentary deposits of later date now forming the floor of Harney Valley, there are reasons for believing that the porous beds near the surface have been charged in part with water from below and furnish artesian conditions.

DRILLED WELLS.

In addition to the testimony furnished by the geological structure and by springs, certain borings made near Harney and Burns favor the hope that flowing water can be had at a moderate depth in Harney Valley.

Harney.—About 5 miles east of Harney, on land belonging to Fred Haines, sec. 2, T. 23 S., R. 32½ E., a well 3 inches in diameter, drilled in 1896 to a depth of 507 feet, struck water at a depth of between 200 and 300 feet, which rose to the surface. The well is not cased, and the water now stands 6 feet below the surface and has a temperature of 49° F. The material passed through was soft to a depth of 100 feet, and below that depth consisted of black lava, clay, etc., but no definite record is available. This well at first yielded a true artesian flow, but, as nearly as can be judged, has caved in, owing to lack of casing, and the water supply at present is from percolation through porous beds near the surface. The temperature of the water now being pumped indicates that it comes from about 50 feet below the surface and has its ultimate source in the neighboring hills. The cost of drilling the well was $1 per foot.

Burns.—A well drilled at the expense of Harney County in 1893, at a locality about 6 miles southeast of Burns, in sec. 13, T. 23 S., R. 31 E., was continued to a depth of 848 feet. The well at the top has a diameter of 6 inches, but narrows near the bottom to 4 inches. At the depth of 350 feet water was reached which rose and overflowed at the surface, but after an attempt to improve the well, made in the spring of 1902, it ceased to flow. The water in August, 1902, stood 3 feet below the surface and had a temperature of 49° F. The first 100 feet of material passed through was sand, gravel, and soft rock, and at a greater depth hard rock was penetrated, but no record as to its nature, etc., is available. Two water-bearing strata are said to have been reached, one at 350 feet from the top, and the other at the horizon, where drilling was discontinued, namely, 840 feet. The outflow from the first water-bearing layer is said to have been small. The well is cased with iron tubing, 6 inches in diameter, to a depth, as reported, of 450 feet. The cost to Harney County was $2,400, not including the casing. The drilling was done by George W. Kellogg, of Salt Lake City, Utah. Work is said to have been abandoned on account of the loss of drilling tools in the well.

A well drilled on land belonging to Thomas McCormick, about 5 miles southeast of Burns, in sec. 12, T. 31 S., R. 24 E., completed in 1900, 6 inches in diameter, has a total depth of 68 feet. The water now rises to within 16 feet of the surface and yielded 100 gallons per hour by pumping. The material passed through was soft, and water is reported to have been reached in blue clay. The cost of drilling the well was $85 and of the casing $21.

Summary.—The evidence furnished by the drill holes in Harney Valley is meager, but so far as it goes it favors the hope that artesian water can be had throughout an extensive territory.

The well near Harney and the county well near Burns furnished flowing water and, I feel justified in affirming, would have continued to flow and to furnish a valuable water supply in each case had they been properly cased and cared for.

The well on Mr. McCormick's land is too shallow to be of significance in judging of the artesian conditions at the locality where it is situated.

Nearly all the evidence I have been able to gather in reference to the geological structure, the warm and hot springs, and the results of drilling certainly favor the conclusion that beneath the extensive plain east of Harney and Burns, on which Malheur and Harney lakes are situated, there is an artesian basin.

Conditions which may exert an adverse influence upon the value of the basin, so far as flowing wells are concerned, are the low pass on the northeast of Malheur Lake, through which the water of that lake formerly escaped, and the somewhat indefinite character of the rim of the basin to the south of Silver Lake. In addition are the "accidents" that may be present in any artesian basin, such as changes in the texture of the beds, the occurrence of breaks across the strata, and the presence of dikes.

In reference to the low pass which extends in an easterly direction from the flat country east of Malheur Lake through the hills to Camp Creek, it is evidently the lowest place in the rim of the Harney artesian basin and may perhaps determine the artesian head within the basin, but there are reasons for delaying a conclusion in this connection. The channel referred to is strongly defined and has a broad, level floor, formed by a recent basaltic lava flow. The bottom of the previously cut river channel is thus concealed and is at least 20 to 30, and perhaps more, feet below the present surface. The highest point in the pass or old river bed (as shown, I have been informed, by surveys made with the view of drawing off the waters of Malheur Lake for irrigation purposes in Malheur Valley) is but 20 feet above the level of Malheur Lake. Evidently, then, the buried stream channel beneath the lava is lower than the broad valley lands about Malheur and Harney lakes and cuts across any porous bed that occupies the entire extent of the basin. If water-charged porous beds were cut by the channel, springs would be expected to occur in it. No springs are present, however, and it is possible that the silting over of the porous beds and the burial of the silt beneath lava has sealed them, so as to prevent the escape of water from them. While this is not such an indefinite hypothesis as it may at first seem, it does not remove all anxiety in reference to the influence of the old river channel referred to on the artesian conditions in Harney Valley. The question here raised can not be answered by the facts now known; neither can a positive opinion be expressed in reference to the position of the rocks to the southwest of Silver Lake, but my judgment is that neither of these possibly adverse conditions is of sufficient weight to discourage the drilling of test wells in Harney Valley.

