GEOLOGY AND WATER RESOURCES OF THE MIDDLE DESCHUTES RIVER BASIN, OREGON

By Harold T. Stearns

ABSTRACT

The middle Deschutes River Basin lies in Deschutes and Jefferson Counties, in central Oregon. The principal town in the area is Madras, and the principal streams are the Deschutes, Crooked, and Metolius Rivers. These rivers occupy deep canyons in a northward-sloping, elevated lava plain which is bounded on the west by the Cascade Range and on the east by a low mountain range that has no general name.

The Trail Crossing basalt, not less than 200 feet thick, is the oldest rock exposed. Above it lies the Clarno (?) formation, of Eocene (?) age, consisting essentially of fine-grained consolidated yellow, cream-colored, gray, green, and red tuffs. Some beds are soft; others are massive and resistant. The Clarno (?) formation has a probable thickness of over 1,000 feet. Dark-colored massive andesite, usually containing glassy feldspar phenocrysts 2 to 4 millimeters in diameter, crops out in the southern part of the area. The age of this andesite is unknown, but it is tentatively correlated with the andesite flows of the Cascade Range, which are in general Pliocene.

Separated from the andesite and the Clarno (?) by a marked unconformity is the Deschutes formation, consisting of sand, silt, gravel, and stratified fluviatile deposits of volcanic detritus, mostly basic, intercalated with and in most places capped by basalt flows. Several of the cinder cones that were the sources of this basalt are still preserved. This formation, which is about 1,000 feet thick, contains commercial deposits of diatomite.

Partly filling the Deschutes and Crooked River Canyons cut in the Deschutes formation is an intracanyon basalt flow which originated south of the area and which has in places filled these canyons to a depth of 900 feet. A considerable part of this lava has been removed by erosion, but the remnants form conspicuous benches along these rivers.

The geology of the upper and lower box canyon dam sites on the Crooked River is described in detail. The upper site is considered not feasible for a dam, because of the presence of a cave in one abutment. The Metolius dam site, on the Deschutes River, is described and also the hydrologic conditions which affect its success.

The monthly maximum, minimum, and mean discharges of the Deschutes, Crooked, and Metolius Rivers are given for all gaging stations in the area. The quality of the surface and ground water of the area is excellent. The rivers are mostly fed by large springs, many of which lie within the area described. Records of all the wells and a map showing the contours of the water table are given. All the rocks older than the Deschutes formation yield water sparingly or not at all, but wells obtain large yields in the Deschutes formation, especially in the intercalated basalt flows below the water table. The intracanyon basalt also is very permeable but usually yields water only near the base.

The springs in the area are too numerous to describe in detail. There are dozens of them that discharge over 1 cubic foot a second. Opal Springs, the largest of all, discharge about 300 cubic feet a second. The spring inflow into the Crooked River in a stretch of about 19 miles amounts to about 950 cubic feet a second, or 620 million gallons a day. Likewise, the Deschutes River in traversing the area gains about 400 cubic feet a second of spring water. The total annual ground-water discharge of this area amounts to about 1,000,000 acre-feet.

The power possibilities and the existing plants on the Deschutes and Crooked Rivers are described.

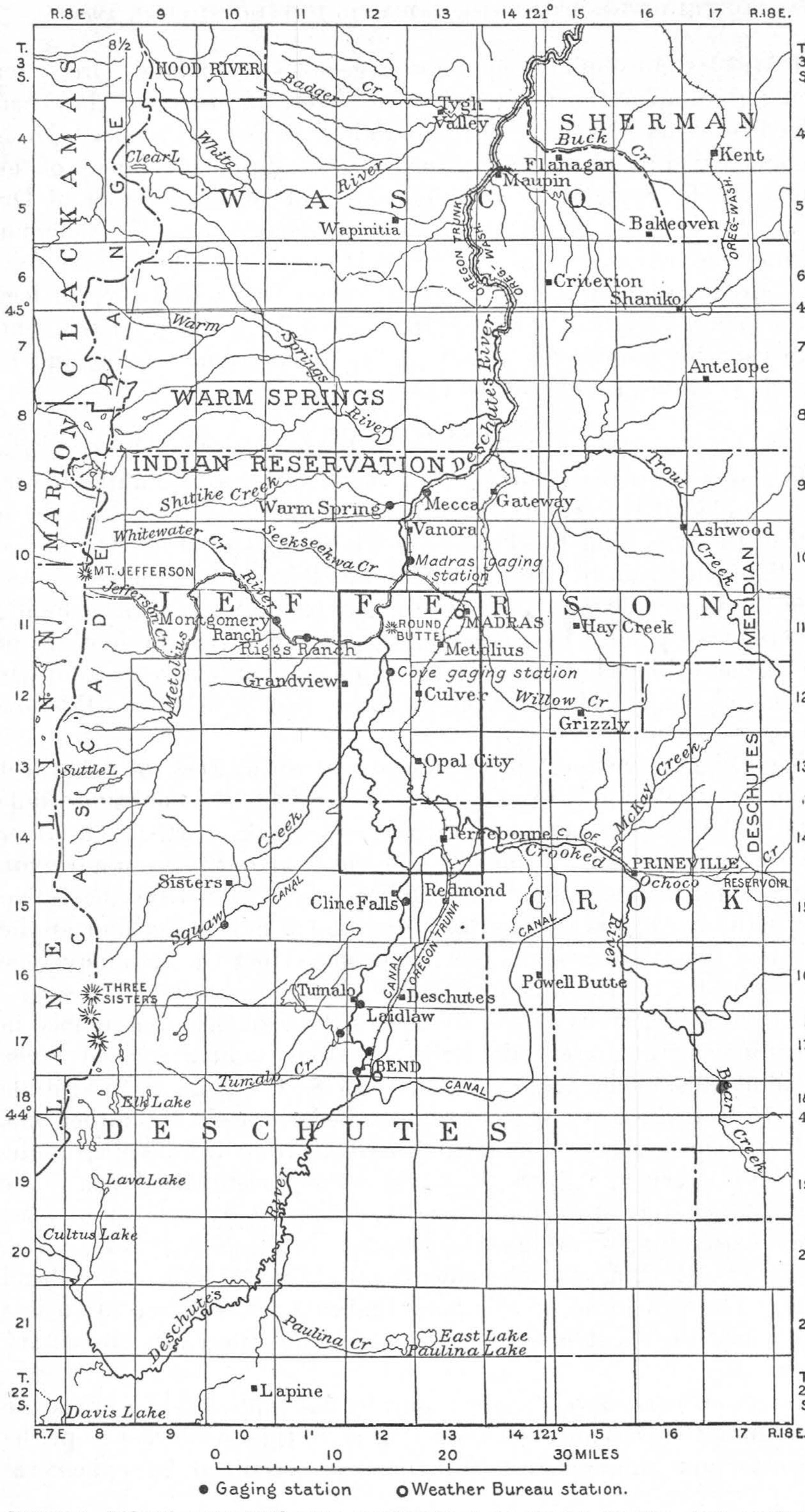
INTRODUCTION

Location and extent of area investigated.—The area covered by this report lies in central Oregon, 96 miles south of The Dalles and 28 miles north of Bend as measured along The Dalles-California Highway, which crosses the area from north to south. The distances are only 66 and 18 miles, respectively, by air line. (See fig. 5.) The area has no natural boundaries but occupies the middle portion of the drainage basin of the Deschutes River. It is 24 miles long north and south and 12 miles wide east and west, and thus covers about 288 square miles. It lies midway between the forty-fourth and forty-fifth parallels and the one hundred and twenty-first and one hundred and twenty-second meridians, in Deschutes and Jefferson Counties. The northwest corner is in the Warm Springs Indian Reservation. It includes Tps. 11 to 14 S., Rs. 12 and 13 E. Willamette meridian. (See pl. 10.) Its altitude ranges from 4,006 feet at Haystack Butte, on the eastern edge of the area, to 1,470 feet in the bottom of the Deschutes River Canyon, on the northern edge. The principal towns in the area from north to south are Madras, Metolius, Culver, Opal City, and Terrebonne. The Oregon Trunk Railway, running from Wishram to Bend, crosses the area from north to south.

Purpose of the investigation.—The purpose of the investigation was to make a geologic examination of dam sites on the Crooked River from its mouth to Trail Crossing. It was made at the request of O. C. Merrill, executive secretary of the Federal Power Commission, and was in part paid for by that commission. A report entitled "Geologic examination of dam sites on Crooked River" was submitted in October, 1925, and the present report is a by-product of that work. The writer spent from August 8 to September 5, 1925, in the field, and of this time about one week was devoted to a reconnaissance of the headwaters of the Deschutes River.

The topography shown on Plate 10 was taken from the Bend and Madras topographic maps of the United States Geological Survey, which were made after the writer did the geologic mapping. In transferring the geologic boundaries to the new base a certain amount of unavoidable error is involved, especially in the altitude of the formations in the canyons.

Acknowledgments.—The writer is greatly indebted to Mr. F. F. Henshaw, then district engineer, United States Geological Survey,



- ● Gaging station
- ○ Weather Bureau station.

FIGURE 5.—Index map showing location of middle Deschutes River Basin, Oreg gaging stations, and Weather Bureau stations

and Mr. Ira A. Williams, consulting geologist, Portland, Oreg., for spending time in the field, imparting freely information they had gained by years of work in Oregon, and criticizing the report. He is particularly grateful to Mr. S. Murray, assistant chief engineer of the Union Pacific System, for permission to publish an abstract of Dr. A. C. Boyle's report on the diatomite deposit near Terrebonne. Acknowledgments are due also to the Columbia Valley Power Co., for maps and data on the area; to the Oregon Trunk Railway, for logs of the railroad wells in the area; to many drillers and residents, who gave valuable information regarding the underground water; and to Mr. H. V. Gates, for his cordial hospitality.

PHYSIOGRAPHY

The area is crossed from south to north by the Deschutes River. The Crooked River enters from the southeast and in the northern part of the area joins the Deschutes River. Two miles north of the mouth of the Crooked River, the Metolius River enters the Deschutes from the west. These rivers occupy canyons in a northward-sloping elevated lava plain, which is bounded on the west by the foothills of the Cascade Range and on the east by a low mountain range that has no general name. Haystack and Juniper Buttes belong to this low range.

The Deschutes River enters the area at an altitude of 2,720 feet above sea level, in a canyon about 100 feet deep and one-eighth mile wide. The canyon increases in depth toward the north. The river leaves the area at an altitude of 1,470 feet, where it flows in a canyon nearly a mile wide and about 850 feet deep. Between these two points the canyon is usually less than half a mile wide, and at the mouth of the Metolius it is 1,000 feet deep. The river has an average fall within the area of 35.2 feet to the mile.

The three waterfalls on the Deschutes River in this area, named in order downstream, are Odin Falls, Big Falls, and Steelhead Falls. At Odin Falls, in the SE. ¼ sec. 26, T. 14 S., R. 12 E., at an altitude of 2,675 feet, the water drops from one bed of basalt to another one, 10 feet below. About 8 miles downstream from Odin Falls, in the SE. ¼ NE. ¼ sec. 9, T. 14 S., R. 12 E., is the graceful Big Falls. (See pl. 11, *A*.) It is 30 feet high and is produced by a layer of hard basalt between softer sedimentary beds. In the SW. ¼ NW. ¼ sec. 27, T. 13 S., R. 12 E., 4½ miles downstream from Big Falls, is Steelhead Falls. The Deschutes at this place makes a vertical leap of 15 feet over a bed of basalt interstratified with soft strata of sedimentary origin.

Numerous narrow valleys separated by flat-topped ridges break the west rim of the Deschutes Canyon. Most of these valleys, except the Metolius and Squaw Creek Canyons, are occupied by ephemeral streams. The Metolius River is fed by numerous large springs and flows throughout the year. The only tributary on the east side of the Deschutes is Crooked River, which above its junction flows nearly parallel to the Deschutes for about 10 miles. The greater part of the strip of land between the canyons of these two rivers is known as the Peninsula. It is a northward-sloping, flat-topped, soil-covered lava bench bounded by the nearly vertical cliffs of the Deschutes and Crooked River Canyons. The top of the Peninsula near the north end lies nearly 1,000 feet above the two rivers. North of the Peninsula and at a slightly lower altitude, in the angle between the Deschutes and Crooked Rivers, is the Island, a mass of solid basalt 2 miles long, three-fourths of a mile wide, and about 900 feet thick, separated from the Peninsula by a low V-shaped pass through which a road crosses. (See pl. 11, *B*.)

The physiographic development of the Deschutes Valley has a long and complicated history, which is described at length on pages 150 to 152. It will suffice to note at this place that there is a northward-sloping lava bench on the east side of the Deschutes Canyon extending for a distance of about 10 miles north of the point where the river enters the area, and that remnants of this bench are found to a point within 4½ miles of the mouth of the Crooked River. In the remaining 4½ miles there are remnants of a southward-sloping bench that is much higher above the river.

The altitude of the Crooked River where it enters the area is about 2,750 feet; at Trail Crossing, in the NE. ¼ sec. 33, T. 13 S., R. 13 E., it is 2,550 feet above sea level. Upstream from Trail Crossing there is a fairly wide canyon with a narrow flood plain. The south wall is steep and consists of soft tuff beds surmounted by a rim of basalt about 40 feet thick. The opposite canyon wall extends to the crest of a ridge which is about 500 feet above the river. This wall is composed of tilted light-colored tuffs of unequal hardness. Weathering has caused some of these beds to stand out as spiny, serrated ridges and pinnacles. Russell[1] named this part of the canyon "Monument Canyon," but his name has not come into common use. The prominent spur in this area around which the river bends is known as Smith Rock. One mile upstream from Trail Crossing the north side of the canyon changes from light-colored tuffs and picturesque erosion forms to a ruddy brown slope covered with rounded knobs. This abrupt change is due to the cropping out of dense but minutely fractured ancient weathered basalt.

At Trail Crossing the Crooked River plunges into a narrow lava canyon. The following quotation from Russell[2] admirably describes this interesting crossing:

---

[1] Russell, I. C., Preliminary report on the geology and water resources of central Oregon: U. S. Geol. Survey Bull. 252, p. 87, 1905.

[2] Idem, p. 86.

Below Forest [now O'Neil] all the way to the Deschutes, a distance of over 30 miles, Crooked River flows in a narrow canyon with essentially, and often actually, vertical walls, and there is no alluvial land in its bottom. Throughout this portion of the river there is but one place where a team and wagon or even a pack train can be taken across it, namely, at Trail Crossing, about 18 miles below Prineville and 7 miles below Forest. Toward this locality Indian trails formerly converged on each side of the river; later frontiersmen, with their saddle ponies and pack horses, sought the same breaks in the canyon walls; and within the past few years a road has been graded on the declivities of the opposite facing precipices and a good bridge thrown across the river. Trail Crossing is thus an instructive locality in reference to the control exerted by geographic conditions on the affairs of men. The canyon, too, is of great geologic interest and on account of its wildness and picturesqueness will no doubt, in the future, attract to its secluded depths many curious travelers.

Trail Crossing was abandoned in 1926 because of its dangerous grades, and now the highest single-arch highway bridge in the United States, 350 feet above the stream and 330 feet long, spans the canyon, half a mile downstream from Trail Crossing. The canyon at this place is shown in Plate 12, *A*.

Below Trail Crossing the Crooked River Canyon increases in depth until at the mouth of the river it is more than 1,000 feet deep. The canyon is more remarkable, however, for the presence in places of an inner gorge. At the confluence of the Crooked and Deschutes Rivers the altitude is 1,614 feet above sea level. Thus the Crooked River falls 837 feet between Trail Crossing and its mouth, having an average gradient of nearly 40 feet to the mile. No falls occur in this stretch, although there are many rapids. The outer canyon ranges in width from half a mile to a little over a mile. The inner canyon is not present everywhere, but in long stretches of the river there is a northward-sloping lava bench, first on one side of the stream and then on the other, which has the same altitude as the rim of the inner canyon. In places this bench is over half a mile wide and carries sufficient soil to be farmed. It is 250 feet above the river at Trail Crossing, where it first appears, and its height increases downstream to 800 feet at the mouth of the river.

A remnant of the same bench forms the Island, and many portions of it are still preserved in the Deschutes Valley, the northernmost one occurring half a mile north of the area here mapped. Small remnants of this same bench are found also in the Deschutes Canyon for a distance of 4½ miles upstream from the mouth of the Crooked River (pl. 11, *B*), and two small remnants occur in Metolius Canyon. It is significant that the remnants of the bench along the Deschutes upstream from the mouth of the Crooked River slope southward, whereas those along the Crooked River slope northward. Likewise, those in the Metolius Canyon slope westward, whereas the remnants in the Deschutes Canyon downstream from the Crooked River slope northward. The significance of these differences is discussed on pages 145–148.

Squaw Creek and the Metolius River are the two remaining perennial tributaries of the Deschutes River in this area. Squaw Creek enters the area in sec. 18, T. 13 S., R. 12 E., and after flowing 2 miles northeastward joins the Deschutes in sec. 7. It rises at the foot of the glaciers on the east slope of the Cascade Range and, where it enters the area, occupies a canyon about 500 feet deep and a mile wide.

The Metolius River enters the area at an altitude of 1,625 feet and after flowing nearly 3½ miles joins the Deschutes at 1,555 feet. It occupies a canyon 1 to 1½ miles wide and about 1,000 feet deep. Like many parts of the Deschutes Canyon, the walls show a "grained" effect as a result of the erosion of hard and soft horizontal sedimentary beds. This canyon, like the others already described, is not visible from a point 1 mile from the rim.

Two miles northeast of the confluence of the Metolius and Deschutes Rivers, Round Butte rises from the canyon rim. Viewed from the south it is seen to be a dome 4 miles wide rising from the plain with slopes of about 5° and surmounted by a conical hill 350 feet high. (See pl. 13, *B*.) The top of the butte is about 700 feet above the adjacent plain. Viewed from either the east or west, however, it is found to be crowned by two conical hills, the northern hill being less conspicuous than the southern hill. On the north and east sides of Round Butte are Willow and Dry Creek Canyons, both 200 feet deep and occupied by ephemeral streams.

Another conspicuous feature on the Deschutes plain in this area consists of the Tetherow Buttes, in T. 14 S., R. 13 E. These buttes have a northwest trend and rise about 300 feet above the adjacent plain. Half a mile east of them, in secs. 21 and 28, is an abandoned canyon 2 miles long and in one place 200 feet deep, which is now farmed. About 2 miles northwest of Terrebonne rim rock outlines another abandoned canyon tributary to the Crooked River, but this is much less distinct than the one east of the Tetherow Buttes. Smaller abandoned canyons southwest of the Tetherow Buttes are also indicative of a disturbed drainage.

The dry canyon half a mile east of Tetherow Buttes is an abandoned spring alcove similar to those along the Snake River in Idaho described by Russell.[3] Some of the canyons near by also appear to be spring alcoves modified by later lava flows. These abandoned alcoves suggest that the springs now entering Deschutes and Crooked Rivers once may have discharged farther upstream. The writer has found evidence in the study of the spring alcoves along the Snake River to indicate that the size of the alcove reflects the volume of the water and the geologic age of the spring. As the large springs along the Deschutes and Crooked Rivers discharge from basalt

[3] Russell, I. C., Geology and water resources of the Snake River plains of Idaho: U. S. Geol. Survey Bull. 199, pp. 127–129, 1902.

similar to that along the Snake River, and as they do not have alcoves, it follows that the positions of their vents are geologically recent. This deduction is further borne out by the place in geologic history of the rocks from which most of them issue.

GEOLOGY

PREVIOUS GEOLOGIC WORK

Very little geologic work had been done in this area prior to the present investigation. In 1903 I. C. Russell made a hurried reconnaissance through central Oregon. On this trip he traveled down the Crooked River as far as Opal Springs and visited the Deschutes Canyon south of Squaw Creek. His admirable description of this part of the area appears in Bulletin 252 of the United States Geological Survey.

In 1921 A. C. Boyle, jr., made a geologic report to the Union Pacific Railroad Co. on the diatomite deposit near Terrebonne. An abstract of this report is given on pages 152–155.

In 1924 Ira A. Williams examined several dam sites below the confluence of the Metolius and Deschutes Rivers for the Columbia Valley Power Co., and he has imparted freely to the writer geologic information regarding the area.

STRATIGRAPHY

GENERAL CHARACTER AND AGE OF THE ROCKS

The middle Deschutes River Basin contains both sedimentary and igneous rocks. The sedimentary rocks are composed chiefly of volcanic materials, and no sediments older than Eocene are known in the area. The igneous rocks comprise lava flows, cinder cones, and fragmental volcanic deposits. Because the chief problems of underground water and possible leakage through and around proposed dams rest with the igneous rocks attention was centered on their structure and character.

A tabular summary of the general stratigraphy of the basin is given below and is followed by a detailed description of the rock units and a further discussion of their age. The general absence of fossils in the area makes the lithologic descriptions essential for the recognition of the formations in the field, and it is upon the lithologic characteristics that the interpretations regarding stratigraphy and structure here given depend.

Stratigraphic section of the middle Deschutes River Basin

Geologic age	Formation	Thickness	General character	Water-bearing characteristics
Recent.		Not measured.	Alluvium about 20 feet; pockets of fluviatile pumice; and 1 inch to 3 feet of loess.	Permeable, but occurs in too small an area to be an important source of water.
Late Pleistocene or Recent.		100–800 feet.	Fresh blue-black columnar-jointed basalt flows occupying and partly filling the Deschutes and Crooked River canyons and other tributary valleys; for convenience called intracanyon basalt.	Permeable, but contains no water, except in the vicinity of Trail Crossing, where springs issue from it. Elsewhere it lies above the water table.
Unconformity				
Early Pleistocene or late Pliocene.	Deschutes formation.	1,000± feet.	Horizontal beds of yellow, brown, and black partly consolidated sand, silt, gravel, and stratified fluviatile deposits of volcanic detritus, mostly basic, intercalated with and in most places capped by basalt flows. The lower basalt flow, more than 150 feet thick, is named the Pelton basalt member, and the upper flow, 25 to 150 feet thick, is for convenience referred to as the rim-rock basalt. Includes in a few places beds of white diatomite, which have a maximum thickness of 40 feet.	A little water found in the fluviatile portions, especially the black sand. The intercalated basalt flows are extremely permeable, and the lower ones are full of water. A great number of springs issue from them. The Pelton basalt is the chief water bearer of this formation. The rim-rock basalt is permeable but contains no water because it lies above the water table.
Unconformity				
Pliocene (?) or Miocene (?).		Not measured.	Dark-colored andesite, usually containing glassy feldspar phenocrysts 2 to 4 millimeters in diameter; believed to be flows from sources in the Cascade Range to the west.	Poor water bearer and in most places impermeable.
Unconformity				
Eocene (?).	Clarno (?) formation.	Not measured. Probable thickness over 1,000 feet.	Fine-grained consolidated yellow, cream-colored, gray, green, and red tuff, some beds soft and others massive and resistant.	Poor water bearer. A few seeps occur from these beds, and wells in them have small yields.
	Unconformity (?)			
	Trail Crossing basalt.	Estimated at not less than 200 feet.	Dipping massive brown columnar-jointed basalt, in most places minutely fractured. Outcrop usually characterized by reddish-brown soil containing small chips of weathered basalt.	A poor water bearer, and yields from wells in it are small.

TRAIL CROSSING BASALT (EOCENE ?)

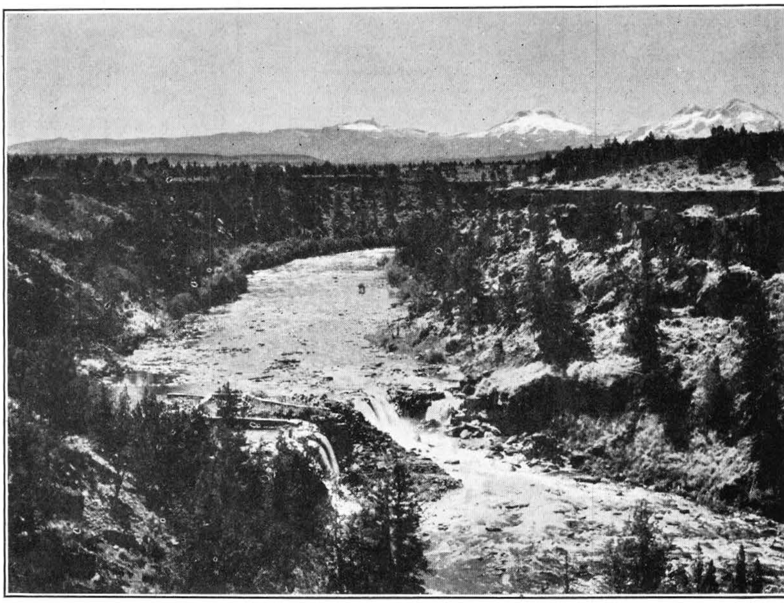
The oldest rocks that crop out in the area are weathered, minutely fractured basalt. They are exposed on both banks of the Crooked River at Trail Crossing and extend northeastward across the Haystack Butte country in a belt about 1 mile wide. Rocky ledges are absent, except in the river canyon. Elsewhere the basalt is traced by a dark-brown residual soil containing chips of weathered basalt. The boundary of this basalt is shown in most places on Plate 10 by a broken line, because time was not available to trace out carefully its contacts. Russell,[4] in his reconnaissance report on this area, refers to an outcrop of a great basic dike 1,000 feet wide at this place. A careful search was made for this dike, but it was not found. Instead, tilted basalt exhibiting typical columnar structure such as characterizes extrusive and not intrusive basalt was found exposed for a mile upstream. Some of the columns on the south side of the Crooked River in the Trail Crossing dugway are 2 feet in diameter. The basalt lacks the tight and regular jointing so characteristic of intrusive basalt. The tuff resting on it shows no sign of metamorphism at the few contacts observed, such as would be expected from a body of lava of this size, but time was not available to study the contacts in the hills north of Smith Rock. Consequently, the question whether the basalt is a sill or an extrusive mass will be left to the future investigator.

The tilted basalt in this canyon is exposed for more than 5,000 feet along the Crooked River. At Trail Crossing it is separated by an angular unconformity from overlying fresh black basalt flows.

Except near Trail Crossing it was difficult to determine strikes and dips with certainty because of poor exposures. At this place the basalt strikes N. 43° W. and dips 22° SW. and has an exposed thickness of over 200 feet. Between this basalt and the fresh black basalt in the canyon rim in the NW. ¼ sec. 3, T. 14 S., R. 13 E., several feet of thin-bedded greenish-yellow tuff is exposed, which strikes N. 68° W. and dips 20° SW. There is a marked angular unconformity between the tuff and the overlying black basalt, but the tuff appears to be nearly conformable with the underlying weathered basalt.

The tuff beds resting on the Trail Crossing basalt lithologically resemble the Clarno formation. Because the main purpose of the field work did not involve the basalt nor the overlying tuffs the stratigraphic details of these formations were not worked out. A reconnaissance of the area north and east of Trail Crossing suggests that this basalt may be intercalated with the Clarno and that some of the tuff near Haystack Butte is stratigraphically below the basalt. In any event this basalt is below the great mass of tuffs described in the following

[4] Russell, I. C., op. cit. (Bull. 252), p. 88.

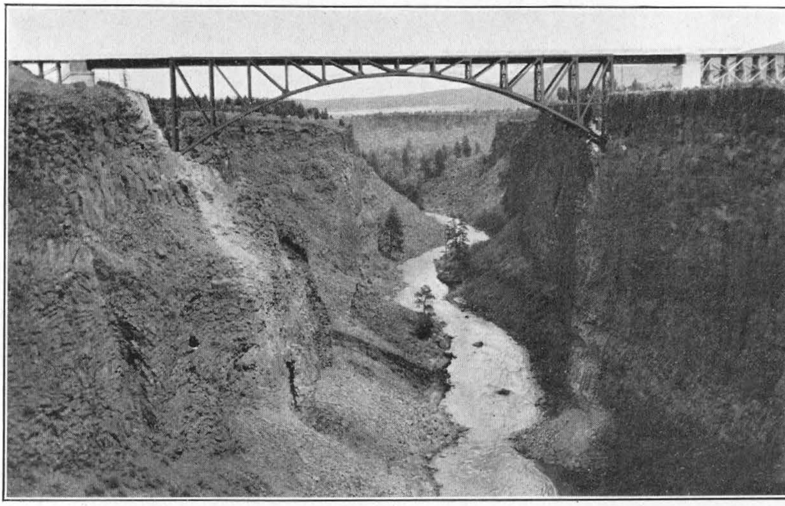


A. BIG FALLS OF THE DESCHUTES RIVER

View looking southwest, showing the Three Sisters in the background. August 24, 1925.

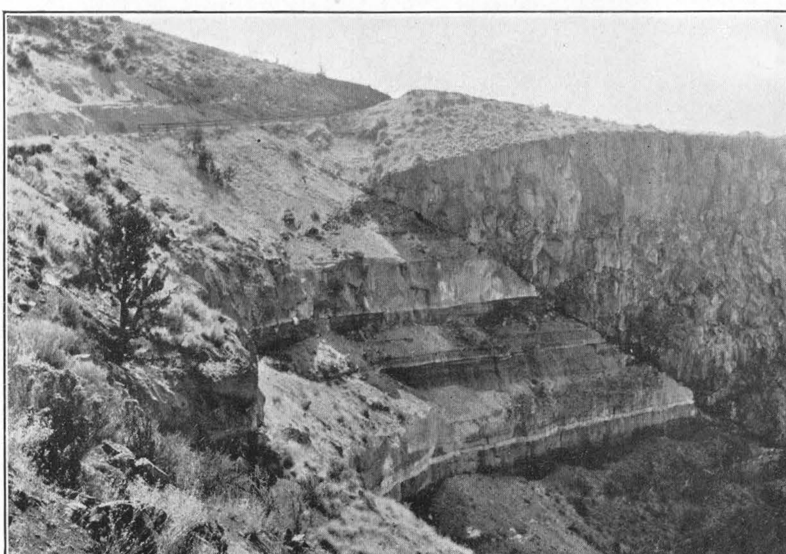
B. VIEW LOOKING SOUTHWEST FROM THE EAST RIM OF CROOKED RIVER CANYON

Shows the pass between the Peninsula and the Island. The Island is a solid mass of intracanyon basalt. In the right background is a remnant of the same basalt in Deschutes Canyon.

