DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 231

GEOLOGY AND WATER RESOURCES

OF

THE HARNEY BASIN REGION, OREGON

BY

GERALD A. WARING

WASHINGTON
GOVERNMENT PRINTING OFFICE
1909

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GEOLOGY AND WATER RESOURCES OF THE HARNEY BASIN REGION, OREGON.

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INTRODUCTION.

CHARACTER OF RECONNAISSANCE.

Ever since white men first made their homes on the great plains of the Northwest and began to use them as ranges for cattle and horses the region about the Harney basin in Oregon has been preeminently a stock country, for the great areas of rocky plateau and of desert valley were valuable chiefly for grazing purposes. Within the last few years, however, many settlers have immigrated to this northwestern region, mainly perhaps because of the growing scarcity elsewhere of Government land worth homesteading. This recent influx has brought the region into notice and has given rise to a demand for reliable information concerning it, to supply which the writer was detailed to make a reconnaissance of Harney Valley and adjacent territory. Seven weeks during the summer of 1907 were spent in this work, which is an eastward continuation of a similar study that was carried out in Lake County in the fall of 1906. The areas covered during each of these seasons is shown on the index map (Pl. I). Special attention was paid to the water supply, both from streams and from underground sources, and to the structural geology of the region in its relation to artesian conditions.

With the exception of those compiled from the Land Office plats no maps of this area have been published. Since a topographic base is essential to a careful study of underground water conditions as affected by drainage basins and rock structures, the accompanying map (Pl. II, in pocket) has been prepared from all available data, and from field observations made during the course of the examination. This work was secondary to the main purpose of the investigation, and it is realized that there are many inaccuracies in it, but for the purpose of showing the main elements of the relief and drainage and their relations, and as a basis for a study of ground-water conditions, the map is considered to be sufficiently trustworthy.

ACKNOWLEDGMENTS.

Occasion is here taken to thank the several ranchers and settlers who aided the writer in many ways during the field work. Especially is appreciation expressed to Dr. W. L. Marsden, of Burns, for much information, and to Mr. J. W. Hanley for the hospitality extended at the ranches that he superintends.

PREVIOUS STUDY.

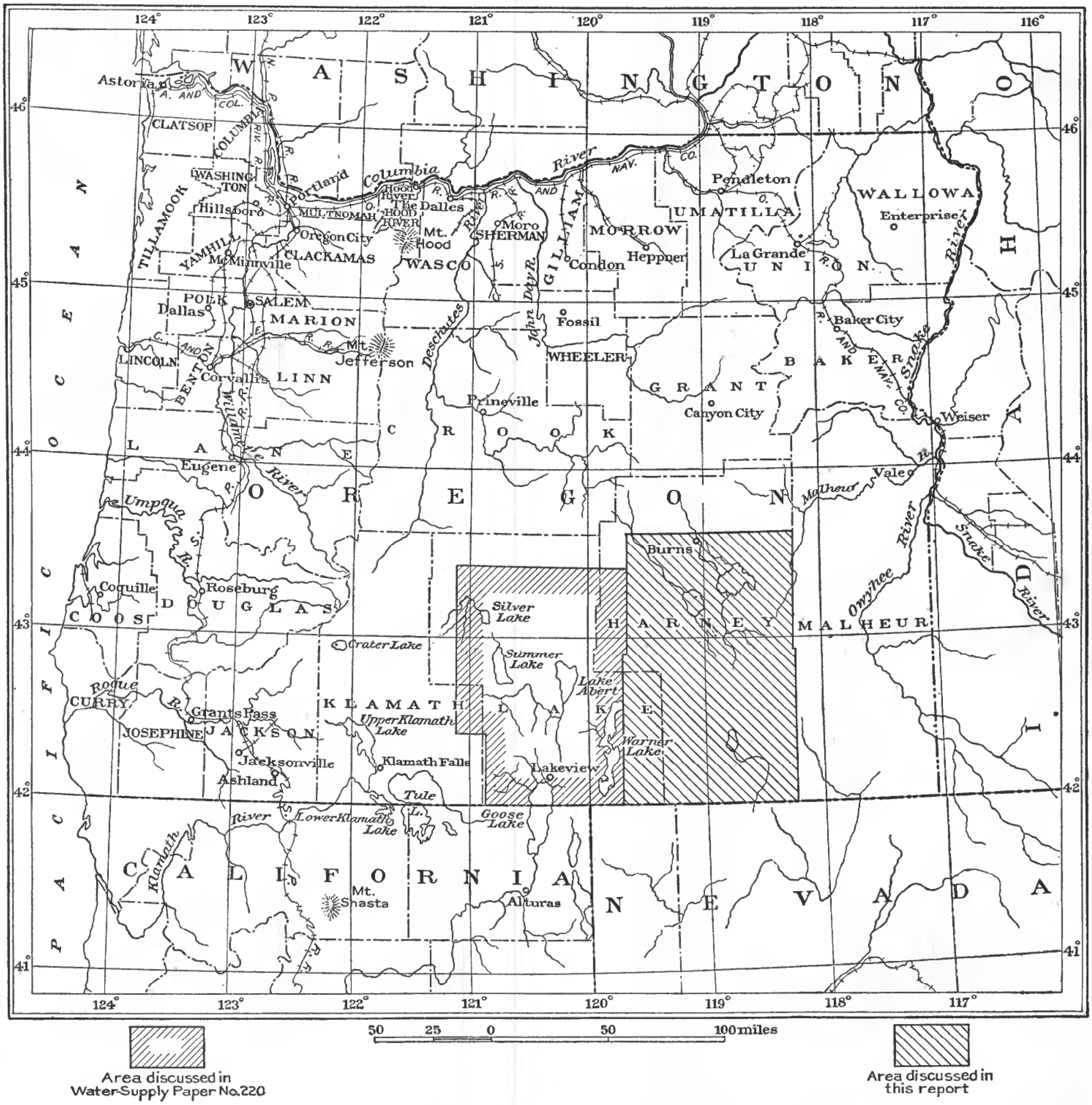
In 1882 I. C. Russell made a very general examination of this region in connection with his study of Quaternary lakes.[a] At this time he visited Alvord Valley, traveling through it from Alvord Lake to its northern end; thence he crossed the divide into Harney Valley, followed along its eastern and northern borders, and passed westward into Lake County. In his paper he describes the general features of this region, especially its geologic structure, in which faulting is the predominant factor, and speaks of the great lakes that existed in its valleys during Quaternary times. In the summer of 1902 he made a second trip through southeastern Oregon, this time more especially to examine its geology and to note its water supply. The results of this study appeared in two publications of the Survey—a water-supply paper (No. 78)[b] and a bulletin (No. 217).[c] In his water-supply paper he describes the kinds of rocks and their geologic structure, speaks in greater detail of the valleys and their water supply, and gives evidence which he regards as indicating the existence of water under artesian pressure in the rocks underlying Harney and Whitehorse valleys. In his bulletin of the same year he treats more fully of the structure and the classes of rocks, especially of the recent volcanic materials, and also describes the character of the several lakes. In 1903 he made a third journey through this part of the Northwest and gathered additional information concerning northern Harney County, which is published in another bulletin of the Survey.[d] In this report he describes the rocks and rock structures along the route traversed, and also mentions the prominent mountains and their characters. In speaking of the water supply he names the several major streams, and considers the possibilities of water storage on them for irrigation in the valley lands. In his discussion of underground water he calls attention to the shallowness of the ground-water level throughout the valleys and the plentiful supply of such water, and advocates the drilling of deep wells for artesian flows.

[a] Russell, I. C., A geological reconnaissance in southern Oregon: Fourth Ann. Rept. U. S. Geol. Survey; 1884, pp. 431-464.

[b] Russell, I. C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: Water-Supply Paper U. S. Geol. Survey No. 78, 1903.

[c] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: Bull. U. S. Geol. Survey No. 217, 1903.

[d] Russell, I. C., Preliminary report on the geology and water resources of central Oregon: Bull. U. S. Geol. Survey No. 252, 1905.



INDEX MAP OF OREGON, SHOWING LOCATION AND EXTENT OF AREA EXAMINED.

As their titles indicate, these papers also treat of the country to the east and to the west of Harney County. Concerning the country immediately north of it there appears to be no literature; while for that on the south an article by James Blake[a] on the Puebla (Pueblo) Range of mountains, in Nevada, is the principal publication. This paper treats mainly of the structure of the mountains and the kinds of rocks that were noted in them.

GEOGRAPHY.

TOPOGRAPHY.

GENERAL CHARACTER.

As a whole southeastern Oregon forms a great uneven plateau region with an average elevation of between 4,000 and 5,000 feet. Large areas of it are nearly level or only gently undulating, but the stretches of table-land are broken in a few places by extensive escarpments, which trend in general from north to south. The escarpments border flat valleys, which also occupy a great part of this region, usually lying but a few hundred feet lower than the plateaus. These valleys contain shallow lakes, or at least playas or wet-weather lakes, but for the most part their surfaces form wide level expanses of alluvial sagebrush-covered plain.

The largest of these is Harney Valley, which comprises roughly 700 square miles of plain, marsh, and lake surface, in the central part of Harney County. In the southeast lies Alvord Valley, a long, narrow basin limited by escarpments and rugged hills, while in the southwest the Warner Lakes lie in a similar basin, bordered by great cliffs. Catlow Valley, in the south-central part of the area studied, is a fourth area of level plain, which lies several hundred feet higher than the other valley lands. On the east its edge is marked by bold escarpments, but westward its surface rises gradually to the higher plateau.

These valleys are not without breaks in their monotonous levels, for half-buried buttes rise here and there. Many small sand dunes and hillocks also dot their floors, and in some places flood water has cut minor channels in the loose alluvial material of their surfaces.

The plateau character is best developed in the west-central part of the area examined and extends westward across Lake County, but it is broken by escarpments that border the lake basins existing there. Eastward the same topography persists, but it is deeply notched by Owyhee River and its tributaries. Northward the surface rises in more mountainous slopes to the Strawberry Mountains, and the plateau-like character is not so well developed. In the southeast, also, a long gentle upward slope culminates in the crest of Steens Moun-

[a] Blake, James; On the Puebla Range of mountains: Proc. California Acad. Sci., vol. 5, 1875, pp. 210–214.

tain, and, together with the southward extension of this higher mass in the Pueblo Mountains, forms a different type of relief from that of the remarkably uniform plateau country.

The great mass of Steens Mountain[a] is the dominant topographic feature in southeastern Oregon, rising as it does to an elevation well above 9,000 feet. Along the western border of Alvord Valley it extends, trending east of north, from opposite Alvord Lake for a distance of 40 miles or more. Its eastern face is a precipitous escarpment, which in its central, higher portion rises over 5,000 feet above the valley at its base and is deeply scored by ravines and canyons. From its crest the surface slopes uniformly northwestward, for a distance of 15 or 20 miles, to the lowlands of the Harney basin and the western plateau country. The northern end of the mountain merges with lower though rugged slopes and buttes, while southward its limit is marked by an escarpment that swings northwestward along the border of the Catlow basin. Southward the mountainous character persists in the Pueblo Range, but these mountains do not have the remarkable features of an eastward-facing scarp and long gentle westward slope, which are so pronounced in Steens Mountain.

STREAMS.

Within the western United States there is a great area from which no streams flow to the ocean, hence it is known as the Great Basin area of interior drainage. The Harney drainage basin occupies the northern end of this area. North of it are the tributaries of John Day River, and on the east the streams join Malheur River and thence unite with Snake River, but to the south and west the streams are small and have no outlet to the ocean.

Within the Harney basin Silvies River from the north and Donner und Blitzen River and its tributaries from the south flow into Malheur Lake and carry the larger part of the run-off. In the other basins smaller streams flow from the surrounding slopes to the valley lands. Those that rise in Steens Mountain are perennial, but those having their sources in the western part of the county are dry during the greater part of the year.

LAKES.

The run-off of the nortneastern part of the area studied ultimately reaches the ocean through Malheur River, the Snake, and the Columbia; that of the rest of the region collects in the numerous depressions of the great plateau, and where it is sufficient in quantity perennial lakes are formed.

[a] On some maps this name appears as Stein or Steins Mountain, but as it was named for Col. Enoch Steen it seems proper to adopt the spelling here used.

Of such water bodies in the Harney basin region, Malheur Lake has the largest area, but it is very shallow, probably not over 10 feet at the deepest; and for some distance out from its margin the water is only a few inches deep. As its basin slopes so very gently, the lake varies much in extent, being usually greatest in May and June and least in January and February, when wide areas of tule land and mud flat are left around its borders. During high water it extends 16 or 18 miles eastward from Narrows and has a maximum width of about 8 miles, while at its lowest stage it shrinks to perhaps two-thirds that size.

Harney Lake, 7 or 8 miles across, is more definitely limited, for although its surface also fluctuates several feet during the year it lies in a deeper basin, with steeper shores, so that its extent is little affected by the change in depth. During the greater part of the year a shallow strait unites Harney and Malheur lakes, making them parts of one continuous water body.

Silver Lake, on the western border of the Harney basin, is supplied mainly by the overflow from Silver Creek during the spring season. Like the other lakes it is shallow, and all of its bed, which is 3 or 4 miles across, is not covered by water in the fall.

Warner Lake, to the southwest, lies in a long narrow valley which in its southern portion is bordered on each side by great cliffs. The supply to the lake is meagre, from only a few small streams and the rain and snow that fall in the lowland itself, so that during the autumn the lake shrinks to a number of detached water bodies or a chain of lakes.

In Alvord Valley, on the eastern side of Steens Mountain, Alvord Lake in wet winters extends northward and covers the desert of the same name to a depth of a few inches. During the summer months the desert is a barren mud plain, while the lake itself shrinks to a small area bordered by an alkali-incrusted flat. Juniper and Mann lakes are smaller fresh-water lakes in separate depressions in the northern end of Alvord Valley. They are supplied mainly by creeks rising in the slopes of Steens Mountain, upon whose cliffs lingering patches of snow furnish water to the streams throughout the year.

CLIMATE.

CONTROLLING CONDITIONS.

The elevation of most of the valleys of Harney County is about 4,100 feet, while that of the plateaus is from 4,500 to 5,500 feet. This rather high elevation renders the climate colder than it would be in this part of the Northwest were the country lower.

The Cascade Range, which trends from north to south through the State, from 125 to 200 miles west of the area under discussion. acts as a great wall separating the abundantly watered coastal side from the eastern portion, where the precipitation is slight. This lack of moisture, combined with the low mean temperature due to elevation, gives the region an arid and a rather severe climate.

RECORDS.

In Harney County and adjacent territory weather observations have been made at four volunteer stations, and partial records extending over several years have been kept. The following summaries of precipitation and temperatures at these stations are from records furnished by Edward A. Beals, district forecaster of the U. S. Weather Bureau, at Portland, Oreg.

Records of precipitation at Burns, Oreg.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1890	......	......	0.15	0.00	0.40	0.00	......	......	......	......	......	0.03	......
1891	0.16	......	......	......	......	......	......	......	0.10	0.00	3.77	1.69	......
1892	1.05	0.00	.25	.25	1.65	.00	0.01	Tr.	.75	......	Tr.	.16	4.12+
1893	1.35	.50	.60	.10	Tr.	Tr.	Tr.	0.00	1.25	1.04	......	.80	5.64+
1894	1.90	1.70	.70	.70	1.80	1.30	.15	.00	.00	1.85	.00	......	10.10+
1895	1.20	.00	.00	.00	.00	......	.00	.00	......	.00	......	......	......
1896	1.50	......	2.10	1.30	......	......	.60	......	.70	.00	1.00	.60	......
1897	1.10	1.10	.60	1.10	Tr.	......	.75	.25	2.50	.25	1.35	.95	9.95+
1898	1.45	......	Tr.	Tr.	1.52	.32	.00	Tr.	Tr.	Tr.	1.40	.20	4.89+
1899	1.90	.00	.61	.57	.16	......	......	......	......	1.32	4.55	1.80	......
1900	Tr.	1.80	.54	1.15	.34	.34	.00	.17	.24	.62	.47	.90	6.57
1901	1.20	1.67	.30	.34	.12	.15	.00	.22	.07	.07	......	......	......
1902	.72	3.31	.90	......	......	......	......	......	......	......	......	......	......
1903	......	......	......	......	......	......	......	......	......	.34	3.53	.74	......
1904	.77	2.52	2.88	1.50	......	.71	.58	.15	1.67	.86	.37	2.84	14.85+
1905	1.93	.28	1.89	.65	.53	2.45	.01	.15	.62	.55	.81	.57	10.44
1906	4.24	1.38	3.94	.27	2.43	1.41	.36	.43	.59	.23	.96	1.88	18.12
1907	2.08	2.36	2.33	1.06	.51	1.59	.26	.10	1.01	.27	.51	3.49	15.57

Records of precipitation in Happy Valley, Oregon.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1890	......	......	......	1.38	0.50	1.75	0.00	0.26	0.54	0.09	......	......	......
1891	0.65	2.70	2.35	1.57	3.14	2.55	2.12	.24	.74	.32	0.99	1.94	19.31
1892	.57	.57	1.62	2.12	1.76	.83	.39	.00	.77	.36	1.06	1.05	11.10
1893	1.09	1.11	1.33	2.16	1.39	.00	.32	.00	1.63	1.15	2.24	.65	13.07
1894	1.72	1.78	1.48	1.25	3.25	2.76	.53	.27	.77	1.74	.24	.87	16.66
1895	.66	.48	.33	1.41	1.87	.01	.20	.12	2.29	.00	.30	2.08	9.75
1896	1.76	.55	......	2.02	2.02	.34	.20	1.51	.71	.89	2.08	.74	12.83+
1897	1.32	2.53	1.54	2.33	1.39	1.61	.33	.09	.36	.39	1.78	1.74	15.41
1898	1.17	.62	.35	.48	2.45	.76	.04	.46	.50	.88	1.89	.59	10.19
1899	1.39	1.57	2.79	1.62	2.15	.42	.04	1.05	.05	1.74	2.08	1.72	16.62
1900	1.67	1.56	.54	1.44	2.06	1.13	.06	.73	1.78	......	......	......	......

Records of precipitation at Riverside, Oreg.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1897	......	......	......	......	......	......	0.35	0.10	0.14	0.15	1.86	1.61	......
1898	0.66	0.25	Tr.	0.14	1.17	0.31	.11	.06	.21	.29	......	.28	3.48+
1899	1.68	1.25	1.95	.82	1.38	......	.15	Tr.	Tr.	1.67	1.21	2.06	12.17+
1900	.87	.59	.50	1.23	.81	.95	.00	.50	.61	1.05	......	......	......
1901	.40	2.12	.14	1.02	.50	.35	Tr.	.34	.38	.42	.44	1.24	7.35
1902	.65	2.43	......	.93	......	......	.15	.17	.31	.21	1.01	......	......
1903	2.44	.50	1.02	Tr.	.40	......	......	.52	......	.10	......	.15	......
1904	.16	1.05	.60	1.60	.45	......	.50	.70	.65	.98	.25	1.15	8.09+
1905	2.10	.55	.60	.42	2.16	1.47	.27	Tr.	.05	......	.45	......	......
1906	2.15	1.70	3.93	.50	2.82	1.07	......	Tr.	.29	.15	.35	2.20	15.16+
1907	.60	2.39	1.30	.60	1.15	1.19	1.31	......	.55	.74	.10	2.70	12.63+

Records of precipitation at the P ranch, Oregon.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1897	......	......	0.30	0.15	......	......	0.00	0.16	1.14	0.10	1.42	1.72	....
1898	0.79	0.11	.21	.10	2.37	0.33	.00	Tr.	Tr.	.00	2.00	.00	5.91
1899	.00	.01	1.34	.02	1.17	.00	Tr.	.87	.00	......	......	2.61	....
1900	1.27	.28	.24	1.11	1.08	.00	.00	......	......	......	......	......	....

Monthly, seasonal, and annual means of temperature and precipitation at stations in southeastern Oregon.

Month.	Burns.[a]				Happy Valley.[b]				Riverside.[a]			
	Mean temperature.	Mean maximum temperature.	Mean minimum temperature.	Mean precipitation.	Mean temperature.	Mean maximum temperature.	Mean minimum temperature.	Mean precipitation.	Mean temperature.	Mean maximum temperature.	Mean minimum temperature.	Mean precipitation.
	°F.	°F.	°F.	In.	°F.	°F.	°F.	In.	°F.	°F.	°F.	In.
December	26	49	−1	1.2	30	56	0	1.3	28	54	0	1.4
January	23	48	−8	1.4	29	54	−1	1.2	28	52	−6	1.1
February	27	51	−5	1.3	31	56	−1	1.4	33	59	−1	1.3
Winter	25	49	−5	3.9	30	55	−1	3.9	30	55	−2	3.8
March	33	62	3	1.1	36	67	10	1.4	40	66	9	1.1
April	43	73	18	.6	44	76	18	1.6	48	81	18	.7
May	49	82	22	.7	50	83	22	2.0	54	91	22	1.2
Spring	42	72	14	2.4	43	75	17	5.0	47	79	16	3.0
June	57	89	27	.7	57	89	26	1.1	63	97	28	.9
July	66	97	33	.2	64	96	30	.4	70	105	33	.3
August	65	96	31	.1	63	94	32	.4	70	103	33	.2
Summer	62	94	30	[c]1.0	61	93	29	1.9	67	102	31	1.4
September	53	88	22	.7	54	88	23	.9	58	94	24	.3
October	46	79	16	.5	45	78	14	.8	47	81	15	.6
November	34	65	4	1.4	37	67	4	1.4	36	69	6	.7
Fall	43	77	14	2.6	45	78	14	3.1	47	81	15	1.6
Annual	43	73	13	[d]9.9	45	75	15	13.9	48	79	15	9.8

[a] Computed from records of monthly mean, maximum, and minimum temperatures, and monthly precipitation, furnished by Edward A. Beals, district forecaster, U. S. Weather Bureau, Portland, Oreg.
[b] From Bulletin Q of the U. S. Department of Agriculture: Climatology of the United States, by Alfred Judson Henry. Chapter on Oregon by Edward A. Beals, p. 967. (Mean precipitation for June corrected from original records.)
[c] Given as 0.66 on Pl. I of First Biennial Report of the Oregon State Engineer, 1906.
[d] Given as 9.33 on Pl. I of First Biennial Report of the Oregon State Engineer, 1906.

A study of the precipitation records shows that, as in other arid regions, the rainfall varies greatly from year to year, a fact that in regions of slight rainfall has a vital bearing on the possibilities of dry farming. During the years 1904–7 the rainfall at Burns was above the average, in two of them being over 50 per cent above the normal, and in 1906 nearly twice the average amount. But the incomplete records of earlier years indicate that in some of them the rainfall was only about half the mean for the last seventeen years. In the last table, from the means of precipitation prepared from the figures of the preceding tables, it is seen that the moisture is fairly well distributed through the winter and spring months. As is to be expected, the rain and snow fall is greater in Happy Valley, near the mountains, than it is over the more open country near Burns, owing mainly to a greater spring rainfall. Near the protecting mountains the mean annual temperature is somewhat higher than in the open valley land, perhaps because the portions near the mountains are sheltered from the desert winds; and for similar reasons the extremes of temperature are not so great in those sections. But the temperature has a considerable range, often going below zero in winter, and occasionally reaching 100° in summer. Sudden or extreme changes are unusal, however, and though the nights of summer are cool there is a considerable period in which there is little danger of frost. Of the Harney basin region as a whole it may be said that the average rainfall is between 10 and 15 inches, and the mean annual temperature between 45° and 50°.

VEGETATION.

Only along the northern border of the area mapped on Plate II are the slopes timbered, hence it is from this portion that lumber for the country to the south is obtained. The growth consists almost wholly of open forests of yellow pine. The dense growth of young trees in portions of these open forests is gratifying, both as a source of future lumber supply and as an aid to the lengthening of the summer flow of the streams. Junipers are scattered over parts of the plateau lands, and furnish good fence-post material, which is used extensively in inclosing fields and homesteads, while cottonwoods grow along the upper courses of the mountain streams. But the gray sagebrush, which is so characteristic of the Northwest, is the chief growth over the plateaus and mountain slopes as well as the valley lands. This brush extends even to the crest of Steens Mountain, over 9,000 feet above sea level, though at this elevation it is dwarfed to a few inches in height, and its stalks are reduced to tough twigs that carry only a few leaves.

The remarkable absence of timber on Steens Mountain has been discussed by Russell,[a] who attributed it to the overlapping of the lower border of the cold timber belt and the upper border of the dry timber belt. The former extends down the mountain slopes from the summit and prevents timber growth in the higher elevations, while the deficiency of moisture on the lower slopes prevents the growth of pines there. The main exceptions to the scanty covering of vegetation on this mountain are the cottonwoods along the streams, a small group of firs in one canyon, and occasional patches of mountain mahogany on the upper slopes.