From the elevations of the several localities at which warm and hot springs issue and of the surface of the two wells referred to above, the artesian head may be assumed to be at such an elevation that wells below the level of Harney or Burns would furnish a surface flow of water. The area of the basin below the horizon stated can not be accurately told at present, but embraces practically all the level land in Harney Valley about Malheur and Harney lakes and probably also the flat lands in the valley of Silver Creek and about Silver Lake. Extensive tracts of rich land in the region drained by Donner and Blitzen River are also within the area in which artesian water may reasonably be expected if drill holes properly cased are put down. A rough estimate based on the general map of Oregon, issued by the United States Land Office, indicates that the area within which artesian water may be expected is in the neighborhood of 1,000 square miles, but this includes Malheur and Harney lakes and the swamps bordering them.

To test the artesian conditions in the Harney basin, wells may be put down at any locality below the level of Burns or Harney. Perhaps the most favorable situations are near the warm and hot springs referred to, and at such places wells should be drilled on the side of the spring chosen, which is in the direction of the center of the basin or, in general, toward Malheur or Harney Lake. The depth to which wells should be drilled must be determined by experiment, as sufficient information is not in hand in reference to the sections exposed in the rim of the basin to warrant a judgment in this connection.

The successful well near Harney and Burns, however, suggests that favorable results may be expected anywhere in the basin below their surface elevation, at a depth of less than a thousand feet and possibly at a depth of only a few hundred feet. The possibilities of the basin, however, will not be exhausted when the drill has reached a depth of even 1,000 feet or, indeed, at a depth of 5 or 10 times that measure.

In the development of the basin an effort should be made to discover all of the water-bearing beds that are present within a reasonable distance below the surface, and in case several wells are drilled near each other, they should, so far as practicable, derive their water supply from different strata.

WHITEHORSE ARTESIAN BASIN.

Stein Mountain, as already stated, is the western slope of a great anticline. The central part of the upward fold referred to has been deeply eroded, and where faults occur, a subsidence has taken place. The position of the central and now deeply eroded portion of this great fold is occupied by Alvord Desert and the sharp-crested ridges running northeast from it. To the east of the Stein Mountain anticline or upward fold there is a flat-bottomed syncline or downward fold, in which Whitehorse Valley is situated. The rocks beneath this valley are bent into basin shape and the rim of the basin is high on all sides except the one adjacent to Alvord Valley. The rocks which have been bent so as to form a basin consist of reddish and brownish rhyolitic tuff in which angular fragments are conspicuous, black basalt, and light-colored and usually nearly white lacustral sediments and sheets of volcanic dust, resembling those characteristic of the Payette formation. The thickness of the beds exposed in the upraised rim of the basin—as, for example, in the mountains between Whitehorse Valley and Oregon Canyon, the next valley to the east—is several thousand feet. The bold bluffs on the west side of Oregon Canyon (which in the part here referred to is a broad valley with several ranches in its bottom) are formed of the edges of the sheets of rock, mostly basalt, which dip west and pass under Whitehorse Valley. Several springs issuing from the bluffs, well above their base, indicate that certain of the beds are water charged. These springs may reasonably be supposed to be the leakage from the basin to the west and suggest an abundant store of water beneath Whitehorse Valley.

In the southern part of Whitehorse Valley, about 6 miles south of the site of the former military post and at an elevation of fully 150 feet above the general level of the floor of the valley, there are springs with a temperature of about 100° F., which rise through soft white lake beds. In the northern part of the valley, about 10 miles north of the site of the former military post, as I have been informed, there is another warm or hot spring.

The facts stated above are such as to warrant a careful test of the artesian conditions in Whitehorse Valley. A boring should be made near the warm springs in the south end of the basin, a few rods north of the localities where their water now reaches the surface. A boring at Whitehorse ranch (the former military post) would probably yield flowing water, but the chances are nearly equally favorable all along the eastern side of the flat lands, which extend northward from the ranch for 10 or more miles. The area of good land within Whitehorse Valley, where it is reasonable to expect that flowing water can be obtained, is by a rough estimate not less than 30 square miles.

In the structure of the Whitehorse artesian basin there is one condition which may be detrimental to the occurrence of water in it under pressure, namely, the lowness of the rim of the basin on the west side in the vicinity of Sand Gap. The eroded borders of the beds emerging from beneath Whitehorse Valley there form a line of westward-facing bluffs, which define the east border of Alvord Desert. For the reason that there are no springs along the base of these bluffs, however, and for other reasons, the lowness of the rim of the basin need not be considered sufficiently important to deter the testing of the artesian conditions within it.

ARTESIAN WELLS IN ALLUVIAL DEPOSITS.