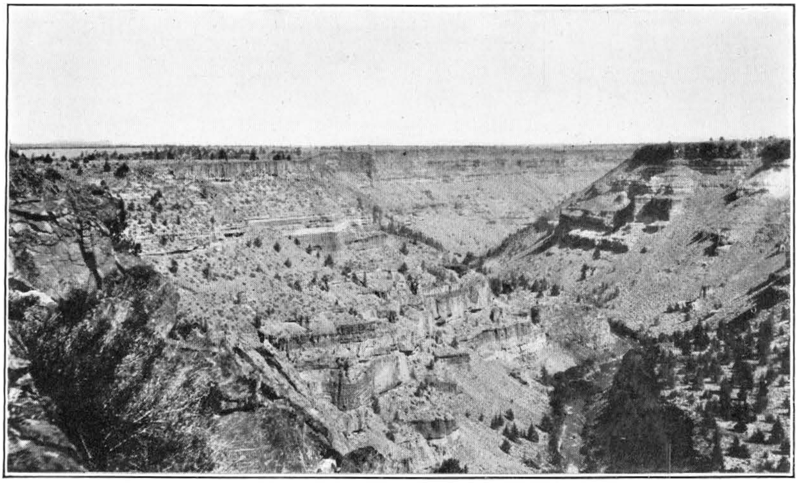


A. CROOKED RIVER CANYON

View looking up the canyon, showing railroad bridge and location of new highway bridge. The walls are intracanyon basalt.

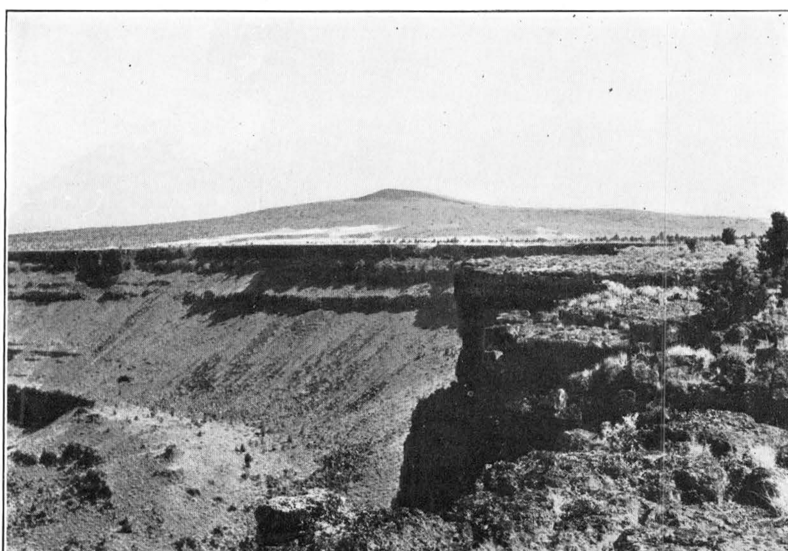


B. EROSIONAL UNCONFORMITY OF THE INTRACANYON BASALT WITH THE DESCHUTES FORMATION IN NE. ¼ SW. ¼ SEC. 11, T. 12 S., R. 12 E.



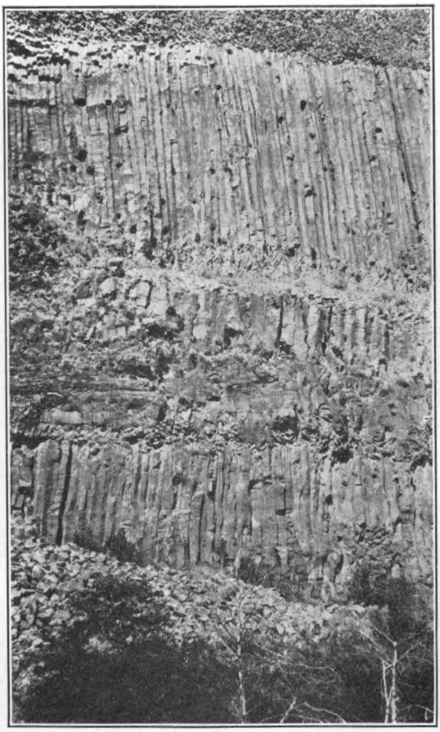
A. DESCHUTES CANYON

View looking up the canyon from the NE. ¼ sec. 6, T. 13 S., R. 12 E. Shows the horizontal beds of the Deschutes formation. The cedars in the lower right corner grow on a remnant of the intracanyon basalt.



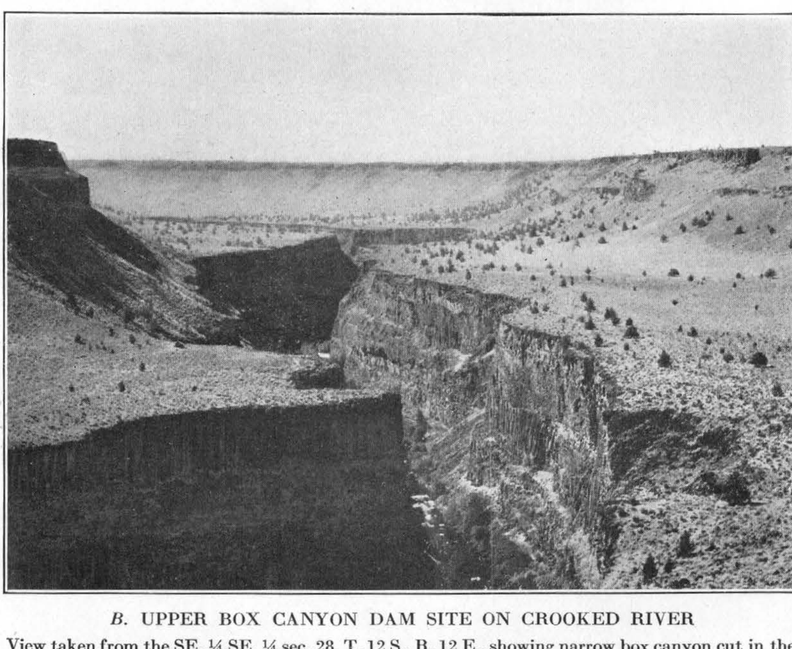
B. ROUND BUTTE

A cinder cone surmounting a low lava dome and the source of the rim-rock basalt which forms the rim. Looking northeast from east rim of Crooked River Canyon in the SE. ¼ sec. 35, T. 11 S., R. 12 E.



A. COLUMNAR JOINTING IN THE INTRA-CANYON BASALT

View on west abutment of the upper box canyon dam site on Crooked River.



B. UPPER BOX CANYON DAM SITE ON CROOKED RIVER

View taken from the SE. ¼ SE. ¼ sec. 28, T. 12 S., R. 12 E., showing narrow box canyon cut in the intracanyon basalt.

pages as Clarno (?) formation; hence the basalt is believed to be as old as Eocene.

CLARNO (?) FORMATION (EOCENE ?)

Resting upon the Trail Crossing basalt and so far as observed nearly conformable with it is a great series of soft but consolidated light-colored tuff beds. Although no fossils were found in these beds, a visit to the type localities of several Tertiary formations in the John Day Basin convinced the writer that these beds are lithologically similar to the Clarno. As a whole these beds contain less coarse pyroclastic material than at the type locality. Calkins[5] describes the Clarno formation in the John Day region as follows:

> Lithologically, the Clarno is a volcanic formation, in which truly detrital matter plays an unimportant part. The lower portion of the Clarno is composed in greater part of pyroclastic material, while in the upper half lavas including several different varieties are abundant.

Among these lavas Calkins describes a quartz basalt and Collier[6] shows a basalt sill in the Clarno.

The tuffs mapped as Clarno (?) formation in this report are estimated to be at least 1,000 feet thick. They are well exposed in both thin and thick beds in the region of Smith Rock, in the Crooked River Canyon above Trail Crossing. They also form Haystack and Juniper Buttes and occupy most of the adjacent country. The area covered by them is shown on Plate 10. This area, wherever traversed, was searched for fossils, but none were found. However, the mountainous area north of Smith Rock, where the beds are well exposed, is worthy of a careful examination. Two outliers of the beds were found in sec. 11, T. 12 S., R. 13 E.

Two specimens from this formation were examined under the microscope by C. S. Ross, of the United States Geological Survey, who describes them both as volcanic tuffs. Specimen B–10 is composed chiefly of pumice fragments. The pumice is partly silicified, and small veinlets of quartz cut the feldspar phenocrysts.

On the east side of Lone Pine Valley, 12 miles due east of Trail Crossing, there are exposed some white tuff beds overlain by basalt.[7] Although no fossils were found here, it appears very likely that these white tuffs belong to the John Day formation and that the overlying basalt is of Miocene age, as determined by Merriam.[8] Again, half a mile north of the area mapped basalt lithologically similar to that

---

[5] Calkins, F. C., A contribution to the petrography of the John Day Basin: California Univ. Dept. Geology Bull., vol. 3, p. 113, 1902.

[6] Collier, A. J., The geology and mineral resources of the John Day region: Mineral resources of Oregon, vol. 1, No. 3, fig. 1, Oregon Bur. Mines and Geology, 1914.

[7] The writer is indebted to F. F. Henshaw for showing him this locality.

[8] Merriam, J. C., and Sinclair, William, Tertiary faunas of the John Day region: California Univ. Dept. Geology Bull., vol. 5, pp. 303–305, 1907.

at Pine Valley crops out in the Deschutes Canyon. These basalts are traceable into known Columbia River basalt in the lower part of the Deschutes Valley. Through the personal guidance of Mr. Williams the writer saw the contact of this basalt with underlying white tuffs of the John Day formation at Mecca, about 10 miles north of the area shown on Plate 10. From the hurried visit to these two localities it seems that the John Day formation and the basalt at Mecca were once connected with outcrops on the east side of Lone Pine Valley and have since been removed by erosion from the top of the great anticlinal fold, with the subsequent exposure of the Clarno (?) tuffs in the Smith Rock and Haystack Butte region.

ANDESITE (MIOCENE? OR PLIOCENE?)

In the southern part of the area occur masses of andesite which have been uncovered by erosion. The age of the andesite is unknown, but it is separated from the overlying horizontal sedimentary beds by a steep erosional unconformity. The proximity of these andesite masses to the great andesitic volcanoes of the Cascade Range suggests that they originated in that range. They are correlated tentatively with the older andesitic lava flows of the Cascades, which are usually assigned to the Pliocene. One large mass of andesite covering about 3 square miles occurs along the line between Tps. 13 and 14 S., R. 12 E. Three other areas of it were mapped in the southwestern part of T. 14 S., R. 13 E. One small outlier in sec. 15, T. 13 S., R. 12 E., on the Peninsula, consists of only a few large weathered blocks, which appear to be in place. An excellent contact of the andesite with the overlying sediments is found along the Deschutes River in sec. 4, T. 14 S., R. 12 E. At this place blocks of andesite are distributed through the overlying beds of tuff and pumice close to the contact in such a way as to show that they accumulated as successive talus heaps during intermittent ash showers. At other places the contact is not conspicuous. The andesite is black in fresh specimens, but in the field it forms weathered brown knobs a few feet high. All the andesite examined in hand specimens is porphyritic, containing phenocrysts of glassy yellow feldspar 2 to 4 millimeters in diameter embedded in a black matrix. Specimen B–7, collected in the N. ½ sec. 7, T. 15 S., R. 13 E., was examined under the microscope by C. S. Ross, who describes it as follows: Porphyritic andesite with phenocrysts of plagioclase and augite. The groundmass consists of very fine-grained feldspar laths in a glassy matrix.

DESCHUTES FORMATION (LATE TERTIARY OR EARLY PLEISTOCENE)

Character and occurrence.—Resting unconformably upon all the rocks previously described is a remarkable series of horizontally bedded, partly consolidated sand, silt, gravel, and stratified fluviatile deposits of volcanic materials, with volcanic débris, mostly basic, resulting from ash showers of volcanoes. These beds make up the Deschutes formation. (See pl. 13, A.) Intercalated with them and in most places capping them are basalt flows and in a few places diatomite deposits.

At the contact of the Deschutes beds with the andesite in the Deschutes River Canyon in sec. 4, T. 14 S., R. 12 E., is field evidence that some of the horizontal and evenly bedded ash and pumice members of this formation were deposited subaerially. Within a few feet of the andesite the lamination and bedding loses its distinctness, and the beds end abruptly in wedge-shaped masses filled with andesite talus. (See fig. 6.) Without this striking contact it would be natural to think that all the evenly laminated volcanic beds of the Deschutes formation were subaqueous.

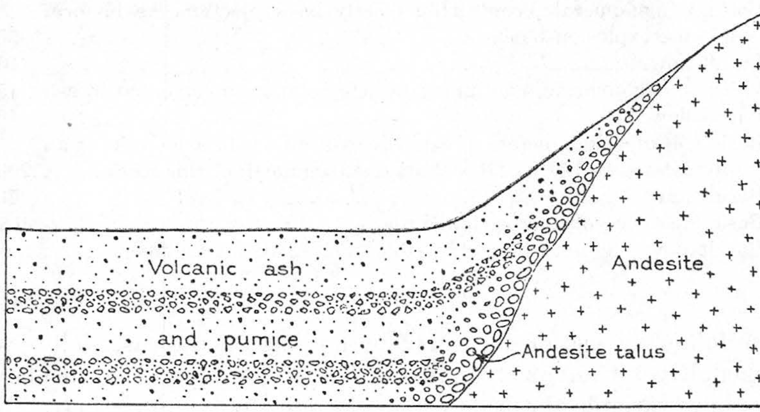


FIGURE 6.—Subaerial depositional contact of ash and pumice of the Deschutes formation with andesite in sec. 4, T. 14 S., R. 12 E., Oregon

The Deschutes formation, as these interbedded sediments and basalt flows are here designated, is known to be present over nearly 250 square miles of the area mapped, and it has been traced many miles in all directions from this area. (See pl. 10.) It is estimated that when fully mapped it will cover at least 1,000 square miles. It has an exposed thickness of more than 1,000 feet in the Deschutes Canyon. The uppermost basalt flows of the formation are for convenience designated rim-rock basalt, because they form the rim of the Deschutes and other canyons, and for the lowest intercalated basalt member Ira A. Williams has suggested the name Pelton basalt.

The Deschutes formation was first described by Russell,[9] who suggested the name Deschutes sand for it. Because it contains lava

[9] Russell, I. C., op. cit., p. 90.

beds, diatomite, and many other deposits, the name Deschutes formation was given to it by Williams [10] in 1924.

An aneroid measurement of the Deschutes formation was made along the foot trail descending to the Metolius dam site on the east side of the Deschutes Canyon. The section at this place is as follows:

Section of east wall of Deschutes Canyon in sec. 22, T. 11 S., R. 12 E.

	Feet
Yellow loess soil	0.5
Deschutes formation:	
Basalt flow (rim-rock basalt)	10
Two basalt flows (rim-rock basalt), total thickness	15
Volcanic agglomerate, containing mostly basic ejectamenta with some lenses of gravel	55
Bed of columnar-jointed basalt	40
Two basalt flows, total thickness	55
Volcanic agglomerate, containing mostly basic ejectamenta in form of dense explosion blocks	55
Basalt flow	10
Volcanic agglomerate, containing basic ejectamenta cemented in ash	15
Basalt flow	15
Basic volcanic agglomerate of explosive volcanic débris, containing an intercalated bed of basalt a short distance north of this section	290
Basalt flow	20
Basic, massive volcanic agglomerate	215
Basalt flows, number indeterminable (Pelton basalt member)	150+
	945+

The following section measured by aneroid on the east wall of the Crooked River Canyon, 3½ miles south of the section given above, shows how variable the beds are in the Deschutes formation:

Section of Deschutes formation in east wall of Crooked River Canyon in sec. 11, T. 12 S., R. 12 E.

	Feet
Massive columnar-jointed basalt flow (rim-rock basalt)	30
Basalt flow (rim-rock basalt)	15
Thick and thin beds of water-laid black and yellow sand, pumice, tuff, and coarse gravel	700
Bedded basalt flows, number undetermined (Pelton basalt member)	130
	875

The following section is incomplete for the exposed part of the Deschutes formation on the east wall of the Crooked River Canyon but is complete from the top of the bench near Opal Springs to the river. Above this section 325 feet of the Deschutes formation crops out.

[10] Williams, I. A., Geology of the Pelton dam site, Oregon, unpublished report in the files of the Federal Power Commission.

Section of Deschutes formation from altitude of 2,375 feet to Crooked River in sec. 33, T. 12 S., R. 12 E.

	Feet
Stratified sand and tuff	30
Aa basalt, porous and brecciated	50
Red tuff, fine grained	20
Fine-grained tuff and agglomerate	115
Coarse conglomerate	20
Pahoehoe basalt flow	25
Soil, probably loess	4
Basalt flow	36
Stratified sand and tuff, with thick bed of coarse conglomerate at base	125
	425

In the Deschutes Canyon the beds are even more complex in places. (See pl. 13, *A*.) It is known that some of the interstratified basalt flows were erupted in the basin, because buried cinder cones have been penetrated by the drill. In well 5 (pl. 10), in the NE. ¼ sec. 2, T. 12 S., R. 13 E., 84 feet of red basaltic cinders was struck below 221 feet of conglomerate. Deposits of cinders such as were struck in this well are indicative of a cinder cone near by. Some of the other wells in the basin also encountered cinders.

Pelton basalt member.—The lowest interstratified basalt in the Deschutes formation is exposed in the Deschutes Canyon from the line between Tps. 12 and 13 S., R. 12 E., all the way to the north boundary of the area. It was not traced beyond this point but is known to continue for several miles downstream. In the northern part of T. 11 S., R. 12 E., this basalt forms a bench nearly a quarter of a mile wide on both sides of the Deschutes River. It also extends northward and underlies the former railroad station of Pelton. Because of the importance of this bed as a water bearer and its critical relation to the dam sites in the region, it has been named, for convenience, the Pelton[11] basalt member, after the old railroad station. It has a known thickness of over 150 feet and is traceable up the Crooked River nearly 4 miles from its mouth. It also extends up the Metolius River for at least 2 miles and then passes under the sedimentary beds of the Deschutes formation. Undoubtedly it is the most extensive and the thickest of all the interstratified basalt members of the Deschutes formation. The Pelton basalt usually consists of several beds that were laid down in rapid succession, and it is not unlikely that they were all poured out during a single eruption. Mr. Williams has kindly furnished the following microscopic description and analysis of a sample of the Pelton basalt taken from a hill on the west side of the Deschutes Canyon at the Pelton dam site, 3 miles north of the area mapped.

[11] This name has been hitherto used in private reports by Ira A. Williams.

Microscopic description: Diabasic, micropoikilitic, and vesicular in texture. Pore space amounts to about 10 to 15 per cent. Feldspar laths 2 millimeters in length, and some olivine the same size. The amount of glass is small and filled with magnetite.

Percentage composition: Labradorite, 65; augite, 15; olivine, 15; magnetite, 3; glass, 2.

Rim-rock basalt.—The Deschutes sedimentary beds are capped in about one-half of the middle Deschutes River Basin by beds of basalt. In the rest of the area this basalt cover has been removed by erosion. It is very prominent because it forms the rim rock to the canyons and underlies at shallow depths much of the agricultural area. Its thickness varies according to the distance from its source, and most, if not all, of its sources are still visible as cones on the plain. This upper member of the Deschutes formation also forms a wide plateau, known as Agency Plains, extending northward from the area mapped and from the Metolius River. Because this basalt is conspicuous as the protective, resistant rock of the region it is here referred to as the rim-rock basalt, a term in common use among the local people. The distribution of this basalt and the cones from which most of it issued is shown on Plate 10. Fourteen well-preserved cones were found in the area, but they were not the source of all of this upper member of the Deschutes formation, for basalt flows entered the area from the west, overlapping and interfingering with the flows from these cones. The largest vent in the area is Round Butte, which is a double cinder cone surmounting a low lava dome. (See pl. 13, *B*.) Considerable lava issued from this vent before activity ceased, but most of it has since been removed by erosion. The effect of a semiarid climate on erosion is clearly exemplified by this butte. Its form is perfectly preserved, and its surface has been scarcely rilled by water. The cinders of which it is composed are weathered at the surface but are fresh at shallow depths. Sufficient wind-blown dust has been deposited on its lower slopes to make agriculture feasible, but otherwise its form is the same as it was eons ago. This is due largely to its extreme permeability. Its lava flows were spread out evenly upon the plain, and if it were not for the great canyon carved through them no one would suspect that the cone had long been silent. However, not only has a 1,000-foot canyon been carved since it was in eruption but also a second canyon nearly as deep in the intracanyon basalt.

From points on the rim of the Deschutes Canyon is seen a striking contrast between the canyon, representing immense lapses of time, and the perfect cone with the seemingly short interval of time since its last eruption—a view which gives a geologist a deep impression of the work of a swift river in a desert land. (See pl. 13, *B*.)

An inconspicuous symmetrical round cinder cone about 40 feet high occurs in sec. 3, T. 13 S., R. 12 E. Its weathered cinder surface is covered entirely by grain fields. In the heaps of stone cleared from this land are numerous large cindery masses and a great number of round breadcrust bombs. Dozens of spiral or twisted bombs also lie on the surface of the cone. The flows from this cone spread out in all directions. In the NE. ¼ sec. 11 of the same township there is a lava knoll about 40 feet high that may be another vent. It has a cone shape, but no cinders were found on it. It was not mapped as a cone because of insufficient evidence.

Two other low cinder cones are present in secs. 18 and 20, T. 13 S., R. 13 E. They are very inconspicuous, but numerous cinders are scattered on their surface in the loess cover. One of these cones gave vent to an aa flow which is seen in a railroad cut in sec. 13, T. 13 S., R. 12 E., where it is overlain by 3 to 5 feet of soil and caliche. The vesicles of the lava are filled with a transparent white mineral that was not determined.

In the northeast corner of sec. 31, T. 13 S., R. 13 E., there is a cinder cone whose structure is excellently exposed in the adjacent railroad cut. In this excavation there are beds of black and red cinders as fresh as those formed on Kilauea Volcano, Hawaii, in historic time. They are overlain by a little wind-blown sand and caliche.

The Tetherow Buttes, in T. 14 S., R. 13 E., are three cinder cones in a line running northwest and southeast. They rise nearly 200 feet above the plain, and their slopes are cut in places by erosion. A fine exposure of cinders occurs in a pit on the slope of the southern one from which road material is being removed. The three cones are connected by a deposit of cinders, and it is believed that they were all in eruption at the same time. Doubtless a considerable portion of the rim-rock basalt flowed from these vents.

In a line with the Tetherow Buttes and about 5 miles northwest of them on the Peninsula is a group of cones. The northern one is about 75 feet high; the others are not over 25 feet high. The lava from these vents flowed northwestward down a gentle slope, indicating that the Deschutes had begun its work of erosion. The rim rock basalt on the opposite canyon rim did not come from these vents but from others southwest of the area mapped.

An inspection of Plate 10 shows a northwest-southeast alignment of the cones. They were certainly formed by eruptions along a fissure, and their direction may indicate buried fault lines in the Deschutes Valley. The fact that the alignment is almost parallel with the axis of the valley suggests that northwest-southeast faults may have played an important part in the formation of this valley.

Age and correlation.—The Deschutes formation was carefully searched for fossils, but none were found, except the minute one-celled siliceous algae skeletons that make up the diatomite deposits. Mr. Charles Heim, of Terrebonne, informed the writer that an Indian who worked for him but who was away at the time had found fossil shells in the vicinity of Steelhead Falls. He kindly sent one of his other men with the writer to search for the fossil bed, but it was not found. The age of the beds therefore remains unknown. In the John Day region, where the stratigraphy has been carefully worked out, there exists a formation, very similar in structure and lithology to the Deschutes formation, known as the Rattlesnake formation. The following short description of the Rattlesnake formation, by Calkins,[12] shows this similarity:

> This lies in almost horizontal attitude upon the tilted and truncated Mascall beds in the elongated area mentioned above. Doctor Merriam named this formation and considered it of Pliocene age. It appears to be of fluviatile origin in large part and comprises a large amount of coarse gravel and sandstone, together with fine material that may be tuffaceous. Somewhere in the middle of the section there occurs a widely spread sheet of light-colored pumiceous tuff, overlain by a glassy gray rhyolite.

If the Deschutes formation is the correlative of the Rattlesnake it is Pliocene. However, Williams[13] found unconformably above the Columbia River basalt in the Columbia River gorge a similar series of sedimentary beds which have been correlated with the Satsop formation of the Pacific coast of Washington. Dr. R. W. Chaney identified from these beds numerous fossil plants tentatively referred to the Pleistocene, and the Satsop formation as recognized in the Cascade Range has been assigned to that epoch. Mr. Williams, who is very familiar with the middle Deschutes Basin, believes that the Deschutes formation may possibly be a correlative of the Satsop because of its lithologic resemblance to the Satsop and because it rests unconformably on the Columbia River basalt. However, in the Columbia River gorge the beds called Satsop are overlain in places by andesite flows, whereas in the middle Deschutes River Basin the Deschutes formation everywhere rests upon andesite; hence the Deschutes formation may be younger than the Satsop. Andesite flows were erupted in the Cascade Range over a long interval of time; hence the andesite that overlies the beds identified as Satsop in the Columbia River gorge may be much younger than the andesite in the middle Deschutes Basin. In the northern part of the Deschutes Valley, near Maupin, the Deschutes formation certainly occupies the same position in relation to the Columbia River basalt as the beds identified as Satsop formation[14] occupy in

---

[12] Calkins, F. C., op. cit., p. 114.

[13] Williams, I. A., The Columbia River gorge: Oregon Bur. Mines and Geology Bull., vol. 2, No. 3 (revised reprint), p. 128, May, 1923.

[14] A recent article by J. P. Buwalda and B. N. Moore (Science, new ser., vol. 66, p. 236, Sept. 9, 1927) states that they have obtained from the Dalles formation of the Columbia River gorge fragmentary mammalian fossil remains of upper Miocene or lower Pliocene age, and that inasmuch as they have found that the so-called Satsop formation in the eastern part of this gorge underlies the Dalles formation it can not be correlated with the typical fossiliferous marine Pleistocene Satsop formation of the Washington coast. They have therefore renamed the gorge deposit Hood River formation and assigned it to the upper Miocene or lower Pliocene.

the Columbia River gorge. It would be unwarranted to assign the age of the Deschutes formation by means of such long-range correlation; hence it is tentatively classified as late Tertiary or early Pleistocene. It is possible that fluviatile deposition continued from Tertiary into Pleistocene time in the Deschutes Basin without cessation and that the Deschutes formation represents deposits during both Rattlesnake and Satsop epochs.

LATE PLEISTOCENE OR RECENT BASALT (INTRACANYON BASALT)

After the excavation of canyons 200 to 1,000 feet deep in the Deschutes formation many basaltic lava flows were poured out in the vicinity of Bend, some of which spread northward and entered the canyons of the middle Deschutes Basin. Because all of this basic lava occupies ancient or existing canyons in the middle Deschutes Basin it is for convenience here referred to as the intracanyon basalt. South of this area it will probably be found on the surface and be conformable in places with the rim-rock basalt. This intracanyon lava ranges from 100 to about 800 feet in total thickness, in places consisting of only one thick bed and in others of a number of beds. Nearly all of it came from the same source at the same general time. It is separated from the underlying formations everywhere in the middle Deschutes Basin by a sharp, steep erosional unconformity. (See pl. 12, *B*.) A specimen of the intracanyon basalt, collected by Ira A. Williams on the east side of the Deschutes Canyon 1 mile upstream from the Metolius dam site, was examined by the writer. It has a blue-gray color and resembles a diabase in appearance. Small pale-yellow crystals of olivine and minute crystals of feldspar are determinable under the hand lens. The specimen abounds in tiny irregular-shaped cavities as well as spherical vesicles 1 millimeter or more in diameter. Under the microscope labradorite, olivine, augite, and magnetite are readily distinguished. The augite and olivine appear in about the same amounts, and numerous well-formed magnetite crystals are present as inclusions. The augite and olivine in the specimen examined do not exceed 0.2 millimeter in diameter, and the feldspar rarely exceeds 0.5 millimeter in length. Transparent glass may be present in exceedingly small amounts.

The intracanyon basalt along the Crooked River is a remarkable flow. It was not traced to its source, hence its total length is unknown. However, the numerous exposures of this lava in the Crooked River Canyon throw considerable light on its history. Above Trail Crossing it has a thickness of 10 to 50 feet wherever exposed. It is believed to be considerably thicker than this, for the Crooked River was pushed northward by the lava flow, and its ancient buried channel lies about half a mile south of the present river. A mile downstream from Trail Crossing, near the railroad bridge, the river has not yet exposed the underlying Deschutes formation—a fact indicating that the lava exceeds 350 feet in thickness. (See pl. 12, *A*.) The present river at this place lies above its buried channel. In the south wall of the canyon near the bridge some remarkable fan jointing similar to that described by Judd [15] is exposed. The upper 25 feet consists of imperfect columnar-jointed basalt crossed by parallel horizontal joints that make blocks about 1 cubic foot in volume. This material changes downward abruptly into about 100 feet of finely jointed basalt. The joints in this mass are tight and divide the lava into long, slender blocks a few inches in diameter. In several places these slender blocks are arranged like the ribs of a fan 30 feet long radiating downward from points 25 feet below the surface of the flow. There are several such fans side by side which spread out in arcs of about 45°. The upper joint structure indicates that the top 25 feet cooled by fairly rapid radiation through vertical shrinkage cracks. The fan jointing seems to indicate that below this upper 25 feet cooling progressed downward in all directions from certain definite points. These points were probably determined by large deep cracks in the surface of the flow. Below the massive bed, with slender jointing, where no definite pattern exists, except for the few fans near its top, there are three beds with regular columnar jointing. All these patterns are apparently developed in one thick flow.

From the south boundary of the area mapped to the railroad bridge the intracanyon basalt has a width of a mile or more, apparently obliterating an open canyon. Below the bridge the flow narrows to a width generally not exceeding half a mile, as a result of being confined in a narrow, deep canyon. About 1½ miles downstream from the bridge, in sec. 31, T. 13 S., R. 13 E., the entire south wall of the canyon is made up of the Deschutes formation, except for a narrow tongue of basalt that occupies what appears to have been an ancient gulch tributary to the Crooked River. Along the south line of this section the intracanyon flow of the Crooked River merges without a perceptible break into the intracanyon lava in the Deschutes Valley to the south. It appears that at this place the Deschutes flow was concurrent with the Crooked River flow and that it spilled over the rim of the Crooked River Canyon and united with the intracanyon basalt of the Crooked River. The relative age of the two great flows can not be determined definitely until they have been traced southward to their sources.

Because lava is considerably more viscous than water, the surface of the flow does not retain the gradient of the prelava valley bottom, but the flow thickens downstream. Thus at the Cove power plant the top of the flow is 2,380 feet above sea level, and it is 580 feet thick.

[15] Judd, J. W., Volcanoes, p. 106, New York, D. Appleton & Co., 1881.