It is from the timbered slopes in the northern part of the county that fuel for the greater part of the population at Burns and at

[a] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: Bull. U. S. Geol. Survey No. 217, 1903, p. 11.

Harney is obtained. When snow is on the ground, logs are easily skidded down from the mountains and can then be cut up into stove wood at leisure. In the southern part of the county dependence is placed mainly on the scattering junipers, which have already been largely cut for this purpose and for fence posts. In many parts the sagebrush is the most accessible fuel, though it is a disagreeable one to handle and burns out quickly.

GAME.

A few mountain sheep are said still to inhabit the more inaccessible parts of Steens Mountain, while deer and antelope are rather numerous, and in winter come down into the valleys to feed. It is affirmed by residents that during severe weather a few elk still come down from the mountain and mingle with the cattle on the Alvord ranch. Good trout fishing may be had in the larger mountain streams during the summer. Of feathered game, an occasional flock of sage hens may be seen on the dry plateaus or in the valleys, while thousands of waterfowl frequent Malheur and Harney lakes and the tributary marsh lands. The wagon bridge at Narrows is locally famous as a stand for sportsmen, who take advantage of the flight of ducks and geese over the narrow strip of water connecting the two lakes.

SETTLEMENTS.

Within the area studied there were fourteen post-offices in the spring of 1909. Burns, the county seat of Harney County, is a town of 800 or 1,000 inhabitants. It is the initial or terminal point of four stage lines that connect with railroads at Shaniko and Austin on the north, Vale on the east, and Winnemucca, Nev., on the south. These places are respectively about 213, 102, 131, and 284 miles distant from Burns, according to the post-route map. Harney, the second town in size, has perhaps 100 inhabitants. Lawen and Narrows, near Malheur Lake, and Denio, near the Nevada line, each consists of a small group of houses, with a general store and accommodations for travelers. At Riley, Diamond, and Andrews one can also obtain a few supplies and accommodations for the night. Smith and Venator post-offices are at ranch houses, while Harriman, Alberson, Waverly, and Voltage post-offices were recently established at new homesteads, the former being located near the line of a preliminary railroad survey of the Northern Pacific system.

For the southwestern part of the area under discussion the nearest store and post-office is at Plush, in Warner Valley. Two slightly traveled roads cross the plateau between it and Harney Valley. The most direct road runs west of south from the Double O ranch, near Harney Lake, to Warner Valley, and along its western side to Plush. From the P ranch, at the head of the marsh of Donner und Blitzen

River, another road leads southwest across the Catlow basin and follows the general trend of Rock Creek to its upper course, then turns west and descends the escarpment into Warner Valley. On this road there are two ranches on upper Rock Creek, those of Messrs. E. T. Flook and Steve Young, which are used as stopping places by travelers. On the other road there is no habitation between the Double O ranch and the Bluejoint ranch, a distance of 65 or 70 miles. In summer the only two watering places on this road are those at Buzzard Spring and Mule Spring.

INDUSTRIES.

GRAZING.

As stated in the introduction, grazing is the most important industry in this region. The plateaus and valleys furnish a cattle range that formerly was restricted only by the location of watering places; and the bunch grass has in the past been plentiful enough to supply feed to thousands of head of stock. In the early fall the herds are rounded up, the several brands are separated by their owners, and the animals intended for market are driven to the railroad. The others are pastured for the winter on the marsh lands, practically all of which are controlled by the larger stock owners. During the summer these marshes are mowed and the wild hay is stacked for winter feeding.

Within the last few years the high price of sheep and the low price of cattle have led to the introduction of rapidly increasing numbers of sheep. As in every other grazing region that they have entered, sheep are rendering the none too abundant range unfit for cattle and horses, except in those portions of the high desert from which the scarcity of water excludes them; and already in the mountain regions the results of overgrazing are very apparent. The influx of settlers and the fencing of valley land has also restricted the cattle range. Of late years these three factors—low prices, the introduction of sheep in large numbers, and the settlement of the valley land—have caused a very noticeable retrenchment in the cattle business. But it seems that this will always be mainly a stock-raising country, because of the great areas of plateau that are fit for little except grazing; and it may be that, as has been found true in the Middle West, when the limited areas of arable land have been brought under cultivation and are producing crops of alfalfa, grain, and other feed, many more head of stock will be marketed than when the entire region was unrestricted range.

AGRICULTURE.

Comparatively little farming has yet been done within this region, though most of the common fruits and vegetables are grown for home use. Increasing acreages of barley, wheat, and oats are also being raised each year, to supply the increasing demand for grain and hay, while rye is a common first-year crop on new land. In a few places, where water is available for irrigation, there are small fields of alfalfa, but much lowland on which this forage crop might be more profitably raised is still given over to the natural grasses, which in the spring are irrigated by overflow water from the larger streams.

The rapid influx of settlers during the last two or three years promises to make farming a much more important means of livelihood than it is at present. While it may be found easy to raise such grains, fruits, and vegetables as are required at home for the table and for stock feed, the remoteness of the region from railroads limits the market for farm produce to the amount required for local consumption; and until a ready outlet to wider markets is obtained, the development of the country can not be expected to proceed very rapidly.

LUMBERING.

A sawmill in the mountains north of Burns and one in the timber a few miles north of Harney supply lumber for the county. Yellow pine is almost the only kind of timber available, the rough material being sold at from $12 to $14 a thousand board feet at the mill.

MINERALS AND BUILDING STONE.

During the last few years renewed interest has been aroused in indications of copper in the mountains west of Denio. Some prospecting has been done and a few good specimens of carbonate ore and the native metal have been found, but no body of ore has been uncovered, nor has development work been undertaken to any extent.

Deposits of volcanic ash and coarser fragmental material form beds of tuff that in a number of places have been quarried to some extent to obtain building stone. At Burns squared blocks of rhyolitic tuff from the neighboring slopes have been employed in the construction of a church and a bank building; and rougher blocks of the same material have been used in several other buildings, as well as in foundations and retaining walls. But the irregular mottling of this dark-brown stone, which contains fragments of lighter-colored material, is not very pleasing when put to this use. At Narrows a light-buff tuffaceous sandstone has been used in the construction of one or two buildings, and for chimneys, foundations, and similar purposes. In other parts of the county similar material is also quarried for such uses.

GEOLOGY.

THE ROCKS AND THEIR SUCCESSION.

AGE OF THE ROCKS.

The rocks of the Harney basin region consist almost wholly of effusives and varieties derived from them. The greater part of these seem unquestionably to belong to the same period of outpouring as those that cover northern Oregon and southern Washington, which are known as the Columbia River basalt. These latter have been determined to be of Miocene age by fossils found along Columbia and Yakima rivers and in the basin of John Day River, in sediments that are interbedded with the lavas. But in at least one portion of the area covered by this report there are rocks of an older series than that of the effusives, and successive flows of these effusives also bear such relation to each other as to warrant the recognition of the following classes of material in addition to the main Miocene lava flows: Plutonic and metamorphic rocks, earlier effusives, tuffaceous sediments, later eruptive lava, and the unconsolidated sediments filling the valleys. The approximate extent of these several classes of material is shown on the geologic map (Pl. III, in pocket), but their boundaries as there shown must be understood to be indicated only in a very general way; for the main purpose of the examination did not permit their detailed mapping.

PLUTONIC AND METAMORPHIC ROCKS.

Pueblo Mountain and the range south of it are composed of rocks that belong to an older series than do the lavas to the north. These mountains were only cursorily examined, but from float specimens that were collected along the eastern base of the range they appear to be made up of andesitic porphyries, micaceous schists, and granitic rocks, which have been more or less extensively affected by mineralizing agents.

In a paper published in 1875 Dr. James Blake[a] describes the southern extension of these mountains in Nevada. There he found micaceous and talcose schists and metamorphic limestones, which dip away from the mass of porphyry that forms the crest of the eastern ridge of the range.

The rocks of this range are the oldest that were noted, but to what earlier period than the lavas they belong there are no facts at hand to suggest.

EARLIER EFFUSIVES.

In a few places masses of lava were noticed that from their structure and positions seem to be older than those associated with the main flows, for they show little bedding structure and rise high

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[a] Blake, James, The Puebla Range of mountains: Proc. California Acad. Sci., vol. 5, 1875, pp. 210-214.

above the surrounding lavas, which extend only part way up on their bases and apparently never completely covered them. Of these masses, Iron Mountain and Flagstaff Butte are the most prominent. The slopes of the former are composed largely of rock that has been identified by E. S. Larsen, jr., as hornblende basalt. From its shape and the relation of its material to the surrounding olivine basalt the mountain is considered to be an early volcanic cone.[a] Flagstaff Butte is composed of rhyolitic rocks, and has the characteristics of an old volcanic neck, or plug. It is possibly the source from which issued the sheets of greenish rhyolite that is the surface rock west of it.

On the western side of Alvord Valley, opposite the middle portion of Alvord Desert, and also 4 or 5 miles south of Andrews, there are hills of light-colored rhyolite. This rock apparently underlies the great series of basaltic flows that forms the mass of Steens Mountain, and it is thought to belong to an older period of effusion than the basalt.

TUFFACEOUS SEDIMENTS.

In five localities sedimentary beds of fine-grained volcanic tuff and ash were noted. In Alvord Valley, west of the Alvord ranch, beds of siliceous tuffs are exposed at the base of Steens Mountain. The thickness of these beds is given by Russell[b] as over 1,000 feet. There is a prominent outcrop of the material between the elevations of about 5,300 and 5,200 feet, but the lower portion of the deposit is obscured by talus and stream wash.

Northwest of Tumtum Lake, light-colored tuffaceous rocks form hills on the western side of Alvord Valley. These beds form a lower topographic belt, distinct from that of the basaltic escarpment farther west. The tuffs are less siliceous than those farther north, and in them the bedding is better developed. A ripple-marked surface is usually presented along parting planes. These tuffs, like those west of the Alvord ranch, underlie the main basaltic flows, or at least are near the base of this series.

East and northeast of Flagstaff Butte, in the flat valley of Willow Creek, there are nearly horizontal beds of fine white volcanic ash, which are interspersed every few inches with more sandy layers, and are overlain by coarse fragmental tuff. Mr. J. C. Beatty has opened a quarry in the fine-grained beds about 2½ miles east of Flagstaff Butte, in which a very good section of the material is exposed. From the white layers of volcanic ash beautifully preserved plant

[a] See Russell, I. C., Preliminary report on the geology and water resources of central Oregon: Bull. U. S. Geol. Survey No. 252, 1905, p. 47.

[b] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: Bull. U. S. Geol. Survey No. 217, 1903, p. 16.

remains were collected, which have been identified by F. H. Knowlton, paleobotanist of the U. S. Geological Survey, as of Upper Eocene age. The specimens examined contained leaves of the fossil oak, alder, birch, willow, and maple. Of these trees the following species were recognized:

Quercus consimilis Newberry.
Quercus simplex Newberry.
Alnus serrulata fossilis Newberry.
Betula heterodonta Newberry.
Salix perplexa? Knowlton.
Acer osmonti Knowlton.

Near the southern base of Flagstaff Butte, at the eastern end of the small valley along Trout Creek, similar tuffaceous sediments are exposed that dip gently eastward beneath the basalts.

The siliceous sediments noted at the two localities in Alvord Valley possibly are also of the same series as those near Trout and Willow creeks, but the evidence that was obtained is not sufficient to warrant correlating them definitely with these Eocene deposits.

The fifth locality where sedimentary beds were noticed is south of Narrows, where an area of a number of square miles is covered by a light-colored felsitic tuff or sandstone. Near the southeast border of Harney Lake it forms bluffs 200 feet in height. The material is of homogeneous texture and is well bedded. No fossils are known to have been found in it. This material has been assigned by Russell[a] to a position overlying the basalt. When traced southward, however, it seems to pass beneath the lava of the plateau, and detailed study may show that it is interbedded with the upper portion of the basalt.

In a few other localities layers of fine-grained and well-bedded tuffs were seen, where they are exposed along bluffs, but the surface extent of the material at these places is not sufficient to warrant indicating it on the geologic map (Pl. III). Such beds were noted near Silver Lake, at the point of the bluff about 2 miles north of the Seventyone ranch, and on the north side of the canyon of Silver Creek, about 3 miles north of this point. At the former place the material is a soft, well-bedded, light-gray sandstone, of which a small amount has been quarried as a building stone. At the latter place there is exposed a thickness of 50 feet of the rock, which dips about 2° northward.

On the eastern edge of the county, where Swamp Creek joins South Fork of Malheur River, similar material is found at the bluff between the canyons of these two streams. The exposure is made prominent by a private road that cuts into the sandstone, and also by the face of a quarry that has been opened to obtain the material for building purposes.

[a] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: Bull. U. S. Geol. Survey No. 217, 1903, p. 16.

MAIN LAVA FLOWS.

By far the greater part of the area over which the rocks are exposed is covered by lavas that are thought to belong to the same period of effusion as the Columbia River basalt. These rocks are mainly basalts and basaltic tuffs. There is much variation in texture and composition in the former, from hard black fine-grained varieties to coarsely crystalline rocks composed chiefly of basic feldspar; and in the latter from fine-grained homogeneous tuffs to coarse agglomerates. Associated with the basalts and in many places interbedded with them there are sheets of rhyolite and rhyolitic tuff, so that sections exposed in some escarpments show an alternation of basaltic and rhyolitic layers. About 2 miles northeast of Diamond the road to Happy Valley ascends a 350-foot bluff in which is exposed, from the bottom up, basalt along the border of the flat of Swamp Creek, white and light-colored tuffs for over half the way to the top, and over that a gray, glassy rhyolite, covered by a thin capping of basalt. On descending to Smith this series is crossed in reverse order, but on this eastern side of the plateau the tuff is much thinner and the lower basalt is met higher above the valley land. On the east side of Alvord Valley the road from Andrews to Whitehorse ranch climbs across a similar alternation of layers. The series at this place consists of basalt overlain by about 100 feet of rhyolitic tuff and rhyolite, and over this approximately 100 feet of tuffaceous sediments, covered by a thin layer of basalt.

The siliceous rhyolitic rocks were noticed principally in the eastern and northern portions of the county, where rhyolitic tuffs cover wide areas. On the northern and northwestern borders of the Harney basin the surface rocks are also mainly such siliceous varieties. The rim rocks back of Harney and the lower slopes on each side of Silvies River are composed of them. In the southeast also the rim rocks bordering the stream gorges near Diamond are of rhyolitic tuff, while on the eastern edge of the county great sheets of it cover the plateau that extends southward from Venator. The greater part of the more elevated masses of Steens Mountain, and of the hills draining to Malheur River, is composed of basaltic rocks, as is also the great expanse of plateau in the southwest. Siliceous rocks were noticed at numerous other points in these great areas, but basalt is by far the predominant rock.

Occasional dikes were seen that cut almost vertically through the flat lava beds. The most prominent of these are two parallel dikes of basalt which extend along the scarp of Steens Mountain, about two-thirds of the way toward its crest. The larger of these is very prominent throughout a great part of its exposed length, being 10 to 60 feet in thickness at places where it was seen at close range, and standing 50 feet or more above the slopes of the scarp. Its course was traced from a mile north of Whisky Hill to the most rugged portion of the scarp, northwest of the Alvord ranch, a distance of 17 or 18 miles. Of siliceous dikes perhaps the most notable one is on the eastern edge of Harney Valley, near the stage road to Vale. There a dike of white porphyritic rhyolite crosses a stream channel and forms what is locally known as the "reservoir site."

LATER ERUPTIVE LAVA.

Several miles northwest of Diamond there is an area of basaltic and scoriaceous lava surrounding craters from which it issued. This recent lava is but sparingly covered with thin patches of soil, though sagebrush has obtained a foothold over much of it. A number of the craters or cinder cones, which are built up of scoria and small bombs, still have their original forms, while numerous pressure ridges in the lava, near the edge of the flow, are also interesting features of the surface.[a]

The flat country that lies between Malheur Gap and the Mule ranch and extends to Indian Creek is covered with basalt that is raised into pressure ridges and otherwise much resembles the recent flow near Diamond, though it supports a heavier growth of sagebrush.

Malheur Cave is a low arched chamber in this basalt, between Camp and Indian creeks. It is said to be about a mile long, from 50 to 100 feet wide, and in places 20 feet high. The entrance to the cave is an opening about 25 feet wide and 4 feet high, at the end of a slight depression in the lava plain. The cave slopes gently downward toward the back, and the farther half of its floor is covered with water, which seems to be the accumulation from surface drainage and from seepage. This cave was possibly formed by cooling of the surface of the lava flow so as to make a crust, while the still molten inner portion flowed out from beneath it and left a long tube or tunnel. Caves of this character are common in other basaltic regions, and this theory of their origin has been spoken of by Russell and others.

An area of similar basalt covers the valley of Crane Creek from a mile or two below the mouth of Coyote or Little Crane Creek to near the mouth of Coleman Creek.[b] Possibly these two areas of basalt are parts of the same flow, their connection through the valley of Camp Creek now being obscured by alluvium. Although this lava is very probably of more recent age than the main flows, it is evidently older than that of the Diamond craters, and hence it is not classed with the latter on the geologic map (Pl. III). In other localities

[a] These craters and the surrounding lava have been fully described by Russell in Bull. U. S. Geol. Survey No. 217, 1903, pp. 54–56.

[b] This is also described by Russell in Bull. U. S. Geol. Survey No. 252, 1905, p. 37.

smaller areas of similar basalt were noticed that appear to be of later effusion than the main flows, and it may be that when the geology is studied in detail the extent of these later flows can be mapped and their sequence determined.

The succession of rhyolites and basalts and their associated tuffs forms a series the greater part of which is of middle Tertiary age; but the basalt flows in Anderson Valley and along Crane Creek, which are evidently of later date, and the comparatively recent craters near Diamond suggest that effusion has continued almost to the present.

VALLEY FILLING.

All the valleys are filled by silts and sandy deposits, which have given them their fine-grained coatings of soil. Records of the few deep wells that have been sunk in Harney Valley show that in its central portion the sediments consist chiefly of clays with a few interbedded layers of sand, while nearer the borders of the basin sandy and gravelly layers predominate.

Such a condition is found where streams bring down alluvial material and discharge it into lakes; for on entering the quiet water their currents are checked, and the coarser, heavier portions of their loads are deposited first near shore, while the finer material that is held longer in suspension is deposited farther out in more evenly assorted layers. Borings in Harney Valley show that these unconsolidated deposits are relatively shallow, probably in few places over 300 feet in depth, while structural conditions in Whitehorse and Catlow valleys indicate that in them the deposits are still less extensive. In the formation of the Alvord basin faulting and other deformation of the lavas have played such important parts that the position of the rock floor of the valley can not even be approximated from the evidence now obtainable. Wells have been bored south of Andrews to a depth of 200 feet without encountering firmer material than coarse gravel, and one drilled near its northern end by Mr. J. H. Neal to a depth of 435 feet did not reach solid rock.

The alluvium deposited directly by the streams merges so imperceptibly into the sediments that have been held longer in suspension in the lake water and finally laid down in more homogeneous strata that in many places the two classes of material can not be separated. Since the disappearance of the former lakes the wind has reassorted much of the finer material, transporting it from one locality to another and mixing with it residual soil from the plateaus, so that the records of deposition are still further obscured.

In some districts, however, areas covered by purely stream deposits still remain. On each side of the valley of Silver Creek above Riley, beyond the limits of the creek bottom, there is a belt of gravelly bench land formed of stream wash. Similar beds of gravel border the western side of Warm Spring Valley along Malheur River, in the northeast corner of the area examined. On the western side of Alvord Valley numerous short streams from Steens Mountain have brought down quantities of gravel, and have built up large alluvial fans that extend far into the lowland. Between Mann and Juniper lakes the amount of material brought down has been sufficient to form a low alluvial divide across this narrow part of the valley, which separates and probably has also formed these two small lake basins. In Catlow Valley, Home and Threemile creeks have built extensive alluvial fans where they debouch into the lowland, while Skull Creek has formed similar deposits where its narrow valley opens to the broader plain. Nearly all the streams entering Harney Valley have such low grades that they have not built noticeable alluvial deposits. Instead, the finer valley sediments extend for some distance within their canyons and form stretches of meadow land bordering the stream channels.

GEOLOGIC STRUCTURE.

Since the outpouring of the great sheets of lava that now cover most of this region, movements in the earth's crust have disturbed them and altered the surface features. In some places the rocks have been bent into great low folds; in others immense blocks have been broken loose from adjacent parts of the crust and uplifted or depressed. By these movements and dislocations valley basins have been formed and escarpments have been produced that are now prominent features in the topography.

The most notable structural feature in southeastern Oregon is a great uplift, the western portion of which forms Steens Mountain. Bordering the western side of Alvord Valley a great fault extends, along which the movement took place that formed the escarpment of this mountain. On the opposite side of the valley lower escarpments and the gentle eastward inclination of the rocks show that the major structure is that of a great arch or anticline. This has been broken, and its central portion, or the keystone of the arch, has been dropped. It is upon this faulted block or keystone that Alvord Valley lies, bordered on each side by the escarpments that were produced by the dislocation. The maximum displacement of this faulting is attained west of the Alvord ranch. At this locality the height of the rim rock above the valley shows a displacement of fully 5,000 feet, but how much this is increased by the depth of the rock floor below the valley surface is at present only conjectural. The hills that rise from the valley floor seem to be tilted blocks that were broken off and displaced by the movement that produced the greater topographic feature. The ridge between Wildhorse Creek and Alvord Desert may be a great splinter that was partially left behind in the uplift along the major scarp, while a similar smaller block clings to the side of the bluffs west of Mann Lake.

Although the lavas have been more or less disturbed over all this country, and have been bent into arches and troughs, few dips greater than 15° were seen, while most of the beds are inclined at angles of less than 10°; thus the folding is characterized by low broad structures. The Harney basin is the largest of these low folds, being in effect a great shallow depression in the plateau, 50 miles or more in diameter. The several buttes and ridges within it show that it is not a simple saucer-like basin, but its synclinal form is the major structural feature of the central part of the county. Whitehorse and Catlow valleys also lie in basins that seem to be shallow synclinal troughs. The structure of the Catlow basin is not so clear as that of Whitehorse and Harney valleys, for an escarpment borders its eastern side, which in its highest portion rises 1,400 feet above the plain, while another cliff 400 feet high extends for several miles along the northeastern end of the valley. These escarpments are thought to have been produced by erosion and weathering rather than by faulting, however, and the reasons for this assumption are given later in the discussion of Catlow Valley (p. 68). The upper part of the course of Donner und Blitzen River has been mentioned by Russell[a] as being in a plunging synclinal trough. Along the middle course of this river, between the P ranch and the Buena Vista ranch, this fold seems to develop into a fault, for an escarpment that attains a height of over 1,000 feet forms the western side of the valley. Northward this scarp dies out in the nearly horizontal beds of the plateau land. An escarpment that borders the eastern side of Warner Valley exceeds a height of 2,000 feet for a great part of its length, and is very probably the face of a fault block.

Not all the scarps of the Harney basin region are of fault origin, however. Those of Catlow Valley have been mentioned as probably the results of erosional forces, and Harney Valley is bordered in part by scarps 100 to 400 feet high, which are evidently due to such agencies. In this connection it may be stated that the rocks dip gently away from the scarps of Steens Mountain, of Warner Valley, and of Donner und Blitzen River, which have almost undoubtedly been produced by faulting, while the dip is toward the escarpments bordering Catlow and Harney valleys. It is not to be understood that this is a distinctive difference between scarps of erosional and those of fault origin, but it is characteristic of the tilted block structure.

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[a] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: Bull. U. S. Geol. Survey No. 217, 1903, p. 15.

On the northern side of the canyon of Trout Creek, from about 2 miles west of Flagstaff Butte to the mouth of the canyon, there is exposed a thickness of several hundred feet of greenish rhyolite, while the hills south of the creek are mainly basaltic. This fact, taken together with the attitude of the rocks, suggests that there has been some faulting along the course of this canyon, although there are no marked topographic features to confirm the suggestion.

The mountains north and northwest of Harney Valley are anticlinal in structure, as are other smaller uplifted masses in the area examined. All the minor features that have been mentioned, however, are subsidiary to the two great structures that dominate the deformation in southeastern Oregon, namely the Steens Mountain uplift and the wide shallow depression of the Harney basin.

The structure is shown in a general way on the geologic map (Pl. III) by heavy black lines that follow the major faults, and by red lines along the axes of the principal folds that were noticed. There are also dip symbols indicating the general inclination of the lava beds in other portions.

PHYSIOGRAPHY.

TOPOGRAPHIC CHANGES.