In regions like southern Idaho and eastern Oregon, which have an arid climate, and where bold mountains are bordered by wide valleys, the streams from the uplands deposit much and in many instances all of the sand, gravel, etc., which they bring down from the high-grade upper portions of their courses on the border of the valley which they enter. In this way alluvial cones or fans are built about the mouth of gorges where they open out onto a plain. These alluvial cones are not infrequently several miles in radius at the base and several hundred or perhaps 2,000 or 3,000 feet high. The apex of each cone is at the mouth of or some distance within the gorge from which the débris of which it is composed was derived, and from which a stream usually flows, at least during a part of each year. These beds of débris are thus in a position to become water charged, and their structure is such that pervious beds may be confined between impervious beds. Large alluvial cones may thus furnish conditions for the storage of water under pressure, and especially on the outer portion may yield flowing water if drill holes are put down.

Alluvial cones are sometimes greatly extended and have low surface slope, and in fact merge by insensible gradations into the flood plains of streams. This is frequently the case in arid regions, where the valleys are in many instances deeply filled with alluvium. Valleys when thus partially filled have broad, flat bottoms, with a perceptible gradient or surface slope down their courses. In such instances the surface material is usually fine, but becomes coarse at a depth of a few feet or a few score feet below the surface, and as the beds are gently inclined the coarse beds at a depth may be charged with water under pressure. If flowing water is obtained by drilling in alluvial cones or flood-plain deposits it is normally cold, for the reason that it has not descended into the earth far enough to be influenced by the interior temperature of the earth. The water is similar to that supplied by hillside springs, and in Idaho and Oregon would have a temperature of about 50° F.

There are a few localities in the region examined by me in Idaho and Oregon where the conditions warrant the drilling of shallow wells in alluvial cones on flood plains. Some of these located in Idaho are mentioned in Bulletin 199, already referred to. In Oregon tests of the nature referred to should be made in Willow Creek Valley, to the northwest of Vale, and in neighboring flat-bottomed valleys which have a perceptible downstream slope.

The alluvial cones on the east side of Stein Mountain, at the mouths of gulches down which streams flow, should also be tested with the drill. The most promising localities for such tests are from the outer margin of a cone to midway up its slope. When the cones are steep, however, the chance of water being stored in them under pressure decreases rapidly as their summit portions are approached. The test referred to should be carried down to at least the level of the flat lands in the adjacent valley unless favorable results are sooner reached.

SIZE OF DRILL HOLES, THE CASING OF WELLS, ETC.

In the development of the artesian conditions of the Lewis artesian basin, as experience has already shown, light, portable drilling rigs will probably be all that are required, since the beds to be penetrated are soft. In the other artesian basins named, however, it seems highly desirable that only the most efficient of drilling machinery should be employed, as hard rocks will have to be penetrated in probably all wells that are more than a very few hundred feet deep. An extensive experience in drilling wells in the oil fields of the United States has shown that the best outfit for use in the artesian basins of Oregon is the square derrick walking-beam rig, provided with the best tools that can be procured. It is perhaps needless to add that only well drillers of wide experience and known integrity should be employed.

The wells to be put down should, in my opinion, be 8 inches in diameter, or drills of this size should be use to as great a depth as possible before tapering the hole to any smaller size.

In all instances the wells drilled should be well cased with iron casing. Neglect in this particular has led to failures in many instances in both Idaho and Oregon where success, as there are reasons for believing, would have been attained if proper casing had been put in. For the sake of emphasizing the statement just made, it may be truthfully said that water should not be expected to rise in a hole drilled through rocks of various descriptions, many of them, as is usually the case, being porous, any more than it should be expected to remain in a standpipe full of holes rising above the surface of the ground. The water in an artesian well is under pressure—frequently great pressure—and tends to flow laterally wherever the rocks are porous or fissured. More than this, the walls of an uncased well are apt to cave and thus render useless all the work that has been expended on it.

In drilling a well the pressure of the water at each horizon where it is encountered should be carefully tested. One way of doing this is to lower a tube into the well, such, for example, as a three-fourths-inch iron pipe, with a leather bag filled with flaxseed encircling it near the lower end. The pipe should be lowered until its end is just above the place where water was struck. In such an experiment the flaxseed will swell and expand the bag containing it so as to shut off the escape of water about the outside of the pipe and allow it to rise within it. If the water overflows at the surface of the ground it demonstrates, of course, that an artesian flow has been secured, and if the pipe is continued upward the height to which the water rises within it will show the artesian head. Other suggestions in this connection may be found in a paper by Chamberlin, and in a report on Nez Perce County, No. 3 and No. 21, respectively, of the list at the end of this report.

Wells should be located as far apart as practicable, and when two or more water-bearing beds are present neighboring wells should have different depths, so as to draw their water supply from different sources. The distribution of wells in reference to the direction of flow of the underground water is also important. Obviously, if there is to be a series of wells, more or less in line, their alignment should be at right angles to the direction of underground flow, so as to decrease to a minimum the influence that one well exerts on its neighbor. Information in this connection is contained in the paper by Chamberlin, No. 3 of the list at the end of this report.