At the railroad bridge 16 miles upstream it has an altitude of 2,800 feet and is about 400 feet thick. For the intervening distance of 16 miles it has a gradient of 26 feet to the mile, whereas the gradient of the valley bottom is about 38 feet to the mile. All long lava flows are thicker toward their terminations, because lava becomes cooler and hence more sluggish as it flows.

The general character of the Crooked River flow changes considerably from place to place. Near Opal Springs four distant layers of jointed basalt occur, some vertically and others irregularly jointed. (See pl. 14, *A*.)

Where it entered the Deschutes Canyon the Crooked River flow made an immense triangular fill occupying the combined width of Deschutes and Crooked Canyons. The flow did not stop here, however, but continued on down the Deschutes for many miles. The farthest known remnant of this flow downstream is 125 feet thick and lies in Deschutes Canyon, 8 miles below the mouth of the Crooked River. However, this remnant is only a small piece of the flow and does not represent the total thickness, hence it is not unlikely that the flow continued at least another 10 miles down the canyon. A small remnant of the flow was found over 2 miles up the Metolius Canyon, showing that the Crooked River intracanyon lava not only flowed many miles down the Deschutes Canyon but also flowed up the Metolius Canyon. Thick remnants of intracanyon basalt that slope southward, or upstream, occur in the Deschutes Canyon for a distance of 4½ miles above the mouth of the Crooked River. These remnants are parts of the Crooked River flow that flowed up the Deschutes Canyon. Such a statement sounds paradoxical, for it has just been said that lava is less fluid than water. The feat was accomplished, nevertheless, by an accumulation of lava sufficiently thick at the confluence of the two rivers to cause a down grade for the lava in the direction from which the Deschutes River had previously been flowing. These lava masses at the confluence of the Deschutes and Crooked Rivers and of the Metolius and Deschutes Rivers acted as immense dams that temporarily ponded these rivers. Evidence of this ponding is shown by the alluvial deposits 20 feet thick on top of the intracanyon remnants in the Deschutes Canyon east of Grandview. One of these lava remnants is shown in Plate 11, *B*.

The question immediately arises how such a flow with a known length of 36 miles and a probable length of 50 miles could keep hot enough to flow such a distance. This question would be difficult to answer from observations in the Crooked River Canyon, for the structure of the flow throws little light on the subject. However, as pointed out above, the jointing and bedding vary from outcrop to outcrop. On the west wall of the Deschutes Canyon in sec. 15,

T. 11 S., R. 12 E., the intracanyon basalt consists of 23 distinct layers. Such variations in structure indicate that the flow at no time or place was a great moving river of lava several hundred feet thick. The distribution of lava to such distances as are indicated by the length of this flow is accomplished by means of a great subway system of tubes connecting the source with the end of the flow. The tubes or tunnels through which the lava moves are formed within the flow itself by the crusting over of a lava river. Once they are formed the lava is able to travel long distances underground without any great loss of heat, for radiation through the crust of a lava flow is very slow. This method of distribution has been frequently witnessed. Thus during the great eruption of Mauna Loa, Hawaii, that lasted for nine months in 1880–81 lava flowed about 30 miles underground and at the margin of the advancing flow was still very fluid. Furthermore, people walked on the crust of the flow near the vent and saw through cracks the molten lava flowing in great subterranean channels. The occurrence of numerous caverns in every great basaltic lava field is proof that this is the usual method of flow of lava of such types.

A great intracanyon fill similar in most respects to the Crooked River intracanyon basalt was formed in historic time in Iceland. In June, 1783, Skaptár Jökull poured out immense volumes of lava that exceeded in volume any other eruption of historic time. According to Henderson,[16] the lava descended Skaptâ Valley for a distance of 50 miles, making a lava fill in places 600 feet deep. It also sent a tongue down the valley of the Hverfisfliot for 40 miles, and yet after the eruption ceased the river again returned to its valley. The Skaptâ Valley was filled in about a month, although the vent was in eruption for several months before it ceased flooding the surrounding country with lava. It must have been a similar eruption that sent the immense flow down the Crooked River Canyon.

A prehistoric intracanyon flow of andesite over 15 miles long in the Tieton and Naches Valleys, Wash., has been described by Smith.[17] Intracanyon lava flows are not uncommon in the western part of the United States, but few of them were formed during a single great eruption such as the one in the Crooked River Canyon.

In several places in the Deschutes and Crooked River Canyons, especially near Cove Crossing, erosion has left the intracanyon basalt as wedge-shaped segments high on the canyon walls. The open and slaggy contacts of the basalt with the Deschutes sediments serve as drains for ground water seeping out of the sediments at the contact and for surface water running off the canyon wall. In places where conditions have been favorable these wedge-shaped masses of

---

[16] Henderson, E., Iceland, p. 229, Edinburgh, 1819.

[17] Smith, G. O., U. S. Geol. Survey Geol. Atlas, Ellensburg folio (No. 86), 1903.

the basalt have been detached along the contact by this process and have slid into the bottom of the canyon.

The intracanyon basalt flow in the Deschutes Canyon is not as well exposed as the Crooked River flow, but it plays an important part in the routes of underground water and in the displacement of streams. It enters the area in three distinct divisions occupying the same number of ancient valleys, indicating that the whole region not far upstream was deluged with a great flood of lava that drained northward through these three valleys. In sec. 31, T. 14 S., R. 13 E., the lava flowed south up a valley and not north down the valley, as one would naturally suppose. Plate 10 does not clearly show this condition. One mile north of the point where they enter the area the three intracanyon flows unite as two flows, each over a mile wide. Separating the two flows at this place is a narrow outlier of rim-rock basalt 2 miles long that formed a flat-topped ridge between two ancient valleys. Farther north the two flows unite into one flow 2 miles wide. Still farther north, in sec. 12, T. 14 S., R. 12 E., the flow again separates into three streams. One small stream flowed north to the Crooked River; another stream terminated 3½ miles to the north against the rim-rock basalt of the Peninsula, and a third stream flowed down the valley of the Deschutes. Near Lower Bridge this third stream of lava flowed 2 miles up an unnamed canyon. In secs. 29 and 30, T. 14 S., R. 12 E., there is a short intracanyon flow that came from two small vents in the same sections. This flow has no connection with any of the other intracanyon lava. One of the vents is a driblet cone in the NW. ¼ sec. 29, the other a lava cone in the SW. ¼ sec. 30.

The Deschutes intracanyon lava obliterates an intricate drainage pattern. As the field work was largely centered on the Crooked River the details of the drainage disturbances on the Deschutes were not worked out. It appears, however, that the Deschutes River is entirely displaced from its former channel from the point where it enters the area to the line between Tps. 13 and 14 S., R. 12 E., where it again enters its prelava channel. The position of the buried portion of the old channel is not definitely known. The erosion remnants of rim-rock basalt with their cliff walls and the great stretch of intracanyon basalt suggest that the Deschutes formerly flowed due north for 7½ miles after it entered this area and then flowed northwest. If the Deschutes did not follow such a course it is certain that some tributary did. This buried channel has an important bearing on ground water and is believed to cause the numerous springs that enter the west side of the Crooked River in sec. 14, T. 13 S., R. 12 E. The presence of two other partly filled valleys west of Tetherow Bridge points to the former existence of two other streams. Whether these valleys were occupied by tributaries to the Deschutes is not known. In order to determine this question the geologic mapping will have to be carried a considerable distance south of T. 14 S. It is possible that the valleys were both formed by the Deschutes River and that flows of basalt have occurred at this place on different occasions separated by long intervals of time during which the Deschutes excavated new canyons.

The remnants of basalt in the Deschutes Canyon indicate that the last flow went within 4½ miles of the mouth of the Crooked River. These remnants do not exceed 100 feet in thickness and lie low on the canyon wall. If this flow occurred simultaneously with the one in the Crooked River Canyon, the two flows must have met in the vicinity of the confluence of the two rivers. It is believed that this occurred, but that the lava flowing down the Deschutes was much less in volume and probably reached the confluence in the later phases of the eruption, owing to its pooling in the area north of Tetherow Bridge. In any event, it was so overwhelmed by the great Crooked River lava flood that all traces of it below sec. 29, T. 12 S., R. 12 E., are gone.

The age of the intracanyon basalt is unknown, but from its stratigraphic position it is thought to be late Pleistocene or Recent. It is little weathered, and all the original surface features of the flows are preserved, except the thin glassy crust a fraction of an inch thick, which has flaked off and lies in the depressions on the surface. The immense canyons cut into it give an impression of great antiquity, yet the jointed and fractured lava yields readily to the swift rivers of the region. The great postglacial canyon of the Niagara River is mute evidence of the gigantic erosive power of a river during the time that has elapsed since the end of the Pleistocene epoch. Dry River,[18] a wide, dry canyon, dozens of miles long, that enters the Crooked Canyon a few miles upstream from this area, may have contributed immense volumes of water to the Crooked River during the final stages of glacial time and aided considerably in the task of excavating a canyon in the intracanyon basalt.

RECENT ALLUVIUM

Recent alluvium occupies too small an area to be shown on Plate 10. The largest deposit found covers only a few square yards at the top of the highway grade, 1½ miles east of Grandview post office. At this place there is a bed of coarse gravel 20 feet thick on the intracanyon basalt. The gravel has been exposed by an artificial cut made to obtain material for road building. A similar bed also appears to cap the remnant of intracanyon basalt on the east wall of the Deschutes Canyon. It was deposited at this level by the Deschutes River soon after the canyon was filled with the intracanyon basalt. Another deposit of fine débris is associated with the intracanyon basalt

[18] Russell, I. C., op. cit., p. 76.

at Trail Crossing. A few alluvial deposits occur elsewhere in the area, as, for instance, thin gravel layers covering a few square feet or pockets of fluviatile white pumice on the surface of the benches formed of intracanyon basalt.

LOESS

Fine yellow loess covers most of the rim-rock basalt and in places is 3 feet thick. It is composed chiefly of fine volcanic ash that has drifted eastward during volcanic eruptions in the Cascade Range.

STRUCTURE

The structure of the area is relatively simple. The Trail Crossing basalt and the Clarno (?) formation have been folded into a broad anticline. The axis trends northeast and the beds dip away from it at angles of 5° to 30°. Near Trail Crossing the anticline plunges southwest and passes under later rocks.

The relation of the andesite to the Clarno (?) beds is unknown, but it is believed to be separated from them by an erosional as well as a deformational unconformity.

The Deschutes formation in contact with the andesite is well exposed in sec. 4, T. 14 S., R. 12 E. At this contact the sedimentary beds of the Deschutes rest unconformably on the andesite. Elsewhere the contact is not exposed, but it is believed that the Deschutes formation is later than the andesite and everywhere rests unconformably upon it. A few miles upstream from the area mapped the Deschutes formation rests unconformably upon the Trail Crossing basalt and Clarno (?) beds, indicating that the andesite does not completely underlie the middle Deschutes Basin. The andesite appears to have flowed into the basin along ancient valleys and is in the form of long tongues. The volcanic origin of much of the Deschutes formation suggests that the andesite may not have been long separated in time from it. The thick Pelton basalt member at the base of the Deschutes formation, though very different physically from the andesite, is chemically very much like it, and hence there may not have been a long interval between the two kinds of lavas. The volcanoes of the Cascade Range may have poured out andesite about the same time basalt was issuing from vents in the Deschutes plain.

Considerable time intervened between the deposition of the Deschutes formation and the intracanyon basalt flows, for they are everywhere separated by a steep erosional unconformity. The Deschutes formation is horizontal or inclined at angles of less than 5° wherever exposed. There are no signs of folding or faulting, but the whole formation was probably uplifted, because the long cycle of deposition gave way to one of rapid erosion.

GEOLOGIC HISTORY

The geologic history of the area began with the downwarping of the Trail Crossing basalt and the Clarno (?) tuffs, accompanied perhaps by faulting. This movement aided by erosion formed a broad basin more than 1,000 feet deep, bordered on the east by the upturned beds of the Clarno (?) formation and on the west by the volcanoes of the Cascade Range. These volcanoes must have been active soon after the basin was formed, for they poured andesitic lava into it.

The next event chronicled by the rocks of the area is the flooding of the basin by basalt flows, which accumulated to a thickness of at least 150 feet. Where this lava came from is unknown, but it probably issued from cones along some buried fissure in the Deschutes Valley. Soon after or perhaps during this period of volcanism the ancestral Deschutes and Crooked Rivers, together with lesser streams, began depositing silt, sand, and gravel in the depression. The occurrence of cross-bedding indicates that the streams were wide and braided, like the Platte River of to-day. Frequently the ash or pumice from adjacent volcanoes fell in the basin. These ash deposits also blanketed the surrounding hills, with the result that erosion was increased and streams tributary to the basin brought in large amounts of volcanic detritus. The horizontal beds of pumice, 10 to 15 feet thick, exposed continuously for several miles in the canyon walls of the Crooked and Deschutes Rivers, testify to the violence of some of the explosions.

During the accumulation of this débris basaltic lava was occasionally extruded from cones and fissures and spread out on the floor of the basin in thin sheets covering many square miles. Often several volcanic outbreaks occurred in rapid succession, so that the lava accumulated to a thickness of 75 to 150 feet before fluviatile materials were deposited on it. The fact that these flows are basic and that practically all the pumice is more acidic in composition signifies that there were concurrent eruptions of basic lava in the valley and of andesitic pumice somewhere in the adjacent area. It is safe to assume that the pumice corresponds to the explosive decadence of the Cascade volcanoes in Pleistocene time.

The stratigraphic record also shows that occasionally sufficient time elapsed between eruptions for several hundred feet of sediments to be deposited. Beds of diatomaceous earth seen here and there in the Deschutes formation and particularly prominent at Lower Bridge (across the Deschutes) indicate that shallow spring-fed lakes were at times formed by damming of the drainage by lava. Diatoms will form pure deposits only in clear water where the tributaries do not bring in sand, silt, and other foreign substances. Such conditions exist only where the lake is supplied by springs on the bottom or along the shores. Spring-fed lakes are not uncommon in the lava fields of Oregon, and the permeable basalt flows in the Deschutes formation may have formed many such lakes. Diatomite deposits of good commercial quality are known only in the upper part of the Deschutes formation, suggesting that in the earlier stages of Deschutes deposition local spring-fed ponds were not able to exist for any considerable period of time but were either filled with volcanic sediment or drained by erosion.

The closing phase of the Deschutes formation was another period of volcanic activity during which numerous basic flows of the rim-rock basalt welled out from cones and fissures in the basin, spreading out in thin sheets of great extent that completely covered the Deschutes sedimentary beds. The cones and chains of cones marking the site of the fissures from which the rim-rock basalt issued are shown on Plate 10.

After the rim-rock flows were extruded, deposition ceased in the basin and a new cycle of erosion began. As the beds of the Deschutes formation are everywhere horizontal, the new cycle of erosion must have been initiated without local disturbance. The field work did not extend over a large enough area to determine whether this cycle was due to regional uplift or to the filling of the basin so that the rivers found an outlet. As soon as the rivers had sawed through the rim-rock basalt the rate of erosion was doubtless accelerated because of the softness of the sedimentary beds in the Deschutes formation. However, temporary checks in the rate of erosion occurred wherever the rivers reached interstratified beds of basalt. Falls often resulted, and the arrested streams slowly cut these falls back and then renewed their work in the soft sediments. Big Falls and Steelhead Falls on the Deschutes River and many rapids on the Crooked River are caused by the water tumbling from hard beds of lava to underlying soft sediments.

At the junction of the Deschutes and Crooked Rivers a canyon 1,000 feet deep had been excavated before this erosion cycle was interrupted by volcanic eruptions that occurred several miles south of this region. A flow of lava spilled into the canyon of the Deschutes River near Tetherow Bridge and partly filled the canyon for many miles downstream. The river was forced to change its course in many places. The several abandoned channels near Tetherow Bridge may mean that this order of events was repeated at intervals or else that there were several tributary canyons at this place which were all filled at the same time. The details of these accidents to the Deschutes can be worked out only by investigating the area south of the middle Deschutes Basin. However, these interruptions were small and insignificant compared with the great change wrought by a flood of lava spilling into the canyon of the Crooked River near

Smith Rock. This lava flowed downstream, filling every nook in the canyon and in a few places flowing up tributary valleys. The lava continued to pour into the canyon until near Smith Rock it obliterated all signs of the former canyon and spread out in the form of a plain. At the junction of the Deschutes and Crooked Rivers it made an immense fill and flowed up the Deschutes Canyon for several miles. The lava also flowed downstream from this point for more than 8 miles before it stopped. This intracanyon lava fill initiated another cycle of erosion, and the rivers began to excavate new canyons. The Deschutes and Metolius Rivers were temporarily dammed by the Crooked River intracanyon basalt, but doubtless it was not long before they overflowed their dams and began the long task of sawing through 700 feet of lava. The rivers have now practically completed this task and in most places are again cutting into the underlying members of the Deschutes formation.

DIATOMITE DEPOSITS

Sufficient time was not available to investigate the diatomite deposits of the region. A deposit of apparently commercial quality occurs in the Deschutes formation in the east wall of the Crooked River Canyon in sec. 27, T. 12 S., R. 12 E., above the intracanyon basalt. It has a heavy overburden, including the rim-rock basalt, hence it will be necessary to work it by tunneling. Other diatomite deposits are reported to exist in the area, but they were not visited. The only diatomite deposit that is being quarried is in sec. 16, T. 14 S., R. 12 E., about 6 miles by road west of Terrebonne. (See pl. 10.) The following description of this deposit is abstracted from a report to the chief engineer of the Union Pacific system by Dr. A. C. Boyle, jr., dated December 30, 1921. It is published here for the first time by permission of the author and Mr. S. Murray, assistant chief engineer of the Union Pacific system.

The diatomite deposit near Terrebonne is owned by the Western Diatomite Co. The area underlain by the deposit is shown in Figure 7. It has a maximum thickness of about 40 feet and is covered in nearly all places by tuff and sand of the Deschutes formation. It thins out slightly, however, toward the southwest corner of sec. 16. In some places the overburden reaches a maximum thickness of 12 feet, but in others it is thin, and burrowing animals have brought the diatomite to the surface from their shallow holes. An examination of the overburden shows that it averages somewhat less than 11 feet in thickness. In one area the diatomite is overlain by basalt. In order to explore the deposit the Western Diatomite Co. has sunk numerous test pits, the location of which is shown in Figure 7 and their logs in Plate 15.

The deposit of diatomite is tabular in form, and its nearly uniform thickness shows that it was probably laid down in a broad lake of unknown dimensions. The bed has been cut through by the Deschutes River, for it crops out on both canyon walls. In a few places small channels in the deposit indicate that the bed was also eroded before its burial by later sediments. One of these channels is about 10 feet wide and 3 feet deep. The slope of the cross-bedded débris in

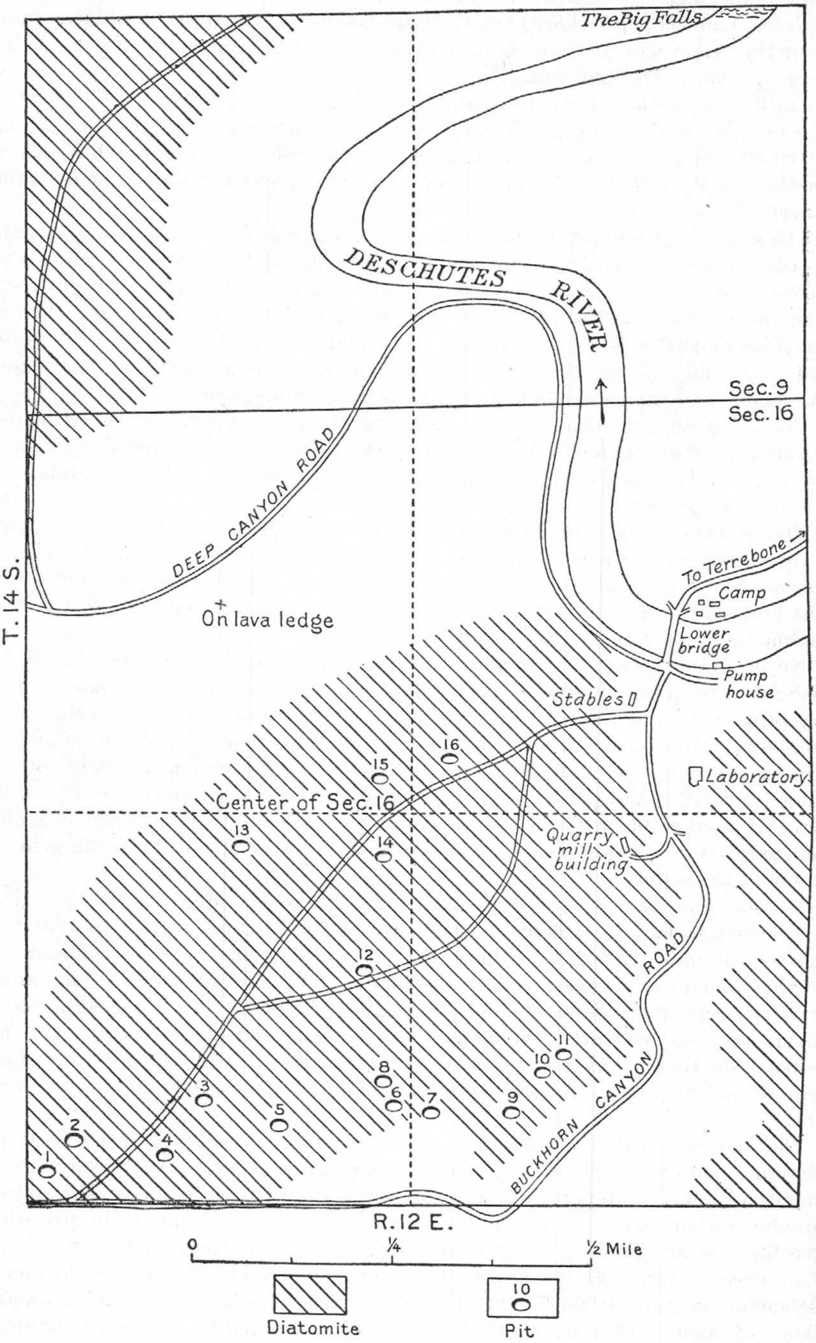


FIGURE 7.—Map of diatomite deposits of Western Diatomite Co., near Terrebonne, Oreg., showing location of test pits. Numbers of pits are the same as those used in Plate 15

this channel suggests that the stream flowed from the southwest. The number of these channels is unknown, but they are believed to be few. Wherever they occur they represent, bulk for bulk, the amount of fossil earth which can not be counted upon in the final computations of quantity.

The deposit is characterized by bands from a few inches to several feet in width. The banding is due to slight variations in the composition of the fossil earth, principally in the content of iron oxide. Although the diatomite has a low specific gravity it is fairly compact and easily supports the weight of a steam shovel.

The stratum of highest grade, known at the quarry as No. 6, is characterized by the absence of bedding planes and by good conchoidal fracture. It is extremely soft, very white, and massive and is easily distinguished from every other member of the deposit by the peculiar pitch of sound produced when a sharp-pointed stick is thrust into it. This stratum is found in most of the pits and varies only slightly from 6 feet in thickness. It is made up of practically one species of diatoms and is almost free from injurious impurities.

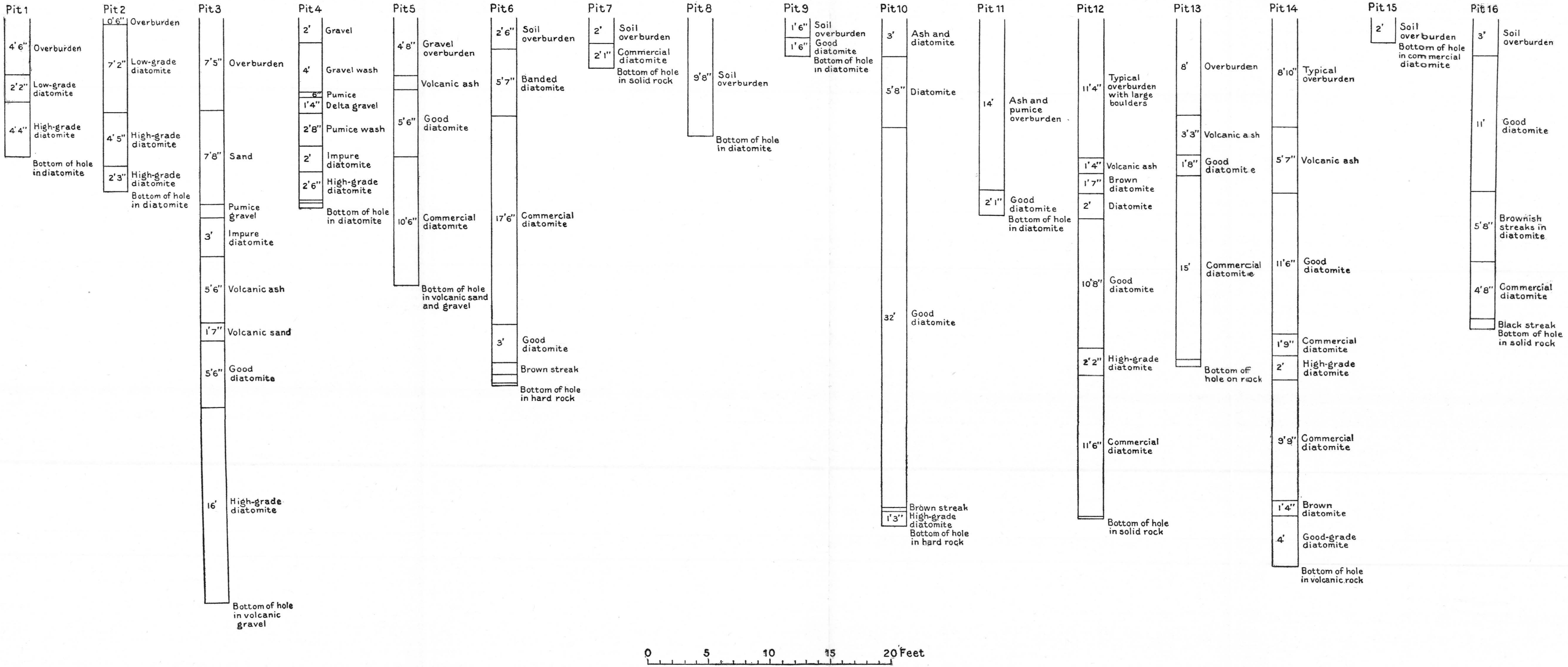
Vertical fissures, in places curved, break up the mass and are probably due to shrinkage. Water percolating through these fissures has deposited foreign substances, chiefly iron oxide, along their faces. The fissures aid considerably in the mining operations.

The overburden is stripped with a steam shovel, and the diatomaceous earth is then quarried and placed in racks or on a platform for air drying. It is then transported to the mill on the property, where it receives a preliminary crushing. The finished product is loaded in 60-pound sacks to trucks that deliver it to the warehouse at Terrebonne, the nearest rail point.

No accurate survey of the area underlain by diatomaceous earth has been made, but by pacing about 265 acres in this unit of the area filed upon by the Western Diatomite Co. was found to be underlain with the fossil earth. The area east of Buckhorn Canyon probably includes 40 acres. This land is underlain by the same bed as that on the west bank of the canyon, but it is not included in the 265 acres of the main deposit. The company reports also about 40 acres of marketable product in the W. ½ SW. ¼ sec. 9. This area also was omitted from the computation. If these areas are ever mined, they will greatly augment the supply.

For convenience of computation the area of 265 acres is taken as the basis and is believed to be everywhere underlain by 36 feet of fossil earth, so that the deposit contains 415,562,400 cubic feet, or 15,391,200 cubic yards, of diatomite. Of this amount it is conservative to estimate that about 9,000,000 cubic yards, or 60 per cent of the deposit, will be ultimately shipped. The other 40 per cent covers the loss by water, thinning of the deposit, and other causes. On the assumption that an average railroad car will carry 153 cubic yards, it would require 60,000 cars to transport the amount of diatomite available in this one unit.

Diatomaceous earth is composed of the residuary remains or hard parts of diatoms, one of the group of aquatic plants called algae, which occur almost universally in all waters from the Arctic to the Torrid Zone, fresh or salt, still or running, hot or cold, and shallow or deep. "The diatom ornaments its shell with fine lines, somewhat over 125,000 to the inch. The fineness in texture of the diatomaceous earth can be appreciated when it is stated that in 1 cubic inch of a Bohemian sample 40,000,000,000 individuals (*Gallionella distans*) find an abundance of room. Diatoms multiply with amazing rapidity, a single individual producing 9,000,000 descendants in a period of four weeks." The diatoms of this deposit appear to have lived in a spring-fed fresh-water lake, probably caused by lava damming a watercourse during the deposition of the Deschutes formation.



LOGS OF TEST PITS OF WESTERN DIATOMITE CO., NEAR TERREBONNE, OREG.

By A. C. Boyle, Jr.

The siliceous shells of these plants accumulated in the bottom of the lake. The chemical purity of the fossil earth varies according to the amount of silt, clay, ash, and other foreign substances deposited simultaneously with the siliceous casings.

The following table of analyses is given in the hope that it may be useful for comparisons. Analyses 11 to 13 represent diatomite from this deposit.

Analyses of diatomaceous earth

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	65.62	86.92	72.50	86.89	86.90	80.53	80.66	81.53	84.15	75.68	86.00	86.26	88.51
Al_2O_3	-------	4.27	11.71	2.32	4.09	5.89	3.84	3.43	1.40	9.88	1.06	3.22	1.28
Fe_2O_3	-------	-------	2.35	1.28	1.26	1.03	-------	3.34	.70	2.92	.92	1.54	1.28
CaO	-------	1.60	.32	.43	.14	.35	.58	2.61	1.75	.29	.27	.05	1.06
MgO	-------	Trace.	.83	Trace.	.51	-------	-------	-------	1.10	.69	.09	Trace.	.91
K_2O	-------	} 2.48	} -------	1.26	-------	-------	-------	1.43	-------	.02	-------	-------	-------
Na_2O	-------		1.88	2.32	1.18	-------	-------	1.16	-------	.08	-------	-------	-------
H_2O	11.00	5.13	9.54	4.89	5.99	12.03	14.01	6.04	10.40	8.37	7.60	4.94	5.15
	-------	100.40	99.13	99.39	100.07	99.83	99.09	99.54	99.50	-------	99.96	100.00	-------

1. Soft shale, Harris, Santa Barbara County, Calif. W. T. Schaller, analyst, 1907.
2. Porcelain diatomaceous shale, Point Sal, Santa Barbara County, Calif. Fairbanks, H. W., California Univ. Dept. Geology Bull., vol. 2, p. 12, 1896.
3. Soft shale, Orcutt, Santa Barbara County, Calif. W. T. Schaller, analyst, 1907.
4. Monterey, Monterey County, Calif. Lawson, A. C., and Posada, J. C., California Univ. Dept. Geology Bull., vol. 1, p. 25, 1893.
5. Fossil Hill, Nev. California State Min. Bur. Bull. 38, p. 289, 1906.
6. Lake Umbagog, N. H. Merrill, G. P., U. S. Nat. Mus. Rept. for 1899, p. 220, 1901.
7. Norris County, N. J. Idem.
8. Popes Creek, Md. Idem.
9. Hanover, Germany. California State Min. Bur. Bull. 38, p. 289, 1906.
10. Diatomite, Richmond, Va. U. S. Geol. Survey Bull. 483, p. 27, 1911. J. M. Cabel, analyst.
11. Standard filtration diatomite, Terrebonne, Oreg. Unpublished analysis by Dr. L. V. Hampton, Portland, Oreg., Feb. 4, 1920.
12. Diatomite No. 10, Terrebonne, Oreg. Gascoyne & Co., analysts, Dec. 14, 1920, for Pomery & Fischer, New York City.
13. Diatomite No. 6, Terrebonne, Oreg. American Sugar Refining Co., analyst, 117 Wall Street, New York City.

