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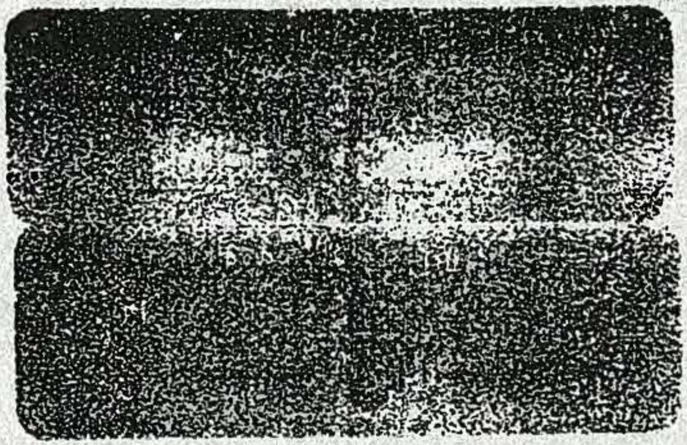
UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGY AND GROUND-WATER RESOURCES OF THE SNAKE RIVER PLAIN IN SOUTHEASTERN IDAHO

Prepared in cooperation with the
IDAHO BUREAU OF MINES AND GEOLOGY
and the
IDAHO DEPARTMENT OF RECLAMATION

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 774



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UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Water-Supply Paper 774

GEOLOGY AND GROUND-WATER RESOURCES OF THE SNAKE RIVER PLAIN IN SOUTHEASTERN IDAHO

BY

HAROLD T. STEARNS, LYNN CRANDALL
AND WILLARD G. STEWARD

Prepared in cooperation with the
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GEOLOGY AND GROUND-WATER RESOURCES OF THE SNAKE RIVER PLAIN IN SOUTHEASTERN IDAHO

By Harold T. Stearns, Lynn Crandall, and Willard G. Steward

ABSTRACT

The part of the Snake River Plain above King Hill, Idaho, is about 250 miles long and has a general eastward trend. This region and the alluvial valleys immediately tributary to it contain about 16,000 square miles. The principal cities in the region are Pocatello, Idaho Falls, and Twin Falls. The discharge of the Snake River at King Hill averages about 9,000,000 acre-feet a year.

The chief purpose of the investigation here recorded was to obtain data regarding the source, movement, and disposal of the ground-water supply of the lava plains that occupy most of the region. By assembling and correlating numerous well records obtained in this and related investigations, tied together by a system of levels, it has been possible to prepare a map of the region showing contours of the water table. This map (pl. 19) shows the direction of movement of ground water in all parts of the region and hence largely indicates the source and disposal of the water. As the altitude of most places in the region is known, this map makes it possible to predict the depth necessary for a well to obtain water. The total annual ground-water supply of the Snake River Plain is here estimated at 4,000,000 acre-feet, of which only a small part is now utilized for irrigation. One result of the study is the conclusion that, in order to conserve this supply, it is desirable so far as practicable to confine future irrigation development to the southeast side of the Snake River above Milner, so that the seepage water may return to a stretch of the river where it will be available for reuse. By heeding this hydrologic condition more land can be irrigated with the remaining available water supply than will be possible if the water is used on the northwest side of the river, because most of the return flow from the northwest side enters the river at too low an altitude to be used again.

The geology of the region in its relation to water supply has been studied with care, and much new information of many kinds has been obtained. One of the principal results of this study is the conclusion that the exceptionally large springs along the canyon of the Snake River owe their existence to the fact that the modern canyon intercepts a series of roughly parallel former canyons of the river that are now filled with especially permeable lava and hence serve as channels for ground water. The coves present where many of the springs emerge are thought to have been formed to some degree by solution. Light is thrown on other peculiarities of the behavior of ground water in basalt by a study of the exceptionally well exposed and very recent volcanic area of the Craters of the Moon National Monument.

The losses and gains in different stretches of the Snake River are estimated on the basis of available stream-flow records. An inventory of the water supply of the plain and its tributary valleys is made. The springs in and near the Snake River Plain are described, and all available records of their discharge are tabulated. Many of the heretofore unpublished ground-water conditions in both the plain and the tributary valleys are summarized.

INTRODUCTION

LOCATION AND AREA

The Snake River, the largest of the tributaries of the Columbia, is the drainage channel for the greater part of the State of Idaho. The South Fork enters southern Idaho from its source in Wyoming and contributes an average annual discharge of nearly 5,000,000 acre-feet. Henrys Fork, which rises in Henrys Lake and derives its waters chiefly from sources in Idaho, contributes an average of fully 1,250,000 acre-feet annually. Below the junction of the two forks the river takes first a southwestward and then a westward course through southeastern Idaho. In addition to the surface stream, a great quantity of water percolates underground, largely through the system of ancient channels of the Snake River that are now filled and covered with permeable lava, and reappears in many large springs in the canyon of the river above King Hill. The total discharge of these springs amounts to about 4,000,000 acre-feet a year. At Weiser, where the Snake River leaves southern Idaho, it has an average annual discharge of about 13,000,000 acre-feet. For more than 200 miles north of Weiser it forms the boundary between Idaho and the neighboring States of Oregon and Washington, and after receiving the inflow from the Salmon and Clearwater Rivers and from tributaries in Oregon and Washington, it leaves Idaho at Lewiston, where its average annual discharge is about 40,000,000 acre-feet. Plate 1 shows the major features of the topography of this part of Idaho. The waters of the Snake River have aptly been called the lifeblood of Idaho. The river with its tributaries furnishes water for irrigating about 2,000,000 acres of land in this State.

This report deals with the part of the Snake River Plain above the town of King Hill and with the valleys immediately tributary thereto. According to the official definition by the United States Geographic Board, this plain comprises the broad valley of the Snake River, which has a rather gently rolling surface mainly underlain by Snake River basalt and related sediments, beginning near the towns of Spencer, Kilgore, and Ashton, in northeastern Idaho, and extending south and west across the entire State to the point where the valley narrows sharply in the vicinity of Huntington, Oreg. In the region covered by this report the Snake River Plain is about 250 miles long, averages 70 miles in width, and covers about 12,500 square miles. The tributary valleys, whose conditions are described in this report, cover an additional area of about 3,000 square miles. The principal cities in the region and their population, according to the census of 1930, are Pocatello, 16,471; Idaho Falls, 9,429; and Twin Falls, 8,787. As shown in plate 4, the region is traversed by two main lines of the Union Pacific Railroad, one extending westward and one northward from Pocatello. Several branch lines connect with these two main

PURPOSE AND HISTORY OF THE INVESTIGATION

The main purpose of the present investigation was to determine the direction of movement of the ground water in the Snake River Plain above King Hill and the respective amounts of water contributed to the great underground reservoir by seepage from the Snake River and tributary streams, from precipitation on the plain itself, and from irrigation water that percolates below the root zone. Efforts were made also to ascertain where the water lost from certain stretches of the Snake River returns to the river and the time involved in the passage of this water underground. The geology of the region was studied to show the occurrence of the ground water and the geologic structure that affects its movement. (See pls. 4, 5, and 6.) To determine the direction in which the ground water is moving in different parts of the region, the position of the water table (or upper surface of the body of ground water) was found by measuring the depth to the water level in as many wells as possible and by connecting the reference points at the wells with a network of levels. From these data the contours of the water table given in plate 19 and the lines showing depth to ground water in plate 18 were drawn. All reliable records of wells were assembled and studied to determine the changes in the water levels in the wells as a result of differences in precipitation and irrigation development. Dye was used in open cuts and in wells to show the rate of ground-water movement. The movements of ground-water crests through certain areas were studied for the same purpose.

The investigation was begun by the United States Geological Survey May 1, 1928, and was under the general direction of O. E. Meinzer, geologist in charge of the division of ground water. It was conducted in cooperation with the Idaho Bureau of Mines and Geology and the Idaho Department of Reclamation. The North Side Canal Co., the Twin Falls Canal Co., the Minidoka and Burley irrigation districts, and the Idaho Power Co. cooperated financially through the Idaho Department of Reclamation.

During recent years investigations have been made by private and governmental agencies relating in large part to the ground-water conditions of this region, but practically none of the results of these investigations have yet been published. One of the main tasks of the present investigation was the assembling and interpretation of the data in the unpublished reports on these investigations.

Mr. Crandall, now district engineer of the United States Geological Survey at Idaho Falls, spent about 15 years investigating the duty of water, canal losses, and ground-water conditions on the North Side Twin Falls tract and in the Big Lost and Little Lost River Valleys. Much of his work is published here for the first time. He is the author of the text concerning losses and gains in the Snake River, the inventory of the water of tributary valleys, and the inventory of the surface and ground waters in the Snake River Plain above King Hill, except the part relating to the economic use of water and portions of the text relating to consumptive use of water by crops, which were written by Mr. Steward. Mr. Crandall is joint author with Mr. Stearns of the text describing the valleys of the Big Lost, Little Lost, Big Wood, and Little Wood Rivers. In addition he wrote the part relating to the climate and the rate of flow of the ground water. He compiled most of the discharge measurements of the big springs in the Snake River Canyon.

Mr. Steward was responsible for the immense task of collecting, assembling, and checking all well data. In this work he was assisted by H. G. Haight, L. H. Perrine, John McDonnell, J. H. Boone, B. D. Alvord, Jr., and L. T. Burdick. Mr. Steward gave much valuable advice, based chiefly on his long experience in studying ground-water problems during the 20 years he was a member of the United States Bureau of Reclamation engaged largely in research problems in Idaho. He is also author of the text relating to ground water on the Minidoka project and part of that on the South Side Twin Falls tract.

The ground-water conditions on the Blackfoot-Fort Hall and Aberdeen-Springfield tracts were in part described by Mr. Haight. In addition he collected many of the trees and wrote much of the section on tree rings in relation to climate, although all three authors contributed to this section. He aided also in the preparation of the illustrations and in many other ways. C. L. Gazin contributed the data regarding fossils in the Hagerman lake beds. M. N. Short, formerly of the United States Geological Survey, examined the thin sections of the rocks in this region, and prepared a brief report on them which was utilized in this paper.

J. L. Saunders, of the United States Geological Survey, compiled the base maps and plotted the well data on them. This was a difficult task because the well records for each project had a different datum—a condition which required the adjustment of all measuring points to the sea-level datum of the United States Coast and Geodetic Survey.

Prior to this investigation Mr. Stearns spent most of 1921, 1922, and 1923 and parts of 1925 and 1926 in geologic field studies in and immediately adjacent to the region covered by the present report, and all pertinent results of his work during this period are incorporated herein except for the Soda Springs and Mud Lake areas. Mr. Stearns wrote all the text not specifically credited above to his collaborators. In connection with the present investigation, from 1928 to 1930, he mapped in detail the geologic formations along the canyon of the Snake River between King Hill and a point 10 miles downstream from Blackfoot in order to determine the relations of the older Pleistocene and Tertiary rocks, which in the greater part of the region are

hidden under a cover of later Pleistocene basalt and of loess. Because of the lack of adequate base maps for areas at a distance from the river, this work was confined to a strip generally less than 2 miles wide. All available geologic data are incorporated in generalized fashion on plate 4 and those portions of the canyon of the Snake River whose geology cannot be adequately shown on this small-scale map are represented in plates 5 and 6.

ACKNOWLEDGMENTS

The writers are indebted to the personnel of various irrigation projects in the region for many valuable well records and maps. The work was facilitated by the generous and helpful attitude of the late Mr. Burton Smith, former manager of the Twin Falls Canal Co.; Mr. E. B. Darlington, superintendent of the Minidoka Irrigation Project; Mr. R. E. Shepherd, manager of the North Side Canal Co.; and Mr. W. C. Paul, president of the Minidoka irrigation district—all of whom gave a considerable amount of their time and that of their staff. The Oregon Short Line Railroad, the Idaho Department of Public Welfare, the United States General Land Office, and the United States Forest Service furnished most of the data from which some of the base maps in this report were compiled. Numerous residents and drillers in the region supplied records of wells, and several of them donated fossils that were valuable for the determination of the age of the formations. Mr. Elmer Cook, of Hagerman, pointed out significant fossil localities in the Hagerman lake beds. Acknowledgments pertaining to particular areas are made in several places in this report.

Valuable criticisms of the manuscript were made by Messrs. O. E. Meinzer, C. P. Ross, and G. R. Mansfield of the United States Geological Survey.

GEOGRAPHY

SURFACE FEATURES

SNAKE RIVER PLAIN

The Snake River has its source on the Continental Divide, in the southern part of Yellowstone National Park. It flows southward through Wyoming for about 75 miles, enters Idaho, and at Heise emerges from its mountainous headwater area, into the great Snake River Plain. A short distance farther downstream it is joined by its major tributary, Henrys Fork, which drains the upper part of the Snake River Plain. This plain extends for more than 300 miles entirely across southern Idaho, roughly along the arc of a circle. The Snake River flows near the southern boundary of the plain, a position that has been forced upon it by lava flows, which cover the region between the present river and the northern edge of the plain and which have displaced the stream from its ancient channel in the axis of its valley. Plate 2 shows the locality where the river enters a canyon cut in the lava at Milner. The canyon becomes deeper westward until near Twin Falls it is bounded by precipitous lava cliffs about 600 feet high. The Snake River continues in a canyon nearly to King Hill, a distance of about 90 miles. The topography of the region is illustrated by the relief map, plate 1.

Irrigated lands adjoin the river on both sides, extending for a distance of 10 or 12 miles and leaving the major part of the uninhabited plain as a great curved segment between the irrigated sections on the south and the mountains that border the plain on the north. Although this region presents from afar the appearance of a great level valley floor it has been built up by successive lava flows from numerous vents within the valley itself. Its topography is determined by the source and extent of these lava sheets and not by erosion, except that the Snake River and several tributary streams have cut deeply into it.

Though vegetation in one form or another covers much of the area, the desolate black lava flows, the drifting white sand dunes, and the bleak, bare lake beds serve to impress upon the traveler the desert character of the country. Throughout many square miles in the central part of the plain water can be found only in the ice caves in the lava flows or at some stock well at which the water is pumped hundreds of feet. With the increase in the area irrigated on the plain the people inhabiting the area have come more and more to refer to the irrigated part of the plain as the "Snake River Valley." About 1,000,000 acres is now under irrigation in "the valley," and not a small part of it lies hundreds of feet above the Snake River, on the surface of the plain. In the section of the report treating the irrigation development it is convenient to use the term "the valley" to refer to irrigated parts of the plain.

The altitude of the Snake River at Heise, where the stream first emerges from the foothills, is about 5,000 feet. At King Hill, about 250 miles downstream, the altitude is 2,500 feet. The stream thus descends at an average rate of about 10 feet to the mile. About 500 or 600 feet of this difference in altitude between Heise and King Hill, however, is concentrated in falls at Idaho Falls, American Falls, Twin Falls, Shoshone Falls, and other places, so that the average grade of the stream exclusive of these falls is about 8 feet to the mile. The altitude of the plain into which the river canyon is incised ranges from 5,100 feet at Ashton to 3,200 feet near King Hill and averages about 4,400 feet.

BUTTES

The generally flat appearance of the plain is relieved by several buttes, chief among which are Big Southern Butte, West Twin Butte, and East Twin Butte, which stand prominently above the general land surface about 30 miles northwest of Blackfoot. Big Southern Butte rises 2,350 feet above the surrounding plain. It is called by the

RELIEF MAP OF THE SNAKE RIVER PLAIN AND AD

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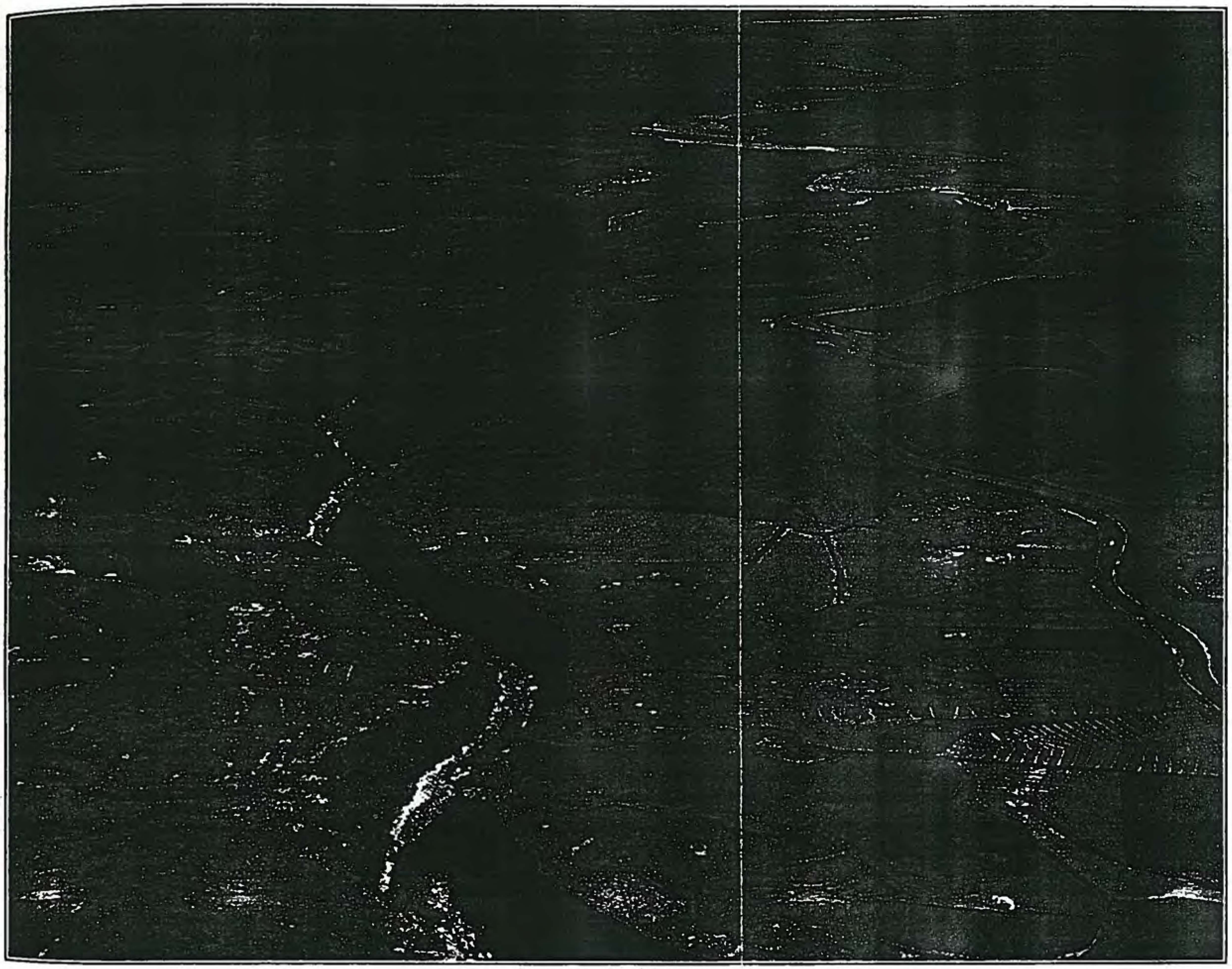

AIRPLANE VIEW OF MILNER LAKE, THE TWIN FALLS CANALS, AND THE CANYON OF THE SNAKE RIVER.
Photo by U. S. Army Air Corps.