Concerning the surface of this country previous to the outpouring of lava that spread over southern Oregon and adjacent portions of Idaho and Nevada, it is known only in a very general way that it was carved into mountains and valleys that formed a well-developed topography. The floods of Miocene lava buried this preexisting topography hundreds and in places thousands of feet deep, and filled up canyons and valleys; so that at the cessation of the period of greatest volcanic activity the surface was that of a vast, nearly level plateau. Farther north the Strawberry Mountains and other large uplifted masses were surrounded but probably not buried by the lava, and still gave some diversity to the surface. Within the southern portion, however, only a few isolated peaks, such as Iron Mountain and Flagstaff Butte, were left projecting above the otherwise slightly undulating surface.

DEFORMATION.

At a later time earth movements began that resulted in the uplift of the Cascade Mountains. Although this range is 150 or 200 miles west of Harney County, the forces that produced it were felt at this distance, and disturbed the relatively level surface. In some places low ridges and shallow basins were produced, while in others the plateau surface was broken into great blocks, having their long axes extending in general from north to south. By unequal subsidence in some places and by uplift in others these were tilted and now form elėvations having an escarpment on one side and a gentle slope on the other. From its extensive development in the Great Basin, and since its study by Gilbert and Russell, this has become known as the basin-range type of structure. Within the area covered by this report, the escarpments of Steens Mountain, of Donner und Blitzen River, and of Warner Valley have been said to be probably of this origin. Aside from these three major fault lines the present topography seems to have been produced mainly by gentle deformation, which produced the Harney basin and other smaller areas of depression, and by low upfolding, which formed the hills to the north and northwest.

PRESERVATION OF LATER TOPOGRAPHY.

The main features of the topography that resulted from this deformation still exist comparatively unmodified. The escarpments are still clear cut, the gentler slopes are dip slopes, and the minor folds are little altered by erosion. The plateau areas indeed appear to be approximately the original surface so far as removal of material by erosion is concerned. This unmodified condition indicates that deformation can not have taken place very long ago, geologically speaking, else weathering and erosion would have succeeded in wearing down the slopes more than they have, for the rainfall was greater during the Pleistocene epoch than it is at present; hence within geologically recent times the erosive action has been much greater than it is at the present day. It would even seem that slight movements have continued nearly to the present time, if a small scarp in the alluvium at the west edge of Alvord Desert be considered a fault scarp.[a]

EROSIONAL AGENCIES.

STREAM ACTION.

The work of erosion has nevertheless carved prominent though secondary topographic forms in the mountains and plateaus. In the higher portions of Steens Mountain, where rain and snow are more abundant than in the lower land, deep gorges have been formed. It is by such stream action that the notches have been cut through which Home Creek, Threemile Creek, and Skull Creek descend from the higher to the lower plateau; that the gorge of the northern branch of Donner und Blitzen River has been formed; and to a certain extent, also, that the precipitous canyons on the eastern face of Steins Mountain have been eroded.

A minor feature that was noticed along several streams is perhaps best exhibited on Smith Creek, where a number of meadows have been formed along its course, which are separated by small gorges

[a] Russell, I. C., A geological reconnaissance in southern Oregon: Fourth Ann. Rept. U. S. Geol. Survey, 1884, p. 445.

that have been cut through low basalt folds. These folds are transverse to the stream course, and it seems as if they have been produced since the establishment of the drainage line, and that the stream has cut down through them as they rose, but not rapidly enough to keep its channel cut to grade. The checking of the water and the consequent deposition of silt behind the low barriers produced the present stretches of meadow land.

GLACIATION.

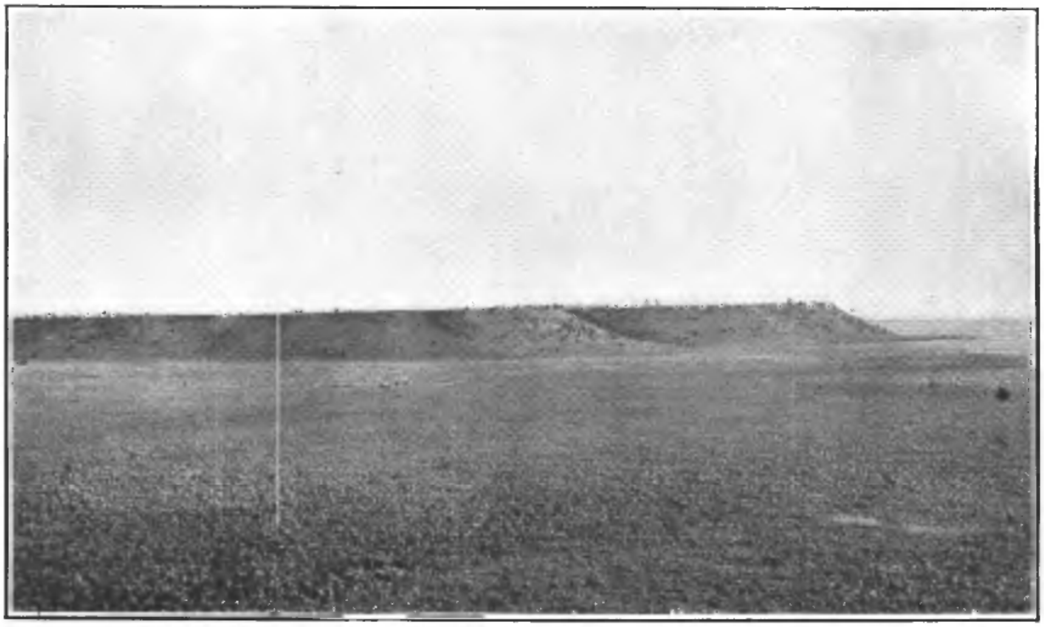
In the highest part of Steens Mountain there is some evidence in the topographic forms that there has been a small amount of glaciation. The gorge of Kieger Creek in its upper 4 or 5 miles is 1,500 feet or more in depth, somewhat U-shaped in section, with small hanging valleys on its western side; and it heads in a deep cirque nearly half a mile across. Beneath the north-facing cliffs there are snow banks that remain throughout the year. In one of his later papers Russell gives a detailed description of this gorge and discusses its possible origin by ice action. Concerning it he says: [a]

> Kieger Canyon is prolonged for some 20 miles below the locality where the lowest evidence of glaciation is discernible, and is not floored with coarse débris, such as occurs downstream from the extremities of existing valley glaciers. No alluvial terraces are present to show that conspicuous variations in the load of Kieger Creek have occurred, such as are present in many valleys which have held glaciers in their higher tracts. There are no recognizable terminal moraines anywhere in the canyon and almost a complete absence of lateral moraines. The evidence of the former presence of a glacier in the upper end of the canyon is furnished principally by a noticeable increase of width in the portion formerly occupied by ice and a change from nearly vertical walls to a U-shaped cross profile. * * * The facts presented by Kieger Canyon * * * are consistent with the idea that a deep water-cut trench existed before the glaciers from the south entered it, and that it has experienced what may be termed a "small degree of glacial erosion." This conclusion finds support also in the fact that, so far as has been discovered, none of the other canyons on the Steen Mountains show evidence of glaciation. Kieger Canyon stands in the highest portion of the upturned block in which it has been excavated, but the advantages thus assured in reference to snow accumulation are not conspicuous. Seemingly the conditions were so delicately adjusted that a glacier was formed at the head of Kieger Canyon, but not in the neighboring canyons. This condition of delicate adjustment of elevation and topographic conditions to the climate of the region is now manifest by the presence of perennial snow banks in the shelter of northward-facing cliffs on the border of Kieger Canyon and their absence on the borders of the neighboring canyons.

WEATHERING.

The processes of weathering and decay have been efficient in forming many escarpments, especially along the valley borders. It is thought that the bluffs back of Harney and the escarpments of Wrights Point and of Windy Point are of such origin. In these scarps the forms produced by the weathering of nearly horizontal beds overlying softer tuffs is ideally developed. In Plate IV, *A*, is

[a] Russell, I. C., Hanging valleys: Bull. Geol. Soc. America, vol. 16, Feb., 1905, pp. 84-85.



A. CHARACTERISTIC SCARP AT WEST EDGE OF HARNEY VALLEY.

B. VALLEY OF RATTLESNAKE CREEK ABOVE HARNEY.

shown a portion of the scarp about 8 miles west of Wrights Point, in which the abrupt transition from level alluvial valley land to flat rocky plateau is well exhibited.

Within the Harney basin the channels of several streams are intrenched between escarpments that seem to be as much the result of weathering as of direct stream cutting. Of such character are the courses of Silvies River above Burns, of Kieger Creek for 6 miles above Diamond, of Rattlesnake Creek near Harney, and of Camp Creek from near Malheur Cave to the valley of South Fork of Malheur River. Low grades and the consequent formation of strips of meadow land that extend far up their courses are also characteristic of these streams. The meadow along the course of Rattlesnake Creek is shown in Plate IV, *B*. It may be that such a strip of meadow is the result of the cutting of the stream nearly to its base level, the level of Harney and Malheur lakes; but in some respects this feature resembles that produced by the drowning of stream mouths. Russell[a] has shown that Silvies River formerly flowed through Malheur Gap and thence to Malheur River. A flow of basalt, probably during the Pleistocene epoch, certainly since the formation of the Harney basin, closed this outlet, produced a great shallow lake, and allowed the basin to be silted up. This may have been the cause of a reduction of the stream grades and the formation of the present meadow lands.

LAKES.

The lakes of southeastern Oregon are very good examples of the dependence of such bodies on the climate for their existence. During the Pleistocene epoch the basins that were produced by earlier deformation of the lavas were occupied by water bodies many of which have left evidence of their extent in slight terraces or water lines along the valley sides. No less than four well-marked and two fainter lines on the eastern side of Alvord Valley show that a lake of varying size once occupied it, and that the water attained a maximum depth of over 100 feet above the present valley floor.[b] In Catlow Valley three well-marked water lines persist along the entire eastern side of the basin and show that water to a depth of over 75 feet once covered it. In the basin of Warner Lake similar high-water marks are to be seen. Even in the small basin of Juniper Lake there are two shore lines, respectively about 30 and 60 feet above the present lake surface. In the largest basin, that of Harney and Malheur lakes, no such record is noticeable, probably because of the shallowness of the ancient lake; but the character of the deposits throughout its extent shows unmistakably that they are of lacustrine origin.

[a] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: Bull. U. S. Geol. Survey No. 217, 1903, p. 22.

[b] In the Fourth Ann. Rept. U. S. Geol. Survey, 1884 (p. 459), Russell assigns a depth of 400 feet to the former lake in this valley, but the evidence for it is not given.

In regions where precipitation is ample to supply the losses by evaporation and possible leakage a lake is a fairly permanent feature; where the balance between gain and loss swings now to one side, now to the other, the lake area fluctuates; and where the annual supply does not equal the loss, only playas or intermittent lakes can exist.

In this region Harney Lake is the best example of a water body where the first-named conditions obtain, partly because it occupies a deeper basin than the others, where evaporation does not cause so marked changes in area, and partly because it draws upon its neighboring lake to supply its own losses. For this latter reason Malheur Lake is an exceptionally good example of a fluctuating water body, for its area is affected not only by the evaporation from its own surface, but from that of Harney Lake as well. Since its shores slope very gently the seasonal variation of its surface causes marked change in its extent. Warner Lake is also a fluctuating one; though if evidence is correct that has been advanced in lawsuits over land acquired in its valley under the terms of the swamp-land act, this water body, which is broken into a number of lakes during the summer time, has been shrinking during late years. Alvord Desert is the largest of the many playas or beds of temporary lakes in this region. In summer it is a dry, barren area; in winter and early spring the melting snow and the water from the adjacent slopes render it a slippery mud flat. During wet years it receives overflow water from Alvord Lake. In the spring of 1882 it is said to have been thus covered to a depth of 7 inches.

SURFACE WATER.

DIVISIONS.

The portion of southeastern Oregon that is shown on the reconnaissance map (Pl. II) may be divided into eight hydrographic basins or drainage areas, if the central plateau region of indefinite drainage, in which there are many small depressions that contain playas, be considered in this respect as a drainage area. In discussing the surface-water supply, the streams and springs of each basin will be taken up in turn, and on pages 39–41 the stream measurements that were made during the field work are tabulated according to their several drainage basins. The discharges of Silvies River and Silver Creek, which were computed from records obtained at the official gaging stations, are given on pages 31 and 34, respectively.

HARNEY BASIN.

AREA AND EXTENT.

The Harney drainage basin comprises about half the area of Harney County, and extends from the south end of Steens Mountain northward to the base of the Strawberry Mountains, in Grant

County. On the east its limit is well marked by hilly divides, but in the plateau to the west and southwest its boundary is not so definite. From the northern timbered portion of the county there is considerable run-off; in the south, too, the slopes of Steens Mountain supply a number of streams. The central portion is occupied by Harney Valley, a wide, flat area in which lie Malheur and Harney lakes, and into these the greater part of the drainage of Harney County discharges.

STREAMS.

Silvies River, one of the main streams of this basin, has its source in streams that rise at the base of the Strawberry Mountains, just south of the divide that at this point marks the northern limit of the Great Basin and the beginning of drainage to John Day River. Emigrant Creek, which drains a part of the mountains northwest of Burns, joins Silvies River about 15 miles above this town. Throughout most of its course the river is a sluggish stream. Between Bear Creek Valley and Silvies Valley, and also at the lower end of the latter valley, it cuts through several miles of rocky canyon; but within the valleys it forms wide areas of meadow land. In its lower course, in the vicinity of Lawen, the water reaches Malheur Lake through a number of sloughs and drainage canals. From May 10, 1903, until July 24, 1906, daily gage readings were recorded on this stream at two stations under direction of the U. S. Geological Survey. The upper station was near Silvies, above the mouth of Emigrant Creek. At the lower station, near Burns, the total flow of the stream was recorded. The monthly discharge, estimated from the records that were obtained at this station, is tabulated below.

Estimated monthly discharge of Silvies River, near Burns, Oreg.

[Station established May 10, 1903; discontinued July 24, 1906. Figures give total flow in acre-feet.]

Month.	1903.[a]	1904.[b]	1905.[c]	1906.[d]
January	....	1,476	[e] 1,608	1,320
February	....	16,390	[f] 500	1,370
March	....	48,640	....	4,770
April	....	146,400	[g] 17,800	75,000
May	[h] 13,702	64,990	12,600	25,600
June	6,010	12,560	4,391	25,500
July	1,414	3,080	1,408	[i] 3,130
August	492	1,347	627	....
September	[j] 129	970	542	....
October	246	1,857	861	....
November	2,321	1,964	1,101	....
December	[k] 1,031	1,888	965	....
	....	301,600	....	....

[a] From Water-Supply Paper U. S. Geol. Survey No. 100, 1904, p. 433.
[b] From Water-Supply Paper U. S. Geol. Survey No. 133, 1905, p. 351.
[c] From Water-Supply Paper U. S. Geol. Survey No. 176, 1906, p. 124.
[d] From Water-Supply Paper U. S. Geol. Survey No. 212, 1908, p. 83.
[e] For 17 days.
[f] February 1 to 6, inclusive.
[g] April 9 to 30, inclusive.
[h] May 10 to 31, inclusive.
[i] July 1 to 24, inclusive.
[j] September 1 to 12, and 17.
[k] December 1 to 26, inclusive.

On the south side of the Harney basin a number of streams rise in Steens Mountain and flow toward Malheur Lake. Nearly all of these are tributary to the trunk stream, Donner und Blitzen River, though much of their water sinks in the marsh of the lowlands before reaching that river. The streams will be mentioned in order, beginning at the south and proceeding northward.

Donner und Blitzen River, the largest of the Steens Mountain streams, and the one to which the others are tributary, rises in the southern part of this great block, and after flowing in a direct course northwestward for 25 or 30 miles enters the lowland near the P ranch. Thence it continues as a sluggish stream, in some places through a number of sloughlike channels, the remaining 30 miles or more to Malheur Lake. No records of its flow have been kept, but a careful float measurement that was made in August, 1907, at a point about $1\frac{1}{4}$ miles above the P ranch and one-fourth mile above the mouth of its canyon, before its water enters the marsh land, indicated a discharge of approximately 45 second-feet. When compared with the discharge of Silvies River above Burns during the same month, this measurement indicates that Donner und Blitzen River is much the larger stream at that season of the year; though it may be that it reaches its greatest flow later than Silvies River. In its lower portion the current of Donner und Blitzen River is too sluggish to admit of even approximate float measurement, but about 5 miles above the point where it is joined by Kieger Creek, a stream that brings considerable water from the southeast, a rough weir measurement indicated a flow of about 55 second-feet, or somewhat less than the sum of the flow near the P ranch and that of the two tributary streams, Bridge and Krumbo creeks.

Mud Creek rises near the crest of Steens Mountain, north of the upper branches of Donner und Blitzen River. Near the head of its drainage basin its channel is not well established, and there are several small lakes and marshy glades. The upper course of the stream lies along a narrow swale that is lightly timbered with cottonwoods, but below the lower limit of these trees, which is at an elevation of about 6,000 feet, the stream has cut a gorge in the basalt slopes. Through this it continues westward to the marsh of Donner und Blitzen River. It is not a large stream, for although it flows from the higher lands it has few tributaries. During the summer its upper course is nearly dry, while at its entrance to the marsh land the flow is only 10 or 15 miner's inches.

Bridge Creek joins Mud Creek at the edge of the marsh land along Donner und Blitzen River. It is only a few miles in length, and its grassy bottom and large flow, about 12 second-feet, indicate that it is supplied by constant springs of large volume. A couple of miles north of this creek springs rise that yield a flow of 80 or 90 miner's inches, but the water barely reaches the edge of the marsh.

There is a wide stream channel 3 miles north of Bridge Creek, but it was dry in August, 1907, and seemed mainly a flood-water channel.

Krumbo Creek, at the point where the road between the Diamond ranch and the P ranch crosses it, was carrying about 5½ second-feet of water in August, 1907. Above this point its canyon is narrow and is cut perhaps 100 feet below the plateau surface; below where the road crosses it, the stream flows through meadow land to the marsh of Donner und Blitzen River. This creek also probably is supplied largely by springs, for its drainage area does not warrant so great a summer flow.

McCoy Creek rises near the head of Mud Creek, in a wide swale, and flows north and northwest in a well-developed canyon to the foot of the mountain slope. In its upper portion this canyon is 300 to 500 feet deep. It has steep but not precipitous sides, and cottonwoods grow along the banks of the creek. In its lower portion the canyon walls are cliffs not much over 100 feet in height, between which the stream flows in a flat-bottomed meadow 100 yards wide. Through this it maintains a fair grade until it reaches the marsh land. Along the sides of its canyon numerous springs rise and materially increase the flow of the creek. The discharge of McCoy Creek, when roughly measured in August, 1907, about 2 miles above the Diamond ranch, was about 3½ second-feet.

Cucamonga Creek lies upon the strip of plateau between the nearly parallel canyons of McCoy and Kieger creeks. For most of its length its channel follows a wide gentle swale, but about 4 miles above the Diamond ranch it has cut down into the rocks and drops 300 feet in less than a mile. Thence it meanders to the marsh through meadow land bordered by cliffs. Its summer flow is small, being only 10 or 15 miner's inches.

The upper course of Kieger Creek, the next stream to the north, has been well described by Russell, whose words are quoted on page 28. From the junction of the two branches of this creek, 6 miles above Diamond, to the open marsh, the stream meanders along a channel thickly overhung with willows and other water-loving bushes, through a strip of meadow similar to that of McCoy and Cucamonga creeks. Its measured summer flow was about 9 second-feet.

Swamp Creek, near Diamond, is a small stream that flows during only a part of the year. In summer it is dry along its lower course, but water is usually to be found in its upper portion.

The last four streams that have been mentioned enter the marsh land that extends southeastward to Diamond, and flow through it

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in several natural channels and in drainage canals to join Donner und Blitzen River.

Smith Creek and Riddle Creek unite in Happy Valley, which is 8 or 9 miles northeast of Diamond, and flow northward and westward to Barton Lake. This lake is a long narrow water body that was probably formed by the damming of the stream course by the lava from Diamond Craters. The lake varies much in size with the season, and while there is no present surface outlet, the spring overflow water is locally believed to reach Malheur Lake through an underground channel. A deep crack in the basalt, a foot or two in width at the surface, at the western high-water line of the lake is locally considered to be the entrance to this channel. The summer flow of the two streams that unite to supply this lake varies with the amount of water that is taken out for irrigation along their upper courses. In August, 1907, the flow at the wagon bridge a mile east of Barton Lake was about 60 miner's inches, but in October the flow was only about half this amount.

Silver Creek is the larger of the two streams that enter Harney Valley on its western side. It drains the southwestern slopes of the mountains north of Riley. After emerging from its canyon approximately 15 miles above this place, it flows in a general southeasterly course to Harney Lake. Within its canyon it is a perennial stream of considerable flow, but it usually becomes dry below Riley, in early summer. From the head of the valley of Silver Creek to Harney Lake, its channel has a gentle grade and extends through alluvial land nearly the entire distance. During 1904 and parts of 1905 and 1906, daily gage readings were noted on this stream near the mouth of its canyon, under the direction of the U. S. Geological Survey. The monthly discharge as computed from these readings is tabulated below.

Estimated monthly discharge of Silver Creek near Riley, Oreg.

[Station established April 19, 1904; discontinued July 14, 1906. Figures give total flow in acre-feet.]

Month.	[a] 1904.	[b] 1905.	[c] 1906.
January	615	3,616	....
February	1,150	2,327	2,150
March	27,670	7,870	5,690
April	55,640	6,545	25,900
May	12,670	3,136	5,070
June	2,303	922	7,320
July	3,333	....	[d] 805
August	357	....	....
September	155	....	....
October	141	....	....
November	369	....	....
December	885	....	....
	105,300	....	....

[a] From Water-Supply Paper U. S. Geol. Survey No. 133, 1905, p. 354. Discharge estimated January 1 to April 14 and July 17 to September 9, inclusive. During latter part of year, gage heights estimated for missing days.

[b] From Water-Supply Paper U. S. Geol. Survey No. 176, 1906, p. 127. Records fragmentary after July 8, as there was no regular observer. Creek was dry in August, September, and the greater part of July.

[c] From Water-Supply Paper U. S. Geol. Survey No. 212, 1906, p. 85.

[d] July 1 to 14, inclusive.

The spring flood water from this creek spreads over and irrigates many acres of natural hay land along its lower course, and also supplies Silver Lake.

Sagehen Creek, the other stream that enters Harney Valley from the west, joins West Fork of Silvies River about 8 miles south of Burns. Its summer supply comes mainly from springs that rise along lower Cold Spring Creek and in the marsh land below the mouth of this stream. Through this saturated ground Sagehen Creek is a sluggish stream of which no satisfactory measurement could be made. In the lower portion of Willow Creek, a tributary to its upper course, a little water was standing during the summer of 1907, but there was no appreciable flow.

Along the northern and eastern sides of Harney Valley there are a number of small streams that flow during only a part of the year. Of these, Rattlesnake Creek, just east of Harney, is the largest. Its bed was dry near Harney in August, 1907, but 3 miles above this town it was flowing about 20 miner's inches.

SPRINGS.

Within Harney Valley there are a number of springs that from their size and the constancy of their flow may properly be mentioned here. Of these, the springs in Warm Spring Valley, at and near the Double O ranch, have by far the greatest flow. Eight springs rise in this lowland west of Harney Lake, the six largest of which issue at the base of bluffs that border the south edge of the valley. Their water is noticeably warmer than that of the shallow wells of the region. The combined flow of the largest springs, which are near the Double O ranch house, is 25 or 30 second-feet. The character of these springs and their significance in respect to underground water conditions will be discussed in speaking of artesian possibilities in the Harney basin.

At Sodhouse, 6 miles east of Narrows, there is a spring similar to the springs of Warm Spring Valley. The water issues at the base of a low hill, where it forms a pool about 75 yards across, and joins Donner und Blitzen River in the marsh land bordering Malheur Lake. An approximate summation of the flow from the many small streams that issue around the border of this pool is 100 miner's inches, while several springs that rise within it probably increase the total flow to twice or three times this amount.

Springs similar to those just described issue at two points from the base of a hill about 3 miles south of Burns. From these two localities a constant flow of about 30 miner's inches is supplied to the marsh land. Of like character are the springs along Sagehen Creek, which have already been mentioned. These rise in the marsh land of its lower course and greatly increase the flow of the stream.

CATLOW BASIN.

STREAMS.

In the southern portion of the plateau lying southwest of the Harney basin the run-off water drains toward Catlow Valley, as the lowest portion of the basin in the southern part of the county is called. The longest stream channel within the Catlow basin is that of Rock Creek, which rises at the northern base of Warner Mountain and flows northeastward. Water flows to the sink of this stream only until early summer. In September, 1907, a flow of 20 or 25 miner's inches reached Steve Young's, on its upper course, near where the road to Plush crosses the creek, but below this point there were only a few pools along its channel.

On the east side of the basin three streams, Home, Threemile, and Skull creeks, which rise in the slopes of Steens Mountain, flow westward to the valley land, in which their waters sink. The two former supply a shallow lake that lies well out on the valley floor.