PRESERVATION OF WELL RECORDS.

If wells are drilled in the artesian basins described in this report a careful record of all facts concerning them should be preserved. This is a matter of great inportance to all the people interested in the development of the artesian basins, and may lead to a great saving of money in other directions. As a practical method of obtaining and preserving information referred to, I wish to suggest that it be made the official duty of the county clerk in every county where drill holes are put down for any purpose to obtain and preserve a record of the facts relating to them. To assist in doing this a schedule is here inserted which can be printed, and which, after being filled in with the data required, should be filed at the county clerk's office for future reference. The schedule referred to is as follows (for greater convenience each item should be given a separate line):

WELL RECORD.

County, ———; State, ———.
County clerk, ——— ———. No. ——. Date, ——— —, 190–.

Owner of well, ——— ———. Driller of well, ——— ———. Post-office address, ——— ———. Location of well: Township ——, range ——, sec. ——. When completed, ——— ——. How put down: Dug, driven, bored, drilled, ———. Size or diameter, ———. Depth: Total, —— feet; to water, —— feet; depth of water, —— feet. Did water rise when struck? ———. Dces water flow over surface? ———. Height to which the water will rise in an open tube, ———. Has the flow diminished or increased? ———. Quality of water: Hard, soft, salty, alkaline, ———. Temperature of the water, ———. How is water raised? ———. Cost of well, $——. Cost of mill and pump, $——. Is the well cased? ———. Cost of casing, ——. Amount pumped or flow per hour or day, ———. Water used for ———. Elevation of surface, —— feet.

Strata passed through and remarks: ——— ———.

LAWS.

As the water supply in an artesian basin may become of importance to a large number of citizens, it is obvious that laws governing its use are as necessary as the laws relating to surface waters, but, so far as I am aware, only one attempt to place legal restrictions on the utilization, or rather on the waste, of subsurface waters has been made in this country,[a] and that act fails in two particulars to meet the requirements outlined above—the proper casing of wells is not made obligatory, and the filling of abandoned wells is not provided for. Each of these regulations is highly important.

The principal restrictions and conditions which it is desirable should be established and enforced by law are as follows:

1. *Every drill hole in an artesian basin should be properly cased.*—By this is meant that an iron casing or tube lining the hole and made sufficiently tight to prevent water from rising outside of it should be put in every well which remains open. The lower end of the casing should be just above the water-bearing stratum.

---

[a] The following law providing for the conservation of artesian water has been passed by the legislature of the State of Washington:

CHAPTER CXXI.

(H. B. No. 203.)

RELATING TO ARTESIAN WELLS.

AN ACT in relation to artesian wells and regulating the flow of water therefrom, and providing a penalty for the violation thereof.

Be it enacted by the legislature of the State of Washington:

SECTION 1. It shall be unlawful for any person, firm, corporation, or company having possession or control of any artesian wells within the State, whether as contractor, owner, lessee, agent, or manager, to allow or permit water to flow or escape from such well between the first day of October in any year and the first day of April next ensuing: *Provided*, That this act shall only apply to sections and communities wherein the use of water for the purpose of irrigation is necessary or customary, and providing further, that nothing herein contained shall prevent or prohibit the use of water from any such well between said first day of October and the first day of April next ensuing for household, stock, and domestic purposes only, water for said last-named purposes to be taken from such wells through a one-half inch stop and waste cock to be inserted in the piping of such well for that purpose.

SEC. 2. It shall be the duty of every person, firm, corporation, or company having possession

The reason why the owner of a well should be required by law to properly case it, as already explained in reference to the personal interest of the owner himself, is that lateral escape of the water may be prevented. The escape of water from an artesian basin in excess of the natural overflow means a decrease in pressure on the portions remaining, and consequently a lowering of the artesian head. In arid regions especially the sources of supply of an artesian basin may be small, and the question of economically using the water it contains and of maintaining the artesian head are matters of public concern.

2. *Every artesian well when not in use should be securely closed.*—The reason why a law to this effect should be enacted and enforced is that an artesian basin is not an inexhaustible reservoir, and every practicable means should be employed for its conservation and legitimate use. The closing of an artesian well when its water is not being used would in many and perhaps most instances be an advantage to its owner as well as to his neighbors, not only for the reason that his water supply would be made more permanent, but because water flowing over land in excess of the amount required for scientific irrigation is injurious.

There are exceptional cases in which it is not desirable that an artesian well should be closed at any time, as, for example, when a well is no more than a developed spring, or derives its water from what is known as an artesian slope,[a] but as such wells will probably be few in number in the artesian basins described in this report, special legislation in reference to them is perhaps not desirable.