AIRPLANE VIEW OF TWIN FALLS AT A LOW STAGE OF THE RIVER.

A resistant basalt bed 120 feet thick causes the falls. The sand banks in the gulch on the right are mined for flour gold and have yielded bones of extinct animals. Photo by U. S. Army Air Corps.

AIRPLANE VIEW OF SHOSHONE FALLS ON SNAKE RIVER SHOWING THE MASSIVE ANDESITE FLOW THAT FORMS THE FALLS.

The falls are dry because the entire flow of the river has been diverted for irrigation. The power plant on the left utilizes all the spring water and return flow that reaches the river below Milner. Photo by U. S. Army Air Corps.

Indians "Be-ah Car-did" (great stay), referring to its permanence. It may be seen from points over 100 miles distant. East Twin Butte rises about 1,100 feet and West Twin Butte about 800 feet above the adjacent plain.

There are many lower buttes scattered over the lava plain, all of which, unlike the three just mentioned, are extinct basaltic volcanoes (pl. 4). Among these may be mentioned Notched Butte; Sugar Loaf Butte, south of Shoshone; Big Cinder Butte, in the Craters of the Moon National Monument west of Arco; and the Menan Buttes, near Roberts. Besides the cones that are prominent enough to have been individually named, there are innumerable minor elevations that can be discerned if the surface of the plain is viewed against the sky line. These features rise to heights of 100 to 300 feet, but their bases, commonly 4 to 6 miles or more in diameter, are so broad that their slopes merge gradually into each other or into the surrounding plain. These minor elevations are also volcanic vents, and from those now visible as well as from many others buried by later eruptions, vast quantities of highly fluid lava formerly flowed in all directions.

FALLS OF SNAKE RIVER

There are many falls along the Snake River, some of which are large and spectacular. However, so much of the water is being used for irrigation that many of them are dry in the summer. The locations of most of the falls and principal rapids are shown on plates 4, 5, and 6. Shoshone and Twin Falls are by far the largest. The former is 200 feet high and results from the superposition of the river on the Shoshone Falls andesite as a result of displacement from its former channel by the Sand Springs basalt. The fall at a period of low water is shown in plate 7. Twin Falls is caused by the river's tumbling over a massive bed of basalt 120 feet thick (pl. 3). The other falls along the Snake River within the region studied are 45 feet or less in height.

TRIBUTARY STREAMS

Many perennial streams, of which the largest are the Blackfoot and Portneuf Rivers, flow into the Snake River from the south, but between the mouth of Henrys Fork, in the extreme northeastern part of the area, and the mouth of the Big Wood River, near Bliss, in the southwestern part, a distance of about 250 miles measured along the stream, the Snake River does not receive a single surface tributary from the north. The drainage area north of the plain is occupied by lofty mountains which rise to altitudes as great as 12,500 feet and the run-off from which forms many streams that sink at the north edge of the lava plain. Part of this run-off flows beneath the lava sheets near the mouths of the valleys through the gravel deposits which were laid down by the ancestral tributary streams and which underlie or are interstratified with the lavas, and a part passes through the lavas that fill these ancient valleys. The flood waters usually form shallow ponds or lakes in depressions on the surface of the Snake River Plain, from which the water not lost by evaporation sinks to the deep underlying water table. Big Wood and Little Wood Rivers are the only streams that succeed in crossing the lava plain, principally because of the more favorable topography along these rivers and the narrowness of that part of the belt of lavas that separates the mountains from the Snake River.

CLIMATE

TEMPERATURE

The mean annual temperature of the Snake River Plain east of King Hill ranges from 41° F. at Ashton (altitude 5,100 feet) to 50° at Bliss (altitude 3,270 feet). In parts of the mountainous areas bordering the plain the mean annual temperature is probably lower. A table showing the mean monthly and annual temperatures at 16 stations on the Snake River Plain is given below.

Temperatures in southern Idaho (° F.)

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

Station	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Yearly mean
Arco	....	14.8	20.1	29.9	36.3	58.9	61.1	65.0	64.0	54.7	44.8	31.6	18.6	41.7
Blackfoot	32	21.9	26.5	38.9	44.9	53.2	61.6	65.3	66.1	56.5	45.4	34.5	22.8	44.7
Boise	65	29.4	34.9	42.7	50.4	57.1	65.3	72.9	71.8	61.9	51.1	41.0	32.1	52.3
Buhl	21	28.0	33.3	40.1	48.1	55.8	64.3	72.9	66.2	60.2	49.6	39.6	28.4	49.2
Burley	11	27.3	32.3	38.8	45.6	55.9	64.3	72.5	69.0	59.5	48.4	38.0	27.7	48.2
Caldwell	24	28.7	35.4	43.2	50.5	57.4	65.3	73.1	68.8	60.7	50.3	39.5	30.7	50.3
Emmett	22	20.3	36.3	44.0	51.5	58.8	67.0	75.1	72.6	63.3	52.2	40.8	30.2	52.4
Fort Hall	14	21.2	28.6	36.2	44.4	53.4	61.8	69.9	66.4	57.0	46.4	35.0	23.4	45.3
Glenns Ferry	20	27.7	35.5	44.0	50.7	58.9	69.0	78.5	74.6	62.5	49.8	39.3	28.7	51.6
Gooding	19	24.2	29.2	39.0	46.7	55.2	63.3	71.4	68.5	58.8	48.1	37.4	25.7	47.3
Idaho Falls	34	19.6	23.4	33.6	44.4	53.9	60.5	68.5	66.5	56.8	45.9	43.5	22.2	44.0
Mackay	....	17.2	20.9	31.0	41.8	51.0	59.4	67.2	64.8	55.3	44.6	31.0	19.6	42.1
Milner Dam	18	27.1	31.0	39.8	47.0	55.0	61.7	70.9	69.5	60.4	48.6	[1] 37.8	26.4	47.9
Oakley	35	28.6	31.8	38.7	46.2	53.9	62.4	70.7	69.2	59.4	49.2	38.8	28.7	48.2
Rupert	22	25.5	30.7	38.6	46.6	54.7	61.9	70.9	67.7	58.1	48.4	37.7	26.5	47.4
Twin Falls	23	27.8	32.4	39.5	47.2	54.9	62.4	70.6	67.9	58.9	48.3	38.0	27.9	47.9
Mean	25.7	26.2	31.5	39.6	47.4	55.6	63.7	71.7	68.9	59.8	48.7	38.6	27.2	48.3

[1] Mean of Burley and Rupert.

At Ashton the average date of the last killing frost in the spring is June 7 and that of the first killing frost in the fall is September 11. At Bliss the dates are May 10 and October 4. July is the month of maximum temperature, the mean for that month ranging from 71° at the lower altitudes to 63° at the higher altitudes on the plain. January is generally the month of minimum temperature, with a range in the mean temperature from 28° to 18° at different stations on the plain.

Like other continental interior areas of fairly high altitude, the Snake River Plain has a large daily range of temperature. The dif-

ference between the mean daily maximum and mean daily minimum is about 20° during the winter and about 38° during the summer, but occasionally much greater variations are experienced. The summers are characterized by hot days and cool nights. Now and then the temperature is 100° or more for a few days at a time, and it has reached a maximum of 106°. On account of the dryness of the atmosphere, however, the daytime heat is less oppressive than it is in more

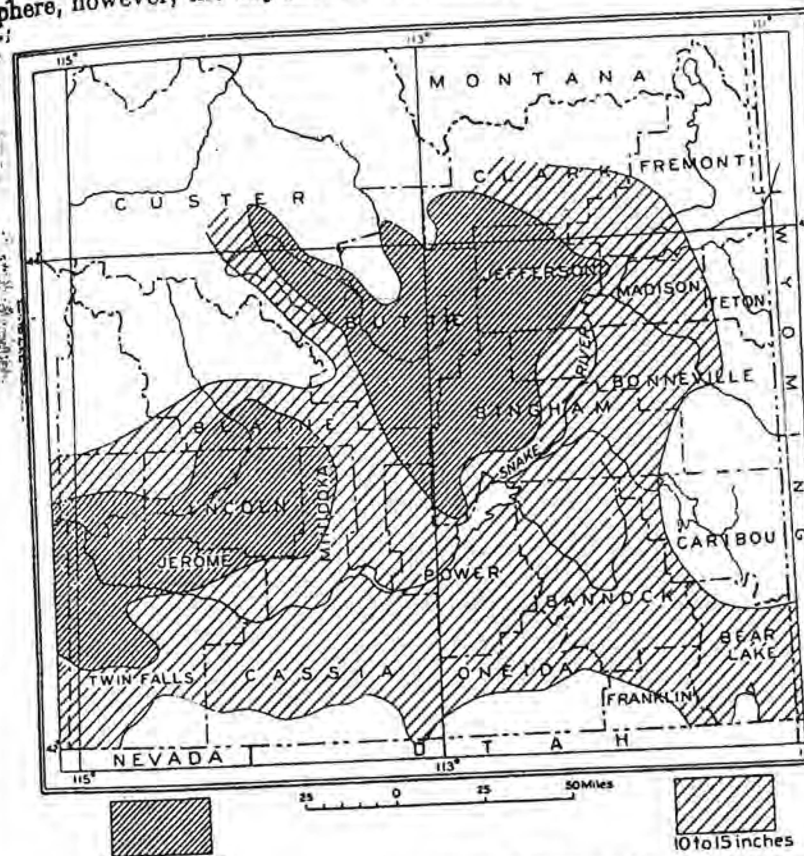

FIGURE 1.—Map of southeastern Idaho showing distribution of precipitation. Areas without pattern have an average annual precipitation of more than 15 inches.

humid regions, and as the clear summer nights allow rapid radiation from the heated land surface, the temperatures become comfortably cool shortly after darkness falls. During the winter the temperature frequently falls below zero and has dropped as low as 40° below zero at the entrances to some of the tributary valleys. In ordinary winters the minimum temperature reached on the plain is from 10° to 20° below zero. In the small area within the Snake River Canyon below Twin Falls and including the Hagerman Valley the temperature at all times is noticeably higher than on the adjacent uplands, doubtl because of the sheltered location and lower altitude of these lands.

PRECIPITATION

Precipitation on the Snake River Plain ranges from an annual ave age of less than 9 inches in some areas of the north-central and wester parts to about 14 inches in some of the eastern, southern, and north eastern areas. Toward the mountain areas that contain the head

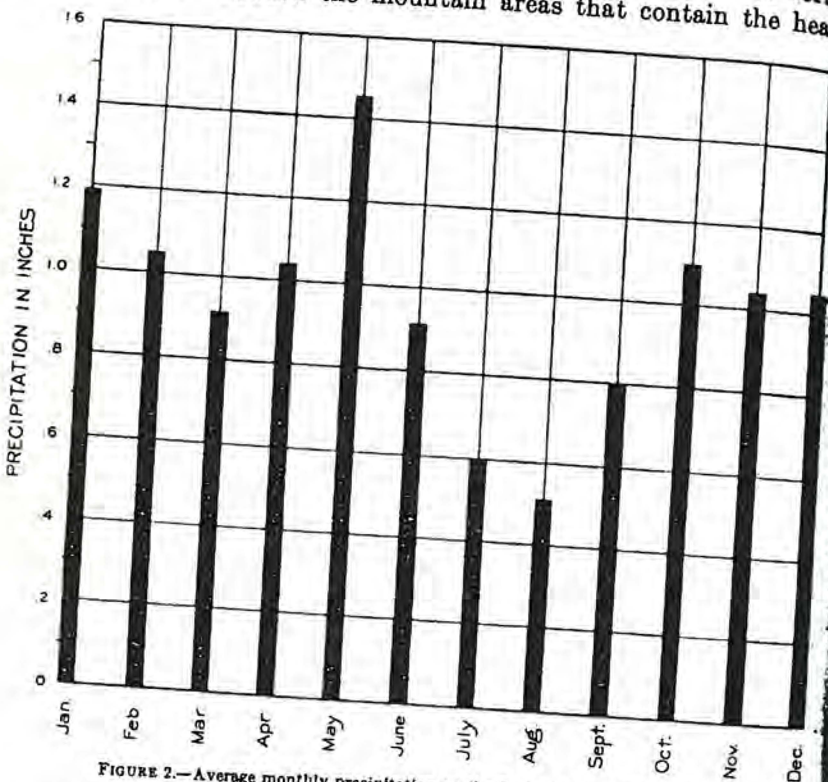

FIGURE 2.—Average monthly precipitation on the Snake River Plain, Idaho.

waters of the river on the northeast and east, the precipitation increases, exceeding 20 inches at high altitudes.

The general distribution of the precipitation is shown in figure 1. Records are lacking to show the precipitation at high points between the tributary valleys, hence there are probably local areas of higher precipitation than are indicated on this map. Unlike many other semiarid regions, the Snake River Plain is favored with a fairly uniform distribution of precipitation throughout the season, as shown by figure 2. The relatively high precipitation during the spring and early summer is probably in large part of local origin and supplied by the reprecipitation of the moisture evaporated from the melting snow fields in the foothills and mountains during these months.

Continuous records of precipitation in the upper part of the plain are not available for the years prior to 1891, but the average annual precipitation at American Falls, Ashton, Blackfoot, Idaho Falls, Oakley, and Pocatello, six stations with long-time records, is shown in figure 3

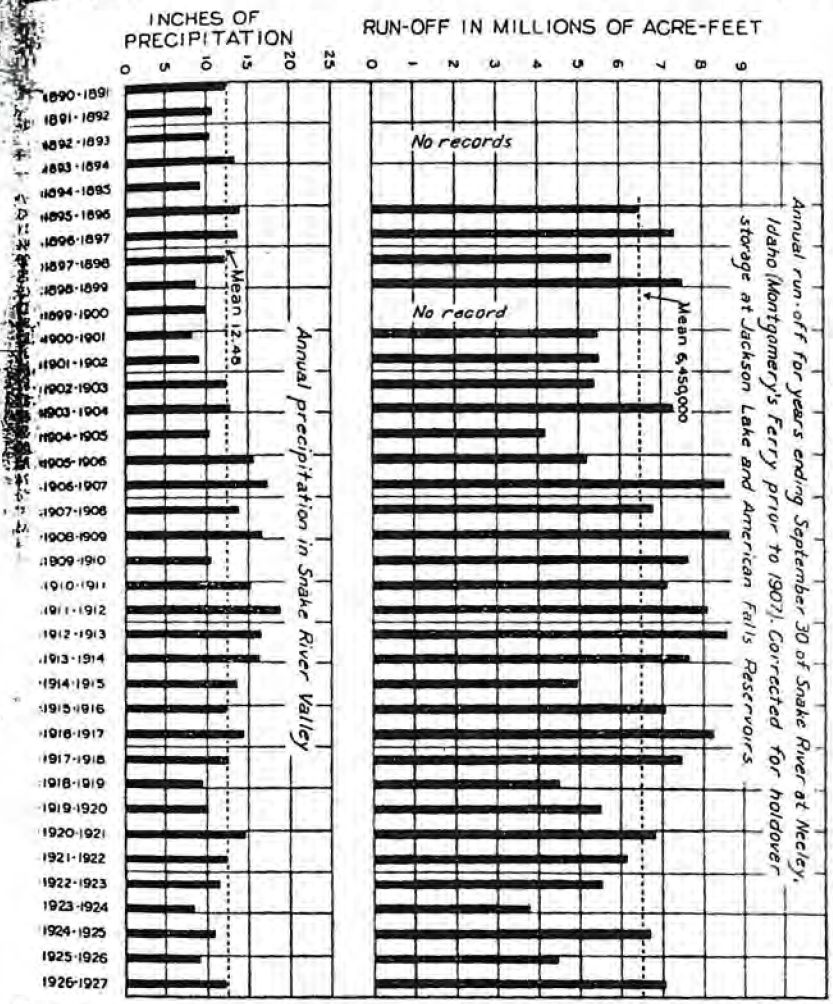

FIGURE 3.—Average annual precipitation and run-off in the Snake River Plain, by years ending September 30, 1891–1927.

together with the discharge of the Snake River at Neeley, corrected for storage hold-over at Jackson Lake and American Falls during the years of record. The table on page 12 gives the mean monthly and annual precipitation at these and other stations for years of record from 1891 to 1927.