SPRINGS.

At Roaring Springs ranch, on the east side of the basin, a constant flow of water issues from a number of springs part way up the bluff, and irrigates the meadow it has produced on the edge of the lowland. A number of similar springs, but of smaller flow, have formed another patch of meadow land farther south, at the HL ranch.

The total summer flow of the three creeks and two groups of springs on this side of the valley is between 15 and 20 second-feet. The discharge of the several streams is given on page 40.

ALVORD BASIN.

STREAMS.

For convenience in discussing its drainage the great sunken area that extends along the eastern base of Steens Mountain will be termed the Alvord basin. This consists of several minor lake basins, but structurally it is a single depression or basin.

In the Alvord basin a number of small streams that are supplied by melting snow from Steens Mountain cascade down its escarpment to the lowland. The largest quantity of water, however, comes from the southeast through Trout Creek, which furnishes the main supply of Alvord Lake. This stream rises near the southeastern corner of Harney County, and drains a considerable area of upland in the Whitehorse Mountains and Trout Creek Hills, which furnish it a perennial supply. There are two smaller lake basins, those of Juniper and Mann lakes, which also lie within the Alvord basin, but are separated from the drainage to Alvord Lake by low alluvial divides. Mann

Lake receives its supply principally from the mountain stream entering its southern end, while Juniper Lake is supplied chiefly by a similar stream that enters it from the north.

SPRINGS.

Within the Alvord basin there are three springs whose flow is sufficient to warrant mention in connection with the surface water supply. The largest of these is a hot spring at the borax works south of Alvord Lake. Here a pool about 275 yards in diameter has been formed around several vents at this place, and a nearly constant flow of about 100 miner's inches is discharged through a ditch on its western edge. From one-quarter to one-half mile north of the borax works there are a number of other hot springs, which yield a considerable supply of water, but one whose quantity is hard to determine, for there is no well-defined stream channel, but rather a series of pools from which the water rapidly sinks again into the alluvium. On the western edge of Alvord Desert there is another hot spring, which yields about 15 miner's inches. The third and perhaps the most valuable spring in this basin, because of the quality of its water and its favorable location for purposes of irrigation, is that near Serrano Point, southeast of Andrews, on the ranch of Mr. A. C. Bustamante. This yields a constant flow of about 25 miner's inches of water.

WHITEHORSE BASIN.

On the southeastern edge of Harney County, east of the Alvord basin, there is a shallow basin in which lie Willow and Whitehorse creeks. Both of these streams rise in the Whitehorse Hills and flow in a direct course northward to their common sink. Willow Creek is much the larger, having a flow of about 70 miner's inches in September, 1907, while Whitehorse Creek at this time carried only about 10 inches.

MALHEUR RIVER DRAINAGE.

The mountains east of the Harney basin are drained by a number of small intermittent streams that are tributary to Malheur River. Crane Creek is the largest of these, and to it the other streams of this part of the watershed are tributary. In its lower portion it is known as South Fork of Malheur River. It rises near the eastern edge of the Harney basin, flows south, then swings through an easterly to a northerly course, and joins Middle Fork of Malheur River near Riverside. In August, 1907, Crane Creek was dry in the valley of its upper course, but about 5 miles below this valley a stream of 5 or 10 miner's inches was flowing. All of its tributaries were dry or nearly so in their lower courses. The area that is drained by Camp and Indian creeks is tributary to Crane Creek, but during the summer there is no surface accession to the latter stream from this southern area. The flow of the two streams is consumed in irrigating a belt of hay land between their junction and Venator post-office.

The main summer supply to South Fork of Malheur River is from several springs that rise close to its banks. The largest of these is at Mr. Chris Dennean's, about a mile above the mouth of Coleman Creek, where a large spring rises within a few yards of the river channel. A careful float measurement of the stream flowing from it indicated a discharge of nearly 200 miner's inches. Near this spring two small flows issue from the opposite bank of the river, while a few hundred yards downstream another spring contributes about 25 miner's inches. Near the mouth of Swamp Creek two similar springs add 30 or 40 inches more to the flow of the river. Perhaps 7 or 8 second-feet represents the approximate summer flow of South Fork of Malheur River, where it turns eastward and crosses the county line.

WARNER LAKE DRAINAGE.

In the portion of the Warner Lake basin included in the area mapped on Plate II there are no perennial streams. Mule Spring is an old well dug in the dry bed of a canyon, near the northern end of this basin, along a former military route. From its neighborhood a flood-water channel trends southward to the lake. Other similar channels carry part of the spring run-off from this region, but during the later months of the year water is lacking over most of the basin

PLATEAU REGION.

In the area lying between Harney and Warner lakes, which may be termed the plateau region, the drainage is only slightly developed. There are no perennial streams and few well-defined water courses within it. A wide coulee-like depression, along which the road passes between Buzzard Canyon and Mule Spring, contains a succession of playas that are collecting basins for the melting snow and the scanty rainfall, but no well-defined drainage channel has been cut along its bottom. Buzzard Canyon contains a more definite channel, which is tributary to Harney Valley, and during the spring run-off it carries some water to the alkaline flat east of Iron Mountain. For the most part, however, the drainage of this plateau is separated into a number of small basins such as that in the lowest part of which Walls Lake is situated.

GUANO LAKE BASIN.

The valley of Guano Lake was not visited by the writer, and little can here be said of its drainage except that Warner Creek, which rises near Warner Mountain, is the principal stream of the basin, and that this stream is dry in its lower course during the summer months.

TABLES OF FLOW.

The streams and springs that were visited and measured during the reconnaissance have been tabulated below, that some idea may be obtained of their relative size and of the amount of water that is available. These are but single measurements, mostly rough approximations by the float method, and were made at a season when many of the steams are at their lowest stage; but in the absence of better data they are all that can be presented at this time in regard to the surface water supply of the region. The discharges of Silvies River and Silver Creek, the only two streams on which systematic measurements have been made, are given in an earlier part of this paper (pp. 31, 34). The locations of the several springs, and the points at which the streams were measured, are shown on Plate III.

Estimates of flow in the Harney basin region, Oregon, during the summer of 1907.

HARNEY BASIN.

Number.[a]	Date, 1907.		Temperature.	Discharge.	
				Second-feet.	Miner's inches.[b]
		STREAMS.	° F.		
101	August 3	Rattlesnake Creek, 3 miles above Harney	....	0.4	20
102	August 26	Smith Creek, at wagon bridge, 1 mile east of Barton Lake.	....	1.2	60
103	November 1	Donner und Blitzen River, 3 miles south of Buena Vista ranch.	....	55	2,750
104	August 28	Donner und Blitzen River, 1¼ miles above the P ranch.	....	45	2,250
105	August 30	Mud Creek, near mouth of canyon	....	.3	15
106	....do	Bridge Creek, at mouth of canyon	....	12	600
107	August 27	Krumbo Creek, at road crossing	....	5.5	275
108	....do	McCoy Creek, 2 miles above Diamond ranch	....	3.5	175
109	August 25	Cucamonga Creek, at head of its meadow	....	.3	15
110	August 24	Kieger Creek, 1 mile above Diamond	....	9	450
		SPRINGS.			
201	August 16	3½ miles northwest of Burns	52	....	1
202	....do	1 mile west of Burns (M. L. Lewis, owner)	56	....	2
203	August 17	3 miles south of Burns	78 to 80	.2	10
204	....do	3¼ miles south of Burns	78	.4	20
205	....	Along Sagehen Creek	....	c 2	c 100
206	August 13	2 miles north of Harriman	d 122	.4	20
207	August 5	North side of Crane Creek Gap	....	....	1±
208	August 18	Sec. 29, T. 25 S., R. 31 E.; developed spring (Mr. Newell, owner).	....	....	1
209	August 17	Sec. 7, T. 25 S., R. 31 E. (developed)	52	....	No flow
210	August 18	4 miles west of Dog Mountain (Mr. Weaver, owner).	51	....	2
211	July 28	At southern edge of Silver Lake	68	.1	5±
212	....do	3½ miles east of Iron Mountain	68	....	1±
213	July 29	3 miles northwest of the Double O ranch	....	....	1±
214	August 20	At the Sodhouse, 6 miles east of Narrows	53 to 56	4 or 5	200 or 250
215	July 29	½ mile northwest of the Double O ranch	56	c .6 or .8	c 30 or 40
216	July 30	1 mile west of the Double O ranch	69	12.5	625
217	July 29	½ mile northeast of the Double O ranch (sum of flow of two canals).	72	20	1,000
218	....do	1 mile southeast of the Double O ranch	67 to 73	4	200
219	....do	1¾ miles southeast of the Double O ranch	72	2	100
220	....do	2½ miles southeast of the Double O ranch	....	.1 or .2	5 or 10

a These numbers correspond to the numbers on Plate III.
b The miner's inch used here is 9 gallons a minute, or $\frac{1}{50}$ second-foot.
c Estimated.
d This is the temperature given by Russell, Bull. U. S. Geol. Survey No. 252, p. 41.

Estimates of flow in the Harney basin region, Oregon, during the summer of 1907—Con.

HARNEY BASIN—Continued.

Number.	Date, 1907.		Temperature.	Discharge.	
				Second-feet.	Miner's inches.
		SPRINGS—continued.	° F.		
221	July 29	3 miles southeast of the Double O ranch	68	0.5	25
222	do	4 miles southeast of the Double O ranch		.9	45
223	August 19	½ mile southeast of Harney Lake	134 to 150	.4	20
224	do	At east edge of Mud Lake	65		1
225	September 16	At west edge of lava from Diamond Craters			1±
226	July —	Buzzard Spring, in plateau southeast of Harney Lake.		[a] .3	[a] 15
227	November 1	5 miles north of the P ranch	78	4	200
228	August 27	4 miles northeast of the P ranch		1.4	70
229	do	1 mile northeast of the P ranch	83		2
230	August 28	1 mile southwest of the P ranch	89	.4 or .6	20 or 30
231	August 30	At lake near summit of Steens Mountain		.1	5

CATLOW BASIN.

		STREAMS.			
111	September 3	Rock Creek, at Steve Young's		0.5	25
112	September 1	Home Creek, at mouth of canyon		3	150
113	September 6	Threemile Creek, at road crossing		4.5	225
114	October 30	Skull Creek, near road crossing		5	250
		SPRINGS.			
232	August 31	Roaring Springs, at Roaring Springs ranch; total flow of numerous springs.	59	5	250
233	September 3	On upper Rock Creek	105 to 115	.1 or .2	5 or 10
234		At Beattys Butte; five small springs		[b] .1 or .2	5 or 10
235	September 6	Near HL ranch; ten small springs		.5	25

ALVORD BASIN.

		STREAMS.			
115	September 14	2 miles north of Juniper Lake		0.3	15
116	do	4 miles south of Juniper Lake			3
117	do	4 miles north of Mann Lake		.1	5
118	do	1¼ miles north of F. Miranda's		.4	20
119	do	At F. Miranda's		.6	30
120	September 13	1 mile west of the Alvord ranch		2	100
121	September 12	2 miles south of the Alvord ranch		.2	10
122	do	4 miles south of the Alvord ranch			3
123	do	2 miles north of Andrews		.3	15
124	do	Wildhorse Creek, 2 miles north of Andrews		.3	15
125	September 9	Trout Creek, [c] at mouth of canyon		1.3	65
126	September 8	Mineral Creek, ¼ mile west of Denio		.1 or .2	5 or 10
		SPRINGS.			
236	September 14	Near divide on road between Juniper Lake and Mule ranch ("Summit Spring").			¼+
237	September 12	3 miles south of the Alvord ranch (boxed and used as domestic supply).	56		No flow.
238	do	At west edge of Alvord Desert	168 to 177	.3	15
239	September 11	2½ miles southeast of Andrews (Mr. A. C. Bustamante, owner).	56	.5	25
240	September 7	¼ to ½ mile north of the borax works	([d])	([e])	([e])
241	do	At borax works	82 to 97(?)	2	100
242	October 29	At roadside, near divide between Alvord and Catlow valleys.	55		2
243	October 27	On north side of Trout Creek, ½ mile below mouth of Little Trout Creek.	128	1	5

[a] From statement of F. M. Anderson, geologist.
[b] Reported.
[c] A measurement on June 15, 1907, near the Trout Creek ranch, is said to have shown a flow of 2,200 miner's inches.
[d] Near the boiling point.
[e] Not measurable.

Estimates of flow in the Harney basin region, Oregon, during the summer of 1907—Con.

WHITEHORSE BASIN.

Number.	Date, 1907.		Temperature.	Discharge. Second-feet.	Discharge. Miner's inches.
		STREAMS.	°F.		
127	September 10	Willow Creek, at road crossing		1.4	70
128	do	Whitehorse Creek, at road crossing		.2	10
		SPRINGS.			
244	do	5 miles northeast of Flagstaff Butte (seeping springs)			2 or 3
245	do	½ mile east of No. 244	96 to 100		3 or 4

MALHEUR RIVER DRAINAGE.

Number.	Date, 1907.		Temperature.	Second-feet.	Miner's inches.
		STREAMS.			
129	August 5	Crane Creek, 2 miles below mouth of Gorman Creek		0.2	10
		SPRINGS.			
246	August 7	Warm Spring Valley, sec. 23, T. 22 S., R. 36 E	138 to 144	.2	10
247	August 6	Sec. 2, T. 25 S., R. 36 E. (Chris Dennean, owner)	58	4	200
248	do	¼ mile east of No. 247	58	.5	25
249	August 8	2¼ miles southwest of No. 247 (seeping springs)	104 to 108	.2	10
250	August 6	Near mouth of Swamp Creek		.6 or .8	30 or 40
251	August 5	On north side of Crane Creek canyon			1+
252	do	On west edge of Crane Creek valley			1+
253	do	Sec. 10, T. 25 S., R. 34 E. (Developed)	55		1+

WARNER LAKE DRAINAGE.

Number.	Date, 1907.		Temperature.	Second-feet.	Miner's inches.
254		Mule Spring (an old military well)		(a)	(a)

a No summer flow.

UNDERGROUND WATER.

DIVISIONS OF UNDERGROUND WATER.

Underground water may be considered in two broad divisions: Ground water, or that which exists in unconsolidated material, such as the alluvium of stream valleys, the sediments of lake basins, and the soil and rock waste of areas where the underlying rock has decayed in place; and rock water, or that which is present in the underlying rocks themselves. The zone of the former extends from the upper surface of saturation, the ground-water level, to bed rock, while the deeper water is present in the bed rock down to a depth below which, because of heat and pressure, meteoric water does not circulate. This lower limit has been theoretically placed at about 6 miles below the surface. In general, rock water is found at a much greater depth than is that of the surficial deposits, but in many places there is no definite line of division between the two classes, the unconsolidated surface deposits passing by easy gradations into the consolidated rock below. It is therefore not always possible accurately to classify underground water, and the supply of many wells is as rightly considered to be from one source as from the other. In few places is the division between these two classes of water as sharply defined as it is in the Harney basin region by the surface of the lava flows. Within the lavas is the rock water, while in the valleys upon the lava bed rock lie the very different deposits of unconsolidated lake sediments and alluvium in which ground water is found.

GROUND WATER.

UNCONSOLIDATED MATERIAL.

The depth to which unconsolidated material may accumulate depends mainly upon climatic, structural, and topographic conditions. When streams bring down quantities of débris from mountain slopes and debouch upon valley lands, where the current becomes slower, the streams drop the greater part of their loads, and alluvial cones or fans are built up. Where streams empty into lakes, deltas are formed by similar deposition, while over the lake bottoms there are formed more even layers of material that was held longer in suspension by the inflowing water.

In many desert regions the wind, when it has been checked by mountain ranges or by contrary air currents, has deposited a deep loose layer composed of fine material picked up elsewhere. When laden with particles of sand and dust, it may also wear down exposed cliffs and peaks, and thus aid in forming the surface deposits of the lowlands.

In regions that are covered by residual soil the depth to which rock decay has taken place varies between wide limits. Over arid plateaus such soil may be only a few inches in depth, or in some parts entirely lacking, while in regions of great rainfall, especially within the tropics, rock decay may extend downward for several hundred feet.

GROUND-WATER LEVEL.

Where the loose material is of sufficient depth, seepage from stream channels and the direct supply by precipitation keep it saturated below a depth that is known as the ground-water level. This level varies with the supply of underground water, rising toward the surface as the supply increases and falling as it decreases. Its surface is closely related to the surface of the ground, to which it conforms in a general way, but it does not rise so high in the uplands and may not drop so far in the lowlands. Consequently along the sides of deep valleys and canyons the land surface in many places intersects the plane of the ground water, and springs result. These dry up when the water level drops below the surface of the ground and increase their flow when it rises so as to produce greater head at the springs.

Within Harney County the ground-water level is at a shallow depth in all the lake valleys, and also in the smaller alluvial basins of the plateau regions. It is from this source that the shallow wells of the valley lands obtain their supply, while within the mountain portions many intermittent springs that issue along the canyon sides show where the ground-water level is intersected by the steep slopes.

ROCK WATER.

Relatively porous beds of rock, such as sandstone, underlie many regions and are the main sources of their water supply. Under the most favorable conditions these beds form the surface in other parts of the country, and directly absorb rain and melting snow; but in many places they are supplied with water chiefly by seepage downward through the overlying material.

The tuffaceous beds that are associated with the basalts of southern Oregon become excellent water carriers where their higher portions are exposed so as to collect rain and melting snow, and are an important source of the underground water supply. At Burns many of the wells pass through a surface layer of compact tuff to a more porous layer, in which a good supply of water is obtained. This is a rock water, since it is obtained from a bedded structural formation, although most of the wells are less than 100 feet deep, and the supply is probably from direct precipitation on the slopes to the northwest.

ARTESIAN CONDITIONS.

Since the time when the term "artesian" was first applied to flowing wells, from their notable occurrence near Artois, in France, the word has been used chiefly in reference to wells in which the water is under sufficient pressure to cause it to overflow at the surface. Within the past few years, however, there has been a looser use of the word, and it has sometimes been applied to any deep well, whether sunk for oil or water. Better usage, however, restricts it to those wells in which the water is under sufficient pressure to cause it to rise notably above the depth at which it is struck, whether or not it overflows at the surface. In this sense it will be used in the following discussion.

Since the publication in 1885 of the excellent paper by Chamberlin[a] the typical trough-shaped or saucer-shaped basin, or alluvial artesian slope, has often been considered essential to artesian conditions.

[a] Chamberlin, T. C., Requisite and qualifying conditions of artesian wells: Fifth Ann. Rept. U. S. Geol. Survey, 1885, pp. 125-173.

In a typical structural artesian area the underlying rocks are composed of alternate pervious and impervious beds, folded so as to form an inclosed basin. Water that penetrates to the pervious beds is confined within them by the impervious layers above and below, and the head produced on the water in the lower portions of these underground reservoirs by that in their upper parts, around the border of the basin, is sufficient to cause the water to rise in wells put down in the lowest parts of the basin.

Although the rocks of Harney County are of effusive origin, and so would not seem at first thought to furnish such conditions of bedding and structure as are demanded of artesian basins, yet the lava sheets interbedded with porous tuffs do give the alternation of pervious and impervious layers that produces artesian conditions. Four of the valleys of this region are to some extent synclinal or saucerlike in structure, and this feature will be treated in detail in considering the water possibilities in them.

In many places alluvium and sediments deposited in former lakes have filled valleys with alternating layers of coarse and fine material, that often act essentially as pervious and impervious beds in the production of artesian head on the underground water. The current of a stream that flows down from mountain slopes is checked on entering the lowlands or on discharging into a lake, hence it drops a great part of its load of sand and gravel and other alluvial material. This is largely assorted by the continued slowing of the current, and the coarser particles are dropped first, while the finer are held longer in suspension. In this manner layers of coarse and fine material are deposited that thin out down the slope into wedgelike sheets. The layers of fine material act as relatively impervious beds, confining water that seeps downward mainly to the coarser layers. These layers, by virtue of their slope toward the lowest portion of the alluvial cone, or of the lake basin, produce a head on the water thus confined that is in many localities sufficient to supply flowing wells when the water-bearing strata are properly tapped.

In certain parts of Harney and Alvord valleys conditions are favorable to the development of artesian water in the valley fillings, and flowing water has been developed in them to a slight extent. The successful wells and their locations are described in the detailed discussion of these valleys.

Although the most important areas where artesian water is found belong to one or the other of the typical classes, many artesian wells and even some flowing wells are obtained in regions that do not have the major structural features, but in which local factors, such as fissures and minor folds, produce artesian conditions in limited areas.

CONSERVATION OF THE WATER SUPPLY.

In concluding the general discussion of the surface and underground water supply of this region a few words may be said about the character of the drainage basins and the relation of forests and other protective growths on the mountain slopes to the flow of the streams.

In most of the streams of the area studied the discharge is at the maximum in the early spring, and is of short duration; and throughout the summer, when water is most needed, many of the streams are dry. In the absence of storage reservoirs the higher brushy and forested areas are the only places where the winter supply of water is conserved, by which the later stream flow is prolonged. The greater part of the drainage basins of Silvies River and of Silver Creek still have their natural protection of open forest, since lumbering has not yet become extensive in this remote section; but even on these streams the records that have been kept show how irregular the discharge is, and emphasize the desirability of preserving the naturally scanty covering of trees. In this respect it is gratifying to note the thick growth of young trees in many parts of the forested slopes on the northern side of the Harney basin. Farther south the slopes are protected mainly by brush and the lower growth of grasses. In Steens Mountain, the Whitehorse Mountains, and the Trout Creek Hills, the injury to this already scanty protection by the overgrazing of bands of sheep is becoming very apparent, as it is in many other parts of the Northwest, and it is to be regretted that these areas have not been incorporated into National Forests, if only for the purpose of limiting the number of sheep allowed to graze within them. It was reported that there were 128,000 sheep in the Whitehorse Mountains during 1907, and that some of the herders were cutting down the cottonwood trees so that the animals might browse on their leaves and twigs. The diminution in the flow of Trout Creek, caused by so many animals feeding along its upper course, was said to be very apparent.

The supply of underground water is also dependent for its constancy upon the accession to it throughout the year of water from the mountain slopes. In some parts of the United States, notably in southern California, the conservation of the winter rainfall in the high mountains and its continual seepage to the lower lands are of vital interest to those who pump water for irrigation. While it is probable that not for many years to come will the underground water supply in the valleys of Harney County be seriously affected by conditions on the surrounding slopes, yet the following two instances show that there is a very appreciable flow of the shallow subsurface water, and that its supply may easily be influenced by storage conditions on the mountains. In summer, during the low stage of Silvies River, many seepage springs appear along its western bank, which seem to be best explained as due to eastward seepage of the underground water. At Harney it was reported that in one well near the bank of Rattlesnake Creek the water stands within 2 or 3 feet of the surface in summer, but in winter, when the ground freezes and stops the subsurface flow, it drops to about 15 feet.

DETAILS OF THE SEVERAL BASINS.

HARNEY BASIN.

LOCATION AND SURFACE CHARACTER.

The central part of Harney County is occupied by a wide, flat, alluvial area that is known as the Harney basin. This term is usually applied to the valley lands and is not here meant to include the entire drainage basin. The main part of this basin is occupied by the rudely square Harney Valley, which is 20 to 30 miles across. Portions of the valley that extend outward along stream courses, or are partially separated from the main area by hills, have local names, such as Happy Valley and Warm Spring Valley.

On the north, gentle slopes rise from the basin's edge to the Strawberry Mountains; on the northeast the steeper slopes of Crow Camp Hills border the valley land; while southward and westward it stretches to the base of Steens Mountain and to the high desert beyond Harney Lake and Iron Mountain. Within its borders a few isolated buttes rise, such as Saddle Butte, near Lawen; while projecting fingers, such as Wrights Point, extend into it and break the monotony of the wide level expanse.

LAKES.

In the southern portion of the Harney Valley lie Harney and Malheur lakes, two large water bodies that occupy the lowest part of the basin. These lakes were formerly separated by a sand spit about 4 miles northwest of Narrows, but it is said that in 1877, during a period of high water, this barrier was broken through, and Malheur Lake is now united with the western and slightly lower water surface by a strait 50 or 75 yards wide.

The water of Malheur Lake is comparatively fresh, while that of Harney Lake is strongly alkaline. This fact has been commented upon by Russell,[a] who cites it as an interesting example of the freshening of one lake by overflow into another. It would seem that the barrier, which separated the lakes prior to 1877 was only a tem-

[a] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: Bull. U. S. Geol. Survey No. 217, 1903, p. 31.

porary one, since connection between the two lakes for a long period was probably required to render the eastern one now fresh and the other strongly alkaline. The following analysis of water from Harney Lake, collected August 5, 1902, is taken from Russell's paper.[a]

Analysis of the water of Harney Lake, Oregon.

[Parts per million. Analyst, George Steiger.]