It is evident from these analyses that Nos. 2, 4, 5, 11, 12, and 13 are products which are in commercial demand.

Diatomaceous earth has a great many uses. In general its uses are closely associated with its physical, chemical, and mineralogical properties, all of which combine to influence the market for the product. It is used as a cleanser and polisher, as a nonconductor of heat, as a pipe covering for heating apparatus, in filtration, and in a multitude of other ways. The two largest uses at the present time are heat insulation and filtration, both of which depend more upon the physical than the chemical composition of the material.

GEOLOGY OF DAM SITES

UPPER BOX CANYON DAM SITE

The upper box canyon dam site is near the south line of sec. 28, T. 12 S., R. 12 E. A rock-fill dam, 100 feet high, has been proposed for this site. The topography of the dam site is shown on Plate 16, and the location is shown on Plate 10. Both the intracanyon basalt and sedimentary beds of the Deschutes formation are exposed at the dam site, and the areal distribution of these rocks is shown on Plate 16. The proposed dam would tie into only the intracanyon basalt cliffs that form the walls of the canyon. Plate 14, *B*, is a view of the canyon at the dam site. The intracanyon basalt is about 450 feet thick here and comprises several beds, which were probably all derived from the same source and laid down in rapid succession, for sufficient time did not elapse to allow any accumulation of soil on one bed before the next was poured out. The basalt is massive and fairly dense, and in cooling it contracted into columnar blocks, some of which now form the talus slopes in the canyon near the dam site. Plate 14, *A*, illustrates the jointed basalt flows that form the west wall of the canyon at the site. The joints are open in the canyon walls but are probably considerably tighter a few feet back.

The geologic cross section of the Crooked River Canyon at the dam site given on Plate 16 shows the relation of the intracanyon basalt to the Deschutes formation in the prelava canyon of the Crooked River. Because of the sluggishness of the lava near the edge of the flow during the period of accumulation it sometimes failed to freeze tightly against the wall of the canyon. As a result cavernous openings exist at the contact of the intracanyon basalt with the buried canyon wall. Plate 17, *A*, is a view of a bat cave about 105 feet above the river at the dam site, where the intracanyon basalt fails to fit closely to the ancient canyon wall. The cave is partly filled with bat guano, and in places the roof is 12 feet above the guano. The cave follows the contact downward toward the river, but because of the steepness of the contact slope it was not explored to the bottom. At a contact between two beds of lava 35 feet above the river there are holes 1 foot in diameter which appear to open into the cave. The original contact of the basalt with the Deschutes formation was probably fairly tight but was later enlarged by percolation from the river during the early stages of cutting, when the river was flowing near the top of the intracanyon basalt.

A dam tied only to the basalt cliffs would fail to impound water, because of leakage through this cave around the east abutment. In order to make a dam hold water at this site it would be necessary either to fill the cave with concrete or to lay a concrete cut-off wall from the dam to the Deschutes formation at the contact. The cost of such a wall would probably make the proposed dam at this site impracticable.

LOWER BOX CANYON DAM SITE

The lower box canyon dam site is three-quarters of a mile north (downstream) from the upper site. It is shown only approximately on Plate 10, because the height and type of the dam at this site will determine its exact location. The water surface at the site is 1,920 feet above sea level and 49 feet below Opal Springs. The geology of this dam site is practically the same as that of the upper site, for intracanyon basalt occurs on both abutments and back of it lies the Deschutes formation. The geologic section is so nearly like that of the upper site that Plate 16 suffices to illustrate both of them.

The success of a dam at this place will depend chiefly upon three factors—a satisfactory foundation must be found for the dam; a reasonably tight contact must be found between the intracanyon basalt and the Deschutes formation; and the height of the dam must not greatly exceed 155 feet above the river, or 2,075 feet above sea level. Test holes should be drilled at the site to determine how far below the river bed the Pelton basalt lies. If a reasonable thickness of Deschutes sediments is found above the Pelton basalt under the river, then it will be safe to assume that the Pelton lavas will not cause appreciable seepage under the dam. The tightness of the contact of the Deschutes formation with the intracanyon basalt in the abutments can be determined by drilling holes through the basalt to the contact. If after testing the holes under pressure the leakage is found not to be great the contact can doubtless be grouted successfully. Water impounded by a dam at this site would flood the bat cave at the upper site, but the water entering the cave would be returned to the river above the dam because a gap exists between the intracanyon basalt of the east abutment of the upper site and the intracanyon basalt of the east abutment of the lower site. If a dam at the lower site were constructed much more than 155 feet above the river the water impounded by it would flood the bed of interstratified basalt in the east wall of the canyon, 105 feet above the river at Opal Springs.

The contact of this bed of lava with the underlying sediments is slaggy and cavernous. The fact that water can find its way along the contact with ease is demonstrated by a group of springs that discharge from it. (See fig. 8.) A slight head of water on this bed of lava would cause leakage around the dam, for the same bed crops out below the lower dam site.

The success of a dam at the lower site depends also upon the origin of Opal Springs. A test hole should be drilled close to the springs to determine whether they rise from the Pelton basalt or some other interstratified lava bed in the Deschutes formation below the river. Further information regarding these springs and their relation to the proposed reservoir created by a dam at this site is given on pages 202–203. If Opal Springs have their source in the interstratified bed of basalt, 105 feet above them, then the construction of a 155-foot dam at the lower site would not cause a reversal of the hydraulic gradient of the springs, and hence the reservoir would not be endangered by leakage.

METOLIUS DAM SITE

The proposed Metolius dam site is near the line between secs. 15 and 22, T. 11 S., R. 12 E., on the Deschutes River. (See pl. 10.) The water surface at this site is 1,527 feet above sea level. A 300-foot dam would back water up the Metolius, Deschutes, and Crooked Rivers for several miles. The river at the site is flowing in a narrow V-shaped gorge nearly 1,000 feet deep, cut in the Deschutes formation. The geologic section of the east wall of the site is given on page 138. The west wall is very similar except for a thin wedgelike remnant of intracanyon basalt that consists of 23 fissured flows apparently laid down in rapid succession.

The river at the dam site is flowing on the Pelton basalt, which is the lowest interstratified basalt member exposed in the Deschutes formation. The Pelton basalt on the east abutment is exposed

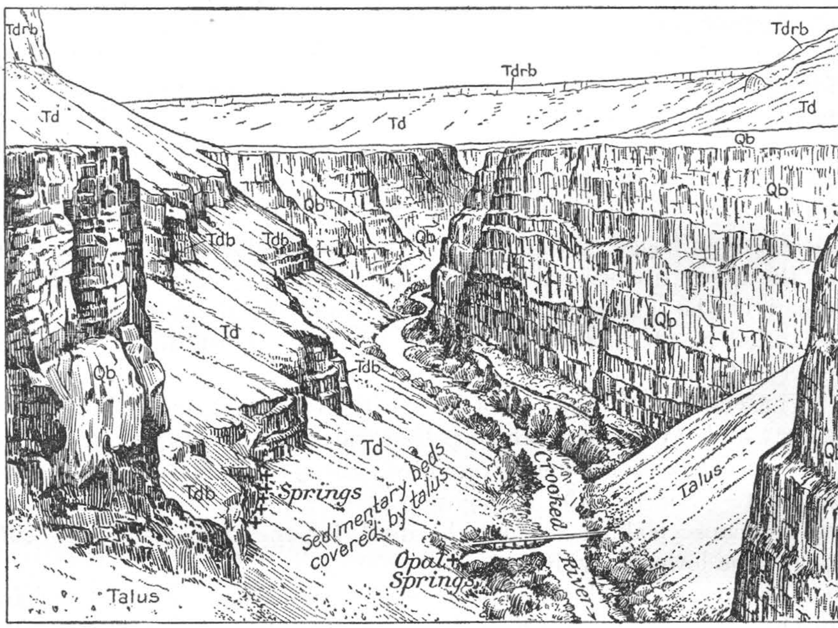
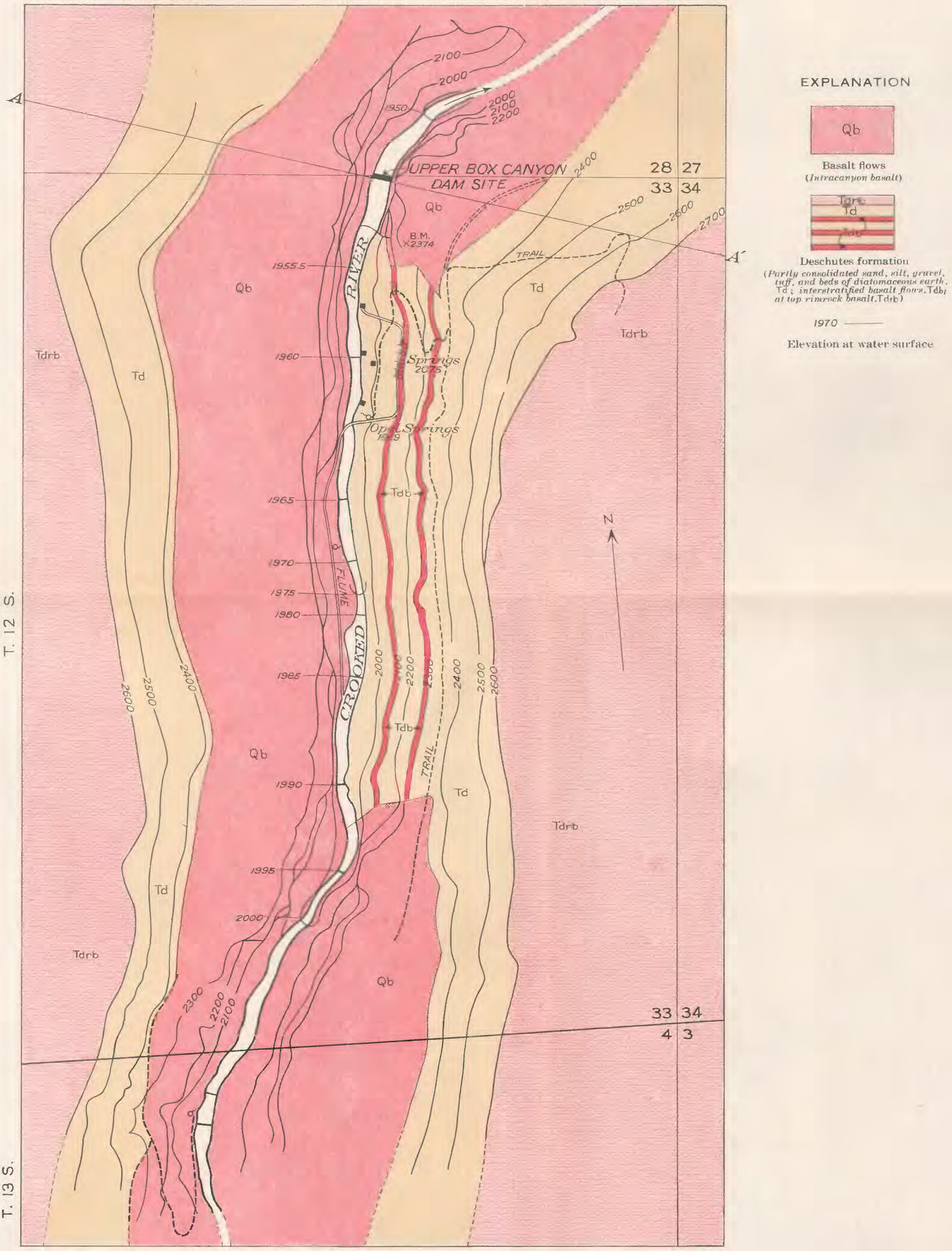
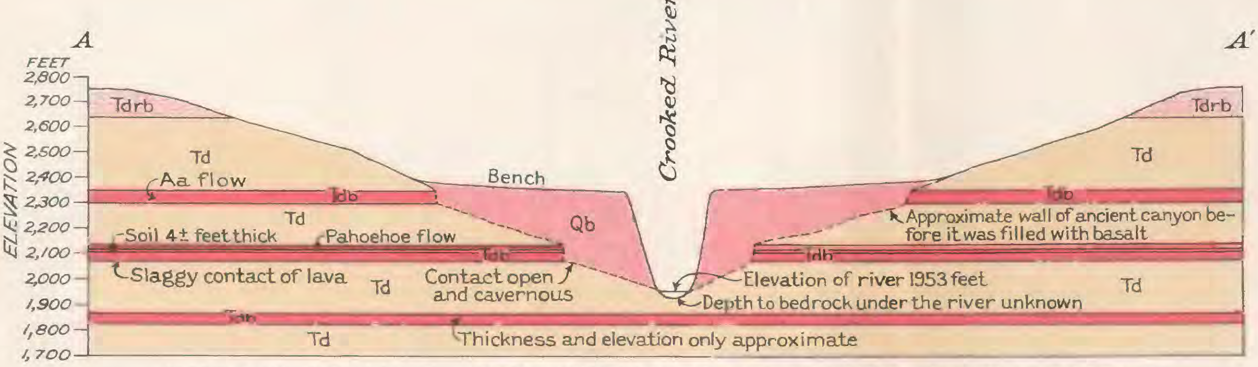


FIGURE 8.—Geologic sketch of Crooked River Canyon near Opal Springs. Qb, Basalt flows (intracanyon basalt); Tdrb, basalt flows (rim-rock basalt) overlying fluviatile deposits; Tdb, basalt flows interstratified with fluviatile deposits; Td, partly consolidated sand, silt, gravel, tuff, and beds of diatomaceous earth constituting fluviatile deposits

above the river for 150 feet and comprises several fissured and jointed flows. Resting on it is a bed of volcanic agglomerate 215 feet thick, which because of its impermeability and its height above the river is not involved in the problem of leakage of the proposed reservoir. The Pelton basalt, which would form the lower 150 feet of the abutments of a dam at this site, crops out continuously up the Metolius River for nearly 4 miles above its mouth, also for about 9 miles up the Deschutes and about 4 miles up the Crooked River. The areal distribution of this lava bed is shown on Plate 10. The extensive exposures of the Pelton basalt indicate that it was spread in successive



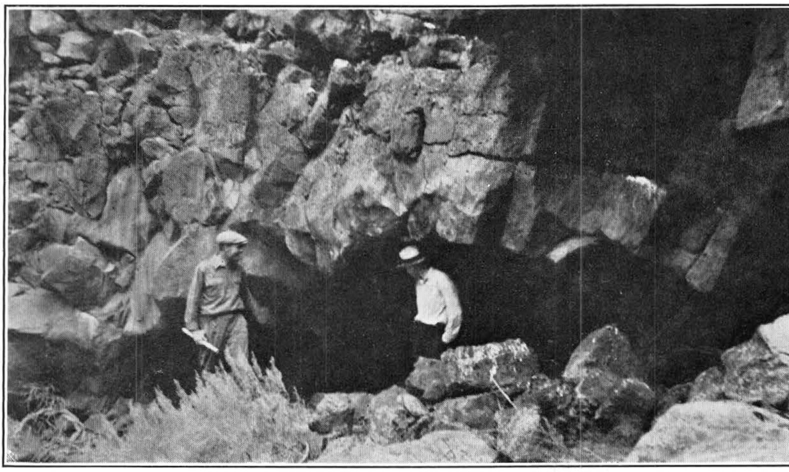


GEOLOGIC MAP AND SECTION OF UPPER BOX CANYON DAM SITE ON CROOKED RIVER, JEFFERSON COUNTY, OREGON

500 0 500 1,000 1,500 2,000 FEET

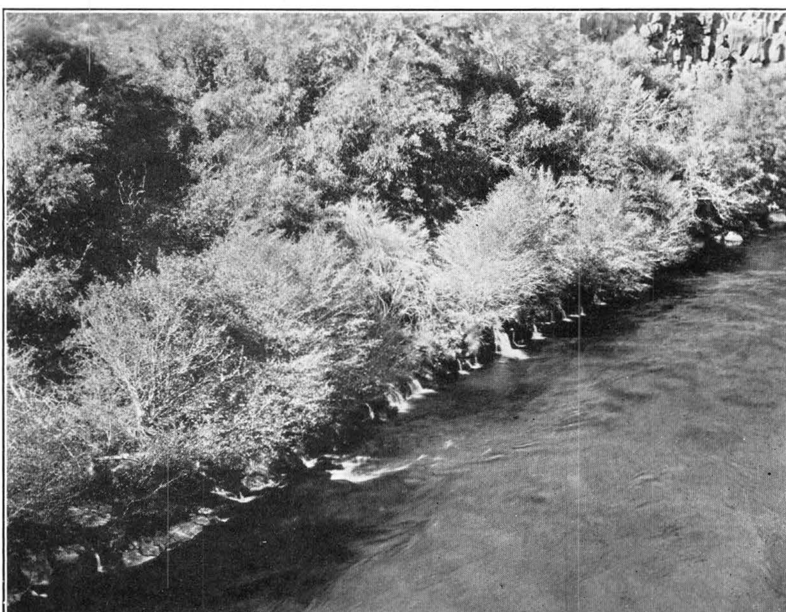
Contour interval 100 feet

Datum is mean sea level

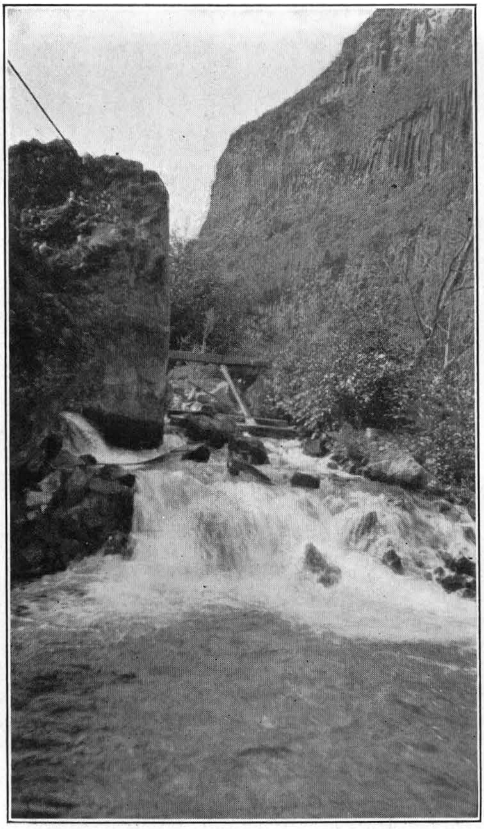


A. BAT CAVE IN THE EAST ABUTMENT OF THE UPPER BOX CANYON DAM SITE

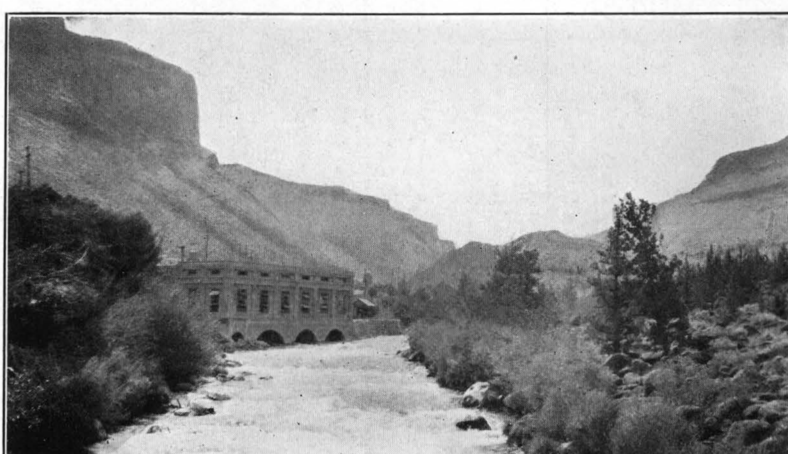
The cave is at the contact of the intracanyon basalt with the Deschutes formation.



B. SPRINGS ISSUING FROM THE PELTON BASALT IN THE WEST WALL OF DESCHUTES CANYON IN SEC. 27, T. 11 S., R. 12 E.



A. OPAL SPRINGS. CROOKED RIVER CANYON
August 26, 1925.



B. COVE POWER PLANT FROM BRIDGE ACROSS CROOKED RIVER
August 12, 1925.

sheets of wide extent in the broad flat valley of the ancestral Deschutes River.

From the Pelton basalt emerge practically all the springs in both the Deschutes and Crooked River Canyons in the middle Deschutes Basin. The total discharge of the springs that issue from it is several hundred second-feet. About half a mile above the mouth of the Metolius River, on the west bank of the Deschutes, there is a line of springs extending nearly three-quarters of a mile. The total discharge is hard to estimate but is probably 80 to 100 second-feet. The view of these springs shown in Plate 17, *B*, gives a conception of their number.

The reservoir created by a dam at the Metolius site would inundate the Pelton basalt for many miles, and the impounding of the water would doubtless cause leakage in some amount around a dam at this site. The exact amount of the leakage, which will increase with the height of the dam, can not be forecast without further drilling or other underground exploration. A thorough drilling program should be carried out to determine the extent of the Pelton basalt at the dam site, and tunnels into the basalt would give additional information regarding its structure. It is understood that all of this investigatory work is included in the proposed program of the company holding the license for the site. This work should be carried on, as it has been in the past, under the supervision of a geologist, and further detailed geologic work should be done at the reservoir site. A power dam at this site has the advantage that it will not have to hold over storage, and any additional underground storage may to some extent offset leakage. A reservoir at this site can stand considerable leakage provided it is made a part of a hydroelectric system with other dams downstream, for the seepage will be returned to the river below the dam and will benefit lower power plants during low-water periods.

CLIMATE

Precipitation.—Only one precipitation station is maintained within the area. It is at an altitude of about 2,300 feet at Madras, in the northeastern part of the plain. Most of the precipitation falls during the winter in the form of snow. In the following table, which has been compiled from United States Weather Bureau reports, the snowfall has been converted to the equivalent in inches of rain:

Monthly, annual, and mean precipitation in inches, at Madras, Oreg., 1909–1926 [a]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1909	------	1.29	0.32	Tr.	0.47	0.46	0.30	Tr.	2.03	0.55	2.17	2.40	------
1910	------	------	------	------	------	------	.05	Tr.	.62	.85	3.10	.73	------
1911	1.25	.09	------	0.02	.90	.63	.00	0.17	2.02	------	.73	.61	------
1912	2.45	.88	.76	.80	1.74	.78	.75	.64	.34	.20	.62	1.30	11.26
1913	.79	.38	.25	.71	1.35	1.27	.15	.00	------	.21	.69	1.24	------
1914	1.91	.75	------	------	------	------	------	------	------	------	------	------	------
1916	------	------	.10	.11	.70	------	------	------	------	------	------	------	------
1920	.32	.04	.58	.63	.03	.74	------	------	------	1.15	1.41	1.29	------
1921	1.25	1.25	.40	.54	1.74	.92	.00	.15	.00	.36	2.74	.71	10.06
1922	.22	.68	1.00	.18	.42	1.69	.00	.63	.08	.98	1.43	1.64	8.95
1923	1.50	.38	.12	1.01	1.06	.58	1.44	.04	.75	1.51	.21	.88	9.48
1924	.24	.42	.56	.02	.03	.15	.01	.19	.21	1.19	1.12	1.29	5.43
1925	.66	.65	.77	1.07	2.89	.15	.02	.27	.99	.08	1.08	.30	8.93
1926	.77	1.30	.11	.70	.56	.13	Tr.	1.32	.02	.37	3.08	.77	9.13
Mean	1.03	.68	.45	.48	1.00	.66	.25	.31	.70	.68	1.53	1.10	8.87

[a] Record from April, 1911, to May, 1916, inclusive, for Metolius, about 3 miles southwest from Madras.

The precipitation over the rest of the plain is about the same as at Madras, although it increases slightly toward the south. The annual precipitation at Bend, which lies 12 miles due south of this area, at an altitude of 3,629 feet, is given in the following table for comparison:

Annual precipitation in inches, at Bend, Oreg., 1902–1926

[From United States Weather Bureau reports]

1902	10.90	1914	8.12	1922	16.41
1903	13.37	1915	11.75	1923	15.66
1904	17.10	1917	8.80	1924	9.39
1906	10.42	1918	10.27	1925	12.78
1907	25.75	1919	11.07	1926	13.27
1912	16.62	1920	11.27		
1913	12.39	1921	12.99	Mean	13.80

An appreciable increase in precipitation occurs in the vicinity of Haystack and Juniper Buttes, where the altitude is more than 1,200 feet higher than Madras.

The snowfall varies considerably from year to year at Madras. Thus, during 1925, when the annual precipitation was 8.93 inches, only 4.5 inches of snow fell, whereas in 1924, when there was only 5.43 inches of precipitation, 24.7 inches of snow fell. In the sheltered canyons the snowfall is usually less than on the plain.

Temperature.—The monthly and annual mean temperature at Madras is given in the following table, and the mean temperature at Bend is given for comparison. Only five years' records are available, and the average annual temperature for the period is 47.8° F.

Monthly and annual mean temperature in degrees Fahrenheit, at Madras and annual mean at Bend, Oreg., 1922–1926

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	
													Madras	Bend
1922	25.0	31.2	[a]37.1	40.7	[a]51.0	[b]61.4	66.8	65.8	59.4	49.2	33.6	28.2	45.8	46.8
1923	35.6	27.6	40.2	46.0	52.0	57.6	67.2	66.2	59.0	45.9	41.2	33.2	47.6	47.5
1924	28.6	40.6	37.6	45.8	56.7	60.5	65.4	63.2	58.2	47.4	37.2	22.2	47.0	47.5
1925	38.2	38.7	39.4	48.6	55.0	60.2	68.2	64.0	58.5	45.4	39.0	35.2	49.2	48.8
1926	32.8	41.6	43.2	52.3	54.0	63.0	67.5	64.2	51.5	48.6	40.8	31.8	49.3	49.9

[a] 1 day missing from record. [b] 5 days missing from record.

There is a wide diurnal range, and extremes of heat and cold are not uncommon in the basin. Frosts occur in all months of the year, except July and August. On June 30, 1924, a maximum temperature of 105° F. was reached, and on December 24 of the same year a temperature of −40° F. was recorded. The lowest temperature on record by the Weather Bureau for the east slope of the Cascade Range occurred at Madras on December 12, 1919, when the thermometer registered −45° F. The climate of the region is similar to that of many other semiarid high plateaus in the Northwest. The air is dry, and the extreme temperatures are not as disagreeable as the records might suggest. Over 200 sunny days usually occur during the year. Even in the middle of the summer the nights are cool, and it is necessary to sleep under blankets.

CROPS, VEGETATION, AND FAUNA

The semiarid character of the climate and the frosty nights preclude any great diversity of agriculture. About 1900 it was discovered that wheat and other cereals could be grown here, and since that time the area has been given over to dry farming. The soil is excellent, and during wet years or years of heavy snowfall good crops are grown. The long periods of dry years or poor markets have driven out a number of farmers during the last decade, so that many of the farms are abandoned and the towns are on the decline. However, in 1925 a bumper crop combined with a good market enabled many of the farmers to pay off their mortgages and left some of them prosperous. The Haystack country, which has a deeper soil and one better adapted for retaining the moisture, yields the best crops.

In the irrigated areas near Terrebonne alfalfa is the principal crop and dairying is on the increase. The cream is shipped by railroad to the nearest creameries through cooperative or private organizations.

Truck gardening is successfully practiced on the Gates ranch, in the Crooked River Canyon, though during some years early frosts prevent the vegetables from maturing. In the sheltered canyon of the Crooked River at Cove Crossing fruit and vegetables are easily grown. Clay loam and sandy loam predominate in the area, but in a few places gravelly loam has resulted from the weathering of a bed of conglomerate in the Deschutes formation.

The natural vegetation of the area is sagebrush, but this has been largely removed except on the stony land. Junipers grow on the hills in the Haystack country and in the vicinity of Round Butte. Sufficient bunch grass grows in uncultivated areas to warrant grazing. On the inaccessible ledges in the Deschutes and Crooked River Canyons bunch grass grows knee high. Russian thistle, as in most other parts of the Northwest, covers most of the abandoned farm land.

Coyotes, jackrabbits, badgers, and gophers inhabit the area. Rattlesnakes are seldom met except in rocky talus slopes along the rivers. Sagehens and a few varieties of ducks are the principal game birds. The trout of the Crooked River are famous for their size and abundance.

WATER RESOURCES

SURFACE WATER

DESCHUTES RIVER

The Deschutes River is described [19] as

a swift-flowing stream of conspicuously clear greenish-blue water broken by many rapids and cascades and is a delight to the beholder on account of its beautiful colors, refreshing coolness, and the picturesque and impressive scenery of its canyon walls. The flow of the river is more remarkably uniform than that of any other river in the United States comparable with it in size, and its economic value is almost incalculable. At the mouth of the stream the maximum discharge is only six times the minimum. Ocular evidence of this uniformity of flow is presented by the low grass-grown banks between which the river flows for much of its course. From the mouth of Crooked River upstream to Benham Falls, near Lava Butte, a distance of about 50 miles, the variation in the height of the river throughout the year is not more than 8 or perhaps 10 inches where the width is not abnormally restricted.

This remarkably uniform flow of the Deschutes, above the Crooked River is due to its being fed by immense springs near Benham Falls. The springs themselves do not vary much, because their drainage areas are covered with thick pumice deposits into which all water sinks. The water drains underground into numerous buried channels or permeable lava beds through which it travels for miles and finally makes its appearance in springs.[20]

Numerous gaging stations have been maintained by the United States Geological Survey on the Deschutes River and its tributaries. Only records for those stations which lie in and adjacent to the

---

[19] Henshaw, F. F., Lewis, J. H., and McCaustland, E. J., Deschutes River, Oreg., and its utilization: U. S. Geol. Survey Water-Supply Paper 344, p. 12, 1914.