The years of high precipitation from 1906 to 1917 constituted the period of great development of dry-farm wheat lands on the Snake River Plain, especially north of the Snake River between Idaho Falls and Minidoka. Most of these lands have been abandoned since 19[illegible] owing to inadequate rainfall and it would thus appear that an av[illegible] age annual precipitation of about 15 inches is essential to success[illegible] dry farming in this region.

Mean monthly and annual precipitation, in inches, at stations in the Snake R[illegible] Plain and tributary areas, 1891–1927

Station	Length of record (years)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	A[illegible]
Albion	13	1.20	1.35	1.18	1.28	1.60	1.09	0.64	0.40	0.71	1.58	1.48	1.29	[illegible]
Almo	8	1.58	1.43	.37	.92	1.95	2.88	1.63	1.01	1.25	2.09	1.42	.80	[illegible]
Aberdeen	14	.53	.71	.65	1.07	1.28	.63	.62	.47	.82	1.02	.74	.59	[illegible]
American Falls	36	1.50	1.21	1.43	1.33	1.66	.94	.64	.54	.70	1.25	1.23	1.41	[illegible]
Arco	25	1.13	.59	.92	.83	1.38	1.16	.59	.53	.58	.67	.65	.87	[illegible]
Ashton	24	1.90	1.41	1.22	1.20	2.02	1.35	.91	.58	1.16	1.51	1.26	1.66	[illegible]
Blackfoot	31	.93	.79	.88	.94	1.41	.80	.74	.64	.83	1.11	.79	.85	[illegible]
Bliss	11	1.25	1.12	.63	.90	1.06	.26	.13	.17	.44	.90	1.27	.99	[illegible]
Buhl	20	.99	.96	.59	.96	1.23	1.01	.48	.22	.54	1.02	.99	.96	[illegible]
Burley	10	.78	.80	.45	1.54	1.02	.81	.41	.78	.74	1.12	.98	.89	[illegible]
Fort Hall	13	.68	.65	.92	1.34	1.34	.60	.71	.74	.92	1.12	.72	.67	[illegible]
Gooding	18	1.18	1.16	.63	.95	.83	.51	.40	.25	.52	.97	1.57	.98	[illegible]
Hailey	24	2.53	2.16	1.34	1.08	1.51	.91	.51	.46	.79	1.12	1.60	1.86	[illegible]
Hazleton	10	.99	1.27	.77	1.01	2.05	.58	.22	.61	.59	1.03	1.10	1.25	[illegible]
Hollister	16	.70	.88	.47	1.19	1.29	.80	.42	.44	.61	1.09	.81	.78	[illegible]
Idaho Falls	33	1.37	1.07	1.25	1.01	1.49	1.18	.65	.69	.90	.95	.85	1.15	[illegible]
Irwin	25	1.35	1.12	1.13	.98	1.87	1.22	1.00	.91	1.33	1.34	1.16	1.20	[illegible]
Jerome	12	.90	1.06	.65	1.03	.92	.45	.18	.32	.40	.95	1.01	.99	[illegible]
Mackay	19	.95	.84	.45	.69	1.18	1.06	.93	.78	.92	.70	.51	.73	[illegible]
Martin	6	2.06	1.28	3.14	.91	2.16	.80	.20	.32	.77	.63	1.79	1.54	[illegible]
Mud Lake	5	.60	.35	.53	.49	1.43	.61	.76	.81	.61	.72	.24	.85	[illegible]
Oakley	34	.81	.76	.85	1.13	1.36	1.05	.64	.63	.81	.98	.78	.58	[illegible]
Pocatello	28	.66	.95	1.65	2.02	2.20	.99	.63	.56	.88	.98	.55	.86	[illegible]
Richfield	13	1.40	.97	.67	.92	1.02	.70	.27	.20	.63	.91	1.22	.93	[illegible]
Rupert	21	1.20	1.04	.82	1.09	1.26	.87	.54	.53	.78	1.16	1.18	1.17	[illegible]
Shoshone	13	1.57	1.17	.55	.68	.91	.51	.24	.11	.70	.95	1.45	1.03	[illegible]
Spencer	6	1.38	1.64	1.38	1.00	2.48	.75	1.48	.80	1.68	1.61	.91	1.76	[illegible]
Springfield	19	1.02	.81	.64	1.03	1.31	.74	.69	.47	.87	1.13	.94	.85	[illegible]
Sugar	20	1.13	.82	.61	.84	1.71	1.13	.78	.46	1.10	1.16	.57	1.18	[illegible]
Twin Falls	22	1.24	1.01	.84	.97	1.14	.90	.43	.26	.70	.93	1.17	1.10	[illegible]
Wendell	18	1.46	1.15	.66	.99	.93	.81	.26	.21	.51	1.19	1.41	.86	[illegible]
Average		1.19	1.05	.91	1.04	1.45	.91	.60	.51	.80	1.09	1.04	1.05	[illegible]

The stream run-off reflects in a general way the fluctuations in precipitation from year to year, but the relation is not definite, probably in part because precipitation at the stations within the valley is not always an index to precipitation on the headwater areas, from which the stream run-off is principally supplied. The precipitation generally takes the form of snow during December, January, and February, and at the higher altitudes often also in November, March, and even April. The snow cover during the winter ranges from a few inches to several feet or more at different places and in different seasons and often melts during warm weather in the winter, particularly at the lower altitudes. The deep snows in the high mountains melt during May, June, and July and then form the source of the water supply that is used for irrigation in the valley.

The mean relative humidity at Pocatello averages about 50 percent for the year, with a daily range from 25 to 60 percent during the summer and 70 to 80 percent during the winter. The average wind velocity at Pocatello is 8.8 miles an hour, and the recorded maximum 58 miles an hour.

EVAPORATION AND TRANSPIRATION

Records of evaporation from water surfaces have been obtained at several stations in the region, principally in connection with studies [illegible] losses from reservoirs. Some are records from floating lake pans, others from pans of the standard class A type of the United States Weather Bureau. The annual evaporation as disclosed by these records ranges from less than 3 feet to about 6 feet, according to the location and type of the evaporation pan. The accompanying tables show total evaporation—that is, the sum of the measured loss plus the rainfall.

JEROME

Fragmentary records of evaporation during 1916 are available for Jerome, in Jerome County. Beginning in 1917 records were obtained from a standard class A Weather Bureau land pan in an irrigated blue-grass pasture in the vicinity of Jerome, in sec. 18, T. 8 S., R. 17 E. Boise meridian.

Evaporation data at Jerome, 1916–27

[Altitude 3,780 feet. From records of North Side Canal Co., Jerome]

Month	Mean air temperature (° F.)	Precipitation (inches)	Evaporation (inches): Land pan 6 feet in diameter, top flush with ground	Evaporation (inches): Pan 27 inches square, floating in canal
1916				
June	60.4	0.01	6.60	5.30
July	69.9	.40	7.00	4.95
August	68.2	.00	6.35	4.50
September	59.8	.00	5.07	3.36
Total or average	64.6	.41	25.62	18.11

Month	Mean air temperature (° F.)	Precipitation (inches)	Evaporation from U. S. Weather Bureau class A pan (inches)	Wind velocity (miles a month): Top of 20-foot building	Wind velocity (miles a month): Ground surface	Mean relative humidity (percent)
1917						
April	42.2	2.43	4.23	---	---	---
May	52.9	1.34	6.40	---	---	---
June	62.2	.00	9.17	---	---	---
July	74.3	.09	8.20	---	---	---
August	69.8	.00	7.03	---	---	---
September	62.5	.54	3.60	---	---	---
October	49.6	.00	2.40	---	---	---
Total or average	59.1	4.40	41.03	---	---	---
1918						
April 17–30	46.7	0.82	3.15	[1]6,544	---	46
May	53.0	1.37	9.39	5,827	---	48
June	71.2	1.15	8.92	4,090	---	51
July	73.8	.42	10.17	4,040	---	56
August	66.0	.42	7.53	4,965	---	58
September	61.8	.95	4.23	4,015	---	57
October	50.4	.96	2.13	4,730	---	72
November	36.0	.42	1.41	6,420	---	69
December	30.6	.54	.70	4,766	---	73
Total or average	54.4	7.05	47.63	5,041	---	59

[1] For full month.

Evaporation data at Jerome, 1916-27—Continued

Month	Mean air temperature (° F.)	Precipitation (inches)	Evaporation from U. S. Weather Bureau class A pan (inches)	Wind velocity (miles a month)		Mean relative humidity (percent)
				Top of 20-foot building	Ground surface	
1919						
January	29.9	0.39	0.52	5,925	----------	
February	30.7	1.47	.45	6,199	----------	
March	38.6	1.21	1.65	6,625	----------	
April	50.0	.69	5.09	6,382	----------	
May	59.0	.05	7.50	6,739	2,510	
June	66.0	.00	10.51	4,300	1,860	
July	73.7	.00	9.37	4,805	1,550	
August	72.9	.00	9.64	4,604	1,655	
September	62.4	.70	5.35	5,383	2,081	
October	42.6	.92	1.89	4,799	----------	
November	35.8	.97	1.09	----------	2,320	
Total or average	51.1	6.40	53.06	5,576	1,996	
1920						
February	34.7	0.48	0.67	4,628	----------	
March	38.8	.68	2.65	4,223	----------	
April	44.3	1.15	4.31	7,995	----------	
May	54.8	.00	6.34	----------	2,539	
June	63.8	.44	6.97	4,653	1,523	
July	74.9	.05	9.90	4,450	1,530	
August	70.5	.28	6.42	4,040	1,490	
September	61.8	.48	2.73	----------	1,040	
October	48.2	1.81	1.83	----------	1,360	
Total or average	54.6	5.37	41.82	5,098	1,580	
1921						
April	44.3	1.16	3.96	----------	2,876	----------
May	55.4	3.16	4.88	----------	1,726	----------
June	65.6	.46	6.29	----------	880	----------
July	72.0	.03	7.71	----------	941	----------
August	70.9	.06	5.02	----------	958	----------
September	54.8	.06	2.61	----------	1,289	----------
October	52.2	.03	1.61	----------	1,137	----------
Total or average	59.3	4.96	32.08	----------	1,398	----------
1922						
April	42.6	1.64	3.89	----------	3,127	----------
May	54.1	.74	6.63	----------	2,449	----------
June	67.0	.87	6.65	----------	683	----------
July	70.8	.05	6.51	----------	966	----------
August	71.8	1.07	3.77	----------	748	----------
September	61.6	.01	2.65	----------	923	----------
October	53.1	.34	1.75	----------	1,275	----------
Total or average	60.1	4.72	31.85	----------	1,453	----------
1923						
April	47.1	1.35	3.72	----------	1,384	----------
May	56.4	1.30	6.51	----------	1,140	----------
June	61.2	1.03	6.50	----------	701	----------
July	74.4	.08	9.79	----------	691	----------
August	70.1	.27	7.64	----------	484	----------
September	63.4	1.37	5.76	----------	541	----------
October	47.2	2.02	3.10	----------	983	----------
Total or average	60.0	7.42	43.02	----------	847	----------
1924						
April	47.3	0.03	5.69	----------	1,522	----------
May	61.6	.15	10.08	----------	1,367	----------
June	65.8	.20	[1] 9.02	----------	1,277	----------
July	73.8	.00	9.54	----------	945	----------
August	71.0	.00	8.28	----------	765	----------
September	63.5	.02	4.98	----------	877	----------
Total or average	63.8	.40	47.59	----------	1,125	----------

[1] Partly estimated.

Evaporation data at Jerome, 1916-27—Continued

Month	Mean air temperature (° F.)	Precipitation (inches)	Evaporation from U. S. Weather Bureau class A pan (inches)	Wind velocity (miles a month)		Mean relative humidity (percent)
				Top of 20-foot building	Ground surface	
1925						
June	64.3	0.70	7.87	----------	544	----------
July	76.8	.41	8.64	----------	479	----------
August	69.7	1.17	7.12	----------	683	----------
September	60.4	.35	4.16	----------	601	----------
Total or average	67.8	2.63	27.79	----------	577	----------
1926						
May	59.4	0.19	4.39	----------	964	----------
June	70.4	.03	6.87	----------	1,314	----------
July	76.0	.52	8.56	----------	1,030	----------
August	73.5	.15	8.82	----------	826	----------
September	56.2	.04	7.43	----------	1,039	----------
October	51.8	.25	4.83	----------	955	----------
Total or average	64.5	1.18	40.90	----------	1,021	----------
1927						
June	66.4	0.02	8.85	----------	898	----------
July	74.2	.00	8.42	----------	658	----------
August	70.6	.05	6.46	----------	474	----------
September	59.0	.41	6.49	----------	753	----------
Total or average	67.5	.48	29.22	----------	696	----------

Average evaporation at Jerome, 1917-27 from U. S. Weather Bureau class A evaporation pan

[Records from North Side Canal Co., Jerome]

Month	Relative humidity (percent)	Mean temperature (° F.)	Precipitation (inches)	Evaporation (inches)	Wind velocity (miles a month)	
					20 feet above ground surface	Ground surface
January	67	26.7	0.90	0.52	5,925	----------
February	73	32.2	1.06	.56	5,414	----------
March	67	38.3	.65	2.15	5,424	----------
April	57	47.2	1.03	4.26	6,974	2,227
May	47	56.4	.92	6.90	6,263	1,814
June	45	65.7	.45	7.96	4,338	1,073
July	47	73.7	.18	8.80	4,432	977
August	47	70.5	.32	7.07	4,736	808
September	57	60.4	.40	4.45	4,699	1,016
October	69	49.8	.95	2.44	4,764	1,142
November	69	38.5	1.01	1.25	6,420	2,320
December	72	28.0	.99	.70	4,706	----------
Total or average	60	49.0	8.86	47.06	5,318	1,433

PIONEER IRRIGATION DISTRICT

Evaporation and transpiration data are available for the Pioneer irrigation district, near Caldwell, in Canyon County. Pan A was a galvanized-iron tank 4 feet square and 3 feet deep, set about 2 feet in the ground in a swamp and surrounded by water from 0.3 to 0.4

foot deep. The space within the pan was planted to cattails or tules, which grew abundantly in the surrounding area. The pan was filled with water twice a week to maintain conditions similar to those in the surrounding swamp.

Pan B was of the same dimensions as pan A. It was set in the ground about 2.8 feet, in a water-logged area, and was filled with soil to the same level as the surrounding ground. In the pan were planted strips of blue grass about 8 inches wide, with intervening 8-inch strips of bare soil. The water level in the pan was maintained from 1.5 to 2 feet below the surface by means of pipes that supplied the water from beneath, so that it rose in the soil from below, as under ordinary field conditions in water-logged areas.

Pan C was a standard Weather Bureau class A evaporation pan, 4 feet in diameter and 10 inches deep, set on a platform of 2- by 4-inch planks resting on the ground.

Evaporation and transpiration in the Pioneer irrigation district, 4 miles southeast of Caldwell, Boise Valley, Idaho [1]

[Altitude 2,370 feet]

Date	Mean temperature (° F.)	Precipitation (inches)	Evaporation and transpiration from soil (inches)		Evaporation from free water surface (pan C) (inches)
			Pan A	Pan B	
1918					
June 12-30	73.6	0.25	6.01	4.23	4.60
July	73.8	.50	13.00	6.23	7.25
August	67.2	.24	14.10	4.13	4.70
September	64.8	1.67	7.20	2.91	2.83
October	54.0	1.47	3.25	1.28	1.28
The period	66.7	4.33	43.56	18.78	20.67
1919					
April 3-30	53	0.85	4.84	4.09	4.77
May	57	.00	6.70	5.60	8.27
June	67	.00	8.92	5.80	8.15
July	74	.00	14.27	6.37	8.20
August	72	.00	13.10	4.20	6.10
September	63	.37	7.86	2.38	3.83
October	45	.52	2.99	2.14	2.29
The period	62	1.74	58.68	30.58	41.71

[1] Steward, W. O., and Coffin, M. H., Experiments conducted to show the comparative evaporation from swamped areas in the Pioneer irrigation district": U. S. Bur. Reclamation unpublished report, Boise, Idaho, 1920.

MILNER

Records of evaporation have been obtained at Milner, in Twin Falls County, in sec. 29, T. 10 S., R. 21 E. The land pan at this point is a standard class A Weather Bureau pan surrounded by bare uncultivated soil. The lake pan is 4 feet in diameter and 10 inches deep, floated on a raft in Milner Lake.

Evaporation at Milner [1]

[Altitude 4,200 feet. From records of Twin Falls Canal Co.]