Silica (SiO_2)	28.7
Aluminum (Al)	None.
Iron (Fe)	None.
Magnesium (Mg)	6.8
Calcium (Ca)	None.
Sodium (Na)	3,604.5
Potassium (K)	192.8
Carbon trioxide (CO_3)	2,974.7
Hydrogen (H) required in formation of bicarbonate	32.3
Surphuric anhydride (SO_4)	773.3
Chlorine (Cl)	2,771.3
Bromine (Br)	None.
Iodine (I)	None.
Boracic acid (B_4O_7)	92.8
Total	10,477.2

Specific gravity, 1.081.

NOTE.—Reaction strongly alkaline. The computation shows that no free carbonic acid is present above that required to form bicarbonates.

Of this analysis he says:

Judging from the analysis given above, the most abundant salts contained in the lake waters are sodium chloride or common salt, sodium carbonate or bicarbonate, and sodium sulphate. Potash and borax are present, but as the total amount of saline matter in solution is only 1.04 per cent by weight, the lake waters can not be considered as being of commercial value.

The seasonal variation in the water level of Malheur Lake and the consequent change in its area have already been mentioned. The record of gage readings that were taken at the wagon bridge at Narrows under direction of the U. S. Geological Survey shows that this change in level during 1903, 1904, and 1905 was in excess respectively of 4.3, 5.7, and 3.05 feet, the lake surface being highest in May and June and lowest in January and February. At low water the strait at the gage was dry, so that the total change in level was not recorded at this station.

SETTLEMENTS.

In 1907 there were four settlements in Harney Valley, at Burns, Harney, Lawen, and Narrows. These are connected with each other by good wagon roads and by telephone lines. Burns, the county

[a] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: Bull. U. S. Geol. Survey No. 217, 1903, p. 31.

seat, is the center of trade for the valley, but at the smaller places, supplies and hotel and livery accommodations can be obtained. Within the past two years a great part of the valley land has been filed upon by new settlers, as homesteads and as desert claims, so that many small houses now dot it and the sagebrush is being cleared off. The land north and east of Dog Mountain, in the region known as Sunset Valley, was being settled most rapidly in the summer of 1907. In the area south of Harriman post-office, and also in the neighborhood of Windy Point, a number of settlers had taken up claims, while along the borders of the valley east of Harney there was another scattered group of new homes.

AGRICULTURE.

Ever since the natural resources of this region first made it a grazing country the valley lands as well as the plateaus have been devoted mainly to stock raising, and agricultural development has been limited chiefly to the increase of the natural hay lands by the construction of irrigation ditches and the use of the flood water. The belt of natural hay land along lower Silver Creek has been greatly widened by this means, and between Burns and Harney a large acreage that is irrigated by overflow water from Silvies River and from streams along the northern side of the valley produces crops of wild hay. But the natural grasses of these lowlands are mainly species of tules and flags, in which there is little nourishment, and unless an animal is in fair condition in the fall, even though it has access to the haystacks, it may not survive a severe winter.

Along the borders of Malheur Lake, in the vicinity of Narrows, the more alkaline soil yields a fair crop of salt-grass hay, which, though coarse, is more nutritious than the tule grasses of the overflow lands. In the upper portions of the meadow lands along the several streams there is considerable timothy, brome, and rye grass, so that the natural hay of these localities is better in quality than that farther downstream. Much of the lower marsh land is overgrown with tules and is covered with water during the greater part of the year. Of such character is the marsh or swamp land on the western border of Harney Lake, that along the sloughs in the neighborhood of Lawen, and portions of the lower course of Donner und Blitzen River and of the streams that enter it near the Buena Vista ranch. A few years ago an attempt was made to drain the portions known as the Buena Vista and Diamond swamps by dredging canals through their centers, but the yielding nature of the saturated peaty land soon allowed these channels to become choked up. Within the last two or three years ownership of these swamps has changed hands, and in the fall of 1907 a second attempt was being made to reclaim them, this time by dredging canals along their borders. A dipper dredge of $1\frac{1}{4}$ cubic yards capacity was in use, and a canal about 30 feet wide and 10 feet deep was being dug. Some attempt was made to use the peat that has formed in portions of the swamp as fuel for the dredger, but where it was cut it contained too much earthy matter to be valuable for that purpose.

Of late years grain, fruits, and vegetables in rapidly increasing quantities have been raised, and the influx of settlers has given great impetus to farming. At and near Burns there are several small farms that supply the greater part of the fruits and vegetables for local consumption, while east of the town several fields containing good stands of wheat and barley were noticed during the summer of 1907. A grist mill on the bank of Silvies River, a couple of miles north of Burns, furnishes much of the flour for local use; but many people still drive southward to Lakeview, or eastward to Ontario, for the winter's supply of apples and for potatoes and other vegetables, and as yet (1908) agriculture can be considered only as an auxiliarv means of livelihood in this valley.

It is mainly the new settlers on the open sagebrush lands who have begun to raise much grain. Rye is a favorite first-year crop, perhaps on account of its suitability to dry farming, and where it has been sown under favorable conditions it has yielded well. Many of the new settlers expect to rely on dry farming, principally grain raising, for a living. They can not yet be assured of success, considering that their fields are in many cases limited to 160 or 320 acres, that the seasonal rainfall is uncertain, and that until a railroad is built through the region the market will be limited to the local demand.

AREAS TRIBUTARY TO HARNEY VALLEY.

In the valley of upper Silver Creek, at and above Riley, there are several ranches that have been occupied for a number of years, but here, as elsewhere, the bottom land is valued chiefly for its natural grass. On each side of the valley there are stretches of gravelly bench land which are at present used only as stock range, but they could be made productive if they were irrigated. Along the middle course of the stream, 6 or 8 miles south of Riley, a few homesteaders have settled, but little development of the land had been accomplished there at the time of this examination. There is a considerable area of good bottom land along this portion of the stream, and water is obtained at shallow depth, but no water is available from Silver Creek at the time when it is needed for irrigation.

Along Silvies River above Burns there are a few small farms, and also along Rattlesnake Creek, above Harney. At Diamond, on the southeast edge of Harney Valley, and in Happy Valley, along Smith and Riddle creeks, there are a few earlier settlers, but as in the other watered localities, which, of course, were settled first, the meadow grass, being a necessity to stock raising, is the most extensive and valuable crop.

Half a mile northeast of Diamond, Swamp Creek has cut through a lava ridge which resembles the ridges along Smith Creek, described on pages 27, 28. This forms a very good dam site for a reservoir of small capacity. The value of such a reservoir for irrigating the meadow of the lower portion of the creek is realized by the owner of the land, but at the time of visit a dam had not been begun.

SOIL.

CLASSES.

In Harney Valley, and also in the other valleys of this basin, six general classes of soil may be recognized by the character of the native vegetation. Nearly all the cultivable areas are covered by rather fine-grained, light, and sandy soil that is easily tilled, but it varies in alkalinity and in the amount of vegetable matter it contains. Near the lakes the percentage of alkaline salts is much greater than in the higher portions, while in the marshy and swampy areas the soil is black from decayed vegetation, and in certain localities, as in the Buena Vista swamp, it is even peaty in character.

The sagebrush land is in nearly all parts the best in quality, usually being light and sandy and free from alkali, while water of fair quality is often found beneath it at a shallow depth.

In the more alkaline areas sagebrush is replaced by greasewood, although the latter does not everywhere indicate especially alkaline conditions. Where it flourishes, however, ground water is usually nearer the surface and more alkaline than in the sagebrush areas.

Over some portions the rayless golden-rod, often called "rabbit brush," is the chief growth. Like the greasewood, it may indicate a dryer as well as a more alkaline condition of the soil.

Rye grass grows luxuriantly in land slightly above the marsh areas, which is overflowed during part of the year. In many places on hillsides it indicates the presence of seepage springs.

The marsh and natural hay lands may be considered as constituting a fifth class of soil, in which water stands close to the surface throughout the year. These lands are dark colored and rich in vegetable matter and are not, as a rule, badly alkaline, perhaps because of a continuous though slow movement of the subsurface water toward the sloughs that drain them.

In the lower lands, especially around the borders of the lakes, the alkaline content becomes excessive, and only salt grass and saltbushes grow.

No attempt can be made here to classify all the land of the Harney Valley, but it may be said that the best areas of sagebrush land were noticed along the borders of the valley between Harney and the Crow Camp Hills, in the neighborhood of Windy Point and Harriman post-office, and north and southwest of Dog Mountain. It is in these areas of sagebrush land that most of the recent settlement has taken place. There is also much similar land lying east and southeast of Burns, but 69,000 acres of this was still, in 1908, reserved by the State under the Carey Act, while 11,000 acres more is Indian land.

The western extension of the valley, in the neighborhood of Iron Mountain and Silver Lake, is an alkaline greasewood flat. A similar greasewood playa lies on the eastern edge of the valley near Malheur Gap, while a belt of rank greasewood borders the north shore of Harney Lake.

South of Malheur Lake the road that leads to Happy Valley crosses a belt of goldenrod land about 1½ miles wide. No homes had been built there, and though the soil is composed of alluvium and lake sediments it seemed hard and dry. South of this locality the surface rises gently to rocky plateau land.

Between Burns and Lawen several fields thickly covered with rye grass were seen; these are probably overflowed during the spring months by water from Silvies River. Other smaller rye-grass areas were noticed in the valley of Silver Creek and in the flat of Swamp Creek near Diamond.

The marsh and meadow lands include several fields east of Burns that are irrigated by means of ditches from Silvies River during high water, as well as the areas of natural marsh that are shown on the reconnaissance map (Pl. II). With the exception of those portions that are partially flooded and grown to tules, and the strongly alkaline areas that support only the saltbushes, these constitute the wild hay lands.

The greatest extent of alkaline salt-grass land noticed is along the western border of Malheur Lake. From parts of this, as has been said, the salt grass is cut for hay.

ALKALINITY.

Since the meaning of alkali is but slightly understood by many, it may be said here that several natural salts are known as "alkalies." The chloride, the sulphate, and the carbonate of soda are the three chief salts thus designated, the two former being "white" alkalies, while the latter is known as "black" alkali. Borax (biborate of soda) is also an alkali, but only here and there is it present in sufficient quantity to affect vegetation. The nitrate and the phosphate of soda and the sulphate of potash are also alkaline salts that are found in nature, but these are nutritive salts and are essential to plant growth. The carbonate of soda or black alkali is the most harmful of these salts, as it attacks the bark of plant stalks just below the surface, and when sufficient in quantity practically girdles them.

Concerning the relative harmfulness of the three chief alkalies C. W. Dorsey says:[a]

> When present in soils to the exclusion of other salts, 0.05 per cent of sodium carbonate represents about the upper limit of concentration for common crops. One-half of 1 per cent of sodium chloride is commonly regarded as the endurance limit of crops, and 1 per cent of sodium sulphate. Sodium sulphate, then, is the least injurious and sodium carbonate the most injurious of the salts usually constituting the greater part of alkali under ordinary field conditions, while sodium chloride occupies a middle position.

Alkali is seldom distributed uniformly in the soil in a vertical direction. In most arid regions it is contained mainly in the upper 6 feet. Other factors besides the total quantity present in the soil modify its effect on plant life, especially the depth below the surface at which it is concentrated. This depth varies with the season and is greatly influenced by irrigation. Where the alkali is contained mainly 3 or 4 feet below the surface, shallow-rooted crops can be grown without injury; and in many places, also, it becomes concentrated in the surface crust, above the roots of plants that might otherwise be affected by it.

A few settlers have taken up claims on the borders of Malheur and Harney lakes. They were probably attracted to this section by the growth of salt grass and by the moist character of the land, but it is to be regretted that they were not informed of the worthlessness of such land for agriculture.

A soil sample was taken to a depth of 6 feet with an earth auger, half a mile south of Narrows, in the zone of greasewood land intermediate between the areas of sagebrush and of salt grass. The amount and character of alkaline salts in it were determined for each foot in depth separately, in order to learn their distribution as well as the quantity in the soil. A similar sample for analysis was taken in rye-grass land about 2 miles north of Lawen, in order to judge of the character of this class of soil. The results of these two analyses are as follows:

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[a] Dorsey, Clarence W., Reclamation of alkaline soils: U. S. Dept. Agr., Bureau of Soils, Bull. No. 34, 1906, p. 10.

Alkali analyses of soils from Harney County, Oreg.

[Walton Van Winkle, analyst.]

PER CENT OF TOTAL SOIL (WATER EXTRACT).

Locality and depth of sample.	Soluble salts.	Ca.	Mg.	Na+K.	SO_4.	CO_3.	HCO_3.	Cl.
One-half mile south of Narrows:								
0 to 1 foot	0.566	0.0286	0.0074	0.144	0.0604	0.0048	0.0996	0.120
1 to 2 feet	1.049	.0028	....	.2383	.0584	.029	.174	.550
2 to 3 feet	.734	.005	....	.367	.096	.059	.062	.145
3 to 4 feet	.662	.003	....	.300	.028	.111	.100	.120
4 to 5 feet	.938	.077	.003	.261	.067	.130	.024	.097
5 to 6 feet	.864	....	....	.282	.048	.080	.110	.084
Two miles north of Lawen:								
0 to 1 foot	.202	.015	....	.055	.055	....	.057	.010
1 to 2 feet	.126	.024	.005	.029	.011	....	.040	.006
2 to 3 feet	.114	.030	.005	.027	.010	....	.036	.006
3 to 4 feet	.140	.018	.006	.029	.010	....	.041	.010
4 to 5 feet	.128	.017	.005	.034	.011	....	.038	.008
5 to 6 feet	.194	.016	....	.055	.017	....	.057	.020

PER CENT OF SOLUBLE SALTS.

Locality and depth of sample.	Ca.	Mg.	Na+K.	SO_4.	CO_3.	HCO_3.	Cl.
One-half mile south of Narrows:							
0 to 1 foot	5.05	1.30	25.44	10.67	0.848	17.6	21.2
1 to 2 feet	.267	....	16.8	4.14	2.05	12.3	52.4
2 to 3 feet	.694	....	50.0	13.1	8.03	8.44	19.75
3 to 4 feet	.453	....	45.3	4.23	16.7	15.1	18.1
4 to 5 feet	8.20	.319	27.8	7.14	13.8	2.53	10.3
5 to 6 feet	....	....	32.6	5.55	9.23	12.7	9.72
Two miles north of Lawen:							
0 to 1 foot	7.42	....	27.2	27.2	....	28.2	4.95
1 to 2 feet	19.0	3.97	23.0	8.73	....	31.7	4.76
2 to 3 feet	26.3	4.38	23.6	8.77	....	31.5	5.26
3 to 4 feet	12.8	4.28	20.7	7.14	....	29.2	7.14
4 to 5 feet	13.2	3.90	26.6	8.59	....	29.6	6.25
5 to 6 feet	8.24	....	28.4	8.76	....	29.3	10.3

The main point to be noted in the figures for the first sample is the high percentage of soluble salts and their persistence to a depth of at least 6 feet. Their proportion, from over one-half of 1 per cent to a little over 1 per cent of the total soil, shows that a harmful quantity of these salts is present; and as drainage conditions are poor the soil is almost worthless for crop production. The second sample, from near Lawen, contains only about one-fifth as much soluble material as the soil from near Narrows, and so far as alkalinity is concerned it may be classed as a good soil. Both are rather deficient in lime, as it is usually considered that for a good soil from 0.1 per cent to 0.3 per cent of this essential plant food should be present. Like nearly all other arid-region soils, however, that of this valley is fertile and will prove very productive where ample water can be supplied and alkali does not become excessive.

In one of his publications on this region[a] Russell gives the following analysis of a sample of the alkaline efflorescence from land near Dog Mountain. This also shows the nature of the salts that are present in this locality.

[a] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: Bull. U. S. Geol. Survey No. 217, 1903, p. 36.

Analysis of efflorescence from Narrows, Oreg.

[Analyst, George Steiger.]

Insoluble in hot water	1.25
Sodium oxide (Na_2O)	47.49
Water (H_2O) of crystallization	10.08
Sulphuric anhydride (SO_3)	11.76
Chlorine (Cl)	2.90
Carbon dioxide (CO_2), carbonic acid gas	26.33
Boracic acid (B_2O_3)	.28
	100.09

Regarding this analysis Russell says:

Judging from the above analysis, the efflorescence from which the sample examined was obtained, if in sufficient quantity and commercially accessible, would be of value for the sodium carbonate and sodium bicarbonate it contains, but not for its borax.

SURFACE WATER.

RECLAMATION PROJECTS.

A few years ago the United States Reclamation Service made preliminary surveys of two irrigation projects within the Harney basin. Of these, the Harney project embraced lands in the northern part of Harney Valley, while the other, the Silver Creek project, contemplated the irrigation of the bench lands along the stream above Riley.

Concerning the larger project, that in the Harney Valley, it is stated in the Third Annual Report of the Reclamation Service[a] that in 1904 there remained about 70,000 acres of unpatented land in the valley, and this had been selected by the State, under the Carey Act, for the Harney Valley Improvement Company. Measurements from May, 1903, to May, 1904, inclusive, showed that 250,000 acre-feet of water was discharged by Silvies River into the valley during that period. Much of the discharge is spring flood water, and it has been estimated that fully one-half the total amount can be stored at comparatively small expense at an excellent reservoir site at the head of Silvies Valley, about 20 miles north of Harney Valley. After making due allowance for the fact that the season of 1903–4 was one of unusual precipitation it was assumed that there is sufficient water to irrigate 40,000 acres, and that the necessary storage and distribution works can be constructed at a cost not to exceed $20 an acre for the land irrigated. But while the present method of irrigation by flooding is practiced, in which from two to five times the amount of water is used that would be necessary if it were properly distributed, it is doubtful if in seasons of average precipitation there is more water than is required to satisfy present claims. In June, 1904, a board of consulting engineers examined the project and recommended that it be abandoned, since the water supply would probably be found

[a] Whistler, John T., Operations in Oregon: Third Ann. Rept. U. S. Recl. Service, 1903–4, 1905, pp. 103–104 and 457–458.

insufficient during ordinary seasons. Throughout 1904 daily gage readings were made at a station on the river a short distance below the reservoir site, and showed a total discharge for the year of 163,400 acre-feet at this point. This station has not been continued, but occasional discharge measurements have been made on the stream, and they indicate, as was thought, that in some seasons the supply would be insufficient.

Concerning the Silver Creek project it is stated in the same report[a] that from preliminary measurements it was estimated that 100,000 acre-feet of water was discharged by Silver Creek during 1904. Since the flood water runs off early it was considered that fully 75 per cent of the total discharge could be stored without injury to the meadows below, and that storage would in fact be a benefit to much of the lower land. This estimate of discharge indicates that the amount available is sufficient to irrigate 40,000 acres, but to allow for a storage supply to tide over dry seasons about half this acreage was tentatively figured upon. The easily irrigable land is estimated at about 15,000 acres, only about 20 per cent of which is improved, and this only in the sense that it grows a light crop of wild hay; but about one-third of the land is patented through a military-road grant. There is a good reservoir site in the southwest corner of T. 21 S., R. 26 E., and in 1904 a preliminary survey of it and of the irrigable land below was made. Stream measurements made during the first half of 1905 and 1906 showed a much smaller discharge than in 1904, and the project has been practically abandoned by the Reclamation Service. In the summer of 1907 it was reported that a private company had purchased the ranch that occupies the reservoir site and intended to build a dam for storage purposes and irrigate part of the land below. The available discharge records of this stream are given on page 34.

MINOR IRRIGATION.

The main streams of Harney Valley, Donner und Blitzen and Silvies rivers and their tributaries, and the minor streams as well, have been described in the general discussion of the surface water (pp. 31–35), so they need not be taken up again here. Up to the present time their supply has been used only in irrigating and somewhat enlarging the natural meadow lands. In this irrigation it is the custom to turn the water upon these hay lands and to leave them flooded as long as the supply lasts or until the hay is ready to cut. In this way a great excess of water is applied to the crop, and in some portions the grass is often drowned out.

Of the several attempts that have been made in a small way at irrigation in Harney Valley, the following were noted in 1907: At the P ranch, at the south end of the marsh land of Donner und Blitzen

[a] Op. cit., pp. 459–460.

River, several fields of alfalfa have been irrigated, but for some years before this examination had been neglected. On Smith Creek and Rattlesnake Creek, as well as along Silvies River above Burns, a small amount of water is diverted from the streams to gardens and alfalfa patches. At Lawen one windmill was noted, which raises water from the slough and by means of a short flume irrigates a small vegetable garden. About 7 miles north of Lawen preparations were being made by one who had filed on a desert claim to raise water from the near-by slough by means of a centrifugal pump, and to conduct it through a wooden flume to the adjacent land. A mile or two west of Riley a dam had been built across the mouth of a natural depression at the valley edge, and the run-off water had been stored and used during the summer. In the spring of 1905 this dam broke, and up to the summer of 1907 had not been rebuilt. At the south base of Dog Mountain Mr. Newell has built across the mouth of a wide draw an earth dam about 1,200 feet long and 7 feet high at the center. This forms a storage reservoir with a capacity roughly estimated at 7 or 8 acre-feet. With the water thus stored he is able to give his wheat field a late spring flooding. A few similar small reservoirs were being constructed by other new settlers in this vicinity.

SPRINGS.

There are a number of springs, both natural and developed, within Harney Valley, which deserve mention in connection with the surface-water supply and its development. The following are the principal ones that were noted:

About a mile west of Burns, on the slopes 100 feet above the town, a spring rises, whose water is used to irrigate a few acres of garden and orchard immediately adjacent. An earth reservoir 300 feet long, 40 feet wide, and about 4 feet deep has been made by banking up around the spring, and a pit which was dug about 25 feet deep at the spring has considerably increased its original flow. This is estimated by Mr. M. L. Lewis, the owner, to be 1,000 or 1,200 gallons an hour, or about 2 miner's inches. Another spring 2 miles northwest of this one has been boxed in and forms a watering place at the roadside. Two or three similar springs rise in the hills southwest of Burns on the drainage slopes of Cold Spring Creek.

The warm springs 3 miles south of Burns and those near the mouth of Cold Spring Creek have been mentioned in an earlier part of this paper (p. 35) in speaking of the surface water supply. These flow in considerable volume, but no use is made of their water except in the irrigation of the natural meadow grasses.

At Mr. Newell's ranch at the south base of Dog Mountain the water supply for domestic and garden use and for several head of stock is obtained from a small developed spring in the coarse-textured tuff that forms part of the mountain. A tunnel 80 feet long has been run into the hillside and yields a constant flow of somewhat less than a miner's inch.

The Weaver spring, 3 miles west of Mr. Newell's, at the edge of the valley, is also in part a developed one. The water issues from the base of a low scarp and supplies a small field of alfalfa, besides the usual garden. The flow is possibly 2 miner's inches.

A couple of miles north of Harriman post-office there is a hot spring, which in the summer of 1907 had been banked up so as to form a pool 100 yards in diameter. The water discharged on the east and south sides through two ditches having a total flow of about 28 miner's inches.

In Crane Creek Gap there is a small spring, which rises on the slope well above the level of this divide. At the time it was visited it formed a pool that was used by cattle as a watering place, but there was little appreciable flow. Farther down the slope there is a second spring and pool. A well-marked watercourse leading from it indicates that these springs flow in considerable volume during the earlier part of the year, and that their supply is mainly of shallow origin.

In the west end of Warm Spring Valley the spring numbered 212 on Plate III has little appreciable flow, but it has formed a small tule area and is a welcome watering place. Of similar origin are springs Nos. 211 and 213, but the former flows into Silver Lake and the latter into a small pond.

With the springs of the southern side of the Harney basin those of Buzzard Canyon may be mentioned. During the summer the water alternately rises to the surface and flows underground along this drainage course. The flow at Buzzard Spring is said by F. M. Anderson, geologist, to have been about 15 miner's inches in July, 1907.

Of the largest springs of Warm Spring Valley, those on the Double O ranch, it has already been stated that the water is used only to a small extent in irrigating the wild-hay land, though canals have recently been dug and preparations have been made for using it more extensively for this purpose.

The water of spring No. 221, southeast of the Double O ranch, is used mainly for garden irrigation, as is also that of spring No. 222, a mile farther east.

A hot spring, No. 223, rises near the southeast shore of Harney Lake through a number of vents in which the water ranges in temperature from 134° to 150° F. At this place a pool 115 yards long and from 10 to 35 yards wide has been formed, which discharges through two ditches at its southern end. The total flow as measured was about 20 miner's inches.[a] A few years ago some attempt was

[a] In Water-Supply Paper U. S. Geol. Survey No. 78, 1903, p. 39, Russell gives the flow of this spring as 6 gallons a second, equivalent to about 40 miner's inches.

made to utilize the water for irrigation on the land near by, but of late it is unused and sinks within 300 yards of its source.

About half way between this spring and Narrows there is a small sulphur spring in the barren flat close to the lake margin. Some one has built a cabin here, fenced in the spring, and attempted to raise a few potatoes, but with poor success.