[20] Meinzer, O. E., Large springs in the United States: U. S. Geol. Survey Water-Supply Paper 557, pp. 64-68, 1927.

middle Deschutes Basin are included in this report. Some of the stations whose records are given do not lie in the area mapped, but the records are included because they are the only data available to indicate the flow of the streams within the area. The location of the stations is shown in Figure 5.

DESCHUTES RIVER AT BEND

Discharge records are available for the Deschutes River at Bend from January 1, 1905, to June 30, 1906, and from January 1, 1909, to November 21, 1914, when the station was discontinued. These records can be found in other water-supply papers.[21]

DESCHUTES RIVER BELOW BEND

A station has been maintained since November 27, 1914, on the Deschutes River 2 miles north of Bend, in the SE. ¼ sec. 20, T. 17 S., R. 12 E., 22 miles south of the area mapped. The gage now in use is a Stevens water-stage recorder on the right bank. The channel consists of coarse gravel and boulders. This gaging station is below the intakes of five large canals (Arnold, Central Oregon, Pilot Butte, North, and Swalley Canals) which divert water from the Deschutes River near Bend. Only small ditches divert water below the station. The flow is regulated by two hydroelectric plants, one at North Canal Dam and one at Bend. The accuracy of the records is good. The maximum discharge for the period 1905 to 1926 was 4,820 second-feet at 7.45 a. m. November 27, 1909, when there were no diversions. The minimum discharge at this station has at times fallen to a few second-feet owing to the large diversions above the gage.

The records given below have been collected by the United States Geological Survey, except those from 1924 to 1926, which were obtained by the office of the State engineer of Oregon.

Monthly discharge, in second-feet, of Deschutes River below Bend, Oreg., for 1914–1926

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1914–15				
October	1,320	940	1,140	70,100
November	1,290	930	1,160	69,000
December	1,450	860	1,210	74,400
January	1,500	1,180	1,380	84,800
February	1,240	860	1,130	62,800
March	1,360	1,060	1,220	75,000
April	1,500	750	1,060	63,100
May	850	580	683	42,000
June	540	260	378	22,500
July	398	175	238	14,600
August	270	170	207	12,700
September	338	190	277	16,500
The year	1,500	170	839	608,000

[21] U. S. Geol. Survey Water-Supply Paper 344, pp. 27–28, 1914; Water-Supply Paper 362, pp. 554–556, 1915; Water-Supply Paper 394, pp. 40–41, 1917; Water-Supply Paper 414, p. 41, 1918.

Monthly discharge, in second-feet, of Deschutes River below Bend, Oreg., for 1914–1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1915–16				
October	760	316	544	33,400
November	1,180	696	967	57,500
December	1,260	1,000	1,120	68,900
January	1,280	1,000	1,130	69,500
February	1,300	950	1,170	67,300
March	1,500	850	1,220	75,000
April	1,570	994	1,350	80,300
May	1,300	961	1,110	68,200
June	1,160	750	879	52,300
July	1,360	732	1,020	62,700
August	741	588	637	39,200
September	830	628	782	46,500
The year	1,570	316	992	721,000
1916–17				
October	1,090	780	937	57,600
November	1,470	960	1,220	72,600
December	1,400	1,040	1,350	83,000
January	1,320	828	1,170	71,900
February	1,090	780	963	53,500
March	1,150	828	1,020	62,700
April	1,680	1,040	1,340	79,700
May	1,900	1,150	1,470	90,400
June	1,650	1,150	1,280	76,200
July	1,210	670	940	57,800
August	758	592	669	41,100
September	910	670	809	48,100
The year	1,900	592	1,100	795,000
1917–18				
October	1,080	763	940	57,800
November	1,340		1,170	69,600
December	1,780		1,370	84,200
January	1,850	1,280	1,640	101,000
February	1,850	1,230	1,540	85,500
March	1,640	1,210	1,410	86,700
April	1,650	890	1,140	67,800
May	1,080	720	902	55,500
June	825	500	627	37,300
July	521	340	435	26,700
August	520	370	430	26,400
September	710	385	583	34,700
The year	1,850	340	1,010	733,000
1918–19				
October	1,140	637	927	57,000
November	1,300	970	1,190	70,800
December	1,240	850	1,150	70,700
January	1,360	900	1,120	68,900
February	1,240	870	1,130	62,800
March	1,360	770	1,100	67,600
April	1,450	1,020	1,250	74,400
May	1,240	680	852	52,400
June	850	464	645	38,400
July	450	265	336	20,700
August	352	238	264	16,200
September	698	228	516	30,700
The year	1,450	228	871	631,000
1919–20				
October	1,300	485	802	49,300
November	1,680	920	1,280	76,200
December	1,730	1,000	1,310	80,600
January	1,540	970	1,190	73,200
February	1,610	1,020	1,160	66,700
March	1,300	970	1,160	71,300
April	1,420	920	1,210	72,000
May	970	418	603	37,100
June	450	285	364	21,700
July	300	125	214	13,200
August	215	70	120	7,380
September	568	212	372	22,100
The year	1,730	70	814	591,000

Monthly discharge, in second-feet, of Deschutes River below Bend, Oreg., for 1914–1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1920–21				
October	808	560	656	40,300
November	1,390	756	1,110	66,000
December	1,390	1,030	1,220	75,000
January	1,590	1,210	1,360	83,600
February	1,440	1,160	1,320	73,300
March	1,590	1,300	1,430	87,900
April	1,590	1,120	1,330	79,100
May	1,340	1,030	1,140	70,100
June	1,490	850	1,210	72,000
July	895	640	745	45,800
August	760	640	686	42,200
September	1,100	688	859	51,100
The year	1,590	560	1,090	786,000
1921–22				
October	1,110	930	1,000	61,500
November	1,910	1,060	1,330	79,100
December	2,280	1,560	1,900	117,000
January	1,700	1,250	1,480	91,000
February	1,430	1,270	1,340	74,400
March	1,430	1,220	1,300	79,900
April	1,560	1,240	1,410	83,900
May	1,490	----------	1,340	82,400
June	1,700	758	1,120	66,600
July	722	406	540	33,200
August	785	370	453	27,900
September	821	382	512	30,500
The year	2,280	370	1,140	827,000
1922–23				
October	1,170	508	881	54,200
November	1,270	800	1,140	67,800
December	1,380	755	1,100	67,600
January	1,490	1,170	1,280	78,700
February	1,220	935	1,120	62,200
March	1,220	1,070	1,160	71,300
April	1,380	800	1,130	67,200
May	845	228	476	29,300
June	630	205	364	21,700
July	408	79	265	16,300
August	295	65	218	13,400
September	403	26	216	12,900
The year	1,490	26	777	563,000
1923–24				
October	678	285	515	31,700
November	845	----------	715	42,500
December	1,120	672	983	60,400
January	1,220	755	995	61,200
February	1,650	755	1,310	75,400
March	1,580	888	1,260	77,500
April	1,080	185	759	45,200
May	470	40	208	12,800
June	423	14	116	6,900
July	285	24	93.7	5,760
August	176	15	101	6,210
September	168	18	120	7,140
The year	1,650	14	596	433,000
1924–25				
October	449	140	256	15,700
November	1,120	764	999	59,400
December	1,120	----------	1,000	61,500
January	1,190	888	1,010	62,100
February	1,510	972	1,300	72,200
March	1,200	825	1,080	66,400
April	1,200	----------	1,050	62,500
May	991	443	674	41,400
June	730	198	422	25,100
July	270	98	163	10,000
August	640	154	262	16,100
September	664	189	484	28,800
The year	1,510	98	721	522,000

Monthly discharge, in second-feet, of Deschutes River below Bend, Oreg., for 1914–1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1925–26				
October	705	537	605	37,200
November	1,200	764	1,050	62,500
December	1,250	782	1,160	71,300
January	1,250	518	1,030	63,300
February	1,300	714	1,130	62,800
March	1,250	722	1,090	67,000
April	756	103	406	24,200
May	391	7	104	6,400
June	154		55.8	3,320
July	111		67.9	4,180
August	124		49	3,010
September	229	5	126	7,500
The year	1,300	5	570	413,000

DESCHUTES RIVER AT LAIDLAW

A gaging station was maintained on the Deschutes River at Laidlaw (now Tumalo) from 1909 to 1912, and records were also obtained for short periods in 1914 and 1915. The accuracy of the records at this station is not very good, because the measuring section was unsatisfactory. The records indicate that there is only a slight increase in flow between this station and the one at Bend; hence they are not included in this report. They can be found in Water-Supply Paper 344, pages 28–29.

DESCHUTES RIVER NEAR CLINE FALLS

The Cline Falls gaging station is in sec. 13, T. 15 S., R. 12 E. (see fig. 5), about 4 miles south of the point where the Deschutes River enters this area. A staff gage was maintained on the right bank from 1910 to 1913. The channel consists of sand, gravel, and boulders and is practically permanent. The records for this station are good.

Monthly discharge, in second-feet, of Deschutes River near Cline Falls, Oreg., for 1910–1913

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1910				
February 15–28	1,600	1,460	1,580	43,900
March	2,480	1,820	2,100	129,000
April	1,820	1,670	1,740	104,000
May	1,900	1,390	1,710	105,000
June	1,820	1,160	1,310	78,000
July	1,160	1,020	1,090	67,000
August	1,270	974	1,110	68,200
September	1,160	974	1,050	62,500
The period				658,000
1910–11				
October	1,110	1,020	1,070	65,800
November	1,530	1,060	1,350	80,300
December	1,600	1,270	1,380	84,800
January	1,330	1,160	1,250	76,900
February	1,270	1,110	1,220	67,800
March 1–4			1,190	9,440
The period				385,000

Monthly discharge, in second-feet, of Deschutes River near Cline Falls, Oreg., for 1910–1913—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1912				
February 19–29	1,670	1,270	1,440	31,300
March	1,330	1,060	1,200	73,800
April	1,460	1,060	1,270	75,600
May	1,740	1,270	1,430	87,900
June	1,820	1,530	1,670	99,400
July	1,530	1,060	1,220	75,000
August	1,160	1,040	1,090	67,000
September	1,250	1,140	1,200	71,400
The period				581,000
1912–13				
October	1,250	1,110	1,190	73,200
November	1,500	1,220	1,330	79,100
December	1,530	1,270	1,430	87,900
January	1,560	1,160	1,390	85,500
February	1,370	1,180	1,300	72,200
March	1,390	1,110	1,280	78,700
April	1,670	1,290	1,490	88,700
May	1,850	1,330	1,510	92,800
The period				658,000

DESCHUTES RIVER NEAR MADRAS

A station has been maintained in the NW. ¼ sec. 19, T. 10 S., R. 13 E., at the proposed Pelton Dam site, 5 miles above the mouth of Shitike Creek, and 9 miles northwest of Madras. (See fig. 5.) A staff gage on the right bank was used up to May 5, 1924, but since then a Stevens 8-day water-stage recorder has been in operation. The channel and control are composed of boulders and heavy gravel and are apparently permanent. The maximum stage for 1924 to 1926, as shown by the water-stage recorder, was 6.54 feet on February 6, 1925, when a discharge of 10,700 second-feet occurred. The minimum stage as shown by the recorder occurred on August 21, 22, and August 30 to September 2, 1926, when the discharge was 3,220 second-feet. The flow is affected by diversions from the upper Deschutes River, the Crooked River, and Tumalo and Squaw Creeks. Most of the low-water flow comes from springs entering the river below irrigation diversions. Some fluctuation occurs, due to power plants and canal intakes near Bend.

Monthly discharge, in second-feet, of Deschutes River near Madras, Oreg., for the years ending September 30, 1924–1926

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1924				
January	6,060	4,160	4,550	280,000
February	7,320	5,060	5,840	324,000
May	3,860	3,360	3,620	223,000
June	3,710	3,320	3,440	205,000
August	3,420	3,240	3,340	205,000
September	3,400	3,240	3,340	199,000

Monthly discharge, in second-feet, of Deschutes River near Madras, Oreg., for the years ending September 30, 1924–1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1924–25				
October	3,710	3,400	3,460	213,000
November	5,940	3,910	4,460	265,000
December	5,440	3,860	4,370	269,000
January	9,230	4,470	5,120	315,000
February	10,200	5,190	6,560	364,000
March	6,320	4,940	5,540	341,000
April	6,940	5,190	6,030	359,000
May	6,820	4,360	4,980	306,000
June	4,580	3,860	4,130	246,000
July	3,960	3,660	3,750	231,000
August	4,010	3,560	3,680	226,000
September	4,110	3,610	3,900	232,000
The year	10,200	3,400	4,650	3,370,000
1925–26				
October	4,010	3,810	3,930	242,000
November	4,580	3,810	4,350	259,000
December	4,700	4,260	4,510	277,000
January	4,580	4,060	4,390	270,000
February	6,820	4,260	5,160	287,000
March	5,820	4,470	5,060	311,000
April	5,060	3,660	4,250	253,000
May	3,710	3,440	3,530	217,000
June	3,510	3,270	3,360	200,000
July	3,330	3,270	3,310	204,000
August	3,340	3,230	3,290	202,000
September	3,410	3,240	3,320	198,000
The year	6,820	3,230	4,030	2,920,000

DESCHUTES RIVER AT MECCA

A station was maintained from June 7, 1911, to January 14, 1927, at Mecca, in the SW. ¼ sec. 20, T. 9 S., R. 13 E., 1½ miles below the mouth of Shitike Creek and about 10 miles north of this area. (See fig. 5.) There was a staff gage at this station until August, 1924, when a Gurley 8-day recorder was installed. The bed of the river is composed of rock and gravel and is subject to seasonal shifts. The maximum stage occurred on the night of January 6, 1923, at gage height 6.90 feet, with a discharge of 15,200 second-feet. The minimum stage was on August 27 to 30, 1920, at gage height 1.95 feet, with a discharge of 3.170 second-feet. The flow at this station is affected by diversions from the upper Deschutes River near Bend, Tumalo, and Cline Falls. The summer flow of the Crooked River above Trail Crossing and of Tumalo and Squaw Creeks is practically all diverted. The records are good.

Monthly discharge, in second-feet, of Deschutes River at Mecca, Oreg., from June 7, 1911, to September 30, 1926

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1911				
June 7–30	5,260	4,540	4,880	232,000
July	4,720	4,040	4,360	268,000
August	4,200	3,880	4,050	249,000
September	4,200	4,040	4,150	247,000
The period				1,096,000

Monthly discharge, in second-feet, of Deschutes River at Mecca, Oreg., from June 7, 1911, to September 30, 1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1911-12				
October	4,200	3,880	4,090	251,000
November	4,540	3,880	4,210	251,000
December	4,370	4,200	4,300	264,000
January	6,800	3,300	5,050	311,000
February	8,490	4,900	5,940	342,000
March	5,830	4,900	5,200	320,000
April	7,410	5,830	6,460	384,000
May	8,270	6,400	7,100	437,000
June	6,800	5,450	6,020	358,000
July	6,210	4,370	4,850	298,000
August	5,080	4,370	4,550	280,000
September	4,720	4,370	4,520	269,000
The year	8,490	3,300	5,190	3,760,000
1912-13				
October	4,900	4,200	4,390	270,000
November	5,260	4,307	4,770	284,000
December	5,080	4,540	4,670	287,000
January	5,080	4,540	4,880	300,000
February	6,020	4,540	4,810	267,000
March	6,400	4,540	5,350	329,000
April	9,410	6,210	7,450	443,000
May	6,210	4,900	5,710	351,000
June	6,020	5,080	5,490	327,000
July	5,640	4,720	5,060	311,000
August	4,720	4,200	4,400	271,000
September	4,540	4,200	4,250	253,000
The year	9,410	4,200	5,100	3,690,000
1913-14				
October	5,080	4,200	4,520	278,000
November	5,080	4,540	4,820	287,000
December	5,080	4,540	4,800	295,000
January	6,020	4,900	5,270	324,000
February	6,400	4,540	5,080	282,000
March	8,320	6,050	7,250	446,000
April	7,890	5,480	6,610	393,000
May	5,480	4,740	5,080	312,000
June	5,100	4,380	4,630	276,000
July	4,740	4,050	4,230	260,000
August	4,050	3,900	4,020	247,000
September	4,740	3,900	4,200	250,000
The year	8,320	3,900	5,040	3,650,000
1914-15				
October	4,740	4,380	4,590	282,000
November	4,740	4,380	4,700	280,000
December	5,100	4,210	4,580	282,000
January	4,920	4,380	4,640	285,000
February	4,740	4,380	4,540	252,000
March	7,260	4,740	5,310	326,000
April	7,470	4,380	5,480	326,000
May	4,740	4,210	4,380	269,000
June	4,050	3,470	3,810	227,000
July	3,750	3,470	3,580	220,000
August	3,750	3,470	3,500	215,000
September	3,750	3,470	3,580	213,000
The year	7,470	3,470	4,390	3,180,000
1915-16				
October	4,050	3,680	3,860	237,000
November	5,860	4,050	4,500	268,000
December	5,480	4,740	4,820	296,000
January	4,740	4,380	4,580	282,000
February	10,400	4,560	7,240	416,000
March	11,700	5,370	7,710	474,000
April	9,350	6,350	7,460	444,000
May	6,850	4,900	5,730	352,000
June	5,850	4,670	5,220	311,000
July	6,600	4,450	5,610	345,000
August	4,670	4,250	4,410	271,000
September	4,450	4,250	4,410	262,000
The year	11,700	3,680	5,450	3,960,000

Monthly discharge, in second-feet, of Deschutes River at Mecca, Oreg., from June 7, 1911, to September 30, 1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1916–17				
October	4,450	4,070	4,370	269,000
November	4,900	4,450	4,740	282,000
December	4,900	4,450	4,750	292,000
January	4,900	4,070	4,550	280,000
February	4,900	4,070	4,470	248,000
March	7,100	4,070	4,730	291,000
April	11,600	4,900	7,580	451,000
May	9,560	6,360	7,720	475,000
June	6,840	5,100	5,850	348,000
July	5,500	4,400	5,110	314,000
August	4,400	4,100	4,250	261,000
September	4,400	4,100	4,300	256,000
The year	11,600	4,070	5,200	3,770,000
1917–18				
October	4,580	4,140	4,310	265,000
November	6,360	4,400	4,670	278,000
December	9,300	4,760	6,010	370,000
January	6,840	5,920	6,480	398,000
February	7,320	5,330	6,040	335,000
March	7,800	5,140	6,020	370,000
April	7,080	4,760	5,390	321,000
May	4,760	4,400	4,560	280,000
June	4,760	3,970	4,420	263,000
July	4,050	3,820	3,950	243,000
August	4,050	3,740	3,860	237,000
September	4,580	3,890	4,040	240,000
The year	9,300	3,740	4,970	3,600,000
1918–19	4,580	3,970	4,290	264,000
November	4,760	4,400	4,560	271,000
December	4,580	4,050	4,480	275,000
January	5,920	4,220	4,820	296,000
February	4,760	4,580	4,750	264,000
March	7,320	4,580	5,050	311,000
April	10,300	6,470	7,550	449,000
May	6,470	4,900	5,310	326,000
June	4,900	4,220	4,600	274,000
July	4,550	4,060	4,180	257,000
August	4,060	3,840	3,920	241,000
September	4,220	3,840	4,120	245,000
The year	10,300	3,840	4,800	3,470,000
1919–20				
October	4,550	3,980	4,260	262,000
November	7,120	4,550	4,940	294,000
December	6,050	4,550	5,000	307,000
January	10,100	4,550	5,380	331,000
February	6,430	4,330	5,060	291,000
March	5,150	4,330	4,720	290,000
April	5,990	4,730	5,350	318,000
May	5,360	3,760	4,520	278,000
June	4,330	3,580	3,870	230,000
July	3,580	3,380	3,500	215,000
August	3,410	3,170	3,320	204,000
September	3,850	3,250	3,590	214,000
The year	10,100	3,170	4,460	3,230,000
1920–21				
October	4,330	3,850	3,960	243,000
November	5,990	4,040	4,780	284,000
December	6,880	4,730	4,930	303,000
January	7,340	5,260	6,030	371,000
February	9,820	5,080	6,420	357,000
March	9,560	6,680	7,440	457,000
April	7,800	6,470	7,040	419,000
May	7,340	5,650	6,410	394,000
June	6,900	5,080	5,860	349,000
July	5,450	4,380	4,720	290,000
August	4,550	4,060	4,240	261,000
September	4,900	4,060	4,320	257,000
The year	9,820	3,850	5,510	3,980,000

Monthly discharge, in second-feet, of Deschutes River at Mecca, Oreg., from June 7, 1911, to September 30, 1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1921–22				
October	4,730	4,330	4,480	275,000
November	9,820	4,730	5,700	339,000
December	10,600	5,360	6,450	397,000
January	5,570	4,330	5,160	317,000
February	5,150	4,730	5,070	282,000
March	6,650	4,730	5,480	337,000
April	9,300	5,780	7,240	431,000
May	7,570	5,570	6,610	406,000
June	6,430	4,330	5,440	324,000
July	4,330	3,850	4,150	255,000
August	4,330	3,760	3,860	237,000
September	4,330	3,760	3,860	230,000
The year	10,600	3,760	5,290	3,830,000
1922–23				
October	4,730	3,760	4,200	258,000
November	4,730	4,330	4,640	276,000
December	5,570	4,330	4,700	289,000
January	12,100	4,940	6,450	397,000
February	5,360	4,730	4,910	273,000
March	7,340	5,150	5,590	344,000
April	7,800	5,360	6,670	397,000
May	5,570	4,110	4,840	298,000
June	5,150	4,140	4,350	259,000
July	4,940	3,670	4,230	260,000
August	3,760	3,580	3,670	226,000
September	3,950	3,410	3,600	214,000
The year	13,100	3,410	4,829	3,490,000
1923–24				
October	4,330	3,760	3,990	245,000
November	4,730	4,040	4,230	252,000
December	5,360	4,330	4,590	282,000
January	6,430	4,330	4,570	281,000
February	7,570	5,150	5,900	339,000
March	5,570	4,330	5,030	309,000
April	5,150	3,720	4,540	270,000
May	4,170	3,400	3,730	229,000
June	3,990	3,400	3,520	209,000
July	3,640	3,320	3,420	210,000
August	3,480	3,310	3,380	208,000
September	3,480	3,310	3,400	202,000
The year	7,570	3,310	4,190	3,040,000
1924–25				
October	--------	3,400	3,490	215,000
November	6,880	--------	4,770	284,000
December	4,900	--------	4,590	282,000
January	10,100	4,710	5,350	329,000
February	11,700	5,400	7,060	392,000
March	6,430	5,200	5,790	356,000
April	7,570	5,400	6,390	380,000
May	7,340	4,620	5,300	326,000
June	5,000	4,080	4,400	262,000
July	4,170	3,720	3,830	236,000
August	4,170	3,560	3,750	231,000
September	4,170	3,640	3,980	237,000
The year	11,700	3,400	4,870	3,530,000
1925–26				
October	4,170	3,900	4,010	247,000
November	4,800	3,900	4,520	269,000
December	5,100	4,440	4,780	294,000
January	4,800	4,350	4,620	284,000
February	7,340	--------	5,370	298,000
March	5,600	--------	5,200	320,000
April	5,200	3,810	4,480	267,000
May	3,810	3,480	3,620	223,000
June	3,640	3,310	3,440	205,000
July	3,340	3,240	3,300	203,000
August	3,380	3,200	3,310	204,000
September	3,320	3,240	3,280	195,000
The year	7,340	3,200	4,150	3,010,000

TUMALO CREEK

Tumalo Creek rises on the east slope of the Cascade Range at the foot of Broken Top Mountain. It flows east and then a little north and joins the Deschutes about 4 miles below the Deschutes gaging station near Bend. The station on Tumalo Creek is in sec. 23, T. 17 S., R. 11 E., 4 miles above the mouth of the creek and a quarter of a mile above the intake of the Tumalo Feed Canal, the principal diversion. (See fig. 5.) The monthly discharge, including diversions, from 1913 to 1926 is given below. Although the creek lies outside of the middle Deschutes Basin (see pl. 10), the records are included here because it is the only perennial stream that enters the Deschutes River above Squaw Creek and below the Bend gaging station. From 1914 to 1926, for which records at Cline Falls are not available, the flow of this creek, except during the irrigation season, should be added to the flow of the Deschutes at Bend to obtain the flow of the Deschutes at Cline Falls or any place above the mouth of Squaw Creek in the middle Deschutes Basin.

Monthly discharge, in second-feet, of Tumalo Creek near Bend, Oreg., for the years ending September 30, 1914–1926

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1913–14				
October			86.5	5,320
November	127		95.9	5,710
December			83.5	5,130
January	86	67	76.7	4,720
February	92	80	85.1	4,730
March	120	82	100	6,150
April	461	90	145	8,630
May	336	140	215	13,200
June	361	122	183	10,900
July	231	82	118	7,260
August	88	63	71.3	4,380
September	97	60	72.7	4,330
The year	461		111	80,500
1914–15				
October	94	74	78.4	4,820
November	130	73	83.5	4,960
December	80	62	71.5	4,400
January	72	62	64.7	3,980
February	76	67	69.9	3,880
March	91	56	68.2	4,190
April	152	88	118	7,020
May	165	107	129	7,930
June	199	101	135	8,030
July	113	67	80.5	4,950
August	67	53	58.2	3,580
September	53	46	49	2,920
The year	199	46	83.3	60,600
1915–16				
October	58	44	48.4	2,980
November	91	52	62.5	3,720
December	66	58	62.5	3,840
January			[a] 50	3,070
February	110	44	62.3	3,580
March	90	50	64.6	3,970
April	155	70	102	6,070
May		144	180	11,100
June	525	126	316	18,800

[a] Estimated.

Monthly discharge, in second-feet, of Tumalo Creek near Bend, Oreg., for the years ending September 30, 1914–1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1915–16				
July	572	172	323	19,900
August	197	97	135	8,300
September	123	73	81.9	4,870
The year	572	44	124	90,200
1916–17				
October	75	61	67.9	4,180
November	92	60	71.7	4,270
December	63	54	60.4	3,710
January	62	60	60.1	3,700
February	71	49	62	3,440
March	75	46	58.9	3,620
April	96	52	67	3,990
May	201	80	133	8,180
June	382	198	293	17,400
July	340	115	266	16,400
August	113	78	94.1	5,790
September	92	65	77.7	4,620
The year	382	46	109	79,300
1917–18 [b]				
October	73	65	68.4	4,210
November	99	62	66.8	3,970
December	455	65	130	7,990
January	225	93	140	8,610
February	122	72	84.4	4,690
March	85	69	73.9	4,540
April	142	76	100	5,950
May	191	117	149	9,160
June	498	149	300	17,900
July	165	89	109	6,700
August	103	70	79.8	4,910
September	77	67	71.4	4,250
The year	498	62	114	82,800
1918–19				
October	104		74.1	4,560
November	90	70	78.2	4,650
December	71		55.9	3,440
January			47.9	2,950
February	60	46	51.8	2,880
March	60	45	51.8	3,190
April	164	65	96.1	5,720
May	482	133	228	14,000
June	302	139	222	13,200
July	318	96	157	9,650
August	95	54	80.9	4,970
September			72.2	4,300
The year	482	45	101	73,500
1919–20				
October			59.7	3,670
November	149		72.1	4,290
December			62.3	3,830
January	248		89.1	5,480
February	114	54	82.2	4,730
March	78	53	69.8	4,290
April	78	57	68.4	4,070
May	194	63	127	7,810
June	283	117	204	12,100
July	219	90	131	8,060
August	109	67	83	5,100
September	111		74	4,400
The year	283		93.8	67,800
1920–21				
October	115	76	93.6	5,760
November	243	88	122	7,260
December	193	69	87.6	5,390
January	160		101	6,210
February	160	85	113	6,280
March	114	77	92.8	5,710
April			112	6,660
May	316		203	12,500

[b] These discharges include diversion above station, mostly in Columbia Southern Canal. Beginning with 1917 discharge includes that of Crater Creek Canal in addition to natural flow of Tumalo Creek.

Monthly discharge, in second-feet, of Tumalo Creek near Bend, Oreg., for the years ending September 30, 1914–1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1920–21				
June	463	189	339	20,200
July	360	119	205	12,600
August	162	102	124	7,600
September	198	83	108	6,430
The year	463	69	144	103,000
1921				
October	100	62	79.9	4,910
November	450	57	104	6,190
1922 [e]				
May	270	114	173	10,600
June	450	252	329	19,600
July	282		191	11,700
August			97.3	5,980
September			94	55,90
The period				53,500
1923				
April			[d] 97.3	5,790
May	291	91	206	12,700
June	366	150	212	12,600
July	266	93	182	11,200
August	95		85.1	5,230
September			[d] 71.3	4,240
The period				51,800
1923–24				
October			[d] 69.0	4,240
November			[d] 72	4,280
December	103		[d] 74.3	4,570
January			67.8	4,170
February	92	66	74.0	4,260
March	73		64.4	3,960
April	119	58	81.1	4,830
May	298	105	190	11,700
June	200	85	109	6,490
July	114	60	71.2	4,380
August	67	56	63.9	3,930
September	61	49	55.9	3,330
The year	298	49	82.9	60,100
1924–25				
October	57	45	[d] 49.5	3,040
November	161	55	[d] 87.3	5,190
December	76		[d] 59.1	3,630
January		58	[d] 66.9	4,110
February	125	60	79.4	4,410
March	80	57	62.0	3,810
April	206	65	116	6,900
May	533	131	280	17,200
June	392	169	258	15,400
July	272	104	172	10,600
August	125		[d] 85.5	5,260
September		66	[d] 73.9	4,400
The year	533	45	116	84,000
1925–26				
October	74	64	68.3	4,200
November	75		66.6	3,960
December	114	62	70.7	4,350
January	70	62	65.2	4,010
February	112	62	74.9	4,160
March	89	64	70.7	4,350
April	225	77	134	7,970
May	272	105	164	10,100
June	199	75	118	7,020
July	96	57	72.3	4,450
August	78	58	63.8	3,920
September		54	59.4	3,530
The year	272	54	85.6	62,000

[e] Diversion in Columbia Southern Canal estimated the same as in 1921.
[d] Partly estimated.