Month	Monthly mean temperature (° F.)	Precipitation (inches)	Evaporation (inches)		Wind movement per month (miles)
			Land	Floating pan	
1927					
[illegible]	45.0	1.02	4.53	4.02	2,790
April	52.0	2.14	6.24	5.79	2,940
May	64.8	.40	8.48	7.27	1,832
June	73.7	.00	10.60	9.20	1,631
July	68.6	.19	8.09	7.20	1,015
August	58.8	.92	5.31	5.69	1,247
September	51.2	.48	3.71	4.11	1,569
October	42.2	1.08	1.41		2,124
November					
Total or average	57.0	6.23	48.37	44.28	1,893
1928					
March 17-31	41.1	0.99	1.00		
April	44.1	.41	6.43	5.66	3,445
May	61.0	.14	8.14	7.38	2,013
June	60.2	1.43	8.34	7.27	2,241
July	72.8	.00	8.70	10.14	1,226
August	67.7	.00	9.00	10.06	1,230
September	61.9	.00	5.49		927
October	49.6	.72	2.53		
Total or average	57.3	3.69	49.63	40.51	1,847

[1] During several of the months shown in the table the lake-pan results at this station are higher than the land-pan results, owing to some undetermined cause. The land-pan results are believed to be more reliable during such periods than those from the lake pan. During the period from Dec. 1, 1927, to Mar. 17, 1928, the land pan was frozen and received precipitation of 1.65 inches, mostly in the form of snow. When the snow and ice had melted, on Mar. 17, 1928, the amount of water remaining in the pan indicated a total evaporation since Dec. 1, 1927, of 0.71 inch. This result may have been affected by snow blown in or out of the pan by winds.

STERLING

Records of evaporation were obtained at Sterling, in sec. 33, T. 4 S., R. 32 E., adjacent to the American Falls Reservoir, in Bingham County. The land pan was a standard United States Weather Bureau class A evaporation pan resting on a frame of 2- by 4-inch planks fully exposed to sun and wind and surrounded by bare ground. The lake pan was 4 feet in diameter and was placed on a small raft chained within a larger raft near the west shore of the American Falls Reservoir near Sterling.

Evaporation at Sterling [1]

[Altitude 4,400 feet]

Month	Mean temperature (° F.)	Precipitation (inches)	Evaporation (inches)	
			Land pan	Lake pan
1927				
May	50.2	1.80	7.95	
June	61.8	.28	10.95	7.73
July	69.1	.11	13.03	9.72
August	64.6	.74	9.83	7.70
September	55.2	1.43	6.65	4.78
October 1-15	47.4	.06	2.60	2.11
Total or mean	58.0	4.42	51.01	32.04
1928				
June	57.0	.78	9.90	7.37
July	68.8	.45	11.76	8.48
August	64.2	.10	11.00	7.91
September	58.0	.13	6.67	4.76
October 1-17	45.8	.47	2.40	1.58
Total or mean	58.8	1.93	41.93	30.10

[1] Newell, T. R., Segregation of water resources, American Falls Basin and American Falls Reservoir: Unpublished repts. to Committee of Nine, Water District 36, 1927-28.

AMERICAN FALLS AND MICHAUD

Records of evaporation were obtained at American Falls Michaud, in Power County. The pans at both places are stand United States Weather Bureau class A land pans, situated adjacen the American Falls Reservoir. The American Falls pan is in sec. T. 7 S., R. 31 E., and the Michaud pan is in sec. 1, T. 6 S., R. 33 Both pans are surrounded by uncultivated ground and are ab 4,400 feet above sea level.

Evaporation at American Falls and Michaud [1]

[Altitude 4,400 feet]

Month	Mean temperature (° F.)	American Falls: Precipitation (inches)	American Falls: Evaporation (inches)	Michaud: Precipitation (inches)	Michaud: Evap[oration] (inc[hes])
1928					
June	57.0	1.49	9.60	1.16	[illegible]
July	68.8	.63	11.48	.30	[illegible]
August	64.2	.25	11.04	.39	[illegible]
September	58.0	.21	7.12	.23	[illegible]
October 1-17	45.8	.50	2.60	.39	[illegible]
Total or average	58.8	3.08	41.74	2.47	[illegible]

[1] Newell, T. R., Segregation of water resources, American Falls Basin and American Falls Reser Unpublished repts. to Committee of Nine, Water District 36, 1927-23.

MUD LAKE REGION

Evaporation and transpiration records have been obtained at Mu Lake, in Jefferson County, and are included in the report on th region.[1]

SUMMARY OF EVAPORATION LOSSES

It is well known that evaporation as measured by land pans even by floating lake pans is greater than the evaporation from lar water surfaces.[2] In the following table the figures for the open-wa months are based on measured evaporation from the lake pans Milner and American Falls, multiplied by a coefficient of 90 perce to give reservoir evaporation losses, and those for the winter month on the Jerome records for evaporation from ice and snow surfaces.

Computed average evaporation and loss from large water surfaces in the Snake Ri plain

[+ indicates gain]

Month	Evaporation (inches)	Precipitation (inches)	Net gain or loss (inches)	Month	Evaporation (inches)	Precipitation (inches)	Net gain or loss (inches)
January	0.52	1.19	+0.67	August	6.91	.51	−6.[illegible]
February	.56	1.05	+.49	September	4.73	.80	−3.[illegible]
March	2.15	.91	−1.24	October	2.95	1.10	−1.[illegible]
April	4.36	1.04	−3.32	November	1.25	1.04	−.[illegible]
May	5.70	1.45	−4.25	December	.70	1.05	+.[illegible]
June	6.67	.91	−5.76				
July	6.83	.60	−7.28	The year	44.38	11.65	−32.[illegible]

[1] Stearns, H. T., Bryan, L. L., and Crandall, L., Geology and water resources of the Mud Lake region Idaho: U. S. Geol. Survey Water-Supply Paper 818 (in press).
[2] Am. Soc. Civil Eng. Trans., vol. 90, p. 266, 1927.

EFFECT OF EVAPORATION AND TRANSPIRATION ON PRECIPITATION AND STREAM FLOW

large amount of water lost by evaporation from reservoirs and ired and evaporated from the irrigated land is not necessarily a loss of water to the region. It has long been recognized that remote from the ocean receive a considerable part of their pre- tion from water lost by evaporation from the land.[3] On account topography of the Snake River drainage basin the prevailing and southwest winds carry a part of the moisture that is evap- on the Snake River Plain to the mountainous headwater n the east side of the basin. There, on account of the greater de, the moisture of the ascending winds is in part precipitated may reappear as stream flow.

TREE RINGS IN RELATION TO CLIMATE

period for which records of precipitation, stream flow, and other itions are available in the Snake River Plain is relatively so that a study was made of tree rings in an endeavor to obtain ea of climatic conditions prior to 1868, when records of precipi- were first started in Idaho.

careful studies of tree rings in their relation to climate made by Douglass [4] have demonstrated that, although there are many factors ich tend to affect the formation of these rings, precipitation has so dominant an influence that it is safe to assume that tree rings form approximate measure of the rainfall. He finds a 70 percent corre- ndence between tree-ring growth and rainfall in a dry climate, and uch closer agreement if the degree of conservation of moisture can taken into account. Although data from a considerable number trees in a given region greatly increase the accuracy of the con- ions by permitting allowance for variable factors, Douglass' work onstrates that study of even a single tree gives results of con- rable reliability provided it grows fast enough.[5]

The only native tree that has a wide distribution over the Snake ver Plain is the juniper, which occurs generally wherever the annual cipitation exceeds 13 to 14 inches. This is somewhat unfortunate the present connection, as Douglass [6] found that in Arizona juniper less satisfactory than some other kinds of trees, particularly llow pine. The native junipers in Idaho usually do not live to be re than 150 to 200 years old, especially where rooted in soil; if oted largely in lava rock they have a longer life, smaller annual ng width, more heartwood, and less tendency to decay. Several

[3] Visher, S. S., Climatic laws, p. 82, 1924.
[4] Douglass, A. E., Climatic cycles and tree growth: Carnegie Inst. Washington Pub. 289, 1919.
[5] Douglass, A. E., A method of estimating rainfall by the growth of trees, in Huntington, Ellsworth, The matic factor as illustrated in arid America: Carnegie Inst. Washington Pub. 192, p. 109, 1914.
[6] Douglass, A. E., Some aspects of the use of the annual rings of trees in climatic study: Smithsonian Inst. Ann. Rept., 1922, p. 236.

specimens were found that ranged from 350 to 600 years old, and one, in the Fifield Basin, grew for 1,600 years before finally falling victim to a farmer's need for fuel. Several pines from 300 to [illegible] years old were found near the edge of the valley, where the plains merge into the adjacent foothills.

In all 20 specimens were cut from different trees scattered over the Snake River Plain. (See pl. 8.) Pertinent data regarding the specimens follows:

1. Craters of the Moon. Limber pine. Taken from Craters of the Moon National Monument, Idaho. Cut by Harold T. Stearns in 1926. Tree dead when specimen taken, having been killed by lightning about 2 years before. Needles still hung from the branches. Grew in a crack at the edge of a recent lava flow where there would be a tendency for a little water to accumulate but for snow to linger. The rock is so permeable that rain and melting snow would soak away rapidly.

2. Massacre Rocks. Juniper. Taken 10 miles west of American Falls, Idaho, on the north side of the Snake River, near the place commonly known as "Massacre Rocks." Cut by Harold T. Stearns and W. G. Steward in the fall of 1928 from a living tree. Grew on a high lava bluff overlooking the river. The lava is partly covered with blow sand, and many juniper trees are growing here. Moisture is retained in the blow sand, which fills the lava cracks, for longer periods than it would remain, where not so much fine sand or soil is present. Center of tree decayed.

3. Black Lava. Western juniper. Taken from a point about 12 miles southwest of Idaho Falls, Idaho, in the Fifield Basin area. Cut by Steve Krolik from a living tree and hauled to his ranch in the NE¼ NE¼ sec. 26, T. 2 N., R. 36 E., in the winter of 1927 or 1928. Specimen cut from tree by W. G. Steward in the spring of 1929. Conditions surrounding the place where this tree stood are not known except that it was cut on the bare lava beds.

4. Fifield. Western juniper. Taken from the bare lava beds about 15 miles southwest of Idaho Falls, Idaho, in the Fifield Basin area. Cut by Steve Krolik from a living tree and hauled to his ranch, in the winter of 1928. Specimen sawed from tree by Harold T. Stearns, W. G. Steward, and H. G. Haight in the spring of 1929. Grew in a crack at the margin of a lava ridge. By far the oldest and best specimen of juniper known to have been taken in Idaho.

5. Woodville. Western juniper. Taken about 12 miles southwest of Idaho Falls, Idaho, in the Fifield Basin area. Cut by Steve Krolik from a dead tree and hauled to his ranch in the winter of 1927 or 1928. Specimen taken from tree by W. G. Steward in the spring of 1929. Conditions surrounding the place where this tree stood are not known except that it was cut on the bare lava beds.

6. Wapi I. Western juniper. Taken 20 miles due west of American Falls, Idaho. Cut by W. G. Steward and H. G. Haight in October 1931 from a living tree. Grew at foot of lava ridge and approximately at central western edge of a grove of junipers estimated to cover 160 acres. Would receive benefit of drifted snow. Lava very broken and permeable. Seepage would carry any rain or melting snow away rapidly. Center of tree decayed.

7. Wapi II. Western juniper. Taken 20 miles west of American Falls, Idaho. Cut by W. G. Steward and H. G. Haight in October 1931 from a living tree. This tree grew about 150 feet west of Wapi I, farther from the foot of the ridge. Center of tree decayed.

8. Wapi II. Western juniper. Unpolished.

9. Wapi III. Western juniper. Taken 20 miles west of American Falls, Idaho. Cut by W. G. Steward and H. G. Haight in October 1931 from a living tree. This tree stood 200 feet southwest of Wapi I, farther from the foot of the high ridge that encircles this grove. Conditions same as described under Wapi I. Center of tree decayed. At the time these specimens were cut, a few posts had been cut from this grove by nearby dry-farmers. Late in the fall of 1932 most of the trees in this grove had been taken for fuel.

10, 11, 12. Graham Canyon. Mountain mahogany. Taken 4 miles west of Almo, in what is called locally "Graham Canyon." Cut by W. G. Steward and H. G. Haight in November 1931 from living trees. Grew on a steep hillside of decomposed rock with a slope to the southwest. Would retain little moisture. Rings of these specimens could not be counted or measured, except for short disconnected periods, because of an overlapping or blurred growth.

13. Minidoka. Western juniper. Taken 24 miles west of American Falls, Idaho. Cut by Viggo Christofferson and Lars Larsen in December 1931 from a living tree. Grew in the center of a small grove of juniper trees on silt-covered lava bed that was sheltered by a high lava ridge.

14. Almo. Piñon. Taken in Graham Canyon 4 miles west of Almo, Idaho. Cut by H. G. Haight and H. G. Haight, Jr., in October 1932 from a living tree. Grew on the southwest slope of a steep hillside of decomposed rock. This slope is exposed to the hot summer sun, and little moisture would be retained. Rain and melting snows would no doubt run off rapidly.

15. Cedar Creek. Western juniper. Taken on the south rim of Cedar Creek, 2 miles below Cedar Creek dam and about 8 miles southwest of Roseworth, Idaho. Slightly decayed at center. Cut by H. G. Haight and Stella Perrine Haight in October 1932 from a living tree. Grew on a rock shelf 12 feet below the top of the rim of Cedar Creek Canyon, which is about 200 feet deep at this point. Partly protected and subject to some snowdrift. Otherwise in a decidedly dry location. The only tree for miles around except those in the bottom of the canyon.

16. San Jacinto I. Juniper. Taken 14 miles southeast of San Jacinto, Nev., on Trout Creek. Cut by H. G. Haight and H. G. Haight, Jr., in October 1932 from a living tree. Decayed at center. Grew on the top of a high rocky ridge overlooking Trout Creek. A large number of junipers in this vicinity. Three selected from the decidedly unfavorable location. No place to collect or hold precipitation and at the mercy of the winds and temperature.

17. San Jacinto II. Juniper. Taken 14 miles southeast of San Jacinto, Nev., on Trout Creek. Cut by H. G. Haight and H. G. Haight, Jr., in October 1932. This tree killed by fire and decayed at center. Grew on the steep side of a rocky gulch about 600 feet southeast of San Jacinto I.

18. San Jacinto III. Juniper. Taken 14 miles southeast of San Jacinto, Nev. Cut by H. G. Haight and H. G. Haight, Jr., in October 1932 from a living tree. Slightly decayed at the center. Grew in a pass between two higher ridges. Stood apart from the other trees. About three-quarters of a mile southwest of San Jacinto I and II.

19. Bliss. Sage brush. Taken about 8 miles northwest of Bliss, Idaho, near the Elmore County line. Cut by H. G. Haight in October 1932 from a living shrub. About 104 years old. This is one of several samples that have been gathered for study in the future.

20. Blue Lakes alcove. Western juniper. Taken 5 miles north of Twin Falls, Idaho, on the north side of Snake River Canyon and the south side of the Blue Lakes Cove. Cut by H. G. Haight and Stella Perrine Haight in October 1932 from a living tree. Decayed at center. Grew on a large shelf 60 feet below the main rim of the Snake River Canyon and on a sharp nose of rim rock that projects

anyon proper and the Blue Lakes Cove. This was
this dry rocky shelf. Conditions are anything but
ady.

instructed by W. G. Steward and H. G. H
the ring widths of all the specimens. The diff
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revolutions.