---

or control of any artesian well, as provided in section 1 of this act, to securely cap the same over on or before the first day of October in each and every year in such manner as to prevent the flow or escape of water therefrom, and to keep the same securely capped and prevent the flow or escape of water therefrom until the first day of April next ensuing: *Provided, however*, It shall and may be lawful for any such person, firm, corporation, or company to insert a one-half inch stop and waste cock in the piping of such well, and to take and use water therefrom through such stop and waste cock at any time for household, stock, or domestic purposes, but not otherwise.

SEC. 3. Any person, whether as owner, lessee, agent, or manager, having possession or control of any such well, violating the provisions of this act shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be fined in any sum not exceeding two hundred dollars for each and every such offense, and the further sum of two hundred dollars for each ten days during which such violation shall continue.

SEC. 4. Whenever any person, firm, corporation, or company in possession or control of an artesian well shall fail to comply with the provisions of this act, any person, firm, corporation, or company lawfully in the possession of land situate adjacent to or in the vicinity or neighborhood of such well and within five miles thereof may enter upon the land upon which such well is situate, and take possession of such well from which water is allowed to flow or escape in violation of the provisions of section 1 of this act, and cap such well and shut in and secure the flow or escape of water therefrom, and the necessary expenses incurred in so doing shall constitute a lien upon said well, and a sufficient quantity of land surrounding the same for the convenient use and operation thereof, which lien may be foreclosed in a civil action in any court of competent jurisdiction, and the court in any such case shall allow the plaintiff a reasonable attorney's fee to be taxed as a part of the cost. This shall be in addition to the penalty provided for in section 3 of this act.

Passed the house March 7, 1901.

Passed the senate March 14, 1901.

Approved by the governor March 16, 1901.

[a] The nature of an artesian slope is explained in the report numbered 21 in the list at the end of this paper, page 112.

3. *Every abandoned drill hole in an artesian basin should be completely filled with impervious material.*—A desirable way in which to do this is to fill the hole slowly with moist clay and ram it down with a heavy, blunt tool, or fill the hole with Portland cement concrete. Tightly fitting rods of dry wood driven into a drill hole until it is filled would serve the same purpose.

Abandoned wells should be filled in the manner suggested in order that leakage may be prevented. Wells in which water rises some distance toward the surface but does not overflow are frequently abandoned, the casing, if any was used, having first been drawn, and in such instances a continuous escape of water occurs into cracks, porous beds, etc., about the hole.

The three rules briefly stated above should be embodied in the laws of every State in which artesian basins occur and their observance should be rigorously enforced.

For the proper development of an artesian basin it is evident that there should be but one center of responsibility. A desirable method of securing this end would be to place the entire control of the artesian wells in each State in the hands of a State engineer, whose duty it should be to determine where wells may be drilled, the depth to which they may be carried, and methods for caring for the water supply, closing abandoned drill holes, etc.

While the aim of this preliminary report is to stimulate and direct the search for artesian water in the region that has been considered, I do not wish to be understood as saying that all of the 2,000 or more square miles of rich lands contained in the four basins described can be irrigated by means of artesian water. The facts are plainly such as to warrant the careful testing of the artesian possibilities, but owing to local conditions, which are at present unknown, many difficulties will no doubt be encountered and numerous failures may occur, and even when all the wells which the water supply will justify have been put down in any one of the basins referred to there will no doubt remain extensive areas that can not be irrigated. While good results may reasonably be expected from the judicious development of the artesian basins, all the benefits that might be derived in that way will be rendered negative unless the suggestions given above in reference to the conservation of the water supply are strictly observed. I may perhaps add as a warning that the wanton destruction of the forests in this country and the now almost complete ruin of the public grazing lands throughout the arid regions leave but little hope that man's greed will be so far restricted in the case of artesian basins that ultimate failures will be avoided.

LITERATURE.

The following-named books and papers contain information in reference to artesian wells which should be of much assistance to persons desiring to develop artesian basins:

1. BARBOUR, E. H. Wells and windmills in Nebraska: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 29.
2. CARLL, J. F. Report on the oil regions of Pennsylvania: Second Geological Survey of Pennsylvania, Vol. III, 1880.
   This report contains a detailed account of the methods used in drilling wells.
3. CHAMBERLIN, T. C. The requisite and qualifying conditions of artesian wells: Fifth Ann. Rept. U. S. Geol. Survey, pp. 125–173.
   This paper contains a clear and comprehensive explanation of the geologic conditions pertaining to artesian wells.
4. DARTON, N. H. Artesian-well prospects in the Atlantic Coastal Plain region: Bull. U. S. Geol. Survey No. 138.
5. —— New developments in well boring and irrigation in eastern South Dakota: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. IV, pp. 561–616.
6. —— Preliminary report on artesian waters of a portion of the Dakotas: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 603–694.
7. —— Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. IV, pp. 719–785.
8. —— Underground waters of southeastern Nebraska: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 12.
9. GILBERT, G. K. The underground water of the Arkansas Valley in eastern Colorado: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 551–601.
10. HAY, ROBERT. Water resources of a portion of the Great Plains: Sixteenth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 535–588.
11. HILL, R. T., and VAUGHAN, T. W. Geology of portions of the Edwards Plateau and Rio Grande Plain adjacent to San Antonio, Tex., with special reference to the occurrence of artesian and other underground waters: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 193–322.
12. LANE, A. C. Water resources of the Lower Peninsula of Michigan: Water Supply and Irrigation Paper U. S. Geol. Survey No. 30.
13. LEVERETT, FRANK. The water resources of Illinois: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 695–849.
14. —— Well waters of Ohio and Indiana: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. IV, pp. 419–560.
15. —— Wells of northern Indiana: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 21.
16. —— Wells of southern Indiana: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 26.
17. ORTON, EDWARD. The rock waters of Ohio: Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. IV, pp. 633–717.
18. —— The Trenton limestone as a source of petroleum and inflammable gas in Ohio and Indiana: Eighth Ann. Rept. U. S. Geol. Survey, Pt. I, pp. 475–662.
19. PECKHAM, S. F. Report on the production, technology, and uses of petroleum and its products: Tenth Census of the United States, Vol. X, Washington, 1888.
    The methods of drilling wells, together with detailed plans and descriptions of machinery, derricks, tools, torpedoes, etc., are given on pages 77 to 85.

20. PHINNEY, A. J. The natural-gas field of Indiana: Eleventh Ann. Rept. U. S. Geol. Survey, Pt. I, pp. 579–742.
21. RUSSELL, I. C. Geology and water resources of Nez Perce County, Idaho: Water-Supply and Irrigation Paper U. S. Geol. Survey Nos. 53 and 54.
22. —— Geology and water resources of the Snake River Plains of Idaho: Bull. U. S. Geol. Survey No. 199.
23. —— A geological reconnaissance in central Washington: Bull. U. S. Geol. Survey No. 108.
24. SMITH, G. O. Geology and water resources of a portion of Yakima County, Wash.: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 55.
25. TODD, JAMES EDWARD. Geology and water resources of a portion of southeastern South Dakota: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 34.
26. VAUGHAN, T. W., and HILL, R. T. (See Hill.)

INDEX.

Page.

Alluvial deposits, artesian wells in 44–45
Anticline, example of 23
Artesian basin, conditions necessary for 10–14
  cross sections of typical 13
Artesian basins, description of 24–44
Artesian head, conditions controlling and manner of determining 12
Artesian water, source of 13
  surface indications of 14–15
Artesian well, definition of 10
Bernard Ferry, Idaho, wells near 32–33
Basalt, occurrence and character of 19
Beulah, Oreg., springs near 29
Boise, Idaho, springs near 27
  wells near 29–30
Bruneau Valley, Idaho, springs in 27
  wells in 30–31
Bully Creek, Oreg., spring near 29
Burns, Oreg., springs near 39
  wells near 40–42
Casing of wells, necessity of 45–46, 47–48
Central, Idaho, wells near 32–33
  temperature and depth of 35
Conglomerate, extent of 16
Davis ranch, Idaho, well on 29
Dikes, occurrence of 21
Drill holes, size of 45
  abandoned, necessity for filling 49
Drilled wells, in Harney artesian basin 40–43
  in Lewis artesian basin 29–37
Earth, temperature of, increase of, with depth 14
Enterprise, Idaho, spring near 27
  wells near 33–34
    temperature and depth of 35
Faults, description of 23
Flow in artesian basin, conditions of 10–14
Folds, descriptions of 22–23
Fossils, occurrence of 17
Guffey, Idaho, wells near 32
    temperature and depth of 35
Harney, Oreg., wells near 40
Harney artesian basin, description of 38–43
  springs in 39–40
  wells in 40–43
Harney Lake, Oregon, springs near 39
Height of water in an artesian well, conditions controlling 12
Hot Spring, Idaho, springs near 27
Hulls Gulch, Idaho, wells in 29
Igneous rocks, description of 18–21
Laws for conservation of artesian water, discussion of 47–49
Lewis artesian basin, description of 24–37
  drilled wells in 29–37
  eastward extension of 37
  springs in 26–29
  cited on wells near Boise 29
Lindgren, W., cited on Payette formation 17

Page.