SQUAW CREEK [22]

Squaw Creek rises at the foot of the glaciers of the Three Sisters and flows northeastward into the Deschutes River. Its drainage basin embraces six glaciers. The largest, Bend Glacier, lies on the north slope of Broken Top; the others rest on the east slope of the Three Sisters. Their areas are as follows:

	Acres
On Broken Top:	
Bend Glacier	250
On South Sister:	
Prouty Glacier	170
Carver Glacier	150
On Middle Sister:	
Diller Glacier	190
Between Middle and North Sisters:	
Hayden Glacier	220
On North Sister:	
Thayer Glacier	60
	1, 040

A gaging station was maintained from July, 1906, to May, 1913, in sec. 29, T. 15 S., R. 10 E., about 4 miles above Sisters and above all diversions except McCallister ditch. (See fig. 5.) The flow of McCallister ditch is included in the published records of discharge. Since May, 1913, the station has been just above the intake of McCallister ditch, the highest diversion on the creek. The drainage area above this station is 45 square miles. This drainage area includes the area tributary to Snow Creek, part of the waters of which are diverted into Three Creek, but excludes Pole Creek, practically all of which is diverted. Of this area 23 square miles, or practically one-half, lies at an altitude of 6,000 feet or more. Three extensive mountain masses rise above 8,000 feet in this basin. The one north of Broken Top comprises about 300 acres; another of 210 acres, mostly covered by Prouty Glacier, is on South Sister; and a third of 1,050 acres is on Middle and North Sisters. The area lying above an altitude of 8,000 feet amounts to practically 2½ square miles. Only a narrow strip of the lower portion of the drainage area above the gaging station lies below 4,500 feet.

The records from 1906 to 1909 published on pages 399 to 405 of Water-Supply Paper 370 and on pages 41 and 42 of Water-Supply Paper 344 may be subject to considerable error. The records from 1909 to 1926, given below, are good. The entire flow of the creek is diverted below this station during the summer. Miscellaneous measurements and estimates show that the flow at the mouth during the irrigation season does not exceed 10 second-feet.

[22] Data furnished by F. F. Henshaw.

Monthly discharge, in second-feet, of Squaw Creek near Sisters, Oreg., for the years ending September 30, 1910–1926

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1909–10				
October	82	58	68.4	4,210
November	1,960	69	255	15,200
December	253	84	133	8,180
January	155	68	86.3	5,310
February	112	54	73.0	4,050
March	253	84	118	7,260
April	172	80	116	6,900
May	310	112	183	11,300
June	317	139	201	12,000
July	226	146	178	10,900
August	144	84	112	6,890
September	188	66	95.0	5,650
The year	1,960	54	135	97,800
1910–11				
October	250	57	81.2	4,990
November	307	41	102	6,070
December	115	62	81.6	5,020
January	76	50	61.7	3,790
February	76	47	52.5	2,920
March	62	42	50.4	3,100
April	97	49	68.5	4,080
May	128	80	93.8	5,770
June	313	144	237	14,100
July	344	163	223	13,700
August	194	97	124	7,620
September	117	65	80.4	4,780
The year	344	41	105	75,900
1911–12				
October	65	45	56.8	3,490
November	65	46	58.3	3,470
December	60	41	47.2	2,900
January	186	49	68.8	4,230
February	130	43	64.5	3,710
March	56	32	45.7	2,810
April	84	46	59.5	3,540
May	261	60	131	8,060
June	395	191	249	14,800
July	261	158	202	12,400
August	336	102	168	10,300
September	152	72	90.2	5,370
The year	395	32	104	75,100
1912–13				
October	102	44	64.7	3,980
November	104	54	70.6	4,200
December	66	50	55.1	3,390
January	....	....	[a] 51.0	3,140
February	43	37	37.4	2,080
March	72	37	40.4	2,480
April	133	56	80.5	4,790
May	....	68	[a] 143	8,790
June	420	195	278	16,500
July	375	210	280	17,200
August	255	135	199	12,200
September	405	80	136	8,090
The year	420	....	120	86,800
1913–14				
October	270	62	81.7	5,020
November	100	62	70.1	4,170
December 1–5	59	50	51.5	1,530
April 7–30	150	75	98.0	4,670
May	270	90	166	10,200
June	288	112	190	11,300
July	288	150	215	13,200
August 1–17	205	125	165	5,560

[a] Estimated.

Monthly discharge, in second-feet, of Squaw Creek near Sisters, Oreg., for the years ending September 30, 1910–1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1915				
May 9-11	150	54	90.4	4,120
June	175	100	133	7,910
July	205	100	149	9,160
August	205	100	126	7,750
The period				28,900
1916				
March 24-31	82	76	77.8	1,230
April	112	76	89.9	5,350
May	197	90	116	7,130
June	404	110	239	14,200
July	514	228	309	19,000
August	268	147	209	12,900
September	206	78	125	7,440
The period				67,200
1917				
April 5-30	90	39	54.3	2,800
May	158	68	108	6,640
June	302	133	233	13,900
July	472	225	347	21,300
August	240	142	184	11,300
September	183	77	118	7,020
October	100	56	76.8	4,720
November	168	51	62.7	3,730
December 1-5	84	63	69.4	688
The period				72,100
1918				
March	67		[b] 60.2	3,700
April	89	62	72.8	4,330
May	139	76	99.8	6,140
June	440	115	267	15,900
July		130	[b] 202	12,400
August			[b] 151	9,280
September	193	93	135	8,039
The period				59,800
1919				
June 25-30	340	255	300	3,570
July	415	187	258	15,900
August 1-23	205	157	176	8,030
The period				27,500
1920				
March 17-31	68	58	62.6	1,860
April	80	60	67.7	4,030
May	179	69	111	6,820
June	248	106	174	10,400
July	248	158	190	11,700
August	176	106	144	8,850
September	170	85	107	6,430
The period	248	60	127	50,100
1921				
May 6-31	233	88	151	7,790
June	433	190	304	18,100
July	388	184	255	15,700
August		111	[b] 156	9,600
September	164		103	6,130
The period	433		195	57,300
1922				
April 23-30	60	52	57.5	912
May	177	64	119	7,320
June	360	197	275	16,400
July	340	161	226	13,900
August	193	98	149	9,160
September	134	67	102	6,070
October	72	42	56.5	3,470
November	114	35	45	2,680
December 1-15	58	22	35.8	1,060
The period				61,000

[b] Partly estimated.

Monthly discharge, in second-feet, of Squaw Creek near Sisters, Oreg., for the years ending September 30, 1910–1926 —Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1923				
April 13-30	92	67	76.6	2,740
May	210	69	144	8,850
June	300	117	178	10,600
July	320	172	224	13,800
August	159	119	138	8,490
September	132	55	93.2	5,550
The period				50,000
1924				
April (8 days)	84	55	65.6	1,040
May	204	76	138	8,450
June	175	94	124	7,380
July	170	98	125	7,690
August	123	78	103	6,330
September	111	43	70.4	4,190
The period	204	43		
1925				
April 23-30	114	92	100	1,590
May	341	116	205	12,600
June	375	144	227	13,500
July	257	163	212	13,000
August	202	92	134	8,240
September	106	58	87.9	5,230
The period (161 days)				54,200
1925-26				
October			[b]55.6	3,420
November	53	44	47.8	2,340
December	110	43	56.7	3,490
January	78	32	47.4	2,910
February	128	36	65.2	3,620
March	53	41	[b]46.1	2,830
April	166	49	89.2	5,310
May	238	80	[b]134	8,240
June	199	102	143	8,510
July	173	96	132	8,120
August	204	75	110	6,760
September	78	39	58.1	3,460
The year	238	32	82.2	59,500

[b] Partly estimated.

CROOKED RIVER

The Crooked River, the next perennial stream north of Squaw Creek to enter the Deschutes, rises in a group of mountains in central Oregon and flows west. At Trail Crossing it enters a deep canyon, and a few miles farther west it turns and flows northward to the Deschutes. Since October 1, 1917, a gaging station has been maintained in the NW. ¼ sec. 11, T. 12 S., R. 12 E., at the Cove power plant, about 6 miles west of Culver. (See fig. 5.) Until February 15, 1922, an inclined staff gage was installed on the left bank one-eighth mile below the power house; after that date a vertical gage was installed on the right bank 100 feet below the power house. The maximum stage was recorded on February 6, 1925, at gage height 5.60 feet, with a discharge of 7,320 second-feet. The minimum discharge was 970 second-feet at gage height 1.70 feet from July 12 to September 5, 1921. Practically all the flow of Crooked River above Prineville is diverted during the irrigation season. Miscellaneous measurements and reliable observations indicate that the summer flow at Trail Crossing was generally less than 10 second-feet from 1900 to 1910. Since then a summer flow of about 50 second-feet has passed Trail Crossing as a result of storage in Ochoco Reservoir and return flow from irrigation. Consequently, nearly all the low-water flow at this station comes from springs between Trail Crossing and the gaging station. The records obtained at this station are good.

Monthly discharge, in second-feet, of Crooked River near Culver, Oreg., for the years ending September 30, 1918–1926

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1917–18				
October	1,120	1,120	1,120	68,900
November	1,210	1,120	1,130	67,200
December	1,460	1,210	1,250	76,900
January	1,530	1,330	1,440	88,500
February	2,010	1,330	1,530	85,000
March	3,300	1,390	2,020	124,000
April	2,900	1,270	1,760	105,000
May	1,270	1,210	1,210	74,400
June	1,210	1,100	1,130	67,200
July	1,100	1,100	1,100	67,600
August	1,150	1,100	1,110	68,200
September	1,100	1,100	1,100	65,500
The year	3,300	1,100	1,320	958,000
1918–19				
October	1,150	1,100	1,110	68,200
November	1,150	1,150	1,150	68,400
December	1,150	1,150	1,150	70,700
January	1,390	1,150	1,210	74,400
February	1,390	1,210	1,260	70,000
March	3,200	1,210	1,490	91,600
April	5,200	2,540	3,430	204,000
May	2,360	1,150	1,420	87,300
June	1,150	1,100	1,110	66,000
July	1,100	1,050	1,080	66,400
August	1,100	1,100	1,100	67,600
September	1,150	1,100	1,110	66,000
The year	5,200	1,050	1,380	1,000,000
1919–20				
October	1,060	1,060	1,060	65,200
November	1,120	1,060	1,120	66,600
December	2,010	1,060	1,260	77,500
January	4,100	1,120	1,460	89,800
February	1,770	1,250	1,400	80,500
March	1,690	1,250	1,380	84,800
April	2,270	1,390	1,790	107,000
May	2,180	1,120	1,460	89,800
June	1,060	1,060	1,060	63,100
July	1,120	1,060	1,060	65,200
August	1,060	1,060	1,060	65,200
September	1,180	1,060	1,090	64,900
The year	4,100	1,060	1,270	920,000
1920–21				
October	1,120	1,120	1,120	68,900
November	1,530	1,120	1,190	70,800
December	1,250	1,120	1,160	71,300
January	2,720	1,180	1,560	95,900
February	4,900	1,250	2,160	120,000
March	4,400	2,360	2,900	178,000
April	3,700	2,270	2,760	164,000
May	3,400	1,490	2,360	145,000
June	2,180	1,020	1,300	77,400
July	1,040	970	995	61,200
August	970	970	970	59,600
September	1,040	970	1,030	61,300
The year	4,900	970	1,620	1,170,000

Monthly discharge, in second-feet, of Crooked River near Culver, Oreg., for the years ending September 30, 1918–1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1921–22				
October	1,120	1,090	1,100	67,600
November	1,250	1,120	1,180	70,200
December	2,340	1,140	1,280	78,700
January	1,190	1,090	1,150	70,700
February	1,310	1,180	1,210	67,200
March	2,630	1,180	1,480	91,000
April	6,240	1,570	3,090	184,000
May	3,420	1,300	2,240	138,000
June	1,400	1,120	1,210	72,000
July	1,120	1,110	1,110	68,200
August	1,120	1,110	1,110	68,200
September	1,140	1,120	1,120	66,600
The year	6,240	1,090	1,440	1,040,000
1922–23				
October	1,180	1,120	1,150	70,700
November	1,200	1,150	1,170	69,600
December	1,280	1,180	1,190	73,200
January	2,450	1,220	1,370	84,200
February	1,510	1,180	1,260	70,000
March	3,280	1,300	1,670	103,000
April	3,720	1,630	2,620	156,000
May	1,760	1,220	1,410	86,700
June	1,260	1,180	1,200	71,400
July	1,450	1,140	1,240	76,200
August	1,140	1,120	1,130	69,500
September	1,180	1,140	1,150	68,400
The year	3,720	1,120	1,380	999,000
1923–24				
October	1,200	1,180	1,180	72,600
November	1,200	1,180	1,190	70,800
December	1,200	1,160	1,180	72,600
January	3,280	1,160	1,240	76,200
February	3,880	1,400	1,900	109,000
March	1,570	1,220	1,340	82,400
April	1,630	1,220	1,360	80,900
May	1,200	1,110	1,140	69,500
June	1,110	1,110	1,110	66,000
July	1,110	1,110	1,110	68,200
August	1,110	1,110	1,110	68,200
September	1,110	1,110	1,110	66,000
The year	3,880	1,110	1,240	902,000
1924–25				
October	1,150	1,110	1,120	68,900
November	1,510	1,150	1,210	72,000
December	1,180	1,160	1,170	71,900
January	5,640	1,160	1,600	98,400
February	6,660	1,510	2,330	129,000
March	3,020	1,400	1,910	117,000
April	2,900	1,690	2,320	138,000
May	2,050	1,300	1,490	91,600
June	1,300	1,180	1,230	73,200
July	1,180	1,180	1,180	72,600
August	1,180	1,180	1,180	72,600
September	1,220	1,180	1,200	71,400
The year	6,660	1,110	1,490	1,080,000
1925–26				
October	1,220	1,220	1,220	75,000
November	1,220	1,220	1,220	72,600
December	1,220	1,220	1,220	75,000
January	1,240	1,220	1,220	75,000
February	2,720	1,260	1,540	85,500
March	2,290	1,400	1,670	103,000
April	2,290	1,220	1,540	91,600
May	1,220	1,160	1,180	72,600
June	1,160	1,160	1,160	69,000
July	1,160	1,140	1,150	70,700
August	1,140	1,140	1,140	70,100
September	1,150	1,120	1,140	67,800
The year	2,720	1,120	1,280	928,000

METOLIUS RIVER

The Metolius River rises at the foot of the snow fields of three great peaks in the Cascade Range—Mount Washington, Three Finger Jack, and Mount Jefferson. Practically all of its normal flow comes from huge springs. Several gaging stations have been maintained by the United States Geological Survey on the river, but none of them are in the part of the basin covered by this report.

METOLIUS RIVER AT RIGGS RANCH

The gaging station at the Riggs ranch is only about 4 miles west of the area mapped. (See fig. 5.) It is 7 miles above the mouth of the river, in the NE. ¼ sec. 28, T. 11 S., R. 11 E. The drainage area above the station is 347 square miles. Only a few small private irrigation ditches divert water above the gaging station. There are no diversions between the station and the mouth of the river, and miscellaneous measurements indicate that the flow at the mouth is the same as at the station. Records of monthly discharge for this station are good.

Monthly discharge, in second-feet, of Metolius River at Riggs ranch, near Sisters, Oreg., for the years ending September 30, 1908–1912

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1908–9				
October 22–31	1,740	1,490	1,550	30,700
November	1,650	1,490	1,510	89,800
December	1,570	1,410	1,470	90,400
January	2,320	1,410	1,650	101,000
February	1,830	1,570	1,640	91,100
March	1,650	1,570	1,620	99,600
April	1,650	1,570	1,610	95,800
May	1,740	1,570	1,640	101,000
June	1,830	1,650	1,710	102,000
July	1,650	1,570	1,610	99,000
August	1,650	1,490	1,530	94,100
September	1,530	1,410	1,470	87,500
The period				1,080,000
1909–10				
October	1,490	1,410	1,450	89,200
November	3,890	1,410	1,870	111,000
December	2,020	1,570	1,730	106,000
January	1,880	1,530	1,610	99,000
February	1,920	1,570	1,610	89,400
March	2,770	1,780	2,090	129,000
April	1,830	1,700	1,750	104,000
May	1,920	1,700	1,740	107,000
June	1,740	1,610	1,650	98,200
July	1,610	1,570	1,600	98,400
August	1,570	1,490	1,540	94,700
September	1,530	1,450	1,490	88,700
The year	3,890	1,410	1,680	1,210,000
1910–11				
October	1,830	1,450	1,490	91,600
November	1,920	1,450	1,580	94,000
December	1,830	1,530	1,610	99,000
January	1,650	1,490	1,520	93,500
February	1,490	1,410	1,490	82,800
March	1,650	1,410	1,490	91,600
April	1,570	1,490	1,550	92,200
May	1,650	1,570	1,610	99,000
June	1,830	1,650	1,670	99,400
July	1,650	1,570	1,620	99,600
August	1,570	1,490	1,500	92,200
September	1,570	1,490	1,490	88,700
The year	1,920	1,410	1,550	1,120,000

Monthly discharge, in second-feet, of Metolius River at Riggs ranch, near Sisters, Oreg., for the years ending September 30, 1908–1912—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1911–12				
October	1,490	1,410	1,440	88,500
November	1,570	1,410	1,470	87,500
December	1,490	1,410	1,420	87,300
January	2,020	1,330	1,590	97,800
February	2,430	1,650	1,860	107,000
March	1,830	1,650	1,680	103,000
April	1,740	1,650	1,660	98,800
May	2,020	1,650	1,760	108,000
June	2,120	1,740	1,890	112,000
July	1,740	1,650	1,660	102,000
August	1,830	1,650	1,660	102,000
September	1,650	1,490	1,580	94,000
The year	2,430	1,330	1,640	1,190,000

METOLIUS RIVER NEAR GRANDVIEW

A station has been maintained since October 1, 1921, on the Metolius River in the NE. ¼ sec. 19, T. 11 S., R. 11 E., at the Montgomery ranch, 11 miles above the mouth of the river and 10 miles northwest of Grandview post office. A vertical staff is placed on the right bank of the river. The maximum stage recorded was 3.32 feet on January 7, 1923, when the discharge, from approximate extension of the rating curve, was 5,780 second-feet. The minimum discharge was 1,300 second-feet, October 1–30 and December 18–25, 1924. There are no diversions and no regulation above the station.

Monthly discharge, in second-feet, of Metolius River near Grandview, Oreg., for the years ending September 30, 1922–1926

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1921–22				
October	1,610	1,450	1,490	91,600
November	3,870	1,450	1,820	108,000
December	3,710	1,610	2,010	124,000
January	1,610	1,500	1,530	94,100
February	1,500	1,450	1,480	82,200
March	1,500	1,450	1,470	90,400
April	1,660	1,660	1,610	95,800
May	1,830	1,610	1,720	106,000
June	1,950	1,720	1,870	111,000
July	1,720	1,500	1,610	99,000
August	1,500	1,500	1,500	92,200
September	1,500	1,400	1,450	86,300
The year	3,870	1,400	1,630	1,180,000
1922–23				
October	1,400	1,400	1,400	86,100
November	1,610	1,400	1,410	83,900
December	1,830	1,400	1,500	92,200
January	4,370	1,610	2,250	138,000
February	1,610	1,500	1,550	86,100
March	1,610	1,500	1,550	95,300
April	1,720	1,660	1,680	100,000
May	1,830	1,610	1,770	109,000
June	1,950	1,660	1,730	103,000
July	1,830	1,660	1,720	106,000
August	1,610	1,500	1,560	95,900
September	1,500	1,450	1,480	88,100
The year	4,370	1,400	1,640	1,180,000

Monthly discharge, in second-feet, of Metolius River near Grandview, Oreg., for the years ending September 30, 1922–1926—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1923-24				
October	1,450	1,450	1,450	89,200
November	1,950	1,400	1,470	87,500
December	1,660	1,400	1,460	89,800
January	1,660	1,450	1,490	91,600
February	1,610	1,500	1,580	90,900
March	1,500	1,400	1,450	89,200
April	1,400	1,400	1,400	83,300
May	1,610	1,400	1,480	91,000
June	1,500	1,400	1,430	85,100
July	1,450	1,400	1,410	86,700
August	1,400	1,350	1,370	84,200
September	1,400	1,300	1,340	79,700
The year	1,950	1,300	1,440	1,050,000
1924-25				
October	1,400	1,300	1,300	79,900
November	2,480	1,350	1,510	89,800
December	1,720	1,300	1,400	86,100
January	2,200	1,450	1,590	97,800
February	2,930	1,720	2,060	114,000
March	1,720	1,560	1,620	99,600
April	1,950	1,560	1,650	98,200
May	2,340	1,610	1,770	109,000
June	1,720	1,660	1,700	101,000
July	1,660	1,560	1,600	98,400
August	1,560	1,450	1,500	92,200
September	1,450	1,400	1,440	85,700
The year	2,930	1,300	1,590	1,150,000
1925-26				
October	1,400	1,400	1,400	86,100
November	1,450	1,400	1,400	83,300
December	1,720	1,400	1,420	87,300
January	1,400	1,350	1,370	84,200
February	2,070	1,350	1,570	87,200
March	1,500	1,400	1,450	89,200
April	1,500	1,450	1,460	86,900
May	1,500	1,400	1,460	89,800
June	1,450	1,400	1,410	83,900
July	1,400	1,350	1,370	84,200
August	1,400	1,300	1,320	81,200
September	1,300	1,300	1,300	77,400
The year	2,070	1,300	1,410	1,020,000

SHITIKE CREEK

Shitike Creek, the only perennial stream that enters the Deschutes River between the Metolius River and Mecca, rises on the east slope of the Cascade Range and flows eastward to the Deschutes, which enters 1½ miles above the Mecca gaging station. (See fig. 5.) A gaging station on Shitike Creek was located in the NE. ¼ sec. 26, T. 9 S., R. 12 E., at Warm Spring, about 2 miles above the mouth of the creek and below all tributaries. The records are good, except for high water and for certain periods not covered by measurements.

Monthly discharge, in second-feet, of Shitike Creek at Warm Spring, Oreg., from June 11, 1911, to October 31, 1916, and from April 1, 1923, to September 30, 1925

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1911				
June 11–30	248	120	151	5,970
July	134	66	93.2	5,730
August	75	50	59.8	3,680
September	86	50	61.9	3,680
The period				19,060
1911–12				
October	66	57	57.3	3,520
November	147	57	72.9	4,340
December	75	57	63.6	3,910
January	593	57	172	10,600
February	383	112	195	11,200
March	265	190	212	13,000
April	190	102	135	8,030
May	296	112	188	11,600
June	338	148	200	11,900
July	161	102	125	7,690
August	102	66	80.2	4,930
September	112	58	67.2	4,000
The year	593	57	131	94,700
1912–13				
October	73	58	62.5	3,840
November	112	66	83.9	4,990
December	149	73	83.5	5,130
January	156	76	104	6,400
February	130	76	92.1	5,120
March	405	96	122	7,500
April	365	140	191	11,400
May	295	128	178	10,900
June	260	176	195	11,600
July	295	151	161	9,900
August	151	77	95.4	5,870
September	84	72	77.8	4,630
The year	405	58	121	87,200
1913–14				
October	295	77	106	6,520
November	128	70	86.5	5,150
December	91	77	85.9	5,280
January	245	84	105	6,460
February	128	70	79.6	4,420
March	176	91	131	8,060
April	216	91	118	7,020
May	151	100	122	7,500
June	128	91	108	6,430
July	151	70	90.4	5,566
August	70	63	63.9	3,930
September	100	63	80.8	4,810
The year	295	63	98.2	71,100
1914–15				
October	122	62	78.9	4,850
November	147	62	93,2	5,550
December	111		87.4	5,370
January	100	47	63.8	3,920
February	90	54	60.4	3,350
March	122	59	90.6	5,570
April	134	100	116	6,900
May	175	100	118	7,260
June	134	62	82.5	4,910
July	90	47	67.7	4,160
August	47	41	41 8	2,570
September	47	36	41.2	2,450
The year	175	36	78.5	56,900

*Monthly discharge, in second-feet, of Shitike Creek at Warm Spring, Oreg., from June 11, 1911, to October 31, 1916, and from April 1, 1923, to September 30, 1925—*Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1915–16				
October	62	37	41.5	2,550
November	342	62	145	8,630
December	161	100	126	7,750
January	134	90	109	6,700
February	720	111	274	15,800
March	450	147	209	12,900
April	220	171	200	11,900
May	330	140	184	11,300
June	370	155	223	13,300
July	292	155	213	13,100
August	155	77	106	6,520
September	120	57	83.9	4,990
The year	720	37	159	115,000
1916				
October	77	60	64.5	3,970
1923				
April	206	145	176	10,500
May	305	137	202	12,400
June	245	141	172	10,200
July	206	102	154	9,470
August	98	69	81.7	5,020
September	69	61	64.1	3,810
The period				51,400
1923–24				
October	95	58	70.0	4,300
November	370	55	77.7	4,620
December	245	72	110	6,760
January	218	66	92.3	5,680
February	232	88	132	7,590
March	88	66	73.5	4,520
April	95	69	79.4	4,720
May	145	88	111	6,820
June	85	58	68.9	4,100
July	58	39	46.7	2,870
August	39	32	36.2	2,230
September	47	32	36.1	2,150
The year	370	32	77.9	56,400
1924–25				
October	72	37	45.5	2,800
November	440	52	105	6,250
December	520		87.7	5,390
January	392	77	136	8,360
February	445	123	219	12,200
March	123	99	116	7,130
April	310	115	163	9,700
May	410	131	189	11,600
June	172	108	131	7,800
July	128	76	105	6,460
August	87	56	68.3	4,200
September	67	46	53.5	3,180
The year	530	37	118	85,100

MISCELLANEOUS MEASUREMENTS

All the miscellaneous measurements that have been made in the middle Deschutes Basin from 1897 to 1927 are given below. These records are invaluable for the determination of the quantity of ground water in the basin, and they are discussed further on page 204.

Miscellaneous discharge measurements in the middle Deschutes Basin, Oreg., 1897–1927

Date	Stream	Tributary to—	Locality	Discharge
				Sec.-ft.
July 16, 1914	Deschutes River	Columbia River	Former Cline Falls gaging station	604
July 31, 1915	do	do	do	317
Oct. 10, 1897	do	do	Tetherow Bridge	1,720
July 16, 1914	do	do	do	606
Jan. 10, 1906	do	do	Sec. 36, T. 14 S., R. 12 E	1,350
Oct. 13, 1906	do	do	do	1,230
Aug. 23, 1908	do	do	4 miles below Tetherow Bridge	1,400
Aug. 26, 1908	do	do	Above mouth of Metolius River	[a]1,600
Dec. 4, 1905	Squaw Creek	Deschutes River	Sisters, above diversions	49
Dec. 5, 1905	do	do	do	50
Apr. 12, 1907	do	do	Sisters	46
Aug. 23, 1908	do	do	Sisters road crossing	10
Aug. 4, 1913	Crooked River	do	In T. 14 S., R. 14 E., near Terrebonne	41.8
Aug. 23, 1908	do	do	Trail Crossing, NE. ¼ sec. 33, T. 13 S., R. 13 E.	7
Oct. 29, 1919	do	do	do	61
Nov. 28, 1925	do	do	do	110
Aug. 13, 1927	do	do	do	25.6
Aug. 14, 1927	do	do	NE. ¼ sec. 24, T. 13 S., R. 12 E	67
Oct. 29, 1919	do	do	Gates ranch, sec. 14, T. 13 S., R. 12 E	301
Nov. 29, 1925	do	do	Above Opal Springs, NE. ¼ sec. 33, T. 12 S., R. 12 E.	841
Mar. 26, 1912	Metolius River	do	Allen ranch, sec. 14, T. 12 S., R. 9 E	1,040
June 22, 1915	do	do	do	1,100
Oct. 17, 1906	do	do	Mouth	[a]2,800
Aug. 26, 1908	do	do	do	[a]1,800

[a] Estimated.

QUALITY OF SURFACE WATER

The quality of the surface waters in the basin has been well described by Van Winkle.[23] He says:

Deschutes River proper drains a region in which the exposed rocks are Tertiary lavas, tuffs, and basalts, and the mineral matter carried in solution is made up largely of salts of sodium, chiefly bicarbonate, leached directly from the disintegrating rock material. The total amount of dissolved matter carried is small, averaging at Bend between 65 and 75 parts per million and at the mouth about 25 parts per million more. Seasonal variations in mineral content, at least above the confluence of Crooked River, are very small, owing to the remarkable constancy of volume of the run-off. The water of the upper Deschutes is excellent for irrigation, industrial, or domestic use. The amount of soap consumed by the hardening constituents in it is trifling, no treatment is in general required to prevent formation of scale in boilers, a quarter of a pound of lime to a thousand gallons of water at most being an ample corrective, and the water will not foam or cause corrosion in boilers. Though the water is soft it contains sufficient gas and disolved mineral matter to render it palatable and wholesome. With proper precautions against contamination by human agencies the water is almost ideal for domestic use. As almost no suspended matter is carried by it, no trouble from silting up of reservoirs or sedimentation basins need be feared. In short, the water compares favorably with the better waters used for municipal supply in this country or in Europe. Though not so low in mineral content as Portland's supply from Bull Run, it is superior in this respect to the new supply of Los Angeles from Owens River, to the present supply of San Francisco, to supplies of any of the middle western cities, and to many of those on the Atlantic seaboard.

[23] Van Winkle, Walton, in Henshaw, F. F., and others, in Deschutes River, Oreg., and its utilization: U. S. Geol. Survey Water-Supply Paper 344, pp. 85–86, 1914.

Crooked River furnishes only a small quantity of water to the Deschutes but is its chief tributary in point of size of drainage area. It flows from the highlands in the southeastern corner of Crook County westward to the Deschutes, which it enters below the mouth of Opal Canyon. The drainage basin is almost completely covered with tuffs and lavas and contains only a few exposures of Tertiary lake sediments. Though the water is of the same general type as that of Deschutes River it is less uniform in quality, much harder, and less free from suspended matter, owing to the much greater fluctuations in discharge to which it is subject. The marked seasonal variations in quality influence the water of the Deschutes very little because of the relatively small run-off of Crooked River, and the water below the confluence of the two streams is still of good quality and only slightly harder than the water at Bend. During high water the mineral content of Crooked River water is nearly the same as that of Deschutes River, and it is only at low water that high mineralization and consequent poorer quality are apparent. The chief effect of Crooked River on Deschutes River is the increased charge of suspended matter imported by it, but even this is not enough to increase the turbidity of Deschutes River to a very great amount.

In speaking of the Crooked River, Van Winkle evidently refers to the portion of the basin above the sampling station near Prineville. The large inflow to the river from springs below Trail Crossing tends to render the character of the water at the mouth less dissimilar to the upper Deschutes than it is at the Prineville station.

The good quality of the water for domestic supplies in the Deschutes Basin is likely to continue because of the foresight of the Oregon Legislature. In 1911 a law was enacted making it unlawful for any person, company, corporation, or city to contaminate the waters of the Deschutes River or its tributaries. This law required the towns in the basin to provide for the disposal of sewage other than by discharging it into surface streams.