lvanometer, the total ring widths were measu
iod for a selected number of specimens and
plate 8. The specimens were selected for clea
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of the Fifield juniper (pl. 8, specimen 4),
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t 100 years. Several, particularly specimens
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13 and 14 were excluded because their grow
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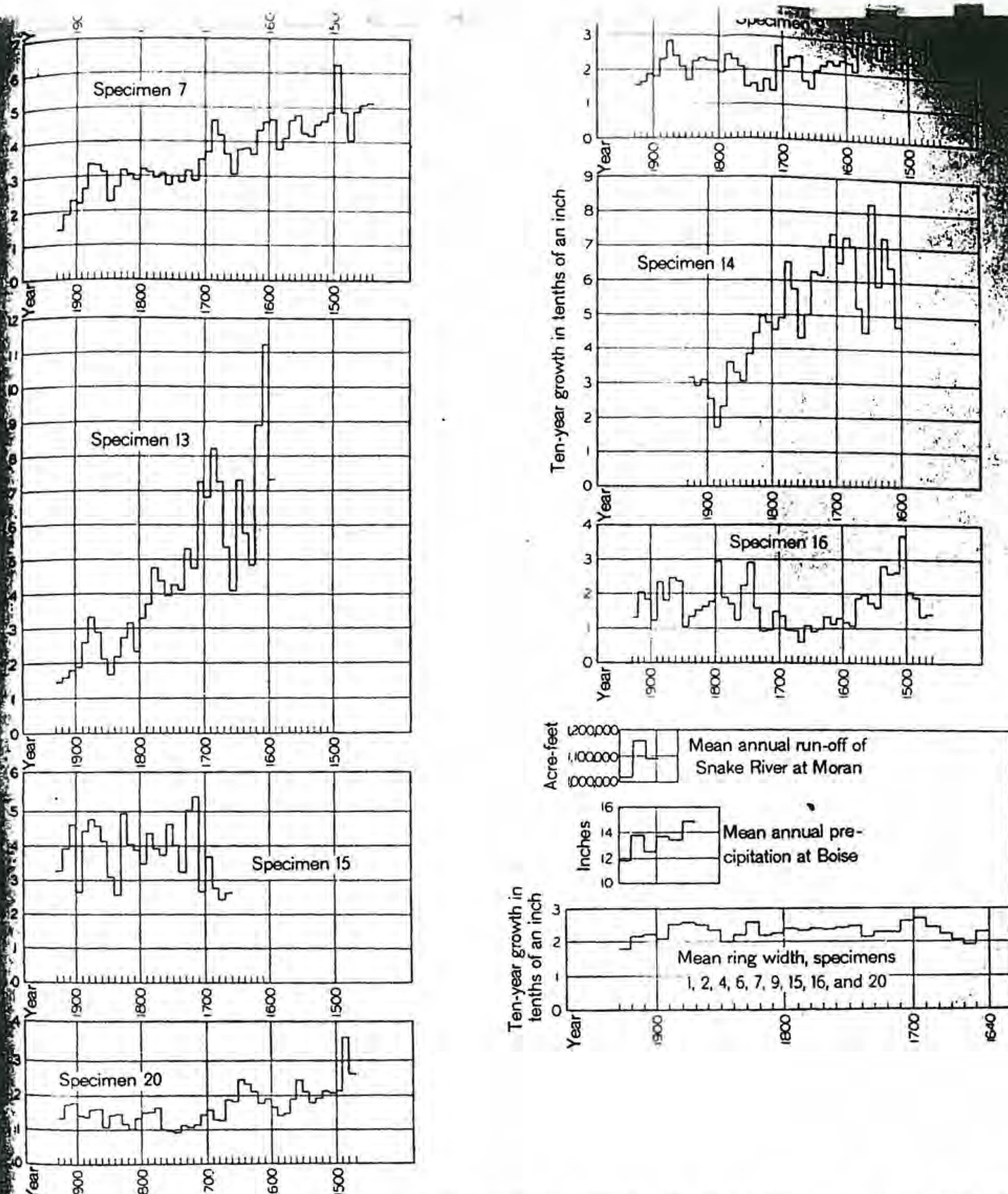
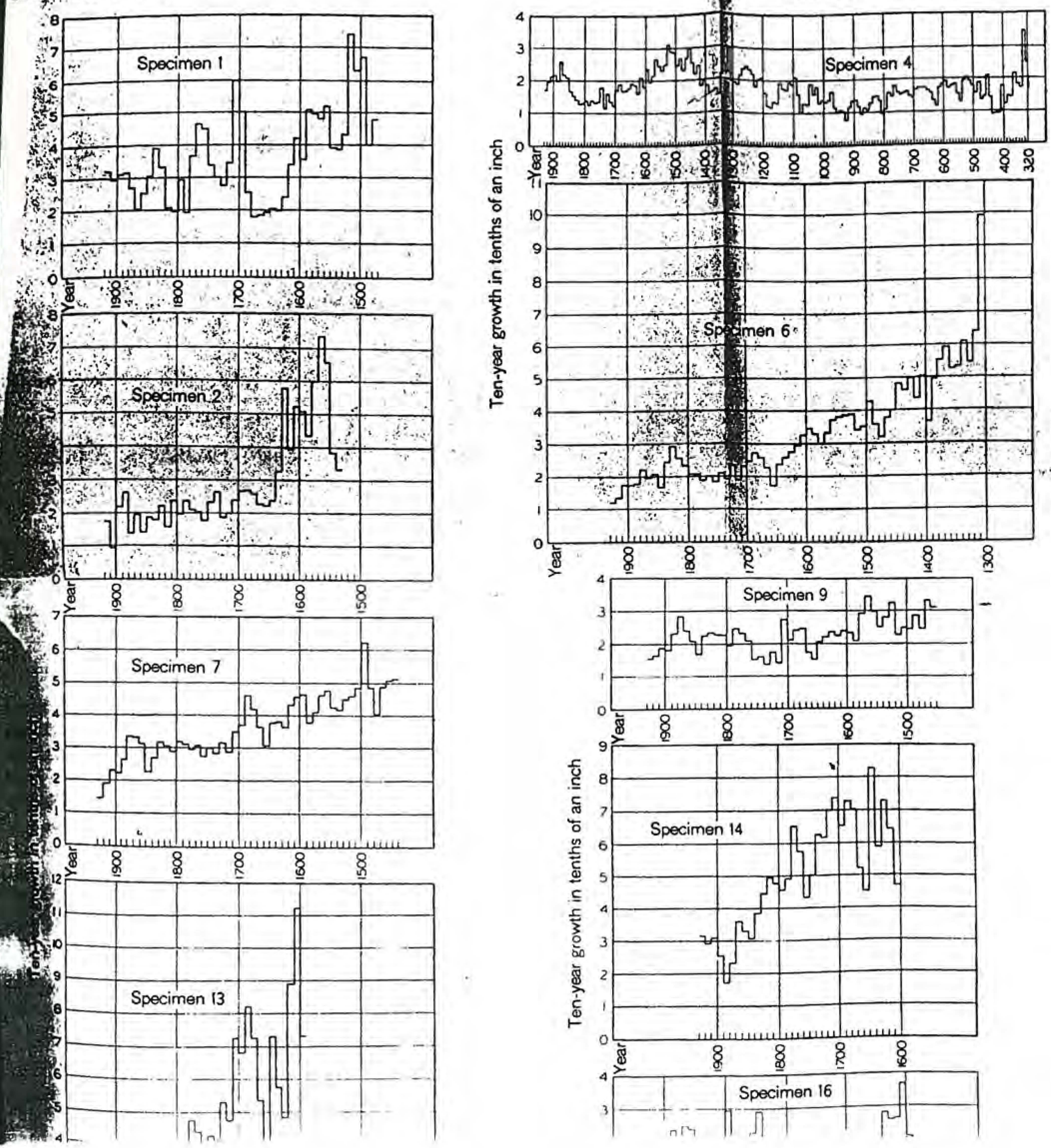
ie to early age growth of some of the specime
cipitation at Boise, the only station adjacent
ng-time precipitation record, and the run-off



GRAPH SHOWING WIDTH OF RINGS IN 11 TREES FROM THE SNAKE RIVER PLAIN AND A GRAPH OF THE AVERAGE RING WIDTH OF 9 TREES IN COMPARISON WITH PRECIPITATION AT BOISE AND THE FLOW OF SNAKE RIVER AT MORAN.



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Snake River at Moran, above irrigation diversions, for years of available records. The precipitation and run-off trends are in substantial agreement. The precipitation record and the mean ring-width record both show a general downward trend from 1870 to date, although the two records do not always show the same relation between adjacent decades.

According to the mean ring-width diagram (pl. 8), the decade 1920–30 was less favorable than any similar period during the last 50 years, although many of the individual tree diagrams (pl. 8) show decades less favorable than that of 1920–30.

SOIL

Nearly half a million acres of the Snake River Plain consists of bare, broken, and fissured lava with practically no soil covering, and a still larger area consists of lava with a scant covering of wind-blown soil that ranges in depth from only a few inches to a foot. Considerable portions of the region, however, are underlain by soils of good depth, in some places 6 to 8 feet.

The soil that covers the lava plain between the river and the mountains on the north is a fine loess, consisting essentially of minute particles of quartz with slight amounts of calcium carbonate as a cementing material. The loess originated chiefly as dust blown by the prevailing westerly winds from the lake beds to the west, but some of the dust was derived from the alluvium of tributary streams and from volcanic ejecta. Its slow rate of accumulation is indicated by the fact that the most recent lava flows in the region, probably not less than 1,000 years old, are still free of soil. Only the cracks in their surface show evidence of some desposits of wind-blown material.

As a rule the soils in the region are fertile and are very productive when irrigated. Several studies of the soils in the region have been published.[7]

Along the borders of the plain, near the mouths of tributary streams, and along the Snake River, occur extensive gravel deposits which yield considerable road-surfacing material and gravel for concrete. In this gravel, particularly in the section of the main river channel from Blackfoot to the mouth of the Big Wood River, near Bliss, appreciable

[7] Russell, I. C., Geology and water resources of the Snake River Plains of Idaho: U. S. Geol. Survey Bull. [illegible], pp. 136–137, 1902.

Mendon, W. E., Soil survey of the Blackfoot area, Idaho: U. S. Dept. Agr., Bur. Soils, Field Operations, [illegible], pp. 1027–1041, 1904.

Lewis, H. G., and Peterson, P. P., Soil survey of the Portneuf area, Idaho: Idem, 1918, pp. 1–52, 1921.

Youngs, F. O., Baldwin, Mark, Kern, A. J., and McDole, G. R., Soil survey of Minidoka area, Idaho: Idem, 1923, pp. 859–902, 1928.

Baldwin, Mark, and Youngs, F. O., Soil survey of the Twin Falls area, Idaho: Idem, 1921, pp. 1367–1394, [illegible].

Mansfield, G. R., Geography, geology, and mineral resources of the Fort Hall Indian Reservation, Idaho: U. S. Geol. Survey Bull. 713, p. 118, 1920.

Poulson, E. N., and Thompson, J. A., Soil survey of the Jerome area, Idaho: U. S. Dept. Agr., Bur. Chemistry and Soils, ser. 1927, no. 16.

quantities of gold are found, and extensive placer-mining operations were carried on in former years. The gold is so fine, however, that its recovery proved difficult, and the placers were abandoned. In recent years, however, attempts to obtain gold from these placers have been renewed. Above American Falls the irrigated lands on both sides of the river have soils that are mainly of alluvial origin.

South of the Snake River, from a point near Pocatello to a point beyond King Hill, occur extensive lake beds, in places more than 1,000 feet thick. Except in a few favorable localities the benches underlain by these lake beds are not readily susceptible of irrigation because of their topography and height above the river.

Residual soils formed by the decay of the underlying rocks occur to some extent in the mountains bordering the Snake River Plain, but the basalt that underlies most of the plain is relatively so recent in origin that it has not disintegrated sufficiently to make any appreciable contribution to the soils of the region. The basalt eroded from the Snake River Canyon has contributed only in minor degree to the alluvial deposits along the river except at the downstream sides of former lava dams as in Hagerman Valley or near King Hill.

In a few areas shifting material consisting mostly of quartz sand forms the surface soil. Most prominent is the sand-dune area between the Birch Creek Sink and the Big Bend Ridge. In this area migrating sand hills attain heights of 100 feet or more and cover many square miles. From Wendell southward to the Snake River Canyon the soil is mainly silt or fine sand, on the whole well adapted to cultivation under irrigation. There are small areas of shifting "blow sand", not so adapted. Similar areas of blow sand occur locally in other areas. From King Hill eastward isolated sandy knolls rise 10 feet or more above the plain and support a sufficient cover of vegetation to prevent shifting of the sand.

CROPS AND VEGETATION

Irrigated lands on the Snake River Plain produce a wide range of diversified crops common to the intermountain region, among which the staples are alfalfa and other hay crops, wheat, oats, barley, potatoes, corn, beans, sugar beets, garden vegetables, and some tree and bush fruits. The largest acreage is in alfalfa. Of the principal crops potatoes have yielded the highest average acre value. Much of the hay and grain crop is used locally for stock feed. Crops entering into interstate commerce include potatoes, onions, beans, clover, small grains, alfalfa seed, peas, and head lettuce. Along the borders of the plain and in the tributary valleys up to the zone where frosts are likely to occur in any month of the year, irrigated areas are devoted largely to the growing of alfalfa, native grasses, small grains, and garden vegetables.

Much of the uncultivated area of the plain supports considerable native vegetation, some of which is valuable for grazing. Sagebrush (*Artemisia tridentata*) predominates and lends a dusty-green hue to the landscape. At the lower limits of rainfall the moisture naturally available for plant growth is so little that practically desert conditions prevail, and the natural growth includes transition desert shrubs, of which rabbitbrush is the most conspicuous. At the higher limits of rainfall a considerable undergrowth of grass is associated with the sage. Where the rainfall is from 15 to 25 inches a year the natural vegetation consists principally of the Idaho and wheat bunch grass and shrubs that furnish excellent spring, summer, and fall range. Grain crops, principally wheat, have been raised without irrigation on large areas of this type.

GEOLOGY AND WATER-BEARING PROPERTIES OF THE ROCKS

SUMMARY

The Snake River Plain is commonly regarded as a structural depression that has been filled mainly by Pliocene and later basalt and kindred volcanic rocks which are locally intermingled with sediments. Subsidence continued intermittently until Pleistocene time, so that the older rocks filling the depression are down-warped in varying degree and locally broken by faults. The basalts covering the surface of the plain are nearly all Pleistocene and Recent and they are practically undisturbed. This great mass of volcanic rock, about 95 percent of which is in the area described in this report, is termed the "Snake River basalt."[8] In numerous places on the borders of the plain rhyolitic flows and pyroclastic and related rocks emerge from beneath the basalt. Locally there is evidence that similar rocks extend well under the plain. Estimates as to the age of the rhyolitic rocks by different authors and in different localities range from early Pliocene to late Oligocene. This wide range in age assignment results in part from inadequate data. It may well be, however, that exposures in different parts of this large region, even though broadly similar in lithology and stratigraphic relations, may record eruptions at materially different times. Beneath the Tertiary strata in the nearby mountains lies a complex aggregate of sedimentary rocks of which the oldest is generally of pre-Cambrian age, and the youngest is either Carboniferous or Mesozoic. The youngest are extensively exposed in the mountains bordering the plain. These rocks are locally interbedded with and intruded by igneous rocks of several different kinds and ages.

[8] Russell, I. C., op. cit., p. 59.

Volcanism and deformation have thus played dominant parts in the development of the present Snake River Plain, although locally stream erosion by the Snake River and its tributaries, as in the Snake River Canyon, and wind action, as in the Mud Lake region, have had noticeable effects. These diverse processes, the results of which can as yet be evaluated in detail only in certain small areas, have, in a general way, produced a great basin floored with relatively impermeable rocks and filled with a variety of materials, many of which are readily permeated by ground water. The many streams issuing from the mountains and the Snake River itself provide a large supply of water for the filling of the partly enclosed underground reservoir thus created. As volcanic processes are inherently catastrophic, intermittent, and irregular, their results in this region have introduced many complexities into the behavior of the ground water. Consequently, an especially thorough understanding of geologic details is required in connection with the study of problems of water supply. Over large areas of the Snake River Plain the lack of stream incisions renders it impossible to examine any but the most recently formed rocks, so that many local details are undecipherable. It so happens, however, that most such areas are of relatively small agricultural value, and large stretches of them are unsuited for cultivation of any kind, so that the incompleteness of knowledge in regard to them is of comparatively minor economic importance.

The salient features of the geology of the Snake River Plain are shown in plate 4. This map is based primarily on data gathered by H. T. Stearns during the present study and related investigations. For areas not covered in the course of these studies, mainly along the mountain border, other data, principally in published reports of the United States Geological Survey and the Idaho Bureau of Mines and Geology, have been utilized. The mapping of the northeastern portion of the area shown in plate 4 is based on a geologic map of the Mud Lake region, one of the parts of the plain studied in especial detail, to be published elsewhere.[9] The geology along the canyon of the Snake River from a point below Blackfoot to King Hill was mapped in detail, and those sections of the canyon along which the data obtained are too complex to be adequately portrayed in plate 4 are shown on a larger scale in plates 5 and 6.

The first of the two following tables is intended to aid in grasping the outstanding features of the stratigraphy of the Snake River Plain. The second table summarizes the stratigraphy along the part of the canyon of the Snake River that was studied in detail.

[9] Stearns, H. T., Bryan, L. L., and Crandall, Lynn, Geology and water resources of the Mud Lake region, Idaho: U. S. Geol. Survey Water-Supply Paper 818 (in press).

Generalized stratigraphic section of the Snake River Plain east of King Hill, Idaho

Geologic age	Geologic unit	General character	Water-bearing characteristics
	Dune sand and loess (not distinguished in mapping from the rock it covers).	Light-colored wind-blown sand, consisting chiefly of round quartz grains and some particles of ash. The loess is somewhat intermingled with soil. Dunes are rare except locally, as in the area east of Mud Lake, but loess covers most of the Snake River Plain to depths of about 10 feet or less. Still in process of formation.	Generally above the water table. Where the loess lies in the zone of saturation, it is so fine-grained as to be relatively impermeable. Extensive deposits in such situations commonly act as confining or perching beds. Dune sand in the zone of saturation carries water but generally causes trouble in drilling by running into the well.
	Landslides and talus.	The landslides form hummocky topography, mainly in canyons, and the talus forms aprons at the foot of cliffs. Both consist largely of jumbled blocks of rock. They are mapped only along the canyon of the Snake River.	Unimportant with relation to water because of the small size of individual masses.
	Younger alluvium (not separated from older alluvium on the maps).	Sand and gravel derived from the erosion of preexisting rock and alluvial deposits, confined to the small recent flood plains along present stream channels. Locally contains unfossilized bones of mammoths and extinct bison.	Commonly contains considerable water at shallow depths, but because it occupies small areas it is of little value as a source of water supply.
	Black basalt and associated fragmental deposits.	Fresh black basaltic flows and fragmental deposits associated with them. The flows consist of about equal amounts of aa and pahoehoe and are free from covering of soil or loess. The lava in the Craters of the Moon National Monument is the youngest of all.	All these recent lavas lie above the water table. They are very permeable and serve as intake areas for ground-water recharge. Locally they contain pools of water in caves and crevices, derived from melting ice, which are valuable as watering places in the desert.
	Local		
	Older alluvium (not differentiated from younger alluvium in mapping).	Floors most of the tributary valleys as well as the canyon of the Snake River. Consists of sand, gravel, and locally boulders. Differs from the younger alluvium chiefly in lying topographically higher on terraces. In numerous places contains bones of elephants, camels, sloths, and bison, as yet scarcely fossilized.	A good water-bearer wherever the topographic situation is suitable. Commonly contains water at shallow depths.
Pleistocene.	Lake beds.	Largely clay and silty clay. Locally sandy where stream deposits are included. In part at least as young as the older alluvium, but in part interfingers with Pleistocene basalt, mostly made up of flows high in the sequence. Locally interbedded with basalt and tuff. Distinguished only near Terreton, Market Lake, and American Falls.	Yield water to wells only in the local sandy parts, mostly nearly impermeable. Intercalated basalt flows are permeable and locally cause springs.