The Sodhouse spring, No. 214, has been described on page 35. No attempt is made to utilize its water, but it forms a welcome drinking place for cattle, especially in winter, when its warm water is greatly appreciated by the animals.

A small spring by the roadside, at the western edge of the lava surrounding Diamond Craters, is worthy of mention, for though its flow is inappreciable it forms a convenient watering place for the traveler.

Numerous cold springs issue along the canyon sides of the creeks that drain the northern slope of Steens Mountain, and considerably increase the stream flows. In two or three places their water is used during the dipping and shearing of sheep, but because of their locations they are put to little other use directly.

GROUND WATER.

The ground-water level has been said to be at a shallow depth in nearly all parts of the basin. Near its borders the shallow ground water is much better in quality than it is near Lawen and Narrows. The level, where it is indicated by the depth to water in a number of wells, is shown on Plate III. Other notes concerning these wells are tabulated in the following list of those that were noted in the Harney basin.

Wells in the Harney basin.

No.	Owner or location.	Class of well.	Method of lift.	Depth to water.	Remarks.
				Feet.	
1	West side of Silvies River canyon.	Dug	Wheel and bucket.	25	Temperature 47° F.; unusually cold.
2	Harney	Bored and dug.		10 to 15	General statement for wells at Harney.
3	Northeast edge of Harney Valley.	Bored	Pitcher pump	5	
4	1 mile east of No. 3	Dug	Wheel and bucket	7	
5	1½ miles east of No. 4	do	do	7	
6	East side of Harney Valley	do	do	20	
7	2½ miles south of No. 6	do	do	9	
8	Fred Haines, sec. 2, T. 23 S., R. 32½ E.	Drilled	Windmill	15	See Russell's statement, quoted on p. 62.
9	7 miles southeast of Harney	Bored	do	10	
10	J. H. Shepard, 12 miles east of Burns.	Dug	Wheel and bucket.	8	
11	Mr. Dennison, sec. 18, T. 23 S., R. 32 E.	do	Windmill	15	
12	Harney County, sec. 13, T. 23 S., R. 31 E.	Drilled	Not used	5	See Russell's statement, quoted on p. 62.
13	Northern part of Burns	Mostly drilled.	Windmills and engine.	75	General statement for wells in upper part of Burns.
14	Southern part of Burns	Bored and dug.	Windmills	30 to 50	General statement for wells in lower part of Burns.
15	Mr. Geer, 2 miles west of Burns.	Dug	do	26	

Wells in the Harney basin—Continued.

No.	Owner or location.	Class of well.	Method of lift.	Depth to water.	Remarks.
				Feet.	
16	I. S. Geer, ½ mile south of No. 15.	Dug	Windmills	7	
17	Cal. Geer, near No. 16	...do	....do	10	
18	NW. ¼ sec. 33, T. 23 S., R. 29 E.	...do	Wheel and bucket.	60	Small supply; in tuff.
19	J. F. Oakerman, Riley	...do	Windmill	14	
20	7 miles above Riley	...do	Wheel and bucket.	10	
21	7 miles south of Riley	...do	Pitcher pump	10	
22	J. W. Sevedge, 9 miles south of Burns.	Bored	....do	8	
23	Dan Harkey, 8 miles south of Burns.	...do	Not used	7+	Pit dug 7 feet deep, nearly to water level, and cased boring sunk to a depth not learned. Water in casing stood 2½ feet below surface of ground.
24	N. B. Sutton, 1 mile east of No. 22.	...do	Pitcher pump	15	Water level at 15 feet, but better quality of water at 71 feet.
25	1 mile north of Lawen	...do	....do	28	
26	½ mile northeast of Lawen	...do	....do	26	
27	Stable yard, Lawen	...do	Windmill	12	
28	Hotel, Lawen	...do	....do	8	
29	G. L. Sitz, Lawen	Drilled			See log of well, and remarks, p. 62.
30	Sec. 7, T. 24 S., R. 33 E. (Burke well).	...do	Artesian flow	6	See description, p. 61.
31	North side of Crane Creek Gap.	Dug	Not used	14	
32	Center of Crane Creek Gap	...do	....do	6	
33	Post-office, Harriman	Bored	Pitcher pump	25	Said to be bored to depth of 148 feet. Black ooze and stagnant water at 70 feet.
34	In flat east of Dog Mountain	...do	....do	7 to 10	General statement for wells in this locality. Several water-bearing strata; better water usually in the deeper ones.
35	T. B. Beck, east base of Dog Mountain.	Dug	Wheel and bucket.	30	
36	T. B. Beck, ¼ mile east of No. 35.	...do	....do	18	
37	I. S. Tyler, east base of Dog Mountain.	...do	Pitcher pump	28	
38	Mr. Porter, east base of Dog Mountain.	...do	Not used	40	Small supply, poor water.
39	A. Barron, 3 miles north of Dog Mountain.	Bored	....do	63	Water struck at 63 feet; rose at first to 38 feet; in tuff.
40	Mr. Saddlemire, ¾ mile north of No. 39.	Dug	Pitcher pump	28	
41	½ mile west of No. 39	Bored	Not used	37	
42	1 mile northwest of No. 39	...do	Pitcher pump	13	
43	Mr. Carpenter, 1½ miles northwest of No. 39.	...do	....do	28	
44	5 miles west of Dog Mountain.	Dug	Windmill	30	
45	10 miles north of Double O ranch.	Bored	Pitcher pump	24	Water also at shallower depths in this section; also better quality at greater depths.
46	1½ miles southwest of Narrows.	...do	Not used	11	Water struck at 11 feet; said to have risen to 4 feet below surface.
47	1 mile south of Narrows	...do	Windmill	12	
48	Narrows	...do	Hand pumps and windmills.	10 to 15	General statement for wells at Narrows.
49	Mr. Springer, 6 miles east of Narrows.	...do	Pitcher pump	12	Water said to come from same red tuff from which the Sodhouse springs issue; when first bored, water rose to within 1 foot of the surface.
50	....do	...do	Windmill	6	
51	County well, Windy Point	Dug	Bucket and rope	16	
52	Mr. Smith, sec. 6, T. 26 S., R. 34 E.	Drilled			See p. 60.
53	O. E. Thompson, sec. 18, T. 26 S., R 34 E.	Dug	Windmill	35	
54	¾ mile south of No. 53	...do	Bucket and rope	24	

Aside from that supplied to gardens by a few windmills, little attempt has been made to use the shallow ground water for other than domestic purposes.

South of Narrows, in the lowland bordering Mud Lake, water under pressure is found a few feet below the surface, and also in a few places along lower Silvies River.

During the fall of 1907 a well was drilled on the east side of the valley, near Windy Point, in sec. 6, T. 26 S., R. 34 E. At a depth of 260 feet water was struck that rose to the surface, but a satisfactory flow was not obtained.

These evidences of pressure in the water of the valley filling make it probable that in some restricted localities flowing wells in the valley deposits will be obtained when the wells are properly sunk and cased. Although these may be obtained only in the lower portions of the valley, they may prove of use for irrigation on a small scale. Since the valley filling is comparatively shallow and the surface is very gently sloping, it is not probable that water exists in the unconsolidated sediments under sufficient head to yield flowing wells of great supply.

The depth of the valley filling could be judged only from the incomplete records of five wells that previous to 1908 had been drilled in it to the underlying rock. From the notes at hand concerning these it appears that in the county well, No. 12, rock was encountered at about 100 feet, and at about this depth also in Mr. Fred Haines's well, No. 8. A sample of the material from a depth of 280 feet in the Smith well, No. 52, indicates that at this depth the bottom of the valley sediments had been passed and that drilling was in a tuffaceous layer associated with the basalts. From the record of the well drilled at Lawen by Mr. Sitz, which is given on page 62, it appears that the valley filling is only 200 feet deep at this place, the remainder of the depth penetrated being through basalt and tuffaceous beds. In the Burke well, No. 30, drilling was stopped when resistant material, probably bed rock, was reached at a depth of 235 feet. Besides the records of these few drilled wells within the valley, the buttes that rise above its floor and the gentle dip of the rocks surrounding it also indicate that the unconsolidated filling is of comparatively slight depth.

The flatness of the valley surface is shown by the elevation of bench marks established by the United States Geological Survey along its margin and at the edge of the lake at Narrows. These elevations given indicate a slope of only about 50 feet from the northern margin of the valley to the lake, or only 2 feet to the mile over a great part of its surface. To the east, Malheur Gap is said to be only about 16 feet above the high-water level of Malheur Lake.

Although it is unlikely that strong flowing wells will be obtained in this valley in the alluvium and lake sediments, it is probable that the deeper water-bearing beds of unconsolidated material will later prove valuable sources of water for pumping. But the development of this underground supply will depend mainly upon the cost of pumping and the values that can be obtained from produce raised by irrigation; and until an easy outlet is obtained to a more extensive market than the local one it is not likely that extensive pumping will be found profitable.

The supply obtained at ground-water level has proved ample for domestic use, but it is not thought that this shallowest water will prove sufficient for extensive irrigation. On this matter the notes kindly furnished by Mr. W. E. Burke on his well (No. 30) northeast of Lawen are very instructive. At first a pit 6 feet square and 22 feet deep was dug, water being struck at 6 feet. It was the intention to pump from this shallow ground-water supply, but it was found that the pit yielded little greater supply than a 2-inch well. A 9-inch hole was then drilled, and at a depth between 90 and 100 feet a layer of sand was encountered, which yielded water that rose to within 7 feet of the surface. This layer was tested by pumping for two or three hours a day for several days, and when yielding 600 gallons a minute the level lowered to 32 feet below the surface; while when pumping 1,000 gallons a minute it lowered to 38 feet. At the bottom of the well another water-bearing bed was encountered, which yielded a surface flow of about 10 gallons a minute. In the summer of 1907 this well was still flowing sufficiently to form a pool 30 to 40 yards across, which had become a regular watering place for the range stock.

ROCK WATER.

STRUCTURAL CONDITIONS.

Around the borders of the Harney basin the bedded lavas slope toward it from all sides, as shown by the dip symbols on the geologic map (Pl. III), so that as a whole it is structurally a great saucer-shaped basin or syncline. Within this basin there are minor irregularities, of which Saddle Butte and other similar buttes are surface evidences, and probably there are other minor structural features of which there are no surface indications. In general, however, these are not considered to be sufficient to seriously affect artesian conditions within the basin.

DRILLED WELLS.

Of the five deep wells that have been mentioned, three were sunk into the bed-rock layers in an effort to obtain flowing water. The first important drilled well was put down in 1893 at the expense of Harney County. Of it Russell says:[a]

A well drilled at the expense of Harney County in 1893, at a locality about 6 miles east 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 a 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.

During the summer of 1907 the water in this well stood about 5 feet below the surface, little, if any, above the ground-water level.

Russell mentioned the well belonging to Mr. Fred Haines,[b] of which he says:

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 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.

In a later paper[c] he gives the following record of a third drilled well, belonging to Mr. G. L. Sitz, which was put down at Lawen:

Record of Sitz well, Lawen.

	Feet.
Sand and clay	200
Lava, about	50
Gravel, cemented	4
Hard and soft layers, from 8 inches to 4 feet thick	100
"Hard blue granite" (basalt)	78
	432

He refers to this as a flowing well, but more recent information states that it did not flow.

The evidence furnished by the drilled wells indicates that porous beds of tuffaceous material, similar to those exposed at numerous places along the borders of the basin, exist beneath the valley and

[a] Russell, I. C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: Water-Supply Paper U. S. Geol. Survey No. 78, 1903, pp. 40–41.

[b] Op. cit., p. 40.

[c] Russell, I. C., Preliminary report on the geology and water resources of central Oregon: Bull. U. S. Geol. Survey No. 252, 1905, p. 42.

are interbedded with rocks of firmer texture. These tuffs associated with the lavas do not form so uniform and persistent beds as do marine sandstones; they seem rather to form great irregular lens-shaped masses. These, however, are of sufficient extent to act as collecting reservoirs for percolating water, and by leakage from one bed to another some of them may serve the purpose of a continuous permeable stratum. An attempt is made to illustrate the relation of these tuffs to the basalt in the geologic cross section on Plate III, in which the thicker lines in the bedding planes represent lenses of tuffaceous material.

Of the three drilled wells that had been sunk in this valley to bed rock previous to the spring of 1908, the one that was put down at the expense of the county is considered to have been the best test for artesian water, for it is situated some distance out in the valley, was cased to solid rock, was sunk to a depth sufficient to be determinative, and did yield an artesian flow. The well of Mr. Fred Haines is nearer the valley edge and is of less depth, but the fact that it yielded a slight flow is favorable to the belief that valuable flowing wells can be obtained by deep drilling and proper casing. It is probable that had drilling been carried to a greater depth in the well of Mr. Sitz, at Lawen, a good flow of water would have been obtained, for beneath this central part of the valley conditions are thought to be especially favorable to the collection of water under pressure.

WARM SPRINGS.

Besides that furnished by the drilled wells in Harney Valley, other evidence of artesian conditions is given by the several warm springs that rise within it, especially by those about 3 miles south of Burns, and those of Warm Springs Valley, west of Harney Lake. In those places where the immediate source of the spring was seen, the water issues from coarse tuffaceous material that is interbedded with the lava. Its temperature is noticeably higher than that of the shallow ground water, and the flow is more constant and of greater volume than can well be accounted for by local surface supply. In all respects these springs resemble those that are found in other valleys in which flowing artesian water is obtained. The largest of these springs, near the Double O ranch, are locally considered to be supplied by water from the Cascade Range. Aside from the difficulties involved in distance and in the structures that intervene in the way of water that may travel eastward from these mountains, the position of the slopes of Steens Mountain as a collecting area, and probably also the plateau region south of Warm Springs Valley, favor a nearer source of supply. The fact that their flow has a seasonal variation, and is said to be one-third more in August and September than in April, also favors a more local source for their supply.

Of the spring 2 miles north of Harriman post-office, Russell,[a] writing in 1904, says:

About 4 miles northeast of Saddle Mountain Butte is a spring which, as observed by H. C. Dewey, forms an irregular pool from 75 to 120 feet in diameter and 20 to 30 feet deep. The water is clear, without odor, and near the margin of the pool has a temperature of 122° F. The discharge, which is about 430 cubic inches per second, is now utilized for watering stock. This spring rises at a locality on the broad surface of the valley, at least 4 miles from the nearest upland, and is a true fissure spring, having a deep source, shown by its temperature to be probably not less than 3,500 feet below the surface. Like other hot springs in the valley some account of which has been published,[b] it indicates the presence of artesian conditions.

In August, 1907, the discharge of this spring was about 20 miner's inches. The highest temperature that was recorded was 95° F., where the water rises near the center of the pool. This discordance in the measurements of 1903 and 1907 seems to corroborate the local statement that the spring is of variable flow and temperature. Concerning the origin of this spring it has been suggested by Dr. W. L. Marsden, of Burns, that faulting in the hills to the east, which has been discussed by Russell, may continue westward into the valley, and that this spring rises along a fault plane. Possibly the displacement continues across Harney Valley and up the valley of Sagehen Creek, and also furnishes a means of escape for the water of the springs along the lower course of this stream.

If such is the case, this faulting may render it impossible to obtain flowing wells near the fault line, but it is not considered that it seriously affects artesian conditions in the northern part of Harney Valley, nor in the cultivable area of its southern portion.

CATLOW BASIN.

DESCRIPTION.

Beyond the rocky table-land south of Harney Lake, and lying between Steens and Warner mountains, there is a long, shallow, relatively narrow basin. Its south-central portion, near the mouth of Skull Creek, is known as Catlow Valley, but as all the arable land of the basin is in one great body, the name Catlow Valley will here be applied to it as a whole. The valley is about 40 miles long, trends a little west of north, and has a fairly uniform width of 6 or 8 miles. On the northwest the rise to the higher land is gradual, but on the south and southwest low escarpments and steeper slopes mark the valley edge more clearly. On the east it is bordered by an escarpment that in its central portion reaches a height of 1,400 or 1,500 feet. The

[a] Russell, I. C., Preliminary report on the geology and water resources of central Oregon: Bull. U. S. Geol. Survey No. 252, 1905, p. 41.

[b] Russell, I. C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: Water-Supply Paper U. S. Geol. Survey No. 78, 1903.

northern end of the valley is also marked by a bold escarpment that is superimposed upon the plateau to which one ascends from the lowland of the P ranch; for Catlow Valley lies 400 feet higher than the marsh of Donner und Blitzen River. Northward this branch scarp unites with the one bordering the marsh land of the river.

Terraces along its eastern border show that Catlow Valley was once occupied by a lake that extended northward nearly to the edge of the plateau overlooking the P ranch, but apparently it never became quite high enough to overflow through the pass at this point to the lowland of Donner und Blitzen River.

Most of the northern part of the valley is level and sagebrush covered, and only along its borders is it trenched by a few arroyos or flood-water channels. South of Skull Creek, in what was probably the deepest part of the former lake, a considerable part of the valley is covered with sand dunes and alkaline areas.

SETTLEMENT.

Catlow Valley was practically unsettled in the summer of 1907. The houses on the several cattle ranches are usually occupied only while the wild hay is being cut and stacked, but during the fall of 1907 a family remained at Home Creek ranch to care for fences and watering places on the range. One homesteader, Mr. Pearl Wise, had filed on a claim near the sink of Skull Creek. During the summer of 1907 he built a ditch to take a portion of the spring flood of this stream and impound it in an earthen reservoir for later irrigation. The lack of settlers in the valley seemed due mainly to the facts that nearly all of the surface water supply is controlled by the cattle ranches and that nearly all the newcomers have taken up claims in the less remote Harney Valley; for Catlow Valley lies away from the main line of travel, so that it is comparatively little known except to the cattlemen.

SURFACE WATER.

The five cattle ranches in this valley use the surface water to a small extent in irrigating the wild-hay land, but hold the several streams and springs chiefly as watering places for stock. Home, Threemile, and Skull creeks rise in the southern portion of Steins Mountain and debouch upon Catlow Valley along its eastern edge. In their middle courses these streams have steep grades, and have cut deep gorges where they descend from the plateau to the valley land. Where they enter the valley they have built extensive alluvial fans. Rock Creek, on the western side of the valley, gets its most constant supply from Warner Mountain, but during the run-off period it also receives the drainage from most of the surrounding plateau country. In the spring most of its water does not flow beyond its sink in the northwestern part of Catlow Valley, while during the summer the stream is dry throughout most of its course. Along its middle portion, west of the Rock Creek ranch, there is an extensive strip of alluvial land, but the discharge of the creek is so floodlike and of such short duration that it could not be depended upon in this portion for irrigation purposes.

Walls Lake, a collecting place for the spring run-off from the neighboring region, lies in the unsurveyed country north of Catlow Valley, and its location as given on the reconnaissance map (Pl. II) is only approximately correct. It is said to be about 1⅛ miles long, ⅜ mile wide, and to average 4 feet in depth during most of the year. The utilization of its water on a body of arable land near it has been considered, but would involve digging a canal half a mile long and 20 feet deep in the maximum, at a cost roughly estimated at $5,000. It is reported that the lake has gone dry in years of slight rainfall, so an irrigation project dependent upon it for water would be likely to prove an expensive venture.

From the bluffs on the eastern side of the valley a number of springs come forth, of which by far the largest are those at the Roaring Springs ranch. The water here issues along the lower portion of the bluffs as two or three large and numerous smaller springs, and flows some distance out on the valley before it sinks. Except for the small area of natural hay land that the water irrigates, no use is made of it, though the amount, which is estimated at about 250 miner's inches, is sufficient to irrigate 800 or 1,000 acres. A similar spring augments the flow of Threemile Creek, while farther southward, near the HL ranch, nearly a dozen springs issue along the bluffs, from the same horizon, and water a small field of wild hay. On the lower slopes of Beattys Butte there are four or five small springs, which are kept cleaned out and form watering places for the range stock. On the upper course of Rock Creek there is a group of hot springs that yield a total flow of 8 or 10 miner's inches, from 105° to 115° F. in temperature. Advantage is taken of the temperature of this water in preparing sheep dip, a use to which a number of hot springs in southeastern Oregon are put.

GROUND WATER.

As very few wells have been sunk in this valley, the ground water conditions can be stated only in a general way, but it is thought that in nearly all parts of the valley water can be obtained within 30 or 40 feet of the surface, and in the lowest areas at much less depths. The wells in which the depth to water was noticed, which are all shallow dug ones, are indicated on Plate III. The well near the sink of Skull Creek, No. 58, which was put down in the summer of 1907, failed to reach water in the sand and gravel at a depth of 40 feet. This well was dug on higher land, in the alluvium brought down by Skull Creek, in which the water probably sinks to a greater depth than elsewhere, but water can almost certainly be obtained here by sinking deeper in the alluvial material. At the Rock Creek ranch there are two wells (Nos. 56 and 57) close to the channel of the stream, in which the water stood respectively at 12 and 19 feet below the surface in September, 1907. North of the valley proper, and about 12 miles west of Walls Lake, the only settler, Mr. Chino, obtains water at about 15 feet in the alluvial land (well No. 55), and by the aid of a windmill is able to irrigate a small acreage.

Between Roaring Springs and the sink of Rock Creek there are two or three shallow ponds. These can hardly be supplied wholly by surface precipitation, and no evidence was seen that they are supplied by springs. Since they lie in slight depressions it seems probable that they represent the ground-water level at this point. If so, water must stand at less than 10 feet from the surface beneath much of the northern part of the valley.

Large alluvial fans have been formed where Home and Threemile creeks debouch upon the valley, and less perfectly where Skull Creek enters the open land. A number of springs as well as the streams themselves flow down and spread over these alluvial deposits, while other water may also enter the sands and gravels by seepage from the bluffs against which these deposits lie; hence it seems probable that small flowing wells similar to those of Alvord Valley, which are described later (pp. 74–77), can be obtained in the valley near the margins of these deposits, for these springs and streams keep the alluvium saturated with water, probably under sufficient head to produce flowing wells around the edges of the fans. A spring at the Home Creek ranch house, which furnishes the domestic supply, is probably of alluvial artesian water that escapes to the surface at this point, along the edge of the fan of Home Creek.

Judging from the slight inclination of the rocks on each side of this valley its unconsolidated filling is perhaps not over 200 feet in depth, and over its greater portion the surface is so nearly level that little head can be developed in the alluvial water; hence, except in the zone just outlined, in the lowlands about the margins of the fans, there is not much probability that artesian flows will be developed by wells sunk into the valley filling only.

GEOLOGIC STRUCTURE.

Since the surface of this region is approximately the original surface of the lava flows, the slopes are in general dip slopes. Along the western side of Catlow Valley the basalts dip eastward at a uniform low angle, and pass beneath the lake deposits. On its eastern border the rocks that form the escarpment along that side of the valley dip gently to the west or northwest. Southward the slopes rise to a more mountainous country, while on the north low scarps in the plateau region also exhibit gentle west and northwest dips.

At first thought, the escarpment along the east side of this valley and the gentle slope toward it of the rocky desert to the west, suggest that the scarp has been produced by faulting, and that the country to the west is the surface of a tilted block. Lake Abert and northern Warner Lake, which are west of Catlow Valley, lie in basins at the lower sides of such blocks, and it is possible that Catlow Valley also lies upon the edge of such a tilted block. However, the following conditions lead to the tentative statement that the scarp bounding the eastern side of this valley has been produced, or at least made steeper and heightened, by progressive weathering action, and that the rocks underlying the valley form a great low syncline.

The escarpment along the middle portion of Donner und Blitzen River divides west of the P ranch. The western branch swings southwest along the border of the Catlow Valley and gradually dies out in the plateau region. The great escarpment along the east side of this valley is formed by slopes that gradually rise southward and culminate in the crest of Steens Mountain. Near Threemile Creek this scarp turns farther to the southeast, is superimposed, as it were, upon the slopes drained by Skull Creek, and unites with the Steens Mountain scarp at Whisky Hill. The remarkable steepness and regularity of this escarpment, and the sharp notches that have been cut in it by Home and Threemile creeks, suggest a fault origin, but no hot springs or other evidences of faulting were seen along any part of it. The springs that issue along it come forth well up on the face of the scarp, not from the edge of the valley alluvium as they would if they rose along fault fissures. One or two blocks were noticed that dip steeply toward Catlow Valley, but these are more probably landslide blocks caused by erosional agencies than blocks due to faulting. In respect to this scarp as a fault feature the statement made in the earlier discussion of structure may be repeated here—that in the case of the recognized fault scarps the rocks forming the uptilted blocks dip away from the bluffs, while those forming the scarp on the eastern side of Catlow Valley dip toward it.