Literature, list of 50–51
Little Sage Hen Valley, Oregon, springs in 39
Little Valley, Idaho, springs in 27
  wells in 31–32
Malheur Lake, Oregon, springs near 39
Malheur River, springs near 28
Mountain Home, Idaho, springs near 26–27
Newell, F. H., letter of transmittal by 7
Ontario, Oreg., wells near 34
Otis artesian basin, description of 37–38
Owyhee Canyon, Oregon, spring near 28
Payette formation, extent and character of 17
Pence, A. H., well of 31
Plutonic rocks, occurrence and character of 21
Poison Creek, Idaho, springs near 27–28
Pressure of water, conditions controlling and manner of determining 12
Rattlesnake Creek, Idaho, springs near 26–27
Rhyolite, occurrence and character of 20
Roberson's ranch, Idaho, well at 30–31
Rocks of region, classification and description of 16–21
Salmon River, Idaho, springs near 27
Sands, Idaho, springs near 27–28
Sandstones, extent of 16
Sedimentary rocks, description of 16–18
Silver Lake, Oregon, springs near 39
Springs, Harney artesian basin 39–40
  Lewis artesian basin 26–29
  warm, artesian conditions indicated by 14–15
Stein Mountain, Oregon, anticlines and synclines near 23
  dikes on 21
Structure, description of 22–24
Syncline, example of 23
Temperature of the earth, increase of, with depth 14
Vale, Oreg., springs near 28
  wells near 34
Volcanic dust, occurrence of 17
Volcanic rocks, description of 18–21
Walters Butte, Idaho, springs near 27
Warm springs, artesian conditions indicated by 14–15
Water, artesian, height of, conditions controlling 12
  source of 13
  surface indications of 14–15
Well, artesian, definition of 10
Wells, artesian, closing of, necessity for 48
Wells, drilled, in Harney artesian basin 40–44
  in Lewis artesian basin 29–37
Well records, preservation of 46–47
Westfall, Oreg., springs near 28–29
Whitehorse artesian basin, description of 43–44
Whitson's ranch, Idaho, well at 31

O

LIBRARY CATALOGUE SLIPS.

[Take this leaf out and paste the separated titles upon three of your catalogue cards. The first and second titles need no addition; over the third write that subject under which you would place the book in your library.]

Series.

United States. *Department of the interior.* (*U. S. geological survey.*)

Water-Supply and Irrigation Paper No. 78 Series B, Descriptive geology, 29 Series O, Underground waters, 20 | Department of the interior | United States geological survey | Charles D. Walcott, director | — | Preliminary report | on | artesian basins | in | southwestern Idaho and southeastern Oregon | by | Israel C. Russell | [Vignette] |

Washington | government printing office | 1903

8°. 53 pp., 2 pls.

Author.

Russell (Israel C.).

Water-Supply and Irrigation Paper No. 78 Series B, Descriptive geology, 29 Series O, Underground waters, 20 | Department of the interior | United States geological survey | Charles D. Walcott, director | — | Preliminary report | on | artesian basins | in | southwestern Idaho and southeastern Oregon | by | Israel C. Russell | [Vignette] |

Washington | government printing office | 1903

8°. 53 pp., 2 pls.

Subject.

Water-Supply and Irrigation Paper No. 78 Series B, Descriptive geology, 29 Series O, Underground waters, 20 | Department of the interior | United States geological survey | Charles D. Walcott, director | — | Preliminary report | on | artesian basins | in | southwestern Idaho and southeastern Oregon | by | Israel C. Russell | [Vignette] |

Washington | government printing office | 1903

8°. 53 pp., 2 pls.

Series L—Quality of Water.

WS 3. Sewage irrigation, by George W. Rafter. 1897. 100 pp., 4 pls.
WS 22. Sewage irrigation, Part II, by George W. Rafter. 1899. 100 pp., 7 pls.
WS 72. Sewage pollution near New York City, by M. O. Leighton. 1902. 75 pp., 8 pls.
WS 76. Observations on the flow of rivers in the vicinity of New York City, by H. A. Pressey. 1902. 108 pp., 13 pls.

Series M—General Hydrographic Investigations.

WS 56. Methods of stream measurement. 1901. 51 pp., 12 pls.
WS 64. Accuracy of stream measurements, by E. C. Murphy. 1902. 99 pp., 4 pls.
WS 76. Observations on the flow of rivers in the vicinity of New York City, by H. A. Pressey. 1902. 108 pp., 13 pls.

Series N—Water Power.

WS 24. Water resources of the State of New York, Part I, by G. W. Rafter. 1899. 92 pp., 13 pls.
WS 25. Water resources of the State of New York, Part II, by G. W. Rafter. 100-200 pp., 12 pls.
WS 44. Profiles of rivers, by Henry Gannett. 1901. 100 pp., 11 pls.
WS 62. Hydrography of the Southern Appalachian Mountain region, Part I, by H. A. Pressey. 1902. 95 pp., 25 pls.
WS 63. Hydrography of the Southern Appalachian Mountain region, Part II, by H. A. Pressey. 1902. 96-190 pp., 26-44 pls.
WS 69. Water powers of the State of Maine, by H. A. Pressey. 1902. 124 pp., 14 pls.

Series O—Underground Waters.

[See last page of this cover.]

Series P—Hydrographic Progress Reports.