Generalized stratigraphic section of the Snake River Plain east of King Hill, Idaho—Continued

Geologic age	Geologic unit	General character	Water-bearing characteristics
Pleistocene—Con.	Pre-Wisconsin glacial deposits.	The only deposits of glacial origin mapped within the region are those near Ashton. Outwash plains occur near Island Park and in Camas Meadows. These consist of bedded sand and gravel, commonly overlain by gumbo clay.	Except where clayey yield water copiously to shallow wells.
Late Pleistocene and possibly locally early Recent. In part contemporaneous with Pleistocene sediments listed above.	Younger basalt flows and related cones, older than the black lava listed above (not everywhere distinguished from the older flows).	Mainly basaltic lava. Flows are locally mantled by and interbedded with loess and soil. Many of the buttes on the plain, some of which are composed of cinders, are the source of these flows. Along the canyon of Snake River several members have been distinguished.	Highly permeable because of the presence of numerous openings of diverse kinds.
	Local.		
	Tuff.	Tuff and unconsolidated lapilli interbedded with basalt. Mapped only in and near Menan Buttes, western Madison County.	Yields water satisfactorily to wells where suitably situated.
	Local.		
Earliest Pleistocene.	Basalt flows.	Blue and gray basalt, with and without feldspar and olivine phenocrysts. Dominantly pahoehoe; contains numerous caves. Thin and restricted loess and clay beds locally intercalated in the basalt. Most of the flows originate from definite cones north of the Snake River, and some fill old tributaries of the river.	Highly permeable and constitute valuable aquifers. Almost without exception water is present in them, the depth depending on the position of intercalated or underlying impermeable beds or other local conditions.
	Unconformity.		
Pliocene and Pliocene(?).	Lake beds and other sediments.	Sedimentary beds at several horizons, older than the Pleistocene basalts. Mainly clay, silt, and sand, with local gravel deposits. In part consist of reworked tuff. A little basalt and tuff intercalated locally. Some of the beds contain Pliocene vertebrate fossils. The age of others is less precisely fixed by their relations to other formations. Mapped near Medicine Lodge Creek, in Clark County, and at several places along the canyon of the Snake River, especially in Hagerman Valley.	The fine-grained beds, which predominate, are relatively impermeable, but the gravel and intercalated basalt constitute aquifers.
Pliocene.	Basalt and related volcanic rocks.	Mainly blue, black, brown, and greenish weathered basalt. Some tuff and other pyroclastic rocks and locally a little intercalated clay and gravel.	Much of the basalt and coarser pyroclastic rocks are permeable and constitute fair aquifers.
	Unconformity.		
Miocene(?).	Intrusive rocks.	Granite and related porphyrites, which cut the Challis volcanic rocks in Blaine and Butte Counties and may be the sources of some of the rhyolitic flows.	Not so situated as to have any appreciable effect on the ground water of the Snake River Plain.

Generalized stratigraphic section of the Snake River Plain east of King Hill, Idaho—Continued

Geologic age	Geologic unit	General character	Water-bearing characteristics
Miocene(?)—Con.	Flows and related rocks.	Include the so-called "rhyolitic rocks" and also the Challis volcanics (Oligocene?) where that formation has been traced into the regions here discussed. Mainly latitic, rhyolitic, and andesitic flows, with large amounts of pyroclastic material commonly welded and locally basalt. Within this region the age is not positively fixed, except that the beds are everywhere older than the contiguous basalt flows of the Snake River Plain.	Not very permeable, except where fractured.
	Great unconformity.		
Pre-Miocene rocks (early Tertiary?, Mesozoic, Paleozoic, and pre-Cambrian?).		The sedimentary and intrusive rocks that compose the mountains and doubtless underlie the Snake River Plain below the Tertiary volcanic rocks.	Relatively impermeable, except where fractured. Form the containing walls of the ground-water reservoirs of the Snake River Plain.

Generalized stratigraphic section of the rocks along the Snake River between King Hill and Blackfoot, Idaho [1]

Geologic age	Formation	Thickness (feet)	General character	Water-bearing characteristics
	Wendell Grade basalt.	25±	A dense black olivine pahoehoe basalt with a soil cover too thin for farming. It covers many square miles near Wendell and is later than the Snake River Canyon, because three branches of this flow cascaded over the rim at Hagerman Valley.	Very permeable but lies above the zone of saturation.
	Local.			
	Minidoka basalt.	30±	A vesicular blue pahoehoe basalt containing tiny crystals of olivine and feldspar and thinly covered with loess. It overlies alluvium at Minidoka Dam and crops out for 5 miles along the north shore of Lake Walcott Reservoir. It displaced the Snake River to the south.	Very permeable and causes leakage from Lake Walcott Reservoir.
Pleistocene.	Local.			
	Sand Springs basalt.	500±	A prominent pahoehoe lava flow, which enters the Snake River Canyon near Sand Springs. From this place it flowed downstream for at least 14 miles and is now preserved as lava benches along the river. It fills a former deep canyon of the Snake River from Paul to Sand Springs. (See pl. 9.) On the upstream side of this lava dam were deposited the Burley Lake beds, which underlie the Minidoka project and are overlain by the Minidoka basalt.	Very permeable and serves as a channel for the movement of ground water under the North Side Twin Falls tract. Many of the large springs are fed by it. Below Thousand Springs water is found in the bottom of the basalt except where it forms isolated small benches along the Snake River. These benches do not contain water. The Burley Lake beds are in part permeable, but water does not move through them fast enough to prevent drainage problems on the Minidoka project.
	Local.			

[1] Each formation along Snake River is underlain by a local erosional unconformity but superposition in the table does not necessarily mean superposition in the field.

Detailed stratigraphic section of the rocks along the Snake River between King Hill and Blackfoot, Idaho—Continued

Geologic age	Formation	Thickness (feet)	General character	Water-bearing characteristics
Pleistocene—Continued.	Bliss volcanics.	100±	Form dikes, a cone, and a flow. The dikes are dense, narrow, and short, and the cone is composed of comminuted basaltic glass and black cinders. Pillow structure and fragmental glassy porphyritic lava characterize the flow. Phenocrysts of olivine and feldspar occur in a glassy brown groundmass free from pyroxene. It crops out at numerous places for 7½ miles downstream in the Snake River Canyon below Malad River.	Sullivan, Bliss, and [illegible] unnamed springs [illegible] from this basalt. It [illegible] permeable but is [illegible] locally a water bearer [illegible] cause it occurs as [illegible] patches above the [illegible] table in most places [illegible] even these springs pro[illegible] have their source [illegible] Madson basalt.
	—Local.—			
	McKinney basalt.	500±	A decidedly porphyritic grayish-black pahoehoe basalt containing phenocrysts of fresh green olivine and long laths of plagioclase. It covers an extensive area north of Bliss and displaced parts of the Big Wood and Snake Rivers between Bliss and King Hill.	Except where it fills a[illegible] cient canyon of the [illegible] River it lies above the [illegible] of saturation, and all [illegible] cations point to a [illegible] small amount of [illegible] water, even in the [illegible] occupying the buried [illegible] ley. This is not due [illegible] of permeability but [illegible] adequate intake area.
	—Local.—			
	Thousand Springs basalt.	100±	An olivine basalt occupying a buried canyon of the Snake River north of the present one and shallower. It is filled with tubes, and open contacts occur between successive layers.	This basalt is very perm[illegible] and is the source of [illegible] Springs, Thousand Sp[illegible] and all other springs [illegible] stream to Riley Spri[illegible]
	—Local.—			
	Malad basalt.	400±	A black basalt containing feldspar, olivine, and pyroxene. It fills an ancient canyon of the Snake River north of the present one. Sufficient soil rests on its surface to make good farm land.	A very permeable b[illegible] The source of M[illegible] Springs and of the sp[illegible] that feed Billingsly C[illegible] Water occurs in it e[illegible] where from 50 to 400 [illegible] below the surface.
	—Local.—			
	Madson basalt.	200±	An extremely fine grained black basalt in places very evenly jointed. It fills a former canyon either of Snake River or Big Wood River carved in the Hagerman lake beds.	Too tightly jointed in [illegible] places to be a prolific w[illegible] bearer but at the base [illegible] open and permeable. [illegible] probably the source [illegible] Steele, Madson, Sulli[illegible] and Bliss Springs.
	—Local.—			
	American Falls lake beds.	150±	Buff even-bedded clay and sand, only partly consolidated. Near the top occur local pebbly lenses, and about 60 feet below the top there is a 6-foot bed of laminated basic tuff. The deposits change northeastward into coarser sediments. Between American Falls and Gibson Butte along the north side of the Snake River aphanitic gray pahoehoe about 10 feet thick is interstratified with the sediments.	The finer-grained beds [illegible] relatively imperme[illegible] but near Springfield a [illegible] ing well yields a small [illegible] ply of water from [illegible] coarser beds. The in[illegible] calated basalt memb[illegible] the source of nume[illegible] large springs on the Sp[illegible] field-Aberdeen tract.
	—Local.—			
	Cedar Butte basalt.	200±	An aphanitic blue pahoehoe basalt with fresh green olivine phenocrysts. It dammed and displaced the Snake River near Massacre Rocks and now forms imposing cliffs along the Snake River and Lake Channel. Its surface supports considerable vegetation.	Permeable but in most p[illegible] lies above the zone of [illegible] ration. However, [illegible] Lake Channel springs [illegible] from it, indicating [illegible] water occurs in its lo[illegible] part, or in general abo[illegible] feet below the surface.
	—Local.—			

[illegible]ailed stratigraphic section of the rocks along the Snake River between King Hill and Blackfoot, Idaho—Continued

Geologic age	Formation	Thickness (feet)	General character	Water-bearing characteristics
[illegible]ocene—[illegible]inued.	Early undifferentiated basalts.	500±	Blue and gray basalt flows, generally containing phenocrysts of olivine and feldspar and covering most of the Snake River Plain and forming a considerable part of the Snake River Canyon. Few individual beds exceed 50 feet in thickness. They contain numerous caves and are predominantly pahoehoe. A few thin and local loess beds are found intercalated in the series. The undifferentiated basalt shown in plates 5 and 6 originated chiefly from cones on the south side of the Snake River and in places fills ancient tributaries of the river.	These flows are valuable aquifers of southern Idaho. Almost without exception water is found in them at different depths, depending upon the depth to the intercalated or underlying impermeable beds.
	Erosional unconformity.			
[illegible]pper Plio-[illegible]cene.	Hagerman lake beds.	600±	Nearly level and partly consolidated buff to white clay and silt beds which in most places contain a gravel cap 20 feet thick and in some places pebbly lenses and sandy beds near the top. Along a considerable part of the Snake River Canyon between Salmon Falls Creek and King Hill there is a thin intercalated basalt flow 200 feet below the top, or a basaltic tuff bed at about the same altitude. Near the mouth of Salmon Falls Creek a bed of diatomite 20 feet thick occurs only a little above the tuff bed. The lake beds contain in places well-fossilized bones of mammals and numerous fresh-water shells.	The sedimentary parts of the series are impermeable and poor aquifers, but the intercalated basalt contains water and gives rise to landslides, segments of it sliding on the saturated clay beneath it during wet periods.
	Banbury volcanics.	300±	Extensive outcrops of this basalt occur along the canyon walls between Salmon Falls Creek and Blue Lakes. It is dark brown but commonly has a greenish hue. Its color is due largely to weathering, and even in a hand specimen it is easily distinguished by its iron stains from any younger basalts. The flows are massive and continuous. Closely associated with it is the tuff of the Riverside Ferry cone. At one place a bed of pebbly alluvium containing a fossil camel bone was found interstratified with it.	A relatively poor water bearer, but numerous seeps have issued from it since irrigation started on some of the land above it. In some places it forms the basement of the great underground reservoir of the Snake River Plain.
	Unconformity—			
[illegible]Middle (?) [illegible]ocene.	Raft lake beds.	200±	Partly consolidated buff-colored beds of clay, silt, and sand, generally in lenticular form and in places filled with concretions. Weather to a brown sandy loam and are eroded into rounded rolling hills except along the Snake River, where they form a terrace.	Contains water in small quantities except where it forms benches above the water table along the Snake River.
	Rockland Valley basalt.	250±	Series of even-bedded blue and black basalts that show considerable weathering. Intercalated with them is at least one bed of clay 15 feet thick. All are tilted about 4° NW.	Permeable but has not been studied sufficiently to determine its water-bearing value.
	Unconformity—			

Detailed stratigraphic section of the rocks along the Snake River between Kin[illegible] and Blackfoot, Idaho—Continued

Geologic age	Formation	Thickness (feet)	General character	Water-bearing charac[illegible]
Pliocene (?) (lower Pliocene?).	Massacre volcanics.		Massacre Rocks is a neck or feeder of a former large cone composed chiefly of pyroclastic debris and a few lava flows. The cindery tuff is exposed for a distance of 11 miles upstream from Massacre Rocks along the Snake River but for only 2 miles downstream. It is well consolidated and is red to brown. In places it contains angular fragments of the underlying older formations. Faulting has greatly disturbed this series. There is one persistent fine-grained blue basalt flow 23 feet thick at the base of the series underlain by 6 inches to 2 feet of partly baked loess soil.	The coarser tuff and th[illegible] are permeable and [illegible] less waterbearing. [illegible] and Mary Fra[illegible] Springs issue fro[illegible] basalt member.
	—Local.—			
	Eagle Rock tuff.	35±	Well-defined sequence of rhyolitic tuffs crops out at different places along the Snake River between American Falls and Massacre Rocks. The sequence from top to bottom consists of red felsitic welded pumice 6 inches thick, welded obsidian tuff 21 feet thick containing spherulites and lithophysae; black comminuted glass only partly consolidated at the bottom, grading upward into a hardened dull obsidian tuff 4½ feet thick; banded gray to white tuff of fine texture 9 feet thick, in places pisolitic. The whole was evidently laid down in rapid succession by a series of explosions from the same volcano.	Only slightly permeab[illegible] since the constructio[illegible] American Falls Rese[illegible] small amounts of wate[illegible] found seeping th[illegible] them.
	Neeley lake beds.	100±	Flesh-colored to brown lacustrine deposits consisting partly of reworked tuffs. Evenly bedded and commonly sandy in texture. Their base is not exposed.	Relatively impermeabl[illegible]
	Unconformity—			
Miocene (?) (upper Miocene?).	Pillar Falls mud flow.	40±	Red and black andesitic waterworn pebbles and boulders intermingled with compact ash and soil. The top few inches is baked by the overlying basalt. Fills the irregularities in the underlying andesite.	Only slightly permeable[illegible]
	Erosional unconformity			
	Shoshone Falls andesite.	200±	Black and purple glassy porphyritic columnar jointed or platy andesite; weathers pinkish brown. On it is a dark soil about 1 foot thick.	Impermeable.
	Unconformity—			
Paleozoic.	Carboniferous.	Not measured.	Isolated outcrops of blue and buff compact limestone.	Contains water in joints [illegible] crevices but has no [illegible] defined water table.

ROCK FORMATIONS AND THEIR WATER-BEARING PROPERTI[illegible]

PRE-MIOCENE ROCKS

The pre-Miocene rocks in the mountains bordering the Snake Riv[illegible] Plain include a great variety of sedimentary and igneous rocks. The[illegible] are alike in being thoroughly consolidated and, in comparison wi[illegible] [illegible] of the younger rocks of the plain, poorly permeable. Except [illegible] faults and other fractures, they appear everywhere to be unable [illegible] transmit water with sufficient readiness to have any material [illegible]ring on problems of water supply in the Snake River Plain.

MIOCENE (?) ROCKS

GENERAL CHARACTER

[illegible]n the mountains on both sides of the Snake River Plain there are [illegible]ge quantities of lava and associated pyroclastic rocks, for the most [illegible]rt materially older and more silicic than the basaltic flows that [illegible]derlie most of the plain. Part of the rocks of this character north [illegible] the plain belong to the Challis volcanics.[10] In most places the [illegible]allis volcanics are dominantly latitic and andesitic, with basalt [illegible]lly abundant and considerable rhyolite high in the formation. In [illegible]ral places clastic beds composed dominantly of tuff are associated [illegible]h the flows and locally make up a large part of the formation. The [illegible] rocks of this character distinguished on plate 4 are those near [illegible]head of Pass Creek, in the Lost River Range. The small mass [illegible] may have been brought to its present relatively low altitude by [illegible]lting. Most similar beds are beyond the area mapped. The total [illegible]ickness of the formation is commonly several thousand feet and [illegible]ally over a mile. Fossils from beds high in the sequence in Custer [illegible]nd Lemhi Counties, according to unpublished studies by R. W. Brown, indicate that the Challis volcanics here are of late Oligocene [illegible] early Miocene age. This tentative assignment accords with the [illegible]ratigraphy and structure of the formation in Custer, Blaine, and [illegible]emhi Counties and adjacent areas.[11]

[illegible]Along the borders of the Snake River Plain and in scattered ex[illegible]posures within its area, there are large quantities of dominantly [illegible]licic volcanic rocks, in part belonging to and in part probably younger [illegible]han the Challis volcanics, which may for convenience be grouped as [illegible]iocene (?) rhyolitic rocks and are thus shown on plate 4. Most [illegible]eologists who have described portions of the region have loosely [illegible]eferred to these rocks as "rhyolite." Some have applied such local [illegible]esignations as "Mount Bennett rhyolite",[12] "Owyhee rhyolite",[13] [illegible]nd "Tertiary late lava" [14] to portions of the group. Although a [illegible]onsiderable part of this lava is correctly termed rhyolite much of it

[10] Ross, C. P., Geology and ore deposits of the Seafoam, Alder Creek, Little Smoky, and Willow Creek mining districts, Custer and Camas Counties, Idaho: Idaho Bur. Mines and Geology Pamph. 33, p. 2, [illegible]ar. 1930.