It is difficult to determine closely the direction of dip of the lava beds of the Catlow basin, for they slope at angles of only 2° or 3° from the horizontal, and in few places is there a distinctive layer of lava or tuff that can be used for such a determination. It seems, however, that the surface rocks of the plateaus to the west, north, and east of Catlow Valley are all at least of the same horizon or period of effusion, if not of the same individual effusion or flow of lava. A dip of 3° westward would carry the upper beds of the scarp at Home Creek beneath the valley 4 or 5 miles out from the scarp, so they may be continuous with those of the slopes on the opposite side of the valley. Or it may be that the beds composing the Catlow Valley scarp overlie those of the scarp along the eastern edge of Warner Valley and of the plateau surrounding Beattys Butte, but never extended so far westward, as is indicated in the generalized cross section on Plate III; and that the Catlow Valley scarp has been made more prominent by progressive eastward subaerial erosion. In the cross section the bedding planes represent series of effusions rather than separate flows, for it is not considered that each relatively thin sheet of lava is as extensive as is usually each bed of a sedimentary deposit.[a] If either of the above explanations of the structure is correct, Catlow Valley lies in the trough of a great shallow syncline.

Progressive erosion may also account for the 400-foot cliff at the northeast end of the valley. There is a small difference between the inclination of the beds composing this escarpment and that of the slopes south of it, which appears to carry the rocks of the latter beneath those of the higher plateau. The beds on each side of the cliff dip in the same direction, northwestward, but there is no evidence of faulting or of tilted block structure along the scarp.

ROCK WATER.

If the Catlow Valley scarp is a fault scarp it of course seriously affects rock-water conditions, if it does not render impossible the existence of artesian water beneath the valley. This is not considered to be the case, however, and the explanation of the structure as being synclinal is believed to be the correct one.

Aside from the structure, the numerous springs that issue along the east side of the valley furnish the best evidence in favor of the presence of artesian water. At Roaring Springs, at Threemile Creek, and near the HL ranch numerous springs issue from a coarse tuffaceous bed that seems to be continuous throughout the length of the scarp. The water of these springs is several degrees above the normal ground-water temperature, and the flow is nearly constant, two factors which indicate that the springs are not dependent on the local surface water for their supply.

The existence of this porous bed and the evidence that it carries much water favor the belief that other water-bearing beds are associated with the rocks underlying the valley; while the synclinal

[a] George Davis Louderback has well expressed this idea of the thinning out and overlapping of successive lava sheets, in a paper entitled "Basin range structure of the Humboldt region" (Bull. Geol. Soc. America, vol. 15, 1904, pp. 302-303). In this paper he says: "Volcanic rocks that are the successive products from several vents are likely to be very irregular in their areal distribution and order of superposition. The failure of a later to cover completely an earlier, or the overlapping of a later over an earlier, or the failure of a later to overlie an earlier at all, lead to some confusion, and make it difficult and sometimes impossible to arrange them in historic sequence."

structure favors the belief that this water is under sufficient pressure to yield flowing wells when the water-bearing beds are properly tapped.

CONCLUSION.

Although Catlow Valley is 400 or 500 feet higher than the other valleys of Harney County, its climate is said to be milder than that of the lower ones, and it is claimed that precipitation within it is somewhat greater. Possibly the bluff along its eastern side protects it from the cold storms that sweep over the more exposed valleys.

There is little available surface water, but the indications favor a plentiful supply of shallow ground water, both for domestic use and for irrigation by means of pumping plants. It is probable that flowing wells of small yield may be obtained in the unconsolidated material near the margins of the alluvial fans on the eastern border of the valley. Deep drilling for flowing artesian rock water is also warranted by the structure and other favorable conditions, and it is probable that a valuable supply of water for irrigation may be developed from the deep-seated sources.

Except in limited alkaline areas in its lowest parts, the soil conditions in this valley seem good, so that when it has become settled and transportation facilities are improved it should support a well-to-do agricultural and stock-raising community.

ALVORD BASIN.

LOCATION AND EXTENT.

The Alvord basin extends along the entire eastern base of Steens Mountain and southward along the Pueblo Range a short distance into Nevada. Throughout its greater extent it has a width of 6 to 10 miles, but in its northern portion its continuity is interrupted to some extent by hills, and the valley portion is much narrower. The elevation of the valley land, as nearly as could be determined by aneroid barometer, is about the same as that of Harney Valley—between 4,100 and 4,200 feet.

SOIL AND VEGETATION.

In the northern part of the basin much of the surface is covered with gravel and alluvium that have been brought down by the streams from Steens Mountain. These materials have formed great alluvial fans, which have built up the divides that limit the basins of Juniper and Mann lakes and separate the drainage areas of these water bodies from each other and from that of Alvord Desert. Wildhorse Creek has also brought down and spread along its lower course a layer of gravel, on which there is a rank growth of sagebrush. Near the mouth of the canyon of Trout Creek, along the east side of Alvord Valley, the stream wash has also built a considerable extent of gravelly bench land. Nearly all of this gravelly land is tillable, and would be valuable for farming if water were applied to it. A narrow strip along Wildhorse Creek and a much larger area along lower Trout Creek yield crops of marsh hay, as do also an extensive acreage of the Alvord ranch and smaller meadows at Mann and Juniper lakes. On the Alvord ranch considerable alfalfa is also raised, and about 5,000 bushels of barley are threshed each year. But there is much waste land in the basin. From the playa of Alvord Desert a wide belt of greasewood land extends southward, includes the land surrounding Alvord Lake, and extends 5 or 6 miles south of the borax works. Along Pueblo Creek, also, for 4 or 5 miles south of Tumtum Lake, there is a band of greasewood land, a couple of miles in its maximum width.

SETTLEMENT.

At Denio and at Andrews there are post-offices and small stores, and a few homes. Throughout the basin there are homesteads wherever there is water for irrigation, but most of the watered land, by which is meant most of the wild-hay land, is controlled by the large cattle companies. Recently a few new settlers have filed on homesteads south of Juniper Lake, but this was the only one of the several areas of vacant sagebrush land in this basin that was beginning to be settled in the summer of 1907. A couple of miles south of Andrews, Mr. A. Miranda has a number of acres of alfalfa, which in early summer are irrigated by water from the mountain stream on the west. A few miles farther south, Mr. A. H. Hollis has a few acres of irrigated meadow; while in the small valley along Trout Creek, near Flagstaff Butte, water is available for irrigation, and much alfalfa is grown. On Little Trout Creek, about one-half mile above its junction with the larger stream, Mr. J. C. Beatty has a small acreage, which has been brought under a higher state of cultivation than any other ranch noticed in this region. As his ranch is a good example of what can be done in this section where water is available, the following statements were obtained concerning the crops he raises. In the narrow strip along the creek that has been brought under irrigation he has a number of acres of alfalfa, from which three cuttings a year are harvested. Nearly all vegetables can be grown, and his potato patch of $2\frac{3}{4}$ acres has yielded 245 bushels to the acre. In this locality it is best to plant vegetables after the first week in May, so that they may escape the late killing frosts. Apples and other hardy fruits do well, but the late-blooming varieties have been found to be the best. Plate V, *A*, shows Mr. Beatty's ranch and the extent of the cultivated land on each side of the stream.

MINERAL DEPOSITS.

For the last nine or ten years borax has been shipped from the works near the hot springs south of Alvord Lake. Of the deposit here Joseph Struthers says:[a]

The marsh deposits of sodium borate in Harney County, which extend over 10,000 acres south of Lake Alvord, have been operated during the last few years, and the refineries have produced a yearly output of approximately 400 short tons of refined borax, which is carried by mules to Winnemucca, on the Central Pacific Railway, whence it goes to Chicago, St. Louis, and occasionally to San Francisco. The Rose Valley Borax Company owns 2,000 acres of the richest portion of the deposit close to the lake. The ground is level and treeless and is incrusted with a layer of sodium borate several inches in thickness, which contains also sodium carbonate, sodium sulphate, sodium chloride, and other salts. During the summer the loose surface deposit is shoveled into small heaps and is replaced by a second incrustation within a comparatively short time. As no mining is done in winter, sufficient material is collected in summer to furnish a supply to operate the refining works throughout the entire year. The crude mineral, containing from 5 to 20 per cent of boric acid, is shoveled into tanks of boiling water, and chlorine or sulphuric acid is added to decompose the alkali salts, and thus free the boric acid. After twenty-four hours the clear supernatant liquor is drawn off into crystallizing tanks and cooled, yielding white pearly scales of high-grade boric acid, and a mother liquor, which is used repeatedly if it contains a sufficient quantity of sodium salts to warrant a separate treatment.

In the collection of the alkali crust Chinamen have been employed chiefly. This crude deposit is first scraped into windrows with shovels and then loaded into wagons and hauled to the works. Sagebrush is used as fuel under the dissolving tanks. The refining plant consists of two of these tanks, of 6,000 and 8,000 gallons capacity, respectively, and 24 crystallizing tanks, each of 1,200 gallons capacity. The crystallized product of borax is sacked and hauled to Winnemucca, Nev., by 16-mule teams.

As has been stated in an earlier part of this paper, new interest has been aroused within the last few years in copper prospects on Pueblo Mountain and the neighboring slopes, but up to the fall of 1907 no extensive development had been undertaken. The metal seems to be associated with the porphyries and the granitic series of rocks that form the Pueblo Mountains.

SURFACE WATER.

Trout Creek, the largest stream in this basin, rises in the hills of the southeastern corner of the county, enters Alvord Valley from the east, and flows northward along it. Half a mile above the mouth of its canyon the rock walls closely approach each other, and open out above into a little valley that forms a very good reservoir site. The advantages of a reservoir here for the storage of water for irrigation have long been realized, but no detailed survey of the site had been

[a] Struthers, Joseph, Borax: Mineral Resources U. S. for 1901, U. S. Geol. Survey, 1902, pp. 870-871.

A. J. C. BEATTY'S RANCH ON LITTLE TROUT CREEK.

B. ALLUVIAL FANS ON WEST SIDE OF ALVORD VALLEY, NEAR MANN LAKE.

made at the time of this reconnaissance. It is said that if a dam 100 feet in height were built at the narrowest part of the canyon it would form a water body about half a mile long and perhaps 300 or 400 yards wide. At the lower end of a larger valley about 3 miles farther upstream there is another good dam site, but the reservoir that would be formed here is, on casual examination, of much greater capacity than the inflow could fill advantageously, while the valley that would be submerged is occupied by two or three farms.

Nearly all the other streams of the Alvord basin are on its western side and are fed by the springs and melting snow of Steens Mountain. This water finds its way to the few lakes or else sinks in the alluvium and marsh lands before reaching these water bodies.

On the talus slopes of the Steens Mountain scarp there are numerous surface springs which are fed mainly by melting snow, and there are also a few cold springs supplied by water from a source not so direct. Of these may be mentioned that known as Summit Spring, No. 236, on the road between Juniper ranch and Mule ranch, and a larger spring on the road between Alvord and Catlow valleys. On the lower slopes also there are a few springs along the canyon sides. In at least one place, at the home of Mr. A. H. Hollis, 6 miles south of Andrews, a seepage spring has been developed by tunneling, so as to furnish a supply of water for domestic use. There are also a number of hot springs in this valley, of which those near the borax works south of Alvord Lake are the largest and hottest. About one-quarter mile north of the works there is a series of vents along a line one-quarter mile long, in some of which the water is near the boiling point. At the borax works there is a pool about 275 yards in diameter, known as Hot Lake. It is on a low mound surrounded by greasewood and salt-grass land, and the edge of the pool is bordered by a hard crust of carbonate deposit. The water rises from the bottom of the pool through several vents and discharges through a ditch, with a fairly constant flow of between 75 and 100 miner's inches. The temperature of the water varies, however. When measured in September, 1907, where it discharges from the pool, it was 97° F., while seven weeks later the temperature at the same place was 82° F. The water is used in the boiling tanks of the borax works and to some extent in irrigating a field of salt grass east of the pool.

On the western side of Alvord Desert there is another group of hot springs, which have a temperature of about 168° F. Their water sinks in the barren land of the desert after flowing a few hundred yards through a salt-grass area.

On Trout Creek, at the base of Flagstaff Butte, there is a fourth hot spring. Five or six vents at this place yield a total of perhaps 5 miner's inches of water, which rises with a temperature of 128° F.

Advantage is taken of the temperature of this water during the sheep-dipping season, when it is used in preparing the dip.

Although its temperature is but slightly above that of the ground water, a spring on Mr. A. C. Bustamante's place, about 2½ miles southeast of Andrews, is mentioned here with the hot springs, inasmuch as its location with respect to the mountain block that terminates in Serrano Point suggests that its existence is due to the dislocation that produced that block, and that its source, like that of warmer springs, is deep-seated water that rises along fault planes, or shallower water heated by the proximity of masses of lava beneath the surface, that have not yet cooled to a normal temperature.

The lakes of Alvord Valley are of course dependent mainly for their supply upon the inflow from streams and springs. Alvord Lake, the largest of these, is an alkaline body that changes much in size with the season. In years of great precipitation, as has been previously stated, it overflows northward to the great playa of Alvord Desert. Tumtum, Mann, and Juniper lakes contain comparatively fresh water, but as each occupies the lowest part of the locality in which it lies the water has not been used for irrigation. Their shores are steeper than those of Alvord Lake, and hence they do not fluctuate so greatly in areal extent. Ten Cent Lake, at the northern end of the valley, receives its supply in large part through ditches that bring to it water from the slopes to the southwest. It is thus made a storage reservoir for water that in summer is conducted southward through a ditch to irrigate land on the Juniper ranch.

GROUND WATER.

As in the other valleys, water is obtained at a shallow depth in the alluvial filling of Alvord Valley, and in the wells that were visited it is of good quality, since it is derived mainly from the snow of Steens Mountain.

The streams that flow down the Steens Mountain scarp have built alluvial fans, in which conditions are favorable for the existence of water under pressure; and the presence of such water is shown in several wells. Fourteen flowing wells, practically all that had been sunk in the valley up to that time, were noted in the fall of 1907.

All of these flowing wells were bored, and work in several unsuccessful ones had to be stopped when coarse gravel was encountered. Three wells, Nos. 65, 66, and 67 (Pl. III), on Mr. A. Miranda's place, 2 miles south of Andrews, have a diameter of only 2 inches, and as the head is slight the flow is small and is used only for domestic purposes and for watering cattle. About 4 miles farther south, in meadow land belonging to Mr. A. H. Hollis, there are six flowing wells, Nos. 70 to 75, inclusive, which are 6 and 7 inches in diameter and yield a total flow of about 25 miner's inches. The water is used to irrigate the grass land immediately adjacent. About 6 miles north of Denio there is a 6-inch well (No. 81) belonging to Mr. J. Thomsen. It was flowing perhaps 2 miner's inches in September, 1907, but little attempt had been made to utilize the water. This well is near the channel of Pueblo Creek, and on the western edge of the alkaline land that extends along its course. Near the edge of the marsh land south of the Alvord ranch (at No. 61) an artesian flow was obtained in the spring of 1907 by Mr. S. Alberson. The other flowing wells of this valley are small ones, only 2 or 2½ inches in diameter, and their flows were not being put to any use at the time of this examination. All of these flowing wells have been obtained in a narrow strip of land close to the center of the valley, and their artesian head is slight. Two wells, Nos. 68 and 76, which were bored a little farther from the trough of the valley than the successful ones, failed to yield flowing water, though water rose in them to within 3 and 4 feet of the surface, respectively. Two other wells near Andrews, Nos. 63 and 64, failed to obtain artesian flows, and the water is said to have risen in each only a foot or two above the depth at which it was struck. The artesian area is thus seen to be limited to a narrow belt along the lowest portion of the valley, and the greater part of this land is not suitable for cultivation, owing to its alkaline quality. Near Denio only one flowing well (No. 82) was noted, and it seems to be a developed spring rather than an artesian well.

The locations of the wells that were noted in this valley are shown on Plate III, and other facts concerning them are listed in the following table:

Wells in the Alvord basin.

No. of well.	Owner or location.	Class of well.	Method of lift.	Depth to water.	Total depth.	Diameter.	Remarks.
				Feet.	*Feet.*	*In.*	
59	South end of Juniper Lake.	Dug	Bucket and rope.	10			
60	F. Miranda's stage station.	do	Wheel and bucket.	12			
61	S. Alberson, sec. 28, T. 34 S., R. 34 E.	Bored	Flows	6	84	6	Artesian flow at 47½ feet; barely flows.
62	Hotel, Andrews	Dug	Wheel and bucket.	20			
63	1 mile southeast of Andrews.	Bored	Windmill	14			
64	do	do	do	6			
65–67	A. Miranda, 2 miles south of Andrews.	do	Flow		(a)	2	Cased only part way; flows are about ½, ¾, and 1 miner's inch.
68	½ mile south of No. 65	do	Not used	3	202		Unsuccessful boring for artesian flow; water under pressure struck at 117 feet.
69	Ed. Carlson, 1 mile southeast of No. 65.	do	Flows		183(?)		Unused.
70	A. H. Hollis, 6 miles south of Andrews.	do	do		150	6	Flow, ½ miner's inch; temperature, 68° F.

a Thought to be between 100 and 200 feet.

Wells in the Alvord basin—Continued.

No. of well.	Owner or location.	Class of well.	Method of lift.	Depth to water.	Total depth.	Diameter.	Remarks.
				Feet.	*Feet.*	*In.*	
71	A. H. Hollis, 6 miles south of Andrews.	Bored ..	Flows........	......	50-100	6	Flow, 6½ miner's inches; temperature, 72° F.
72	.....do................	...do....	.....do........	......	50-100	7	Flow, 6½ miner's inches; temperature, 71° F.
73	.....do................	...do....	.....do........	......	50-100	7	Flow, 4 miner's inches; temperature, 64° F.
74	.....do................	...do....	.....do........	......	50-100	7	Flow, 3½ miner's inches; temperature, 68° F.
75	.....do................	...do....	.....do........	......	50-100	7	Flow, 4 miner's inches; temperature, 68° F.
76	A. H. Hollis, ¼ mile south of No. 75.	...do....	Not used.....	4	170	6	Unsuccessful boring for artesian flow.
77	Mr. Doane, sec. 3, T. 39 S., R. 33 E.	...do....	Windmill.....	20	......	.....	
78	Mr. London, east of No. 77.	...do....	Not used.....	3	(*a*)	.....	Unsuccessful boring for artesian flow.
79	Ed. Catlow, sec. 14, T. 39 S., R. 33 E.	...do....	Pitcher pump	5	......	.....	
80	Mr. Johnson, in slough south of Tumtum Lake.	...do....	Flows........	......	23	2	Flow 2 or 3 miner's inches (reported.)
81	J. Thomsen, 7 miles north of Denio.	...do....	.....do........	......	38	6	Flow about 2 miner's inches.
82	2 miles north of Denio...	...do....	.....do........	......	......	.....	Small flow, possibly a developed spring.

a Said to be over 200 feet deep.

In December, 1908, after the above list was compiled, Mr. J. H. Neal reported that he had drilled a well in the northern end of the basin, in T. 29 S., R. 36 E. The material passed through was mainly "cement" gravel and clay, to a depth of 435 feet. Here a layer of sand was encountered, in which a supply of water, 66° F. in temperature, was obtained, which rose within 86 feet of the surface.

Although strong supplies of water similar to this may be obtained in other parts of the Alvord basin, which will be of value for pumping purposes, it is not probable that flowing artesian wells can be obtained in the higher portions of its cultivable lands.

In January, 1909, Mr. Neal also reported that two small flowing wells had been obtained by Mr. Tudor, about 2 miles south of Juniper Lake. One of these is only about 20 feet deep, and has a flow sufficient to fill a 1-inch pipe without pressure. The other is about 70 feet deep, is cased, and yields two or three times as much water as the shallower one.

It is probable that a few small flowing wells can be obtained east and northeast of Denio, near the course of Pueblo Creek, but it is in the portion of the valley between Alvord ranch and Juniper Lake that the possibilities of development by means of shallow flowing artesian wells seem the greatest. This land is composed mostly of alluvial gravel, and is covered with sagebrush. In by no means all of it is there probability of obtaining flowing wells, but along the center of the valley for 3 or 4 miles south of Juniper Lake, and along the west side of the valley between Mann Lake ranch and the Alvord ranch, artesian flows can probably be obtained from wells sunk in the alluvium near the margins of the fan deposits. The development of these fans near the Mann Lake ranch is shown in Plate V, *B*.

ROCK-WATER CONDITIONS.

On his first visit to southeastern Oregon, Russell[a] considered Steens Mountain to be a great fault block, at the east base of which lies Alvord Valley. After later study of its structure he was inclined to believe it "the western slope of a great anticline,"[b] or at least that in general the structure is anticlinal, but that faulting and also deep erosion have given the present topography to the mountain and to the valley and hills along its eastern base.[c]

This latter hypothesis seems to be the more probable—that the structure is a great low anticline that has been extensively faulted, rather than a great monoclinal block. The Steens Mountain scarp seems to be unquestionably of fault origin, and the blocks within the northern part of Alvord Valley appear to be monoclinal fault blocks rather than erosional remnants; but east of the valley the rocks dip gently eastward, in agreement with the assumption that they belong to the eastern limb of a great low anticline of which the westward-dipping beds of Steens Mountain form the other limb. The eastern portion of the geologic cross section, on Plate III, shows the structure of the valley at the north end of Alvord Desert, where the faulted anticlinal character is best shown.

There is little chance of obtaining artesian flows by deep drilling in this valley. The extensive faulting that has taken place prevents rock water from being stored under pressure in its central and southern portions, while in its northern portion, even if extensive faulting has not taken place, the anticlinal structure does not admit of the collection of deep-seated water.

RÉSUMÉ.

In summing up the agricultural conditions in Alvord Valley, and its further possibilities, the following statements may be made: The climate is milder than in the higher and more open parts of the county, because it is protected even more than Catlow Valley by a great escarpment. The valley contains much fertile land that is still

[a] Russell, I. C., A geological reconnaissance in southern Oregon: Fourth Ann. Rept. U. S. Geol. Survey, 1884, p. 439.

[b] Russell, I. C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: Water-Supply Paper U. S. Geol. Survey No. 78, 1903, p. 43. See also p. 23 of the same paper.

[c] See also Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: Bull. U. S. Geol. Survey No. 217, 1903, pp. 15, 68.

unoccupied, but there is also a great amount of worthless land within it. Water is easily obtained by sinking shallow wells, and except in the lowest lands it is of good quality. In certain parts shallow flowing wells have been obtained, and in certain other restricted areas that have been named it is probable that flowing water can be developed. The rainfall is usually sufficient to raise dry crops of grain, but without water for the irrigation of other crops agriculture can hardly prove successful. The section is remote from market, and probably will be for a number of years to come; but the local consumption of hay and grain is increasing, and there is usually a good demand by sheepmen and cattlemen for such produce during the winter months.

WHITEHORSE BASIN.

DESCRIPTION.

The Whitehorse drainage basin lies east of Alvord Valley, between it and the plateau country that drains northeastward to Owyhee River. The southern slopes of this basin rise to the Whitehorse Mountains, while on the east and west gentler slopes form its sides. The northern part of the basin widens out to a flat alluvial valley, which merges into the higher plateau country that stretches toward Barren Valley, in Malheur County.

At the Sand Gap, in its northwestern end, only a low divide separates this drainage basin from that of Alvord Valley. Toward the northeast a wide arm of the valley extends for a few miles, but no evidence was seen that indicated an opening out of the valley in that direction, nor that flood water has, during recent years at least, extended very far along this northeastern arm.

SOIL.

In the southwestern part of the basin the soil is derived mainly from light-colored tuff and volcanic ash, but near the stream channels it is more gravelly. On the Whitehorse ranch there are some 3,000 acres of wild-hay land, upon which practically all the available surface water is used. Northward beyond the limits of this meadow there is much cultivable sagebrush land, but on the west side of the basin the soil is dryer and probably somewhat alkaline, as it supports only a scanty growth of greasewood.

SETTLEMENT.

The Whitehorse ranch controls all the meadow land of the valley, and from it approximately 3,000 tons of hay, or a ton to the acre, is gathered each year. In the fall the cattle from the surrounding range are rounded up here to pasture during the winter, and are fed from the stacks during the more severe weather.

The only habitations in the valley land during the past year were at this ranch; though in the southern part of the basin, along the upper course of Willow Creek, there were two or three small farms where water was available for irrigation.

SURFACE WATER.

There are two streams in the Whitehorse basin, Willow and Whitehorse creeks. These rise in the hills to the south and flow in a direct course toward its northern end. In late summer Whitehorse Creek is nearly dry, but Willow Creek enters the lowland with a flow of 50 to 75 miner's inches. Through the southwestern part of the basin, which is a wide, sagebrush-covered, gently sloping valley, storm-water channels carry the run-off to Willow Creek.

In this southwestern portion there are two localities of springs. At the western one (No. 244, Pl. III) an acre or more of ground is kept wet by the seepage from numerous small vents; while half a mile farther east four springs a few yards apart, with a combined flow of 3 or 4 miner's inches, discharge water close to 100° F. in temperature.

GROUND WATER.