GROUND WATER

WELL RECORDS

Records were obtained of all the wells in the middle Deschutes Basin. Practically all the wells that were drilled to the water table are successful, except those close to Round Butte. The location of the wells and the altitude of the water surface in them are shown on Plate 10. The records of the wells are tabulated below. The 200-foot contours of the water table shown on Plate 10 were drawn from these data. Many of the dug wells are developed hillside seeps and go dry in the summer. They were not used in plotting the water table. The quality of the well water is excellent.

Record of wells in the middle Deschutes Basin, Jefferson County, Oreg.

No.	Date (1925)	Location				Owner	Altitude above sea level (feet)	Type	Depth reported (feet)	Depth to water reported (feet)	Log	Remarks
		Quarter	Sec.	T.S.	R.E.							
1	Aug. 22	SW.	5	11	13	Jerry Southman	[a] 2,450	Drilled	800	750	Alternating beds of lava, tuff, gravel, sand, etc., of Deschutes formation.	Well was finished in fine ash. Owner reports a small seep between 450 and 500 feet. Yield about 1,400 gallons a day.
2	Aug. 20	SW.	36	10	13	Oregon Trunk Ry	[a] 2,375	do	415	355	Alternating beds of ash, silt, sand, gravel, pumice, and lava. Well ends in gravel.	Railroad company states that it is either 315 or 355 feet to water. Yield over 60,000 gallons a day.
3	Aug. 22	NW.	28	11	13	do	[a] 2,500	do	878	645	Alternating beds of ash, silt, sand, gravel, pumice, and lava.	
4	do	SW.	30	11	13	Fred Hensky	[a] 2,575	do	1,300	750	Alternating beds of sand, clay, gravel, and tuff with one bed of basalt 100 feet thick.	Yield only 1½ barrels a day. Owner states that at 1,295 feet a black shale was struck. Tools kept sticking in claylike beds.
5	Aug. 11	NE.	2	12	13	H. I. Alexander	[a] 2,725	do	441	420	Conglomerate 0–221 feet; cinders 221–305 feet; blue lava 305–434 feet; red lava 434–441 feet.	Driller reports that water disappeared rapidly in the cinders. Strong flow at 434 feet.
6	Aug. 22	NW.	6	12	13	Theo. Hartnagel	[a] 2,575	do	695	690	Basalt 0–100 feet; cinders 100–104 feet; sandrock; lava.	Dug 228 feet. Plenty of water from the lava in the bottom of the well.
7	Aug. 11	NW.	12	12	13	W. F. Thomas	[a] 2,750	do	378	340	Conglomerate or sandrock 0–125 feet; lava 125–275 feet; various soft formations.	Owner states that water is in lava sand.
8	do	SE.	13	12	13	A. W. Boyce	[a] 2,830	Dug	30	23	Tuffs, mostly basic	
9	Aug. 12	SE.	15	12	13	Jess Eads	[a] 2,700	Drilled	342	302	Acidic tuffs	Helper to driller reports that water is found in loose white pumice.
10	Aug. 21	NE.	16	12	13	Orla C. Hale	[a] 2,760	do	630	540	Sandstone 0–210 feet; lava 210–520 feet; soft red rock, probably tuff, 520–620 feet.	Struck water at 560 feet, which rose 20 feet. Owner states that when, wind blows from west, southwest, or northwest, air blows out; when the wind blows from northeast, east, or south, air is sucked in.
11	Aug. 20	SE.	18	12	13	William Barber (Culver townsite well)	[a] 2,640	do	774	700	Alternating beds of sand, gravel, tuff, and basalt.	
12	Aug. 11	NE.	24	12	13	Kate Burson	[b] 2,830	Dug		[c] 18		
13	Aug. 12	SE.	27	12	13	R. L. Tate	[a] 2,800	do		[c] 14.4		
14	Aug. 13	SW.	28	12	13	George Rodman	[a] 2,875	do	18	Dry.	Tuff	Goes dry in July and then used for cistern. Hillside seep developed.

15	---do-----	NE.	29	12	13	-----do-------------------	[a]2,800	Drilled--	760	692	Hardpan 0–18 feet; sandstone and pumice 18–200 feet; red rock 200–600 feet; soft green and red rock 600–690 feet; gravel 690–692 feet; green rock 692–760 feet.	Water obtained in 2 feet of gravel. 692 feet below surface.
16	Aug. 19	NW.	9	13	13	Verne Merchant----------	----------	---do-----	150	Dry.	Gravel and sand in bottom--------	Never completed.
17	Aug. 21	NE.	34	12	13	Perry Reed----------------	[b]2,880	---do-----	148	28	Tuff----------------------------	
18	Aug. 11	SE.	5	13	13	Jacob Harrington----------	[b]2,940	---do-----	852	400	Broken rock 0–30 feet; pumice 30–38 feet; broken rock 38–68 feet; diatomite 68–113 feet; hard and soft lava to bottom.	At 630 feet a small seep of 6 gallons in 24 hours. At 775 feet there was a flow of about 100 gallons in 24 hours.
19	Aug. 19	SW.	10	13	13	L. L. Hobbs--------------	[b]2,980	---do-----	222	150	Tuff----------------------------	Struck water at 215 feet, in soft blue tuff.
20	---do-----	SW.	10	13	13	O. H. Wilson-------------	[b]2,980	---do-----	-------	150	----------------------------------	According to Mr. Hobbs, this well is similar to No. 19.
21	Aug. 29	SW.	12	13	13	J. M. King---------------	[b]3,020	---do-----	82	30	Green acidic tuff-----------------	Plenty of water.
22	Aug. 20	NE.	18	13	13	Oregon Trunk Ry---------	[a]2,859	---do-----	1,690	657	Alternating sand, cinders, gravel, lava, and stratified tuff. The last 800 feet is probably in the Mascall (?) formation.	The first water was struck at 715 feet. Water was obtained at six horizons.
23	Aug. 15	SW.	27	13	13	J. M. Healy--------------	[b]2,925	---do-----	-------	210	----------------------------------	Renter states water tastes of sulphur. Depth to water estimated from the fact that there is 240 feet of pump rods in it. It can be pumped dry.
24	---do-----	NW.	16	14	13	Town of Terrebonne------	[a]2,860	---do-----	392	302	----------------------------------	
25	Aug. 19	SW.	31	12	12	--------------------------	[a]2,600	Dug------	-------	[c]14.5	----------------------------------	In bed of a dry creek.
26	---do-----	SE.	6	13	12	Robert E. Jordan---------	[a]2,800	---do-----	210	dry.	Basalt 0–6 feet; gravel, sand, silt, and tuff to bottom.	
27	Aug. 12	SE.	1	12	11	L. Z. Nance--------------	[a]2,750	---do-----	22	dry.	Basalt underlain by sandstone----	Dry except during November to July. In a dry creek bed.
28	Aug. 22	NE.	34	10	13	Madras State Bank-------	----------	Drilled--	120	-------	----------------------------------	Can be pumped dry. A small seep of water at 60 feet.
29	Aug. 11	SE. (?)	19	12	14	Dayton Grant------------	[b]2,920	---do-----	190	75	Blue clay (like putty) 0–185 feet; red rock 185–188 feet; pumice 188–190 feet.	Driller states that he struck a large flow at 188 feet; there was a small seep at 130 feet.
30	---do-----	NE.	30	12	14	Mason Grant-------------	[b]3,000	---do-----	298	208	Tuff----------------------------	Owner states that a small seep was struck at 130 feet (1 quart an hour). Hit main flow at 290 feet, in a crevice.
31	---do-----	NE.	30	12	14	Jim Brown---------------	[b]2,950	---do-----	154	142	-----do--------------------------	

[a] Determined from Bureau of Reclamation map.
[b] Determined by barometer.
[c] Measured.

The logs of certain wells and numerous reliable data on the water-bearing formations in them were furnished by Mr. W. H. Marsh, assistant chief engineer of the Oregon Trunk Railway, and Mr. H. C. O'Neel, assistant engineer of the Oregon-Washington Railroad & Navigation Co. They throw considerable light on the stratigraphy and the occurrence of ground water. These logs are given in the following tables:

Record of Oregon-Washington Railroad & Navigation Co.'s well at Madras, Oreg.

[No. 2, pl. 10. Altitude, 2,375 feet]

	Thickness	Depth		Thickness	Depth
	Feet	*Feet*		*Feet*	*Feet*
Sand and silt	112	112	Volcanic ash	8	228
Fine gravel	9	121	Kaolin [a] and lava	27	265
Lava (basalt)	16	137	Kaolin [a] and volcanic ash	28	293
Volcanic ash	11	148	Volcanic ash	7	300
Lava (basalt)	39	187	Lava and volcanic ash	30	330
Pumice	11	198	Volcanic ash	25	355
Red basalt	8	206	Mixed rock and gravel	35	390
Trap rock (dense basalt)	14	220	Gravel filled with water	25	415

[a] Probably fine white ash or diatomite.

Record of Oregon Trunk Railway well No. 1 at Metolius, Oreg.

[No. 3, pl. 10. Altitude 2,500 feet]

	Thickness	Depth		Thickness	Depth
	Feet	*Feet*		*Feet*	*Feet*
Dark soil	3	3	Brown sand	10	400
Light-gray, fairly hard cemented gravel	18	21	Cemented gravel	34	434
Black and dark-gray loose rock	22	43	Soft red sandstone	6	440
Black basalt	14	57	Sandy brown clay	95	535
Red basalt	10	67	Sharp black gravel	15	550
Blue basalt	15	82	Coarse black gravel	10	560
Porous blue basalt	2	84	Brown gravel	10	570
Fairly hard gray cemented gravel	15	99	Soft brown shale	35	605
Soft blue sandstone	30	129	Black sandstone	18	623
Fairly hard volcanic conglomerate	50	179	Soft red sandstone; first water	42	665
Soft red volcanic ash and partly cemented gravel	34	213	Hard brown sandstone	30	695
Fairly soft volcanic conglomerate	77	290	Soft red sandstone	30	725
Coarse gravel	3	293	Hard black rock	120	845
Partly cemented gravel (easy drilling	97	390	Soft black rock	33	878

Record of Oregon Trunk Railway well at Opal City, Oreg.

[No. 22, pl. 10. Altitude, 2,859 feet]

	Thickness	Depth		Thickness	Depth
	Feet	*Feet*		*Feet*	*Feet*
Soil and cemented gravel	12	12	Solid brown shale	45	1,101
Hard black rock and boulders	16	28	Hard gray rock	18	1,119
Loose brown cinders	19	47	Soft red shale	2	1,121
Hard black rock and boulders	92	139	Hard gray rock	16	1,137
Loose cinders	75	214	Hard brown rock	20	1,157
Medium hard cemented gravel	24	238	Hard gray rock	8	1,165
Hard black basalt	157	395	Hard brown rock	63	1,228
Soft volcanic conglomerate	184	579	Hard black rock	100	1,328
Soft yellow shale	51	630	Green rock or shale; third water; water rose 740 feet to 605 feet	17	1,345
Medium hard cemented gravel	65	695	Hard black rock	61	1,406
Soapstone (?), caving; first water; water rose 20 feet to 695 feet	20	715	Hard brown rock	8	1,414
Soft brown shale	45	760	Red rock; fourth water; water rose 890 feet to 580 feet	56	1,470
Soft yellow shale	89	849	Dark-brown rock	10	1,480
Soft conglomerate	41	890	Black rock; fifth water; water dropped in well to 657 feet below surface	150	1,630
Soft blue shale	30	920	Green and white shale	15	1,645
Soft red shale	48	968	Black rock	30	1,675
Gray rock; second water; water rose 354 feet to 630 feet	16	984	Green shale; sixth water; water remained at 657 feet below surface	15	1,690
Green rock and shale, medium hard	6	990			
Hard gray rock	10	1,000			
Green shale	2	1,002			
Brown shale	54	1,056			

WATER TABLE

The water table for the area north of the line between Tps. 12 and 13 S. is shown on Plate 10 by 200-foot contours. The contours are not shown south of this line because there are too few wells in that area to give the necessary data. In a general way the water table slopes gently northward for about 6 miles from the southern boundary of the area. From the north side of T. 14 S. the gradient increases, owing to the deepening of the Deschutes and Crooked Canyons, until in T. 11 S. the water table has a gradient of about a hundred feet to the mile. The general northward slope of the water table in the basin is disturbed by the ground water discharged into the basin from the mountains on the east side, which produces a steep northwestward gradient. This steep gradient is doubtless due in part to the fact that the formations in this area are less permeable than in the middle of the basin, and in part to the cascade of the ground water into extremely permeable lava beds that are drained northwestward by the Deschutes Canyon. Thus in the region between Haystack Butte and Round Butte the water table slopes steeply to the northwest, with a gradient of more than 200 feet to the mile.

Ground-water investigations were not carried far enough west of the basin to determine the shape of the water table in that area, but a hurried reconnaissance indicated that the ground water flows northeastward in that area and ultimately discharges into the Deschutes Canyon as springs.

The numerous springs in the Deschutes and Crooked Canyons doubtless derive their main supply of water from the vast area of subdrained, permeable, fissured lava beds in the upper Deschutes Basin. The geologic structure indicates that the springs from interstratified beds of basalt on the west wall of the Crooked River Canyon in secs. 10 and 14, T. 13 S., R. 12 E., near the Gates ranch, are due to leakage from the Deschutes River. Their origin is discussed in detail on page 199. A large part of the ground water comes also from leaking canals and return irrigation water near and south of Terrebonne. It is reported by water masters in that vicinity that less than one-half of the immense amount of water diverted from the Deschutes River near Bend ever reaches the irrigated area because of the great leakage into the basalt through which the canals are constructed. Furthermore, the amount of water used on the land irrigated is large because of the seepage through the shallow soil into the permeable basalt beneath the surface. All the water lost in this way ultimately reaches the Deschutes or the Crooked River and issues in the form of springs. The numerous buried channels near Terrebonne, together with their buried tributaries, also collect great quantities of ground water from an extensive area to the south and east.

WATER IN SEDIMENTARY ROCKS

WATER IN THE CLARNO (?) FORMATION

Wells 16, 17, 19, 20, and 21 are in the area of the Clarno (?) formation and are shown on Plate 10. Wells 15, 18, and 22 may derive their supply of water from these same beds. A few other wells in T. 13 S., R. 14 E., outside the area mapped, were visited in order to obtain additional data on the water-bearing characteristics of this formation. These beds wherever exposed have the appearance of being poor water bearers. Many of the beds consist of fine-grained tuff resembling shale, and others are massive and only sparingly jointed.

Well 29, belonging to Dayton Grant, in sec. 19, T. 12 S., R. 14 E., obtained a good supply of water from this formation. It is on a hill and is reported to be 190 feet deep. The depth to water is about 75 feet, and the water stands about 2,845 feet above sea level. Mason Grant, the driller, states that in this well he struck 185 feet of blue puttylike clay from which there was a small seep of water at 130 feet. Below the clay there is 3 feet of red rock and 2 feet of pumice, the pumice full of water.

Well 30, owned by Mason Grant, in the SE. ¼ NE. ¼ sec. 30, T. 12 S., R. 14 E., lies at an altitude of about 3,000 feet. This well is 298 feet deep, and the water stands 208 feet below the surface. A small seep was encountered at 130 feet, but at 290 feet a crevice was struck that yields a large amount of water. A small pump with a capacity of 400 gallons an hour can not pump it dry.

Well 10 derives its supply at 560 feet from a soft red rock, possibly a sandstone member of the Deschutes formation but more probably a red tuff of the Clarno (?) formation. This conclusion is based on the fact that more of the Clarno (?) beds are red than those of the Deschutes formation.

Well 15 is supplied from a gravel bed, 2 feet thick, 690 feet below the surface. This gravel bed appears from the log to be a member of the Clarno (?) formation. The owner has developed a hillside seep by a dug well (No. 14) which saves considerable pumping during the spring. After this dug well goes dry it is utilized as a reservoir, and water from the drilled well (No. 15) is lifted into it. Such a system is economical and enables the owner to have gravity water in his house.

In general it may be said that drilled wells in this formation are successful and yield ample water for domestic purposes. There seems to be no clearly defined water table, and wells are brought in at various depths according to the depth of a permeable bed or crevice. The pervious beds of the formation seem to be filled with water even at shallow depths. Well 21 obtained a good supply of water at 82 feet.

Shallow dug wells are in general unsuccessful in this formation, although a few have been developed from hillside seeps with success. Such wells are mainly catchment basins for the spring run-off from banks of snow and the locally saturated adjacent ground. Although these dug wells all go dry during the summer, yet they save the farmer hauling water for several months each year.

WATER IN THE DESCHUTES SEDIMENTS

The sedimentary deposits in the Deschutes formation consist of silt, sand, gravel, diatomite, tuff, pumice, and volcanic agglomerate. (See pl. 13, *A*.) The beds of sand and gravel in this formation that lie in the zone of saturation and are not consolidated yield supplies of water sufficient for domestic use. However, very few of the great number of springs issue from the sedimentary beds of the Deschutes formation in either the Deschutes or the Crooked Canyon; hence they must be as a whole less permeable than the basalt members of this formation. Because of the fluviatile origin of most of the beds they are in many places cross-bedded and lens-shaped, and permeable beds are not continuous over a very large area.

Fourteen wells have been drilled into the Deschutes formation in the area shown in Plate 10. Eight of them obtained water in sedimentary beds. Well 22, which has been included in the group, obtains some water also from igneous rocks, but it is highly probable that the last water struck in this well comes from the Clarno (?) tuffs rather than from the Deschutes sediments. The logs of two of the wells are unknown. Four of the wells are supplied from igneous rocks in the Deschutes formation if well 18 is included, and five if well 22 is included. The yields from the wells vary according to their depth or location, and it has been found that the deepest wells do not necessarily yield the most water.

Well 1 is reported to be 800 feet deep. It was finished in ash at a cost of $4,500. According to the owner's statement, he can pump only 400 gallons a day from this well. At about 475 feet water was struck in lava rock but was insufficient for domestic purposes. This well was almost a failure, but at greater depths sufficient water for domestic and stock use was obtained. The cause of the low yield was not the lack of permeable beds but the draining of the aquifers by Deschutes River, which lies only 3 miles west and 170 feet lower than the bottom of the well. Deeper drilling at this place would probably not develop much additional water.

Well 2 obtains its water from a bed of gravel in the Deschutes formation at the bottom of the well. In 1924 60 gallons a minute was pumped from this well during a 72-hour pumping test, without any appreciable lowering of the water level in the well. This test shows that some of the Deschutes sedimentary beds are good aquifers.

Well 3 obtains its water at 665 feet in pink sandstone of the Deschutes formation. Its yield is sufficient to supply the town of Metolius with water and also some of the adjacent ranches.

Well 4 is 1,300 feet deep and is cased for 1,077 feet. A little water was struck at 750 feet but not enough for domestic and stock use. At 1,295 feet black clay was encountered which caused the tools to stick. The yield from this well was only 1½ barrels a day, so it was capped. This hole extends 305 feet lower than the surface of the Deschutes River, which flows 2½ miles west of the well. The owner knows very little about the material in the hole; hence it is difficult to explain why the well was a failure. He states that only 100 feet of lava was encountered. This lava may have been the Pelton basalt. It is interesting to note that in the canyon wall of the Crooked River nearest to the well there are no intercalated beds of lava in the Deschutes formation above the Pelton basalt member. The fact that there existed around this well an area which, during the eruption of the several intrasedimentary basalts, was not flooded with lava until the rim-rock basalt issued suggests that the well may have penetrated some peculiarity of structure or buried outlier of impermeable shale belonging to an older formation.

Well 6, only 1 mile southwest of well 4, obtained plenty of water in the Pelton basalt 695 feet below the surface, a result which gives further support to the suggestion above made regarding well 4.

Well 7 obtains a good yield from a bed of black lava sand that is presumably in the Deschutes formation, although it is very close to some outliers of the Clarno (?) formation. (See pl. 10.)

Well 8 is 30 feet deep and is dug into basic tuff in a dry gulch. Near by, within 1 acre, are nine other wells belonging to farmers in the vicinity. For years this was the only locality in this area where water was known, hence each farmer dug a well in this little gulch and hauled his water from it. In the last few years most of these wells have been abandoned because wells have been drilled on the owners' property. The water in these dug wells is derived from the underflow of an ephemeral stream that flows northward from the Haystack country.

Dry dug well 26 represents an earnest but unwise effort to obtain water by digging in the Deschutes formation in this locality. It lies less than half a mile from the Deschutes Canyon where the canyon is 750 feet deep. The well is 210 feet deep, and much labor could have been saved if the owner had realized that owing to the absence of perched springs in the canyon a well at least 700 feet deep would have been necessary at this place to obtain water.

It is concluded from the data above set forth that the yield of wells in the sedimentary beds of the Deschutes formation is extremely variable and may, in places, be insufficient for even domestic use.

WATER IN ALLUVIUM

According to the statement of J. Southman, of Madras, dug wells in the alluvium of Willow Creek formerly contained water throughout the year. Water was obtained for three or four years in these wells, after which they dried up each summer. At that time Willow Creek flowed until May each year, which it now rarely does. In digging through this alluvial fill in the valley dry lava is struck. The change in the dug wells in Willow Creek near Madras may be due to the extensive dry farming that is now being carried on in its drainage basin. However, water occurs in the Willow Creek Valley about 2½ miles upstream from Madras and 3 miles east of Metolius, in a well about 10 feet above the creek bed. On August 12, 1925, when the creek was dry, the depth to water in this well was 25.8 feet. This well, however, derives its water from the Deschutes sedimentary beds rather than from the alluvium. These beds probably have a lower percolation factor than the alluvium at Madras, and hence water seeps into the well throughout the year. Moreover, this well is seldom used, and the water in it may be only stagnant water that seeped in from the creek during the spring.

Wells 13 and 25 are both shallow wells in ephemeral creek beds and apparently yield a little water throughout the year.

WATER IN IGNEOUS ROCKS

WATER IN THE TRAIL CROSSING BASALT

The Trail Crossing basalt wherever exposed in this basin is minutely fractured but tightly jointed and gives the appearance of being a poor aquifer. No clinkery or aa beds are exposed. If beds of aa basalt occur in the basin there is a possibility of obtaining large yields of water, provided these beds lie in the zone of saturation. Only one well in the basin, well 23, is known to obtain its water from this basalt. It is near the southeast corner of the SW. ¼ sec. 27, T. 13 S., R. 13 E., and is known to be more than 240 feet deep, for there is 240 feet of pump pipe in the well. The renter reports that the water from this well tastes of sulphur and that the well is easily pumped dry with a small lift pump. A small spring discharges about 1 quart a minute from the basalt in sec. 1, T. 13 S., R. 13 E.

Well 18, in sec. 5, T. 13 S., R. 13 E., is 852 feet deep and is unsuccessful. This well has an unusual history, and the log could not be ascertained accurately enough to interpret the exact stratigraphy. The driller and owner, who are both familiar with the diatomite deposit near Terrebonne, state that 45 feet of diatomite was drilled through in this well between 70 and 115 feet below the surface. This indicates that the well penetrates the Deschutes formation, which is at least 100 feet thick at this well, although the nearest outcrops are members of the Clarno (?) formation. At 630 feet a small seep yielded 6 gallons in 24 hours from a medium-hard light-gray rock. At 775 feet a small trickle was encountered that furnished 100 gallons in 24 hours. The water comes from a tough, hard rock, probably diabase. Mason Grant, the driller, states that the first 404 feet was drilled in 13 days and that the last 200 feet of the well took three or four months. The owner believed that the yield of the well could be increased by "shooting it," so they lowered several hundred pounds of dynamite on the end of ordinary barbed wire into the hole and discharged it. The explosion at that depth caused only a sharp thud in the immediate vicinity of the hole and nothing blew out of it. The barbed wire was unrolled from a spool and evidently coiled up in the hole as the dynamite went off. At any rate, the hole was very effectively plugged by balls of wire. The driller spent several months fishing out the wads of wire, and the hole had not been entirely cleaned out when the writer saw it. The last 200 feet or so is probably in the Trail Crossing basalt, although there is a slight possibility that the hole was drilled into a basaltic neck or plug.

On the basis of observations and the record of the wells, it is believed that the Trail Crossing basalt is a poor water bearer and scarcely worth exploring for water in this basin.

WATER IN ANDESITE

Insufficient field work was done on the andesite in the area to decide regarding its capacity as a water bearer. In the outcrops observed it is dense, massive, and tightly jointed, giving the appearance of relative impermeability. No wells or springs occur in it, and without further proof of its water-bearing capacity, it is classed as a poor aquifer. Wells in it will probably have small yields or will be failures.

WATER IN THE BASALT MEMBERS OF THE DESCHUTES FORMATION

All the basalt members of the Deschutes formation are pervious, as is testified by the immense number of springs that issue from them. They are all flows, and because of their similarity of structure and water-bearing characteristics they are discussed together to avoid repetition. Whether water occurs in them in this basin depends entirely upon whether they lie in the zone of saturation or have not been completely drained by the surface streams that expose them.

The open spaces in this basalt through which water can circulate are enumerated in order of their volume as follows: (1) Large open spaces at the contact of one lava flow with another, or of a lava flow with the underlying formation; (2) interstitial spaces in cinders and aa lava formed during deposition; (3) open spaces in joints due to shrinkage of the basalt at the time of cooling; (4) tunnels or caverns formed by the draining away of subterranean rivers of lava during the final phases of eruptions; (5) vesicles and cavities due to the expansion of gases during the cooling of the lava; (6) tree molds resulting from lava surrounding trees and solidifying before the wood has burned away.

The slaggy contact of one flow with another is the principal passageway for ground water in the basin. These contacts are usually recognized in drilling by a thin layer of easily drilled lava rock, commonly red and lying between two layers of hard blue or black lava. Many of these contacts are visible in the walls of Crooked and Deschutes Canyons, and from some of them issue innumerable springs. (See pl. 17, *B*.) The crust of these basalt flows is generally rough and broken, because of the sudden chilling of the lava and subsequent movement of the flow. Inundation by another lava flow never completely fills these irregularities, and the bottom of the overlying flow is usually slaggy for several feet above the contact, owing to the accumulation of doughy masses of lava that cooled from beneath while the flow was in motion. A fine example of such a contact may be seen 105 feet above the river at Opal Springs, on the east wall of the canyon.

Open slaggy contacts result also at the base of a lava flow where it rests upon sedimentary rocks. The permeability of such contacts is variable, for in some places the lava fits tightly to the underlying bed, as shown in Plate 12, *B*, while in other places the two may be separated by a cavern large enough to walk through, as shown in Plate 17, *A*.

Immense volumes of water can flow through the interstitial spaces in cinders and aa lava. In this basin, however, cinders and aa lava are much less common than the regularly jointed basalt known as pahoehoe and hence they play a much less effective part than in many other lava regions. Furthermore, the cinders and aa basalt that are known in the basin lie above the zone of saturation. Cinders are present in several of the wells, notably in 22 and 5. In well 5 there is 84 feet of cinders below 221 feet of conglomerate. Although not prominent in the zone of saturation, good-sized deposits of both cinders and aa basalt occur in the zone of aeration, where they doubtless serve as efficient intake beds. The area of the cinders on the surface of the basin is shown on Plate 10.

Open spaces in the joints due to shrinkage of lava at the time of cooling are so well known that they need no further description. They can be seen in any of the basalt beds and in most of the photographs shown in this report. The distance of gaping of the joints depends chiefly upon the thickness of the flow and the slowness of cooling. Many of the thicker flows are jointed, but the joints are tight and the basalt is not very permeable, whereas the thin flows have more irregular jointing and are much more permeable.

Tunnels and caverns are formed in basalt by the draining away of subterranean rivers of lava during the final phase of eruptions. They are essential to the spreading out of such extensive sheets of basalt as occur in the Deschutes formation. Their presence is indicated in wells by the dropping of the drill when penetrating lava rock. No lava tunnels were discovered during the investigation in this portion of the Deschutes Basin, but many of them are known in the Bend region. The immense volume of Opal Springs suggests that the water is concentrated in a lava tube before it reaches the surface.

Vesicles and cavities due to gas expansion in the lava at the time of cooling are very common, especially near the tops of the flows. They are not everywhere connected, and unless the lava is extremely cellular they probably do not allow any great amount of water to circulate. However, the fact that the vesicles in most of the ancient basalts are filled with minerals deposited from percolating waters indicates that some circulation of water takes place even through these small and apparently disconnected cavities.

Tree molds formed by lava surrounding a tree and solidifying before the wood has completely burned away are roughly circular holes 1 to 3 feet in diameter and as much as 40 feet deep. None were seen in the basin, but this is not surprising because most of the flows are covered with soil. Tree molds were found by the writer in lava flows near Bend. It is an established fact based on observations in the Hawaiian Islands that many tree molds act as conduits for streams of underground water. They occur only locally, hence they are probably the least important water-bearing features in the lava.

Dikes or feeders to volcanic vents are not exposed in this basin. They must exist, however, for fissure eruptions occurred during the extravasation of the rim-rock basalt. They are impermeable and in places act as barriers to the circulation of ground water. The effect of dikes in the basin could not be ascertained.

Wells that penetrate the basalt members of the Deschutes formation that lie in the zone of saturation yield ample supplies of water, and for large supplies these beds should certainly be explored.

WATER IN THE INTRACANYON BASALT

The main mass of the intracanyon basalt in the basin lies above the water table and hence does not contain water. The fact that it contains practically all the features described above indicates that in itself it is permeable. Moreover, near Trail Crossing several springs issue from it. South of this area it is thinner and will doubtless yield water when tapped by drilled wells. The water will occur near the base of the formation, and hence holes several hundred feet deep may be necessary. It is believed that wells will be successful when drilled into it along the axis of the buried valleys north of Tetherow Bridge, but wells on either side of the buried valleys may fail to yield sufficient water.

SPRINGS

SPRINGS IN CROOKED RIVER CANYON

Hundreds of springs occur in the Crooked River Canyon, and many of them are so close together that they issue as sheets of water. The largest are Opal Springs. (See pp. 200–203.) A great number of springs issue in the bed of the Crooked River where they can not be definitely counted, and others issue in the talus slopes and flow into the river unseen.

The first large group of springs downstream from Trail Crossing is near the Gates ranch, in sec. 14, T. 13 S., R. 12 E. The water of these springs has been collected in a flume for the development of power, and because they are typical of the other springs in the canyon they warrant further description. These springs discharge about 20 second-feet of clear, sparkling water which had a temperature of 56° F. on August 20, 1925. About 25 feet above the river, which flows on Deschutes sandstone, there is a bed of basalt 80 feet thick. This bed is made up of three and in places four distinct flows. They were not all laid down during the same eruption, for a short distance upstream there is a wedge of sandstone intercalated with them. Most of the springs issue from the slaggy, open contact between the lowest bed and the one above it, but a few issue from the contact of the second and third flows. The highest spring is 92 feet above the river. Tunnels have been driven into the lava where many of the springs issue. The longest of these tunnels is 185 feet long; most of them are 25 feet or less. They follow the water southwestward and usually rise along joints to the contact above, indicating that much of the water issuing from the contact of the first and second flows has dropped a short distance back of the canyon wall from the contact between the second and third flows. A few small springs issue from this same 80-foot bed of basalt on the east canyon wall, and a large spring bubbles up in the river at this place.