WS 11. River heights for 1896, by A. P. Davis. 1897. 100 pp.
WS 15. Operations at river stations, 1897, Part I. 1898. 100 pp.
WS 16. Operations at river stations, 1897, Part II. 1898. 101-200 pp.
WS 27. Operations at river stations, 1898, Part I. 1899. 100 pp.
WS 28. Operations at river stations, 1898, Part II. 1899. 101-200 pp.
WS 35. Operations at river stations, 1899, Part I. 1900. 100 pp.
WS 36. Operations at river stations, 1899, Part II. 1900. 101-198 pp.
WS 37. Operations at river stations, 1899, Part III. 1900. 199-298 pp.
WS 38. Operations at river stations, 1899, Part IV. 1900. 299-396 pp.
WS 39. Operations at river stations, 1899, Part V. 1900. 397-471 pp.
WS 47. Operations at river stations, 1900, Part I. 1901. 100 pp.
WS 48. Operations at river stations, 1900, Part II. 1901. 101-196 pp.
WS 49. Operations at river stations, 1900, Part III. 1901. 197-292 pp.
WS 50. Operations at river stations, 1900, Part IV. 1901. 293-388 pp.
WS 51. Operations at river stations, 1900, Part V. 1901. 389-488 pp.
WS 52. Operations at river stations, 1900, Part VI. 1901. 489-575 pp.
WS 65. Operations at river stations, 1901, Part I. 1902. 334 pp.
WS 66. Operations at river stations, 1901, Part II. 1902. 188 pp.
WS 75. Report of progress of stream measurements for the calendar year 1901, by F. H. Newell. 1902. 246 pp., 13 pls.

Progress reports may also be found in the following publications: Tenth Annual, Part II; Eleventh Annual, Part II; Twelfth Annual, Part II; Thirteenth Annual, Part III; Eighteenth Annual, Part IV; Nineteenth Annual, Part IV; Twentieth Annual, Part IV; Twenty-first Annual, Part IV; Twenty-second Annual, Part IV; Bulletin No. 131; Bulletin No. 140.

(Continued on fourth page of cover.)

PAPERS RELATING ESPECIALLY TO UNDERGROUND WATERS.

SERIES O—UNDERGROUND WATERS.

WS 4. A reconnaissance in southeastern Washington, by Israel C. Russell. 1897. 96 pp., 7 pls.

WS 6. Underground waters of southwestern Kansas, by Erasmus Haworth. 1897. 65 pp., 12 pls.

WS 7. Seepage waters of northern Utah, by Samuel Fortier. 1897. 50 pp., 3 pls.

WS 12. Underground waters of southeastern Nebraska, by Nelson H. Darton. 1898. 56 pp., 21 pls.

WS 21. Wells of northern Indiana, by Frank Leverett. 1899. 82 pp., 2 pls.

WS 26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett. 1899. 64 pp.

WS 30. Water resources of the lower peninsula of Michigan, by A. C. Lane. 1899. 97 pp., 7 pls.

WS 31. Lower Michigan mineral waters, by A. C. Lane. 1899. 97 pp., 4 pls.

WS 34. Geology and water resources of a portion of southeastern South Dakota, by James Edward Todd. 1900. 34 pp., 19 pls.

WS 53. Geology and water resources of Nez Perce County, Idaho, Part I, by I. C. Russell. 1901. 86 pp., 10 pls.

WS 54. Geology and water resources of Nez Perce County, Idaho, Part II, by I. C. Russell. 1901. 87-141 pp.

WS 55. Geology and water resources of a portion of Yakima County, Wash., by G. O. Smith. 1901. 68 pp., 7 pls.

WS 57. Preliminary list of deep borings in the United States, Part I, by N. H. Darton. 1902. 60 pp.

WS 59. Development and application of water in southern California, Part I, by J. B. Lippincott. 1902. 95 pp., 11 pls.

WS 60. Development and application of water in southern California, Part II, by J. B. Lippincott. 96-140 pp.

WS 61. Preliminary list of deep borings in the United States, Part II, by N. H. Darton. 1902. 67 pp.

WS 67. The motions of underground waters, by C. S. Slichter. 1902. 106 pp., 8 pls.

B 199. Geology and water resources of the Snake River Plains of Idaho, by I. C. Russell. 1902. 192 pp., 25 pls.

WS 77. Water resources of Molokai, Hawaiian Islands, by Waldemar Lindgren. 1903. 62 pp., 4 pls.

WS 78. Preliminary report on the artesian basins in southwestern Idaho and southeastern Oregon, by I. C. Russell. 1903. — pp., 2 pls.

The following papers also relate to this subject: Underground waters of Arkansas Valley in eastern Colorado, by G. K. Gilbert, in Seventeenth Annual, Part II; Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton, in Seventeenth Annual, Part II; Water resources of Illinois, by Frank Leverett, in Seventeenth Annual, Part II; Water resources of Indiana and Ohio, by Frank Leverett, in Eighteenth Annual, Part IV; New developments in well boring and irrigation in eastern South Dakota, by N. H. Darton, in Eighteenth Annual, Part IV; Rock waters of Ohio, by Edward Orton, in Nineteenth Annual, Part IV; Artesian well prospects in the Atlantic Coastal Plain region, by N. H. Darton, Bulletin No. 138.