During harvest season, water for the haying crews is obtained throughout the meadow land of the Whitehorse ranch from dug wells a few feet in depth. At the ranch house, water stands about 15 feet below the surface during the summer. Wells in nearly all other parts of the agricultural lands should also reach water at shallow depths.

Whitehorse and Willow creeks have not formed alluvial fans of noticeable extent, because for most of their lower courses they have relatively gentle grades, and do not debouch from steep canyons upon a flat valley. Hence, conditions do not favor the storage of water under pressure beneath the marsh land of the lower courses of these streams, as they do in portions of the Alvord basin.

From the vicinity of Flagstaff Butte the valley floor slopes to the northeast, but the deposits over this area are bedded volcanic ash rather than alluvium, and the water supply to this surficial material is very limited. It is possible that wells sunk in the lower part of the valley, west and southwest of the Whitehorse ranch, might strike water in the alluvial and tuffaceous material under sufficient head to yield artesian flows, but the chances do not favor the existence of such water in these shallow deposits.

GEOLOGIC STRUCTURE.

Structurally the Whitehorse basin is synclinal, for from the south the bedded lavas composing the mountain slopes dip toward it, and from the east and from the west the rocks also dip gently toward its valley land. A few miles south of the Whitehorse ranch a low rocky divide that separates the channels of Whitehorse and Willow creeks narrows the alluvial land to a belt along Willow Creek and partially divides the topographic basin into an upper and a lower valley. While in this middle portion there may also be some constriction of the structural basin, the attitude of the rocks, where observed, indicates that it is not divided into two separate basins.

ROCK WATER.

That tuffaceous layers are interbedded with the lavas is shown where they are exposed south of Flagstaff Butte and in other places west of the valley, and by layers from which springs issue that are exposed east of the Whitehorse basin, in Oregon Canyon.[a]

The hills to the south furnish a catchment area in which water may penetrate to the deeper rock layers; so that the favorable conditions of structure, pervious beds, and source of supply, necessary for the existence of water under pressure, seem to be fulfilled in this basin. Hence it is very probable that wells drilled to a considerable depth and properly cased will yield artesian flows. A possibly unfavorable condition is the low elevation of the northwestern rim at the Sand Gap, but as the supply of water to the deep layers probably comes mainly from the south it is not considered that this low place seriously affects artesian conditions within the basin. Since it is the lowest, the northern part is that most favorable to the existence of artesian water, but in the southern portion also, in the neighborhood of the springs that rise near the road, artesian conditions probably obtain, as was pointed out by Russell[b] several years ago.

The depth at which an artesian flow in this basin may be expected can not be foretold even approximately, since no deep wells have been sunk in the region. It seems, however, judging solely from the evidence furnished by the springs in Oregon Canyon, that such water should be found within a depth of 1,000 feet. The warm springs in the southern part of Whitehorse basin are possibly artesian in character, and their water may derive its high temperature by coming from deep sources, but it is thought that their abnormal temperature is more probably due, in part at least, to the proximity of heated rock

[a] See Russell, I. C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: Water-Supply Paper U. S. Geol. Survey No. 78, 1903, p. 43.

[b] Op. cit., p. 44.

below the surface. Flagstaff Butte has the appearance of being either a center of effusion or an intrusive mass, and in its vicinity the underlying rocks may still have a higher temperature than is normal for the depths at which they lie. The hot spring at the south base of Flagstaff Butte is also evidence of a disturbance of some sort that has given rise to increase of temperature in the rocks underlying this locality.

MALHEUR RIVER DRAINAGE AREA.

SURFACE WATER.

The portion of the area shown on the reconnaissance map (Pl. II) that lies east of the Harney basin and north of the Alvord basin is drained by a number of streams tributary to Malheur River. The northern slopes are drained in part by Stinkingwater Creek, an intermittent stream, and in part directly into Middle Fork of Malheur River by small drainage courses. The southern portion of the area is drained by Crane Creek and its tributaries. This stream in its lower course is known as South Fork of Malheur River, and joins Middle Fork at Riverside. Most of the tributaries to Crane Creek flow during only a part of the year, while this creek itself is dry in summer along portions of its upper course. From the south, Camp and Indian creeks receive the run-off from a considerable area that lies between the Harney and Alvord basins, and after uniting flow through several miles of meadow land to the valley of Crane Creek.

A number of springs issue from light-colored tuffaceous beds along the canyon sides of Crane Creek. At least one of these, No. 253, has been dug out and enlarged, and furnishes water for domestic use, yielding a constant flow of perhaps two gallons a minute. Other similar springs along the edge of the creek valley flow in small volume during the summer. Several warm springs also rise along the lower course of Crane Creek, but these have been sufficiently described in the general discussion of the surface waters of the region (p. 38).

CULTIVABLE LAND.

The cultivable land of this part of Harney County is confined almost wholly to the courses of the larger streams. Warm Spring Valley, along Middle Fork of Malheur River, is over a mile in width and 5 or 6 miles long. A great part of it supports growths of rye grass and meadow grass, and on the stock ranches that control most of the land some alfalfa is also raised. The Malheur project of the United States Reclamation Service, which contemplated the irrigation of land along the lower course of the stream, included the construction of a dam at the lower end of this valley, which would convert nearly the whole valley into a lake. This was called in the preliminary surveys the Harper Reservoir. In the spring of 1908 work had not been extended beyond these preliminary surveys, and construction had been indefinitely deferred, owing to the high estimated cost per acre of the project.

On upper Crane Creek there is an area of bottom land in which are two or three ranches, and on these ranches the summer flow of the stream is used for irrigation. A short distance below the point where the road through Crane Creek Gap crosses the stream valley the canyon walls approach each other, leaving only a narrow strip of bottom land along the creek for a distance of 3 or 4 miles. Near the mouth of Gorman or Alder Creek the valley widens again, and from this point to a couple of miles below the mouth of Coyote or Little Crane Creek the alluvial land is from a quarter of a mile to nearly a mile in width. Part of this bottom produces wild hay and on a part grain is raised, but the greater share of it was still covered with sagebrush at the time of this examination. On the two or three farms along this lower valley the stream water is used to some extent in irrigating small gardens and orchards. The lower 6 or 8 miles of the part of this stream valley that is shown on the reconnaissance map (Pl. II) is floored with basalt, and there is little tillable land in it.

From the junction of Camp and Indian creeks to near Venator post-office, a distance of 5 or 6 miles, the flood water of these streams has produced a stretch of marsh land, along which there are a few hay ranches. Crane Creek and its tributaries, with the exception of Camp Creek, which will be spoken of later, furnish a supply of water which, if stored, would probably be sufficient to irrigate most of the cultivable land along their courses.

STRUCTURAL CONDITIONS.

As there are warm springs along the lower course of Crane Creek, it may be well to speak of the rock structure in its relation to deep-water conditions in this area. On this subject Russell's notes on the structure along Crane Creek are quoted below:[a]

Crane Creek receives Coyote and Gorman creeks as tributaries from the north. These two creeks and the upper portion of Crane Creek, above the abrupt bend in its course where the road leading to Malheur Lake leaves it, flow south in nearly parallel valleys, due mainly to faulting, and enter a large valley with bold walls, which trends about east and west. This larger valley has several peculiar features which at once attract attention. In a general view it appears as a deep stream-cut valley, about one-half mile wide, leading directly through the hilly country it traverses, and affording a low-grade pass to Harney Valley. The impression is that it was formed by a river which escaped from Harney Valley. * * *

In traversing the Crane Creek Pass, as it may suggestively be termed, from east to west, one ascends Crane Creek, which has a well-defined gradient, until about 10 miles below its ultimate source, where a steep ascent of about 100 feet leads to a divide,

[a] Russell. I. C., Preliminary report on the geology and water resources of central Oregon: Bull. U. S. Geol. Survey No. 252, 1905, pp. 38-39.

or rather a crest that would be a divide if surface waters were present, separating the slopes on the east draining to Crane Creek from the slopes on the west draining to Malheur Lake. On the west the floor of the pass is approximately level. Throughout the two portions of the old valley the width is about one-half mile, and the bordering escarpments are bold and steep, and in general 200 or 300 feet high. The valley is clearly the result of stream erosion, and is a part of the record inscribed on the land, showing formerly greater precipitation than now. The divide which crosses the course of the valley from north to south is due to movements in the rocks subsequent to its excavation, and is of the nature of a fault, the west side of which has been upheaved in reference to its eastern side. Other illustrations of faulting and tilting are present in the same region, and are suggestive of the causes which produced changes in the direction of flow of the modern streams in respect to their former and larger representatives.

This region, near the eastern border of Harney County, shows numerous evidences of having been faulted; and it is probably along fault planes or zones that the water of the springs in Warm Springs Valley (along Malheur River) rises. There are similar springs at Mr. H. C. Luce's, in sec. 20, T. 24 S., R. 37 E., which yield 6 or 7 miner's inches at temperatures of from 106° to 143° F. The water of Mr. Dennean's spring, in sec. 2, T. 25 S., R. 36 E., probably issues through a fissure or other vent from an underlying porous bed. The existence of such beds carrying water under pressure is so uncertain in this region of faulted structure that it would be a very uncertain undertaking to drill for flowing wells should a greater supply of water than the streams furnish ever be needed.

ANDERSON VALLEY.

DESCRIPTION.

In the southern part of the area draining to Malheur River, the course of Camp Creek above its junction with Indian Creek lies for a number of miles in a wide flat valley known as Anderson Valley. The western and northern portions of this valley are rocky, and except for a few playas are not cultivable. Along the southern side of the valley, however, there is much agricultural land. During the past few years several fields have been cleared in this section, and wheat and rye have been raised.

SURFACE WATER AND SHALLOW WATER.

Camp Creek, the main drainage channel through this valley, is dry during the summer months in years of ordinary rainfall. Mr. James Mahan, who owns the Mule ranch, has built an earth dam 24 feet high and 130 feet long at the base across Camp Creek a couple of miles below his ranch. This forms a storage reservoir with a capacity estimated at about 1,800 acre-feet. In the spring the supply from Camp Creek is said to be ample to fill this. During the past summer an irrigating ditch was being extended from this reservoir eastward along the edge of the valley, with the intention of putting much of the land under irrigation.

Few wells had been sunk in this valley when it was visited, as few people had yet filed on land in this locality. Of the four wells marked on Plate III as within it, No. 90 was dug in the gravel wash of a wet-weather stream, where water was easily obtained; the one at Mule ranch was sunk in the bottom land of Camp Creek, where the ground-water level is only about 4 feet below the surface; while in the western part of the valley wells Nos. 86 and 87 reached basalt only 3 or 4 feet below the surface, and failed to reach water at the depths of 10 and 27 feet, respectively, to which they were sunk in the hard rock.

It is probable that drilled wells can reach water within a reasonable depth in this part of the valley, perhaps within 100 feet, but it is hardly practicable to dig wells through the basalt that underlies the playas of the central part of the valley.

During the early part of 1908 a well (No. 88) was being drilled by Mr. J. R. Jenkins near the north base of Riddle Mountain, near the center of sec. 14, T. 28 S., R. 34 E. The following record of material passed through, as reported in February, 1908, indicates a succession of basalts and tuffaceous beds, such as are exposed along several escarpments in this region:

Record of Jenkins well, near Riddle Mountain.

	Feet.
Cement gravel	0–95
Black lava rock	95–155
Brown sand rock and hard cement gravel in stratas of 5 and 10 feet	155–205
Clay and sand (white sand rock, brown and black, in strata of 10 to 20 feet), with very hard streaks	205–335
Clay and shale	335–425
Blue clay, with the odor of sulphur	425–455

Water at a temperature of 66° F. was struck in this well at a depth of 70 feet, but it rose above this depth little if at all, indicating that it was under no appreciable pressure. At 300 feet this water was lost, but on drilling deeper another supply was struck that rose 300 feet. At last accounts (August, 1908) the water stood 200 feet below the surface. This well is situated on the mountain slope, considerably above the valley floor, and hence is not a fair test of conditions in the valley proper.

On the slopes to the south of Anderson Valley numerous springs that issue along the sides of steep canyons may be in part surface springs, though the greater share of their water probably comes from tuff beds that have been cut across by the streams. Water does collect under pressure in these beds, but it is doubtful if at any point on the lower slopes the head developed is sufficient to bring it to the surface when tapped by a drilled well; for the pressure is relieved by the issuance of the water as canyon springs or by its escape northward and downward within the beds.

ARTESIAN CONDITIONS.

As previously stated, lava belonging to a more recent period of effusion than that of the Steens Mountain basalt covers a great part of the floor of Anderson Valley, but the structure of the underlying rock has not been altered by these more recent flows, and it is shown by the attitude of the beds along the sides of the basin. On the south the slopes of Steens Mountain dip beneath Anderson Valley at angles up to 10°; from the north the lava sheets also pass beneath the valley floor; while on the west, over the area of low relief that separates this basin from Harney Valley, the beds are nearly horizontal. The valley lies, therefore, in a synclinal basin whose southern side is much the higher and longer. Its western end flattens out and merges with the structure of the Harney basin, while to the northeast there is an outlet, structural as well as topographical, along the course of Camp Creek.

As elsewhere in this great area of bedded lavas, porous sheets of tuff are associated with the rocks that underlie Anderson Valley. The northern slopes of Steens Mountain are a catchment area for water that can find its way downward through seams and fissures in the harder layers, to these more porous beds beneath. In general, however, the structure of this valley is not favorable to the storage of water under sufficient head to bring it to the surface in drilled wells, for the low western side of the basin, as well as the outlet northward down the valley of Camp Creek, may allow the water to escape in those directions, while the recent lava that floors part of the valley probably issued from fissures beneath it, which are now filled by the congealed rock and form dikes that greatly influence the circulation of deep-seated water in their vicinity.

It is possible that along the southern border of the valley the change from a dip of 10° to near horizontality may be sufficient to produce artesian head in deep-seated water, especially if the water-bearing bed becomes thinner beneath the valley than it is in the mountain slopes, as such constriction gives greater head to the water; but the conditions for obtaining flowing water in any part of the valley are not favorable enough to warrant the drilling of a test well.

TEMPERATURE OF UNDERGROUND WATER.

In a study of the water supply of a region the temperature of water from wells and springs often suggests the depths from which it rises. Shallow underground water varies somewhat in temperature with the season, but below a depth of about 50 feet the temperature is fairly constant throughout the year, and records of deep wells and borings all over the world have shown that in regions where the rocks have been long undisturbed it increases about 1° F. for each 50 or 60 feet of increase in depth.

This rate of increase of temperature with depth is often assumed in estimating the depth from which the water of warm springs rises. In regions of sedimentary rocks and simple structure some reliance may usually be placed on it, but in areas like southeastern Oregon, where the rocks are nearly all lavas, and where abundant evidence exists of very late volcanic activity, other factors influence the temperature of underground water, and it is doubtful if such evidence has value in estimating the depth of artesian water horizons.

There may be several springs in the area studied, for instance those about 3 miles south of Burns and the warm springs near the Double O ranch, whose abnormal temperatures are due solely to the depth from which the water rises. But many others, such as the hot spring on upper Rock Creek, the one near the southeastern end of Harney Lake, and the one on the western edge of Alvord Desert, seem to owe the temperatures of their water to such causes as proximity to underlying rocks that have been heated by enormous pressure and friction along fault zones; to masses of intrusive rock that have not yet cooled; or possibly to residual heat in the lavas themselves. Hence even those springs of the Harney basin region whose temperatures do indicate a considerable depth to the source of the water are not to be regarded as reliably measuring it. Russell [a] used the temperature of the spring north of Harriman as a basis for estimating the depth to the horizon from which it is supplied. Local report, which seems to be confirmed by the discordance between Russell's measurement in 1903 and one made in 1907, indicates that the water of this spring varies in temperature and in volume, and that it is supplied from more than one horizon. It is possible that this water becomes heated largely by rising along a fault plane, where the rocks are above the normal temperature. The spring at the borax works south of Alvord Lake also seems to be supplied from more than one water-bearing horizon, as its temperature varies noticeably, but no series of observations is available to indicate whether this is a seasonal variation or not.

The temperature of shallow well water usually corresponds closely to the mean annual temperature of the region, though, as has been said, that of water less than 50 feet below the surface varies with the season, being a little warmer in summer than in winter. The temperature was noted in most of the wells that were visited, and at this time, in late summer and early fall, was uniformly several degrees above the estimated mean annual temperature. The average temperatures of well water in the sections examined were as follows: At Burns and Narrows, from 51° to 53°; at Riley, Lawen, and near Dog Mountain,

[a] See quotation on page 64.

about 50°, and in Alvord Valley, 54°. The available weather records indicate that the mean annual temperature at Burns is about 43°. In the other localities no records have been kept, but their mean temperature is probably 2° or 3° higher than at Burns.

WELL-SINKING METHODS AND COSTS.

A number of the shallow wells in southeastern Oregon have been dug, since the valley deposits are easily excavated and in most places are sufficiently firm not to require curbing, but most of the wells have been bored. Small domestic wells are easily put down with a 2-inch or 3-inch carpenter's auger welded to a length of rod or pipe, to which other joints can be added as the hole deepens. It may be manipulated by hand alone, but when the string of rod becomes heavy, a tripod and small block and tackle are sometimes used to raise the auger. From 3 or 4 inches to a foot or more may be bored each time the auger is screwed down and lifted. In passing through the drier, more incoherent layers it is only necessary to pour a little water into the hole, so that the material will cling to the auger.

When water is struck, which is in nearly all wells at less than the suction limit of about 30 feet, a length of pipe is lowered into the hole, a pitcher pump is screwed to the upper end of the pipe, and the well is complete. A strainer is seldom placed on the lower end of the pipe, since after a short period of pumping the finer particles of sand are removed from around it, and the remaining coarser material acts as an efficient screen.

In boring wells of larger diameter, of 4 or 6 inches, a cheap and serviceable auger made from a piece of 3-inch or 4-inch wagon tire curled into a spiral is often used. A cutting lip is shaped on its lower end, while a length of pipe is welded or keyed to its upper end. This is used in the same way as the smaller auger, except that on account of its greater weight a small block and tackle is more often used to handle it, and a small platform is constructed from which the instrument is steadied and turned.

At Burns, where layers of firm-textured tuff must be penetrated, many of the wells have been sunk by means of the drop drill or churn drill. These wells are usually made 4 inches or 6 inches in diameter, so as to allow the insertion of a pump cylinder down to within suction limit of the water surface. Few of these wells are cased below the shallow surface coating of soil. The method of sinking is about the same as that described by A. C. Veatch in a recent publication of the Survey,[a] and in an unpublished paper on well-drilling methods, by Isaiah Bowman.[b]

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[a] Geology and underground water resources of northern Louisiana and southern Arkansas: Prof. Paper U. S. Geol. Survey No. 46, 1906, p. 97.

[b] This paper will be published as a Water-Supply Paper of the U. S. Geol. Survey.

In this method of sinking, the drill bit and string of tools are alternately raised and dropped by a spring pole or a walking beam, operated either by horsepower or by an engine. The percussion of the drill chips off fragments of rock, and by slowly revolving it a circular hole is obtained. When so much material is loosened that it interferes with the action of the drill, the tools are drawn out and the mud is removed by a sand bucket. This consists of a joint of pipe a little smaller than the drill hole, with a valve in its bottom to admit the material. When the hole has thus been bailed out, the tools are again lowered and drilling proceeds.

The deeper wells in Harney County have been drilled by portable rigs, using the regular deep-well drill and walking beam. Such rigs are capable of drilling to a depth of 1,000 feet or more, and will probably prove the most effective means of sinking deep wells in the valleys of southeastern Oregon to tap the deeper rock water.

As stated in considering ground-water conditions in Harney Valley, it is thought that wells sunk to the deeper water-bearing strata of the valley filling will be found to furnish an abundant supply of water by pumping. But it must be borne in mind that the value of this water for irrigation will depend upon the cost of pumping and upon the returns from produce that can be grown.

If the shallower underground water supply of southeastern Oregon is developed to any considerable extent, the sand-bucket method, and especially its modification used in California to sink "stovepipe" wells, will probably be found best. This method may be briefly described as follows: The casing used is made of heavy cylinders of riveted sheet steel, about 2 feet long and usually from 4 to 16 inches in diameter. It is made of double thickness, one size of cylinder just slipping within another. The sections are placed so as to break joints, and the outer and inner tubes are united simply by denting the casing with a pick. A section of heavier casing, usually 15 or 20 feet long, and provided at the bottom with a sharp cutting edge or shoe, is used as a starter. This is sunk most of its length by digging a pit for it, and upon it the short lengths of casing are added, the whole being sunk by hydraulic jacks buried at the side of the pit, or by steel rails or I beams used as levers to force it down. As the casing is sunk, the material is removed with a sand bucket, which is churned up and down and handled by a rig that differs from the usual type in that the walking beam is short and is placed at the top of the derrick.

In some regions where only unconsolidated material is to be penetrated, wells are quickly and easily sunk by the jetting process. In this process water under pressure is led into the well through a pipe of relatively small size, and directed against the bottom of the hole through a suitable nozzle. The material is thus loosened and carried upward to the surface through the casing, which is sunk as fast as the hole deepens. Although this is a rapid method of sinking in loose material, it is not entirely satisfactory in developing water, and probably will not prove of as great value in the lake valleys of southeastern Oregon as the stove-pipe method; for unless the depth to water-bearing strata is already known they can hardly be detected when struck, and as sinking proceeds they are cased off, so that no evidence is obtained as to the proper depth at which to perforate the casing in order to tap the water-bearing layers.

In regard to the cost of deep wells sunk in the rock layers, the following extract concerning drilled wells in east-central Washington, where the material to be penetrated is similar to that in southeastern Oregon, is quoted from a paper by Calkins:[a]

The charges for well drilling in the southern part of the wheat lands are as follows: In soil, gravel, etc., above basalt, 50 cents a foot; in rock (which is generally in great part massive basalt, though other varieties after the first basalt is struck are not differentiated), $2.25 per foot for the first 300 feet and 50 cents per foot additional for each 100 feet below that depth. Water for the engine, coal, and board for the outfit are furnished by the owner of the ranch.

In the vicinity of Ritzville [Adams County] the terms are slightly higher; for the first 300 feet the charge is there $2.50, and 50 cents higher for each additional 50 feet. On these terms, however, the driller furnishes coal, the cost of which is estimated at about 25 cents for each foot drilled in basalt. In all cases water is guaranteed, and the risk of losing tools (which generally also necessitates abandoning the hole) is borne by the driller. The average cost of a well at these rates is probably not far from $800, though it reaches a maximum of over $2,000.

These wells, in Washington, are usually not cased. In Harney County casing will be necessary at least to solid rock, in order to obtain artesian flows, and this will add another considerable item to the cost of drilled wells. The following prices for casing, in April, 1908, were furnished by the Baker Iron Works, of Los Angeles, California.

Approximate price per foot of lap-weld screw casing, with coupling.

Inside diameter.	Price.	Inside diameter.	Price.
Inches.		*Inches.*	
$2\frac{3}{4}$	$0.20	$5\frac{5}{8}$	$0.48
$3\frac{3}{4}$	.27	$7\frac{5}{8}$	.70
$4\frac{1}{4}$	.29	$8\frac{5}{8}$	.80
$4\frac{1}{2}$	.31	$9\frac{5}{8}$	1.00

In another publication of the Survey,[b] the expense of sinking wells of the stove-pipe class, in southern California, are given. From it the following table is taken:

[a] Calkins, F. C., Geology and water resources of a portion of east-central Washington: Water-Supply Paper U. S. Geol. Survey No. 118, 1905, p. 60.

[b] Mendenhall, Walter C., Development of underground waters in the eastern coastal plain region of southern California: Water-Supply Paper U. S. Geol. Survey No. 137, 1905, p. 32.

Cost per foot, in cents, of sinking wells of the stove-pipe class.

	4-inch.	5-inch.	6-inch.	7-inch.	8-inch.	9½-inch.	10-inch.
First 100 feet	30	30	35–40	40	40–50	60–65	65
Additional for each 50-foot increase	25	25	20–30	20–35	20–35	20–35	35

Below are prices that were furnished, in April, 1908, by the Baker Iron Works, for sheet-steel riveted double well casing, such as is used in stove-pipe wells:

Approximate cost per foot of riveted double well casing, made up into 2-foot lengths.

Diameter.	Gage.	Price.	Diameter.	Gage.	Price.
Inches.			*Inches.*		
4	16	$0.37	8	16	$0.67
4	14	.45	8	14	.78
5	16	.43	8	12	.93
5	14	.52	9½	16	.79
6	16	.50	9½	14	.92
6	14	.60	9½	12	1.12
7	16	.58	10	16	.81
7	14	.66	10	14	.97

These prices, it must be remembered, are for localities near railroad lines, and in southeastern Oregon the item of freight by team will materially increase the costs. The price of casing also varies with the steel market, so that minor changes take place in it from time to time.

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