[11] Ross, C. P., The geology and ore deposits of south-central Idaho: U. S. Geol. Survey Prof. Paper — [illegible]n preparation).

[12] Russell, I. C., op. cit., p. 42. Piper, A. M., Ground water for irrigation on Camas Prairie, Camas and [illegible]lmore Counties, Idaho: Idaho Bur. Mines and Geology Pamph. 15, p. 8, [1926].

[13] Kirkham, V. R. D., Igneous geology of southwestern Idaho: Jour. Geology, vol. 39, no. 6, pp. 564–591, [illegible]931.

[14] Kirkham, V. R. D., A geologic reconnaissance of Clark and Jefferson and parts of Butte, Custer, French, Lemhi, and Madison Counties, Idaho: Idaho Bur. Mines and Geology, Pamph. 19, pp. 33–38, 1927.

is actually quartz latite [15] or has even more calcic composition and differs little from that of many flows in the Challis volcanics where that formation was originally described. Few of the many isolated exposures of the rhyolitic rocks in and bordering the Snake River Plain exhibit direct evidence as to their age other than the fact that they are all probably older than the Snake River basalt, the main bulk of which is regarded as Pliocene or later. In the few places in which the Challis volcanics have been traced to the vicinity of the plain it has been found that the rhyolitic and associated beds belong to the upper part of that formation.[16] On the other hand it is probable that some of the rhyolitic flows are as young as Pliocene, although for the region mapped on plate 4 evidence in support of this suggestion is at present scanty.[17] There is reason to believe that some, at least, of the rhyolite southeast of the Snake River may be as young as Pliocene. It appears from Mansfield's descriptions [18] that this rhyolite has different relations and is probably much younger than the Challis volcanics. It may be that some of the rhyolitic rocks farther north are similar in relations and age. In southern and southwestern Idaho the rhyolitic rocks are tentatively regarded in the most recent reports [19] as Miocene or Pliocene.

In relation to ground-water problems the different rhyolitic and related rocks are mainly of interest in elucidating structure. Their presence at any locality is evidence that the base of the basalt flows of the Snake River Plain has been reached. The rocks themselves, except where much fractured, are not readily permeable and in few places are so situated that water for irrigation has been sought in them. In the region south of the canyon of the Snake River, where the rocks dip northward and contain intercalated tuffaceous beds, they locally also contain water under artesian pressure.

In areas studied during the present investigation nearly all the nonbasaltic volcanic rocks are included in the Miocene (?) rhyolitic rocks, as the term is here used. The basalt of Big Southern and West Twin Buttes has geologic relations akin to those of the Miocene (?) rhyolitic rocks and consequently may be grouped with them. On the other hand, the rhyolitic Eagle Rock tuff is regarded as younger than most of the Miocene (?) rocks. Available data regarding each

[15] Kirkham, V. R. D., op. cit. (Pamph. 19). Anderson, A. L., Geology and mineral resources of eastern Cassia County, Idaho: Idaho Bur. Mines and Geology Bull. 14, pp. 60–66, 1931. Stearns, H. T., Geology and water resources of the Mud Lake region, Idaho: U. S. Geol. Survey Water-Supply Paper 818 (in press). Also unpublished data by C. P. Ross.

[16] Ross, C. P., op. cit. (Pamph. 33), p. 23. Also unpublished data.

[17] Stearns, H. T., Volcanism in the Mud Lake area, Idaho: Am. Jour. Sci., 5th ser., vol. 11, p. 361, 1926.

[18] Mansfield, G. R., Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, p. 119, 1927; Geography, geology, and mineral resources of the Portneuf quadrangle, Idaho: U. S. Geol. Survey Bull. 803, p. 42, 1929.

[19] Kirkham, V. R. D., Igneous geology of southwestern Idaho: Jour. Geology, vol. 39, no. 6, pp. 564–591, 1931. Anderson, A. L., op. cit., p. 66.

of the areas of Miocene (?) rhyolitic rocks studied in connection with this and related investigations are summarized below.

RHYOLITIC ROCKS IN AND NEAR THE MUD LAKE REGION

Rhyolitic rocks, chiefly welded tuffs, but containing subordinate amounts of agglomerate, andesite, latite and basalt are extensively exposed in the Centennial Mountains, the southern part of the Beaverhead Mountains, Big Bend Ridge, Juniper Buttes, and smaller neighboring hills. These rocks have been described elsewhere.[20] As these flows may in part interfinger with overlying sediments tentatively supposed to be Pliocene, the flows may also be of this age. Whatever their exact age they have the same general relation to the basalt of the plain as the rest of the Miocene (?) rhyolitic rocks. Kirkham [21] has described similar flows on both sides of the valley of the Little Lost River.

RHYOLITE OF BIG SOUTHERN BUTTE

Three great buttes in the lava fields between Arco and Blackfoot form prominent landmarks. Big Southern Butte, about 5 miles in diameter, the largest of these masses, reaches an altitude of 7,658 feet and rises nearly 2,500 feet above the Snake River Plain, 21 miles southeast of Arco.

The butte is composed of basaltic and rhyolitic flows of different textures. The main mass is a light-colored porphyritic rock containing large quartz crystals, which was identified megascopically as a rhyolite. The bulk of the material is glassy or pumiceous and obviously accumulated as explosive debris on the summit of a volcano. If a crater formerly existed, it has been completely dissected by erosion. The summit is made up largely of huge blocks of white pumice among which are a few obsidian bombs. Some of the obsidian is spherulitic. In places beneath the coarse ejectamenta beds of white ash and agglomerate crop out.

Near the mouth of the largest gulch that drains the north side of the butte there is a playa that formerly contained water throughout much of the year. Prior to the drilling of wells this playa was the only water hole between the Fort Hill Bottoms and the Big Lost River, and for many years all stage roads led to it. More recently a stock ranch has replaced the old stage station, and the owner has developed about a third of a second-foot of water by tunneling into the alluvium at the mouth of the gulch. When visited in 1921, the tunnel was 532 feet long and reached bedrock. Water from the coarse alluvium seeps into the tunnel through most of its length. The water is piped about a mile to a small reservoir. After stock and domestic

[20] Stearns, H. T., Bryan, L. L., and Crandall, Lynn, Geology and water resources of the Mud Lake region, Idaho: U. S. Geol. Survey Water-Supply Paper 818 (in press); Volcanism in the Mud Lake area: Am. Jour. Sci., 5th ser., vol. 11, pp. 360–362, 1926.

[21] Kirkham, V. R. D., op. cit. (Pamph. 19), pp. 33–38, 1927.

requirements are met, the surplus is used to irrigate a small patc alfalfa. The tunnel simply recovers the underflow of the gu The fact that most of the water was encountered near the con of the alluvium and bedrock indicates that the water recovered following the old bedrock surface. The success attained in gulch suggests that similar developments might be made at mouths of other gulches around the butte, but is is doubtful if drainage areas of the others are large enough.

In ascending the gulch above the tunnel a porphyritic basalt taining phenocrysts of feldspar and olivine was found. It is deep weathered and appears to be of the same age as the rhyolite and truded from the same crater, although this could not be definit established. Farther up, the narrow gulch opens into an amp theater that may have been originally a crater. In this amp theater occurs a remnant of an asymmetric basaltic red cinder co The feeding dike of aphanitic basalt can be traced down the side of gulch from beneath the cinders. The fresh character of this ba and the associated pyroclastic material, together with its topograph position, shows that it is much younger than the weathered porph ritic basalt described above. A bed of aphanitic vesicular basa flowed northward over the rhyolite from this cinder cone. It is no detached from the cone by erosion. This eruption is definite younger than the rhyolite and seems to be associated with some the older basaltic eruptions of the plain. However, as the flow h been removed by erosion from the side of the butte it must be old than the late basalts encompassing it. The topographic relation the flow and cone to the gulch suggests that the amphitheater i crater and that the basic eruption took place prior to the breachin of the crater by erosion.

TRACHYTE OF EAST TWIN BUTTE

The Twin Buttes rise above the lava plain 15 miles northeast Big Southern Butte. They are about 4 miles apart. The Eas Twin Butte, locally known as East Butte, rises about 1,100 feet abov the plain, and its light color forms a strong contrast to the surround ing dark lava fields.

The beds of trachyte, pumice, and obsidian of which the butte i composed dip about 30° S. and strike east. The trachyte, which i the most abundant, has phenocrysts of glassy feldspar (mainly ortho- clase) and a few of quartz, in a fine-grained white groundmass com- posed mainly of orthoclase. The butte is deeply eroded, like Big Southern Butte, and on the south side an alluvial fan stretches southward for nearly a mile. No vestige of any crater remains on the summit, but the character of the rocks indicates that they accu- mulated near the top of a volcano. Inclusions of porphyritic basalt in the trachyte show that all the lavas of this cycle were not highly

AIRPLANE VIEW OF ROCK BENCH BORDERING BOTH SIDES OF SNAKE RIVER AND FORMIN...
Note the gaping parallel cracks of incipient landslides in the basalt along the rim of the canyo...

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AIRPLANE VIEW OF ROCK BENCH BORDERING BOTH SIDES OF SNAKE RIVER AND FORMING A CONSPICUOUS FEATURE NEAR KIMBERLY.

Note the gaping parallel cracks of incipient landslides in the basalt along the rim of the canyon. Photo by U. S. Army Air Corps.

.The butte is much older than the encompassing basalt ...iewed from a distance appears to surmount an elevated plat-

...win Butte may be an eroded fault block of silicic lava, but ...ive of its structure its lava flows appear to belong to the same ...cycle as those in Big Southern Butte.

BASALT OF WEST TWIN BUTTE

...Twin Butte or Middle Butte rises nearly as high above the ...East Twin Butte and lies about 4 miles west of it. The butte ...osed entirely of basalt that dips 10° S. and has well-defined ... jointing. A thin section examined by Mr. M. N. Short ... abundant feldspar, olivine, and pyroxene, with a little ...al, partly recrystallized brown glass. Abundant calcite has ...sicles and replaced the glass. The minerals are all very ...lthough the texture of this basalt, like that of most of the ...ones described below, is ophitic, the coarser, more abundant ...and nearly colorless pyroxene give it a distinctly different ...nce. The abundance of calcite is another distinctive char-...

...most plausible theory to account for this single block of tilted ...rising above the surrounding basalt fields is that of differential ...of a range made up of acidic and basic lavas. The southerly ...the beds in both East Twin Butte and this one suggests that a ...block several miles long was uplifted and tilted to the south ...n eastward trending fault, but faulting is not essential to ...eory. Subsequent erosion of this block, followed by the erup-...later basalt, left the two buttes as "kipukas."[22] The presence ... inclusions in the trachyte of East Twin Butte and the ancient ...low on Big Southern Butte show that here as elsewhere basalt ...ccompanied the silicic eruptive rocks.

SHOSHONE FALLS ANDESITE

...Shoshone Falls andesite is a massive porphyritic vitreous mass ...known thickness. It has an exposed thickness of about 200 ...and a typical outcrop of it is shown in plate 7. Both Shoshone ...and Pillar Falls owe their origin to the resistance of this rock ...sion as compared with that of the weaker ancient basalts ...tream from the falls. A specimen from the foot of the Perrine ...was examined under the microscope by Mr. Short, who has ...bed it as follows:

> ...rock consists of large tabular crystals of oligoclase and andesine in a ...mass that is composed of a mat of tiny feldspar laths in a brown glass. ...ldspar phenocrysts reach 5.0 millimeters in length and are proportionately ...han in other specimens. Magnetite grains ranging from 0.1 to 1.0 milli-... in diameter are fairly common.

[22] ...ipuka is defined as an island of older rock in a lava flow.

Most of the andesite is massive, with numerous large irr[illegible] shaped vesicles, whose size is increased by weathering. Locall[illegible] platy and exhibits flow structure. Along its upper contact th[illegible] is black and glassy.

The andesite is exposed along the Snake River only from th[illegible] of Twin Falls downstream as far as the Perrine ranch, a distan[illegible] 6 miles by river. (See pl. 5.) It terminates so abruptly downst[illegible] as to suggest the possibility of faulting, but a thick flow of this [illegible] position might well come to rest with a similarly steep front. [illegible] abundance of glass, especially near the top, and the vesicles [illegible] flow structure suggest that this rock is a flow, although the evid[illegible] at hand does not preclude an intrusive origin. The base of [illegible] andesite is not exposed. The rock is separated from the overl[illegible] rocks by an erosional unconformity. A lateritic soil at least a [illegible] thick was formed on its irregular surface before being covered by [illegible] next succeeding formation, the Pillar Falls mud flow. The ande[illegible] is megascopically similar to the rock in Mount Bennett,[23] 30 mile[illegible] the northwest.

In the Twin Falls Cemetery well in the SE¼SW¼ sec. 14, T. 10 [illegible] R. 17 E., the basalts of the plain were passed through at 270 fe[illegible] below which was 23 feet of boulders, probably the Pillar Falls m[illegible] flow. From 293 to 750 feet the well is in hard rock except for th[illegible] streaks of clay 2 to 3 feet thick. A fragment of rock recovered fro[illegible] the well is typical Shoshone Falls andesite, and a specimen of th[illegible] so-called clay at 600 feet is a brown greasy material resembling [illegible] chemical deposit of some sort rather than clay. This 8-inch hole [illegible] reported to have yielded only about 45 gallons a minute at 270 fe[illegible] This well indicates that the andesite extends southeast at lea[illegible] 3 miles farther than mapped and if all the rock below 293 is Shosho[illegible] Falls andesite then it is more than 450 feet thick.

PILLAR FALLS MUD FLOW

From Shoshone Falls downstream the Pillar Falls mud flow rest[illegible] on the eroded surface of the Shoshone Falls andesite. Upstream from these falls basalt rests directly on the andesite, indicating that the mud flow was either local in occurrence or else was removed by erosion prior to the eruption of the basalt. The latter hypothesis is favored, because the mud flow is also absent from some of the high points of the andesite downstream. The mud flow was not differentiated from the andesite in plate 5 because its outcrops are found only in the vertical walls of the canyon, and hence in the horizontal plan of the map their area is negligible. Furthermore, this material

[23] Russell, I. C., Geology and water resources of the Snake River Plain of Idaho: U. S. Geol. Survey Bull. 199, p. 44, 1902. Piper, A. M., Ground water for irrigation on Camas Prairie, Camas and Elmore Counties, Idaho: Idaho Bur. Mines and Geology Pamph. 15, p. 8 [1926].

[illegible] to have no important bearing on the occurrence of ground [illegible]

[illegible] mud flow consists of well-rounded gravel and huge boulders [illegible] feet in diameter composed of silicic extrusive material in a matrix of sand, ash, and soil. The lack of sorting indicates [illegible] the material was deposited by a stream overloaded with ash [illegible] from a volcanic explosion. In the exposure examined angular [illegible] blocks were absent, indicating that the source of the ash [illegible] not nearby. Some of the soil on the underlying andesite is [illegible] mingled with the mud flow. The upper several inches of the [illegible] flow is dull gray to red as a result of baking by the overlying [illegible]. In a few places the mud flow is sufficiently consolidated to [illegible] hang, but in other places it is easily removed with a pick. Rus[illegible] was apparently the first to note it, although the underlying [illegible] ite was described earlier by King.[25]

[illegible] bably at some time subsequent to the eruption of the Shoshone [illegible] andesite a deposit of ash was spread widely over the surrounding [illegible] try. Torrential rain concurrent with or following shortly after [illegible] sh shower swept the incoherent material off the slopes in amounts [illegible] reat as to form a pasty flow of mud, which shoved or floated [illegible] rything movable in its path. The soil on the andesite shows [illegible] t considerable time intervened between the eruption of this lava [illegible] its covering by the mud flow. On the other hand, the absence [illegible] fragments of basalt in the mud flow indicates that it was probably deposited before the episode of basaltic eruptions, which began in late Pliocene time. As the break at the top seems greater than that at the base the mud flow is tentatively assumed to be of Miocene rather than Pliocene age.

RHYOLITIC ROCKS SOUTH OF SNAKE RIVER

In the area between the canyon of the Snake River and the southern boundary of Idaho and extending as far east as the Malta Range there are large areas of rhyolitic rocks, most of which have been studied only in reconnaissance fashion. In the course of the present work these rocks were seen in many places but not mapped.