The source of the water that issues from the lava on the west wall is difficult to determine. It can not be many feet west of these springs that the lava bed is again cut in two by the ancient channel of the Crooked River of preintracanyon basalt time. The explanation must be that the water has been concentrated into this ancient channel from the region to the south and not unlikely by means of the buried Deschutes Canyon, which has a ground-water connection through interstratified basalt. It is forced to escape into the present Crooked River Canyon either because of the extreme permeability of the 80-foot interstratified bed of basalt at this place or because of a change from a permeable to a relatively impermeable condition of the intracanyon basalt occupying the buried valley. The latter explanation seems more plausible, for the interstratified basalt seems to be everywhere permeable, whereas the structure of the intracanyon basalt changes considerably from place to place; hence it might easily form a ground-water dam at this locality.

Another interesting group of springs that represent a perched water table issue near Opal Springs. At this place half a dozen springs pour out from the contact of an interstratified bed of basalt with the underlying Deschutes sediments 105 feet above the river. (See fig. 8.) They are collected into a flume and utilized for developing power.

A large spring issues from the Pelton basalt in the fore bay of the Cove power plant at Cove Crossing, on the Crooked River. It is impossible to estimate the discharge of this spring, because it is submerged. Other springs issue on the bank of the river in this vicinity. A profile of the Crooked River between mile 9 and mile 13 above its mouth is shown in Figure 9 to illustrate the large number of springs that issue along the river between these two points.

Opal Springs are in the NE. ¼ sec. 33, T. 12 S., R. 12 E., on the east bank of the Crooked River. They receive their name from the polished siliceous pebbles that occur in the springs. Many of the pebbles are translucent or transparent chalcedony that have a polish which could not be improved by a lapidary. A few of the tiny pebbles are shaped like cabochon opals ready for setting. People come from long distances to gather these natural polished gems, and a few have been mounted in jewelry. The pebbles have been derived from siliceous veins in the Clarno (?) formation and appear to have been polished by rubbing against one another in the spring water.

Opal Springs have a mean annual discharge of about 300 second-feet, and on August 25, 1925, the water had a temperature of 54° F. The water discharges in a small pool at the level of the river, but a considerable amount breaks out of the coarse talus about 4 feet above the river and tumbles into the pool. (See pl. 18, *A*.) As the formation that yields the water is buried, its character can not be stated.

The Crooked River at Opal Springs is flowing near the contact of the sedimentary beds of the Deschutes formation with the intracanyon basalt. (See fig. 8.) The basalt forms a vertical cliff about 350 feet high at the west edge of the river. The east bank consists of a steep talus slope rising to a vertical cliff of interstratified basalt 105 feet above the river. A steep slope broken by another vertical cliff formed by interstratified basalt at an altitude of 2,345 feet rises above this lower cliff of basalt to the rim-rock basalt. (See fig. 8.) Numerous springs issue from the basal contact of the bed of basalt 105 feet above the river. The talus slope extending from this bed to the river is covered with water-loving vegetation, indicating that the talus is saturated with water, although most of the water from the visible springs is collected in a flume and used for the development of power. The numerous springs

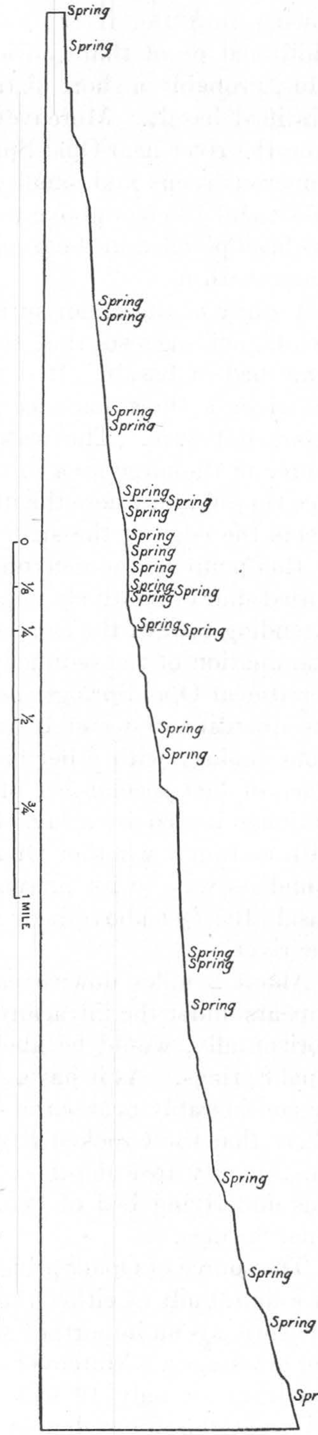


FIGURE 9.—Profile of Crooked River, Oreg., from mile 9 to mile 13 above its mouth, showing location of springs. By W. B. Upton, jr., U. S. Geological Survey

flowing into the river from the talus at the river's edge afford additional proof that considerable water is finding its way into the talus, probably a short distance back from the outcrop of the interstratified basalt. Moreover, a shallow cut made in the talus slope from the river near Opal Springs to the interstratified basalt contains numerous seeps and small springs that come from the base of the basalt cliff 105 feet above the river. The water is ground water that has been perched in the basalt because of the impermeable sediments underneath it.

A study of the minor springs associated with Opal Springs but 105 feet higher suggests that the water in Opal Springs comes from the same bed of basalt. If it does, then the water is leaking down to the river a short distance back from the canyon wall through an enlarged fissure. The water of Opal Springs would then have its source in the large area to the east and south, where there is no surface run-off and where the intake area of the stratified basalt probably meets the edge of the structural basin. The location of the springs at this point in the canyon is doubtless determined by a projecting buried spur of relatively impermeable beds of the Clarno (?) formation extending toward the canyon from Juniper Butte. (See pl. 10.) An examination of the sedimentary beds of the Deschutes formation exposed near Opal Springs shows no bed sufficiently permeable to yield the quantity of water discharged by these springs. It is probable from analogy with other large springs that the accumulation at this place of 300 second-feet of water is due to an elaborate system of drainage buried by a lava flow. However, it is impossible to state with certainty whether Opal Springs are supplied by water that has found its way to its present outlet from the water-bearing bed of basalt 105 feet above it or from another similar bed of basalt below the river.

About 2 miles downstream from Opal Springs the Pelton basalt appears under the intracanyon basalt. This Pelton bed, if continued horizontally, would be about 100 feet below the Crooked River at Opal Springs. As it has a gentle slope to the north, however, it may be considerably nearer the surface than 100 feet. It is not at all unlikely that the Crooked River has at some time eroded its channel in this vicinity to a depth sufficient to tap the water moving through this underlying bed of Pelton basalt and allowed its escape to form Opal Springs.

The source of Opal Springs bears a significant relation to the success of a dam built at either the lower or upper box canyon dam site, for the spring is an important source of supply of the Crooked River during low stages. Moreover, it issues at an altitude of 1,969 feet above sea level, or only 19 feet above the water surface of the Crooked River at the upper dam site and 49 feet above the water surface at the lower site. Consequently, the proposed dam at either site will impose a considerable head of water on Opal Springs. Until the exact origin of these springs is determined it is impossible to state whether a reservoir flooding the springs would hold water. If the springs are supplied by water from the underlying Pelton basalt, then any considerable head on it would cause the water to escape from the outcrops of the basalt downstream from the dam. If the springs are due to water leaking from the interstratified basalt 105 feet above the river, then a head of 105 feet could be safely placed on Opal Springs before the springs would cease to flow and emerge elsewhere.

The fact that all the springs downstream to the Metolius River along the Crooked and Deschutes Rivers issue from the Pelton basalt proves beyond question that it is a great aquifer. The only way to determine whether this bed supplies the water in Opal Springs is to drill near the spring and determine the depth to the underlying lava. The hole should be located 50 to 100 feet upstream from Opal Springs, and fluorescein dye should be pumped into the hole. If the hole is properly cased, the fluorescein should not appear in Opal Springs unless the springs have their source in the Pelton basalt. Such a test should establish the source of the springs.

SPRINGS IN DESCHUTES RIVER CANYON

About 100 feet up the Deschutes River from the mouth of the Crooked River there is a long line of springs which issue from the Pelton basalt and together discharge about 30 second-feet. Upstream from this place the canyon was not explored for springs but probably contains no large groups of springs, for none have been reported by local fishermen.

Downstream from the Crooked River many springs occur. A notable line of springs extends for three-quarters of a mile on the west bank of the Deschutes River half a mile above the mouth of the Metolius River. These springs issue from the Pelton basalt and range from river level to a height of 25 feet above it. (See pl. 17, *B*.) The discharge of this group of springs is between 80 and 100 second-feet. Below the mouth of the Metolius River many small springs enter the Deschutes River, but they are too small and too numerous to warrant description.

QUANTITY OF GROUND WATER

A good idea of the amount of ground water discharged into the basin is obtained from a study of the stream-flow records. Unfortunately, though many records exist, it is difficult to compare them for the different stations because the stations were not all maintained at the same time. More data are available for determining the amount of ground water discharged directly into the Crooked River than into the other streams in the basin.

QUANTITY OF GROUND WATER DISCHARGED INTO CROOKED RIVER

Before 1910 the Crooked River went practically dry at Trail Crossing during the summer. Since then, however, Ochoco Reservoir and one power reservoir have been created in the headwaters of the Crooked River, and these with the increased irrigation in the vicinity of Prineville have caused the summer flow at Trail Crossing to increase from waste water and return flow. Thus, on August 23, 1908, a measurement at Trail Crossing showed 7 second-feet; one on August 4, 1913, 41.8 second-feet; and one on October 29, 1919, 61 second-feet. On this last date a measurement was also made at the Gates ranch, about 9 miles by river downstream from Trail Crossing, and showed a flow of 301 second-feet. A measurement at the Cove gaging station on the same day showed 1,020 second-feet, or a net gain below Trail Crossing of 959 second-feet, or 620,000,000 gallons a day, due to ground-water inflow. No surface stream enters the Crooked River between Trail Crossing and its mouth during the summer and fall.

At the Cove gaging station the mean monthly flow during the period June 1 to November 1, 1919, was 1,092 second-feet, the maximum 1,150 second-feet, and the minimum 1,050 second-feet. The fact that the difference between the maximum and minimum monthly discharge during this entire period was only 100 second-feet is proof of the constancy of the flow of the springs in Crooked River. This remarkably uniform flow is better illustrated by the following table showing the mean discharge of the Crooked River at the Cove gaging station for July, August, and September, 1918 to 1926, during which there was no surface inflow to the Crooked River below Trail Crossing.

On November 28 and 29, 1925, a similar series of measurements was made on the Crooked River to show the distribution of inflow from springs in the stretch of channel below Trail Crossing. They show a net gain in the river between Trail Crossing and a point 14 miles below it of 731 second-feet, and between this point and the Cove gaging station of 349 second-feet.

Measurements of lower Crooked River in 1925

	Second-feet
Trail Crossing	110
Below Opal Springs, NE. ¼ sec. 33, T. 12 S., R. 12 E., 14 miles by river below Trail Crossing	841
Cove gaging station	1, 190

Mean discharge, in second-feet, of Crooked River at Cove gaging station, near Culver, Oreg., for July, August, and September, 1918–1926

Year	July	August	September	Average	Year	July	August	September	Average
1918	1,100	1,110	1,100	1,103	1923	1,240	1,130	1,150	1,173
1919	1,080	1,100	1,110	1,097	1924	1,110	1,110	1,110	1,110
1920	1,060	1,060	1,090	1,090	1925	1,180	1,180	1,200	1,187
1921	995	970	1,030	998	1926	1,150	1,140	1,140	1,143
1922	1,110	1,110	1,120	1,113					

It is conservative to estimate the flow of springs into the Crooked River as 950 second-feet throughout the year, which is equivalent to 56,529 acre-feet a month of 30 days or 687,770 acre-feet a year. This is an immense quantity of ground water to be discharged in a distance of about 20 miles into a single river in a semiarid land where the rainfall is about 12 inches a year. On the assumption that 5 inches of the total annual precipitation sinks into the ground each year it would require an intake area of about 2,570 square miles to supply the ground water discharged into the Crooked River.

QUANTITY OF GROUND WATER DISCHARGED INTO DESCHUTES RIVER

The amount of water discharged directly into the Deschutes River is much more difficult to calculate than the amount discharged directly into the Crooked River, because the gaging stations have not been located so advantageously for a study of this sort.

The following table was prepared to show the gains and losses in the Deschutes from Bend to Cline Falls, Bend to Mecca, and Cline Falls to Mecca in 1910 to 1912, for which comparisons could be made. The stretch of channel between Bend and Cline Falls is not within the middle Deschutes Basin, but the losses in this stretch are believed to contribute water to the springs in the Crooked River Canyon. The stretch of channel between Cline Falls and Mecca practically all lies in the basin, and the gain between these stations represents an inflow of ground water. The records at Cline Falls are incomplete, hence it was necessary to compute the gains between Bend and Mecca for certain months.

Comparison of discharge, in second-feet, of Deschutes River at Bend, Cline Falls, and Mecca, Oreg., 1910–1912

Month	Discharge								Increase or decrease		
	Discharge at Bend plus Tumalo Creek at mouth	Cline Falls	Squaw Creek above diversions	Crooked River at mouth[a]	Metolius River at Riggs	Shitike Creek at mouth	Mecca	Column 7 minus columns 3, 4, 5, and 6	Bend to Cline Falls (1 minus 2)	Bend to Mecca (8 minus 1)	Cline Falls to Mecca (8 minus 2)
	1	2	3	4	5	6	7	8	9	10	11
1910											
March	2,440	2,100	-------	-------	-------	-------	-------	-------	−340	-------	-------
April	2,050	1,740	-------	-------	-------	-------	-------	-------	−310	-------	-------
May	1,810	1,710	-------	-------	-------	-------	-------	-------	−100	-------	-------
June	1,390	1,310	-------	-------	-------	-------	-------	-------	−80	-------	-------
July	1,130	1,090	-------	-------	-------	-------	-------	-------	−40	-------	-------
August	1,210	1,110	-------	-------	-------	-------	-------	-------	−100	-------	-------
September	1,170	1,050	-------	-------	-------	-------	-------	-------	−120	-------	-------
October	1,280	1,070	-------	-------	-------	-------	-------	-------	−210	-------	-------
November	1,510	1,350	-------	-------	-------	-------	-------	-------	−160	-------	-------
December	1,580	1,380	-------	-------	-------	-------	-------	-------	−200	-------	-------
1911											
January	1,410	1,250	-------	-------	-------	-------	-------	-------	−160	-------	-------
February	1,420	1,220	-------	-------	-------	-------	-------	-------	−200	-------	-------
July	1,070	-------	[b]10	1,070	1,620	93	4,360	1,570	-------	+500	-------
August	924	-------	[b]10	1,070	1,500	60	4,050	1,410	-------	+490	-------
September	1,050	-------	[b]10	1,070	1,490	62	4,150	1,520	-------	+470	-------
October	1,140	-------	45	1,100	1,440	54	4,090	1,450	-------	+310	-------
November	1,370	-------	46	1,150	1,470	73	4,210	1,470	-------	+100	-------
December	1,330	-------	41	1,200	1,420	64	4,300	1,570	-------	+240	-------
1912											
January	1,450	-------	69	1,420	1,590	172	5,050	1,800	-------	+350	-------
February	1,600	-------	65	-------	1,860	195	5,940	-------	-------	-------	-------
March	1,430	1,200	46	-------	1,680	212	5,200	-------	−230	-------	-------
April	1,450	1,270	60	-------	1,660	135	6,460	-------	−180	-------	-------
May	1,660	1,430	131	-------	1,760	188	7,100	-------	−230	-------	-------
June	1,860	1,670	[b]200	1,150	1,890	200	6,020	2,580	−190	+720	+910
July	1,350	1,220	[b]10	1,070	1,660	125	4,850	1,980	−130	+630	+760
August	1,230	1,090	[b]10	1,070	1,660	80	4,550	1,730	−140	+500	+640
September	1,430	1,200	[b]10	1,070	1,580	67	4,520	1,790	−230	+360	+590
October	1,430	1,190	63	1,100	[c]1,490	63	4,390	1,670	−240	+240	+480
November	1,560	1,330	68	1,150	[c]1,590	84	4,770	1,880	−230	+320	+550
December	1,660	1,430	54	1,200	[c]1,500	84	4,670	1,830	−230	+170	+400

[a] Estimated on bases of later measurements.
[b] Estimated flow at mouth. Squaw Creek entirely diverted near Sisters during irrigation season.
[c] Estimate based on flow at Hubbard ranch, 9 miles upstream.

The tabulation shows a consistent loss in every month on record in the channel of the Deschutes River between Bend and Cline Falls (column 9). According to Henshaw[24] this loss probably occurs between Laidlaw (near Tumalo) and Cline Falls. It is probably due to leakage into the fissured basalt over which the river flows where the water table lies far below the river bed. Furthermore, the river is swift and, being spring-fed, carries little silt, hence there is little chance for the crevices to silt up even during long periods. It is believed that in this section of the river considerable water is contributed to the zone of saturation.

[24] Henshaw, F. F., and others, Deschutes River, Oreg., and its utilization: U. S. Geol. Survey Water-Supply Paper 344, p. 70, 1914.

The decided gain in the river due to flow from springs between Bend and Mecca, as shown in column 10, is too large to be anything but real, for the records at both stations are good. The great variation in the amount of inflow is due not so much to the fluctuation in the flow of the springs as to surface inflow during the spring season from ephemeral streams not included in the table and to small diversions for irrigation below the Bend gaging station. The gain between Cline Falls and Mecca is considerably larger, and it is believed that the inflow from springs between Cline Falls and Mecca averages 400 second-feet throughout the year. Furthermore, practically all of this inflow occurs along the stretch of the river within the area shown on Plate 10, for miscellaneous measurements (see p. 186) indicate that there is not much loss or gain between Cline Falls and Tetherow Bridge.

The following table shows the mean monthly discharge for the stretch of the Deschutes River between the station below Bend and the station near Madras during the hydrographic years 1925 and 1926, for which there are comparable records. The flow of Squaw Creek is largely estimated because of the lack of records. However, the summer flow of this creek is all diverted, and during the irrigation season the flow at the mouth is only about 10 second-feet. The increase in discharge of the Deschutes River during the spring at Madras is considerably larger than the increase during the summer, due to the flow of ephemeral streams which have not been included in the calculations because of lack of data. In the table on page 206 it is shown that there is probably a loss of more than 100 second-feet between Tumalo and Cline Falls,[25] which would add considerably to the gain at Madras during these years. With this exception for this stretch of channel during the summer the net gains are due to inflow from springs within the basin.

[25] In a letter dated Nov. 14, 1927, Mr. F. F. Henshaw states: "The record back in 1912 showed this. I was never able to account for it satisfactorily, although it may have occurred. However, the round of meter measurements which I made in 1915, at a much lower stage than had previously occurred, indicated no loss to speak of, and during the summer, at least during the later years of low run-off and large diversion, there isn't anywhere near 100 second-feet to lose and no evidence of any considerable loss."

Comparison of discharge, in second-feet, of Deschutes River below Bend and near Madras, Oreg., October 1, 1924, to September 30, 1930.

Month	Discharge								Increase Bend to Madras (8 minus 4)
	Deschutes River below Bend	Tumalo Creek at mouth	Squaw Creek at mouth [a]	Bend plus Tumalo and Squaw Creeks	Crooked River at mouth	Metolius River near Grandview	Deschutes River near Madras	Column 7 minus 5 and 6	
	1	2	3	4	5	6	7	8	
1924-25									
October	256	5	40	301	1,120	1,100	3,460	1,040	739
November	999	38	60	1,097	1,210	1,510	4,460	1,740	643
December	1,000	38	40	1,078	1,170	1,400	4,370	1,800	722
January	1,010	57	50	1,117	1,600	1,590	5,120	1,930	813
February	1,300	64	60	1,424	2,330	2,060	6,560	2,170	746
March	1,080	40	50	1,170	1,910	1,620	5,540	2,010	840
April	1,050	43	80	1,173	2,320	1,650	6,030	2,060	887
May	674	126	100	900	1,490	1,770	4,980	1,720	820
June	422	65	50	537	1,230	1,700	4,130	1,200	663
July	163	49	30	242	1,180	1,600	3,750	970	728
August	262	2	10	274	1,180	1,500	3,680	1,000	726
September	484	8	50	542	1,200	1,440	3,900	1,260	718
1925-26									
October	605	0	60	665	1,220	1,400	3,930	1,310	645
November	1,050	0	52	1,102	1,220	1,400	4,350	1,730	628
December	1,160	13	60	1,233	1,220	1,420	4,510	1,870	637
January	1,040	48	52	1,140	1,220	1,370	4,390	1,800	660
February	1,130	56	72	1,258	1,540	1,570	5,160	2,050	792
March	1,090	42	50	1,182	1,670	1,450	5,060	1,940	758
April	407	66	75	548	1,540	1,460	4,250	1,250	702
May	104	14	10	128	1,180	1,460	3,530	890	762
June	56	9	10	75	1,160	1,410	3,360	790	715
July	68	0	10	78	1,150	1,370	3,310	790	712
August	49	3	10	62	1,140	1,320	3,290	830	768
September	126	0	30	156	1,140	1,300	3,320	880	724

[a] Estimate based on flow at Squaw Creek gaging station near Sisters and miscellaneous measurements and estimates of flow during irrigation season at mouth.

From observations during the investigation it was estimated that at least 350 second-feet of ground water was discharged into the Deschutes River in this basin, for no notable springs enter in the stretch of channel between the north boundary of the basin and Mecca. The net gain in the Deschutes River between Bend and Madras for 1925 to 1926, according to data presented in the above table, was more than 600 second-feet, even during the months of low-water flow. Accordingly it appears that there is considerably more water finding its way into the Deschutes River in the basin than was observed during the investigation.

The annual inflow from springs to the Deschutes River, amounting to 600 second-feet, or 434,380 acre-feet, when added to the inflow to the Crooked River, gives a total annual ground-water discharge into the middle Deschutes Basin of 1,550 second-feet, or 1,122,150 acre-feet. There is no appreciable spring inflow to the Metolius Rivei within the basin. The total annual ground-water discharge in this area therefore exceeds 1,000,000 acre-feet.

UTILIZATION OF WATER

DOMESTIC USE

For many years obtaining water for domestic use has been a problem in this basin, and it has not yet been entirely solved. The pioneers in the region hauled their water many miles in water wagons. As soon as the deep railroad wells were drilled, towns became possible, and the farmers found it no longer necessary to haul water such long distances. The town of Culver drilled a well to supply its inhabitants with water, but this well was abandoned, and the town now uses water pumped from a spring in the Crooked River Canyon, a short distance upstream from Opal Springs. This water is lifted more than 800 feet. Gradually, as the farmers became more prosperous, they drilled wells on their own land or installed rams on the river. The inhabitants of the Peninsula and in the vicinity of Grandview post office still haul their water from the Deschutes or Crooked River or from wells in the foothills of the Cascade Range. Domestic water is still scarce in places, but the scarcity is not due to the lack of underground water but to the great cost of drilling a well, buying equipment, and lifting the water to the surface. Many people in the vicinity of Terrebonne drink ditch water rather than haul it or bear the expense of a well.

IRRIGATION

The amount of land under irrigation at present in the basin is small. Water diverted from the Crooked River near Prineville irrigates a part of the land east of Terrebonne. The irrigable land south and west of Terrebonne is irrigated by water diverted from the Deschutes River near Bend. About 100 acres is irrigated by diversions from the Deschutes near Lower Bridge and Odin Falls. A few acres is irrigated by water pumped from the Crooked River at the Gates ranch and by diversion from the Crooked River at Cove Crossing.

Practically all the land in the basin, except the Haystack country, could be irrigated from the proposed storage reservoir at Benham Falls, on the Deschutes River above Bend. There is about 6,000 acres on the Peninsula alone that could be irrigated. It is only a question of time before this project will become a reality, for the constant increase in population and added demand for agricultural products will ultimately require the complete utilization of the Deschutes River.

WATER POWER

By F. F. Henshaw

The possible water power of the middle Deschutes Basin is only partly utilized. Maximum development will doubtless be made only when there is an adjacent market for the power, and this market will come into existence only when the land is irrigated and will support a larger population.

CROOKED RIVER

Small power projects are feasible in several places along the Crooked River above Opal Springs and below sec. 26, T. 13 S., R. 12 E. Small rock-fill diversion dams placed across the river and canals contouring the canyon walls would develop considerable head, owing to the rapid fall of the river. The amount of power developed in this manner would be determined by the length of the canal and the flow of the river. One such dam could be built at a low cost by blasting loose from the east canyon wall a small remnant of intracanyon basalt about 1 mile upstream from the Gates ranch. The minimum flow at this place is about 250 second-feet.

Power plant of H. V. Gates.—The Gates power plant is in the NE. ¼ NW. ¼ sec. 14, T. 13 S., R. 12 E. It was constructed by Mr. Gates to furnish electric energy for lighting, heating, and small power for farm use in connection with his house, barn, and farm buildings close to the plant. The conditions surrounding the development are unique. The Crooked River receives about 1,000 second-feet of water from springs within about 10 miles of the mouth. Some of these are large, Opal Springs discharging about 300 second-feet. Much of the water reaches the river in innumerable small streams; in the vicinity of the power house the water issues from the side of an almost vertical canyon wall at points between 50 and 100 feet above river level. Several hundred feet of flume and pipe have been built to collect the water into a single forebay. Several tunnels extend into the rock for distances up to 185 feet, intercepting and conducting into the flume water that formerly found its way to the surface at a lower level.

From a concrete fore bay a 24-inch wood pipe extends to a power house of frame construction, on the bank of the Crooked River. The 11½-inch twin Leffel turbine is belt-connected to a 50-kilowatt generator with governor, switchboard, etc. Arrangements are also made for connecting the turbine to a 6-inch centrifugal pump to furnish water for domestic and stock use and for irrigating land in and near sec. 14, at an altitude of about 350 feet above the river. This land is now irrigated by means of hydraulic rams driven by water piped from springs discharging into the canyon a few hundred yards above the upper end of the conduit leading to the power house. Practically no water has yet been pumped by this plant. The pipe line reaching from the head of the supply flume up the canyon is not yet complete, and the water supply now available serves only to run the generator.

The construction of this plant has presented unusual difficulties. Almost everything entering into its construction has been lowered into a box canyon about 350 feet in depth. Now there is a tramway, but when work was started only a steep winding trail was available. The original flume bents were poles from trees cut from the sides of the canyon, but most of these have now been replaced with sawed lumber. The flume has been gradually extended, and the flow of water from the rock gradually developed.

The power-house floor is fairly close to the river, and the generator foundation may be submerged in time of extreme flood. Provision has been made for raising the generator up the canyon slope on skids with block and tackle in case of emergency. The plant has been installed in a thoroughly workmanlike manner, and it runs with attention only twice a day.

Power plant of E. A. Thompson.—The Thompson power plant is used in pumping water for domestic use to settlements and ranches on bench lands lying west of the Crooked River in and near the towns of Opal City, Culver, and Metolius. A loose-rock wing dam in the NW. ¼ SE. ¼ sec. 33, T. 12 S., R. 12 E., diverts water on the left bank into a conduit, mostly in open canal, 1,400 feet long to the power house in the SW. ¼ NE. ¼ of the same section, where a net head of about 20 feet is developed. A 26-inch vertical Leffel turbine is direct-connected to a duplex pump of special design, 3½ by 10 inches, with a capacity of 4,000,000 gallons a month. There is also installed a hydraulic engine, with a capacity of 2,000,000 gallons a month. The pumps take water from a spring discharging into the river close to the power house. The water is carried through a 4-inch pipe down the river for about a quarter of a mile, across a bridge, and thence up the steep slope of the canyon to the Deschutes Valley water district's reservoir in the NW. ¼ sec. 34. The pumping plant and pipe, up to the reservoir, belong to Mr. Thompson; the reservoir and distribution system belong to the district.

Box canyon sites.—A power dam 100 feet high was proposed for the upper box canyon dam site, but for geologic reasons, described on page 155, it is not considered feasible.

At the lower box canyon dam site, about half a mile downstream, a dam at least 155 feet high is feasible providing that drilling shows the geology to be satisfactory. Even if a high dam is not feasible at this site, a diversion dam with a flume contouring the canyon wall could be constructed. The minimum flow at this site is probably over 900 second-feet, so that considerable power could be developed.

Cove hydroelectric power plant.—A hydroelectric plant has been constructed to utilize the flow of the lower stretch of the Crooked River, below Opal Springs. The diversion canal takes water directly out of the river in the SE. ¼ SW. ¼ sec. 11, T. 12 S., R. 12 E., and conducts it to the power house, in the NE. ¼ SW. ¼ of the same section. The canal is about 1,700 feet long, and the head obtained is about 33 feet. One unit was installed in 1912 and 1913, consisting of a 750-horsepower generator, 400 kilowatts, 2,300 volts, 100 amperes. The power house was enlarged and rebuilt in 1923 and a second unit installed, consisting of a 1,225-horsepower S. Morgan Smith 33-inch double-runner turbine and one General Electric alternating-current generator, 700 kilowatts (875 kilovolt-amperes), 2,200 volts. (See pl. 18, *B*.)

The distribution system supplies Prineville, Redmond, Madras, Metolius, and Culver and is also tied in with Bend by a line from Redmond to Bend. The plant is capable of being enlarged to a capacity of about 2,500 kilowatts, and by means of a rock-crib diversion dam the head can be increased to 34 or 35 feet. A flow of 1,100 second-feet of water has been appropriated. This flow has been available about 92 per cent of the time during the last nine years, and this figure is used by the company in the plans for future enlargement.

The plant now belongs to the Deschutes Power & Light Co., with main offices at Portland, which is controlled by interests associated with the Pacific Power & Light Co. of Portland.

DESCHUTES RIVER

The portion of the Deschutes River in this area is not capable of any great power development, except for local ranches above the mouth of the Metolius River, because it has so small a low-water flow, owing to irrigation diversions near Bend. At the Metolius dam site, on the Deschutes River about on the line between secs. 15 and 22, T. 11 S., R. 12 E., there is large low-water flow from the Crooked River, the Metolius River, and springs discharging directly into the Deschutes. This dam site is described on pages 157–159.

INDEX

M

N

T

O