The valley of Salmon Falls Creek above the dam that forms the reservoir is carved in silicic lava and associated pyroclastic material. Farther north these Miocene (?) rocks are largely covered by later beds. Near Castleford a silicic layer 25 feet thick, possibly a welded tuff, is exposed beneath the Pleistocene basalt. Under this layer is 6 to 8 feet of reddish soil, which in turn rests on massive rock, probably an andesite flow, with an exposed thickness of 100 feet.

[24] Russell, I. C., op. cit., p. 43.

[25] King, Clarence, U. S. Geol. Expl. 40th Par. Rept., vol. 1, pp. 592–593, 1878.

Still farther downstream at a point a third of a mile south [illegible] Salmon Falls Hot Spring in sec. 31, T. 8 S., R. 14 E., an ex[illegible] bearing on the relation of an andesite flow to the Hagerman lak[illegible] and the Banbury volcanics occurs. Although this flow is do[illegible] not the same one as at Shoshone Falls, probably it has essentia[illegible] same age. At this point on the east bank of Salmon Falls C[illegible] 60 feet of platy andesite occurs with its bottom going below [illegible] level. Above it is 30 feet of bedded sand and clay with the to[illegible] of clay baked red by an overlying weathered basalt flow 50 feet [illegible] vesicular at the top and typical of the Banbury volcanics. [illegible] this basalt is 30 feet of lake beds. The basalt dies out on th[illegible] side of the canyon and in that side the andesite is overlain by 20[illegible] of lake beds which are capped with a later basalt. The basalt [illegible] east bank appears to have flowed from the north and east an[illegible] andesite from the south. The andesite terminates about 80[illegible] south of the hot spring. Its contact with the overlying sedim[illegible] not exposed but one gets the impression it ends either in a [illegible] margin or by erosion, rather than by faulting. However, it is o[illegible] here as it was not at Shoshone Falls, that the andesite underli[illegible] Hagerman lake beds and Banbury volcanics.

Near the heads of Deep, Cottonwood, McMullen, Rock, and [illegible] Creeks, successively farther east, occur thin widespread even-be[illegible] fluidal pink rhyolitic rocks with glassy tops, apparently largely w[illegible] tuffs, and intercalated ash beds. This series of rocks dips north[illegible] along the border of the Snake River Plain is apparently much dis[illegible] by faulting, with the downthrow generally to the north.

Similar rhyolitic rocks continue eastward into the valley of [illegible] Creek. Here Piper [26] distinguished early Miocene (?) rhyolit[illegible] late Miocene (?) lacustrine beds with "intercalated and capping [illegible] of rhyolitic lava."

Rhyolitic tuff and lava flank Marsh Creek, the next stream [illegible] east, on both sides. On the west these beds rest on Paleozo[illegible] quartzite. Near the mouth of the valley the tuff is quarried fo[illegible] locally as building stone. The ridge on the east, which sep[illegible] this valley from that of the Raft River, is composed chiefly of rhy[illegible] and obsidian with here and there a white tuff bed capped by a p[illegible] ent glassy rhyolite. The mountains east of the Raft River Valle[illegible] least on their east side, contain volcanic rocks of several kinds res[illegible] on Paleozoic sedimentary beds. Presumably the volcanic rocks [illegible] to be correlated in part with those farther west. From this vic[illegible] east and northeast rhyolitic, andesitic, and related flows and [illegible] clastic rocks continue to be exposed at intervals. Most of them [illegible]

[26] Piper, A. M., Geology and water resources of the Goose Creek Basin, Cassia County, Idaho: Ida[illegible] Mines and Geology Bull. 6, pp. 26–35, 1931.

[illegible]scribed by Mansfield [27] and were not closely examined during [illegible]sent work. The information available indicates that the thick[illegible] of rhyolitic rocks, and associated beds west of the Malta [illegible]ither originally thinned out rapidly immediately to the east [illegible]ange or else has been largely obliterated as a result of subse[illegible]vents. The silicic volcanic rocks in the area between the [illegible]iver and the vicinity of Pocatello differ somewhat in appearance [illegible]ickness from those to the west.

SOURCES OF RHYOLITIC AND RELATED ROCKS

[illegible]amount of rhyolite and associated volcanic rocks in and on the [illegible] of the Snake River Plain is much greater than can be accounted [illegible]known vents in this region. Within the region examined there [illegible]ll cone near Fort Hall [28] and several near the Blackfoot Reser[illegible]ut no other cones that appear to be suitable sources for the [illegible] lava are known. Indian Creek Butte [30] in Clark County [illegible] of being a cone, as formerly thought, may consist of a hill of [illegible]ck blanketed with welded tuff.

[illegible] of the vents from which these silicic volcanics issued may be [illegible] beneath the copious Pliocene and later basalt flows. The [illegible]thesis that one of the major sources of the silicic flows was a [illegible]f volcanoes extending from the Yellowstone National Park [illegible] Boise along the axis of the Snake River Plain accords with the [illegible] facts within this region, although it is supported by little direct [illegible]ce. It is clear from the descriptions which follow that the [illegible]e and Pleistocene basalts locally attain an aggregate thickness [illegible]east 1,000 feet, and the maximum thickness is probably much [illegible]. Even this minimum figure is sufficient, especially if some [illegible]nce is made for erosion and possible down-warp prior to the [illegible]c eruptions, to account for the burial of rhyolitic cones of con[illegible]ble size. Kirkham [31] has presented evidence tending to show [illegible]ear the west end of the Snake River Plain the bottom of the [illegible]sion that was filled with Tertiary beds may perhaps now be as [illegible]s 20,000 feet below sea level. However, his evidence of down[illegible] the area studied is chiefly based on the dip of the silicic vol[illegible], which he considered as flows. Because many of them are welded

[27] [illegible]field, G. R., Geography, geology, and mineral resources of the Fort Hall Indian Reservation, [illegible]. S. Geol. Survey Bull. 713, pp. 57–61, 1920; Geography, geology, and mineral resources of part of [illegible] Idaho: U. S. Geol. Survey Prof. Paper 152, pp. 116–130, 1927; Geography, geology, and mineral [illegible] of the Portneuf quadrangle, Idaho: U. S. Geol. Survey Bull. 803, pp. 40–45, 1929. Mansfield, [illegible]nd Ross, C. S., Welded rhyolitic tuffs in southeastern Idaho: Am. Geophys. Union Trans., [illegible]308–321, 1935.

[28] [illegible]field, G. R., Geography, geology, and mineral resources of the Fort Hall Indian Reservation, [illegible]. S. Geol. Survey Bull. 713, p. 72, 1920.

[illegible]field, G. R., Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. [illegible]rof. Paper 152, p. 362, 1926.

[30] [illegible], H. T., Volcanism in the Mud Lake area, Idaho: Am. Jour. Sci., 5th ser., vol. 11, p. 362, 1926.

[31] [illegible]ham, V. R. D., Snake River downwarp: Jour. Geology, vol. 39, no. 5, pp. 473–479, 1931.

tuffs their dip may have resulted from the topography on which they fell and not on subsequent tilting.

The differences in the character of the rhyolitic rocks in different parts of the region accord with the concept that they came from separate vents arranged more or less parallel to the axis of the plain rather than that they flowed widely from a single area, such as the Yellowstone National Park, where rhyolitic flows are abundant.

Whether or not the buried volcanoes suggested above furnished some of the flows, evidence is rapidly accumulating [32] that there are many intrusions in the mountains of south-central Idaho which are of suitable age and petrographic character to have been the source of a large part of the lavas older than the basaltic flows of which the Snake River Plain is built up. Some of these intrusions in the Lava Creek [33] and Alder Creek [34] districts are shown in plate 4. Numerous others, some of which are much larger, are exposed in the mountains farther north and west.[35] Erosion has been so active in this high region since most of the intrusive rock now exposed became solid at depth that any original connection with surface flows has been eroded away or otherwise obscured. Recently Udell [36] has found that there are in the Muldoon mining district, Blaine County, not far from the border of the Snake River Plain, two lines of vents or craters which he regards as the sources of much of the Challis volcanics of this locality. He further finds that there are in the Muldoon district granitic and other intrusions comparable in age and character to those above referred to, and that some of the rhyolitic dikes here are materially younger than the granitic masses. This accords with the concept, expressed above, that the rhyolitic flows of the region may be of more than one age.

PLIOCENE ROCKS

OCCURRENCE AND CHARACTER

Over most of the region mapped on plate 4 rocks as old as Pliocene, if present, are deeply buried. Locally, at the base of the Centennial Mountains, along the canyon of the Snake River and in and near Hagerman Valley, rocks are exposed which may, with different degrees of certainty, be referred to the Pliocene. Some of these are lacustrine and fluviatile deposits, most of which contain fossils,

[32] Ross, C. P., Mesozoic and Tertiary granitic rocks in Idaho: Jour. Geology, vol. 36, no. 8, pp. 682-684, 692-693, 1928. Anderson, A. L., Geology and ore deposits of the Lava Creek district, Idaho: Idaho Bur. Mines and Geology, Pamph. 32, pp. 21-25, 1929.

[33] Anderson, A. L., op. cit. (Pamph. 32), pp. 21-25.

[34] Ross, C. P., Geology and ore deposits of the Seafoam, Alder Creek, Little Smoky, and Willow Creek mining districts, Custer and Camas Counties, Idaho: Idaho Bur. Mines and Geology: Pamph. 33, pp. 13-14, 1930.

[35] Ross, C. P., Mesozoic and Tertiary granitic rocks in Idaho: Jour. Geology, vol. 36, no. 8, pp. 682-684, 1928.

[36] Udell, Stewart, The geology of the Muldoon mining district, Blaine County, Idaho: Idaho Bur. Mines and Geology Pamph. — (in preparation).

ough thoroughly diagnostic collections have been made only in Hagerman Valley. More or less closely associated with the different sedimentary units are beds of basalt and other volcanic rocks whose stratigraphic position (so far as determinable) and degree of weathering indicate that they are of approximately Pliocene age. It appears from the data summarized below that in the region here considered Pliocene rocks make up a relatively small part of the great mass of beds accumulated subsequent to Miocene time.

Four units have been mapped for whose age positive evidence is lacking but whose relations suggest that they are mainly older than the definitely recognizable upper Pliocene rocks and younger than the Miocene (?) rocks above described. These rocks are here grouped as lower Pliocene (?) and are described below. All but those in Clark County lie along the Snake River from American Falls to the east side of the Raft River, and they are considerably disturbed by faulting and in general dip northward, away from the foothills. The Rockland Valley basalt and Raft lake beds appear younger than these rocks but older than the upper Pliocene. They are therefore grouped as middle (?) Pliocene. The Banbury volcanics and Hagerman lake beds may on stratigraphic and paleontologic grounds be confidently assigned to the upper Pliocene.

LOWER PLIOCENE (?) ROCKS

TERTIARY SEDIMENTS IN CLARK COUNTY

A considerable area in the vicinity of Medicine Lodge Creek in northwestern Clark County is covered by fanglomerate and kindred material which overlies and may in part interfinger with the rhyolitic flows so abundant in this area.[37] Most or all of these deposits are stream-laid, and they are evidently but little younger than the rhyolitic flows of the vicinity. Pieces of thoroughly fossilized camel bone from a well in the gravel were regarded by J. W. Gidley as suggestive of Pliocene age. The sediments have therefore been tentatively referred to the Pliocene, although if the rhyolitic flows should prove to be as old as some of the similar flows in other parts of Idaho these sediments may likewise be pre-Pliocene.

NEELEY LAKE BEDS

In the bluffs of the Snake River near Neeley, 5 miles southwest of American Falls, a series of lake beds has an exposed thickness of 100 feet, but its base is concealed, hence it must be thicker. (See pl. 6.[38]) These beds consist of flesh-colored to brown sandy lacustrine deposits

[37] Stearns, H. T., Bryan, L. L., and Crandall, Lynn, Geology and water resources of the Mud Lake region, Idaho: U. S. Geol. Survey Water-Supply Paper 818 (in press).

[38] The geology on this map was originally plotted on a U. S. Bureau of Reclamation map. In replotting on the new U. S. Geological Survey base the geology was adjusted to fit the new base, and this may have given rise to errors.

composed partly of reworked and subaqueously deposited basic... presumably accumulated behind a lava dam. The deposits... even-bedded and dip 3°–5° N. except where disturbed by fault... They are sufficiently indurated to form steep bluffs wherever th... have been eroded.

Although this formation is coarser than some of the other l... beds it is not sufficiently coarse to yield much water. No wells... known to derive their supply from this formation, and no peren... springs issue from it.

EAGLE ROCK TUFF

The Eagle Rock tuff, named from Eagle Rock, near American Fal... is exposed at the base of the American Falls. The following secti... was measured at this place, the type locality:

Section of Eagle Rock tuff on north bank of Snake River at American Falls

	Feet
Red felsitic tuff containing feldspar crystals 2 to 4 millimeters in length	0.6
Welded rhyolitic obsidian tuff containing spherulites and lithophysae. Some of the lithophysae are 3 inches in diameter	20.8
Even-bedded coarse black ash, composed of shards of rhyolitic glass. The top layer is compact and breaks into dull obsidian fragments and grades downward into ash that can be readily removed with a knife	4.5
Even-bedded gray to white rhyolitic ash, in places pisolitic	9.3
	35.2

The following descriptions are based partly on microscopic studies by M. N. Short:

The top bed is a fused rhyolitic tuff which contains large crystals of albite and owes its red color to the numerous minute hematitic inclusions. The 20-foot bed of obsidian tuff next below is less thoroughly fused. It contains a few rounded crystal fragments of microcline and oligoclase but with these exceptions is entirely glassy. The rock lacks joint planes and shrinkage cracks and presents an unusual appearance because of the honeycomb structure produced by the lithophysae and the weathering out of the spherulites from the matrix. In places where hollow spherulites or lithophysae predominate over the tiny symmetrical spherulites the matrix is pink. Small subangular obsidian pellets also weather out between the spherulites, and in these localities the matrix is easily removed with a pick. The next lower bed at the type locality is a compact dark-gray vitreous tuff, which consists of light-brown rhyolitic glass (refractive index 1.497) whose structure indicates welding and flowage. At another exposure along the Oregon Trail this bed is even more compact and megascopically gives no indication of its fragmental structure. The white ash in the lowest bed differs from the ash in the top bed only in its unconsolidated character. It consists of fragments of glass with only a few scattered grains of feldspar.

This formation has a uniform thickness except where eroded. Its component beds are so similar in composition and so closely comparable as to indicate that they followed one another in rapid succes-

...nd came from the same volcano. The presence of pisolites in ...h suggests subaerial deposition. The absence of cross-bedding ...mination indicates that the beds were formed from ash showers ...out appreciable sorting by wind or streams. Wind-blown soil ...s top of the formation if deposited soon after the tuff accumulated ...ld indicate that these rocks were laid down on dry land.

...is formation has been recognized only in the canyon walls along ... Snake River. Beyond it is buried by younger formations. It ...nds for several miles along the river southwest of American Falls. ... the west side of Rockland Valley, about 12 miles south of American ...lls, there is an exposure of white consolidated pumice and ash 100 ... thick which may correspond to the white ash of the Eagle Rock, ...

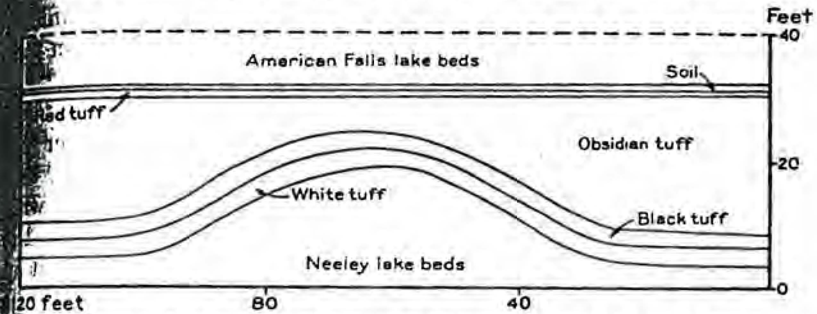


FIGURE 4.—Local unconformity between the Neeley lake beds and the Eagle Rock tuff.

and its greater coarseness and thickness here may be due to its being nearer the source. The pumice at this particular exposure weathers easily and is filled with cavities.

On the west bank of the Snake River in the NW¼ sec. 22, T. 8 S., R. 30 E., a slight variation occurs in the thickness of the beds. At this place a small mound a few feet high in the Neeley lake beds is overlain by the white and black ash beds retaining their usual thickness and conforming to the surface of the mound. The obsidian tuff above the ash thins sufficiently in passing over the mound to make its upper surface level. Consequently on top of the mound there is only about 4 feet of obsidian tuff, as compared with about 18 feet on each side. Above the obsidian tuff is the usual thin bed of red tuff and a few inches of soil containing scattered red basaltic cinders. On top of the soil rest the American Falls lake beds, which are much younger and which are described below. Figure 4 shows the relation of the obsidian to the underlying tuff and lake beds. These relations, coupled with the texture of the obsidian tuff, indicate that the fragments composing the tuff were molten when they fell and consequently coalesced into a mass sufficiently fluid to adjust itself to minor topographic irregularities. This suggests distribution as a hot avalanche or nuée ardente, as at Mont Pelée in the West Indies in

1902, or like the hot sand flow of the Valley of Ten Thousand Sm[illegible] in 1912.

MASSACRE VOLCANICS

In the center of sec. 6, T. 9 S., R. 30 E., is a group of kn[illegible] dense basalt. They are named "Massacre Rocks" because [illegible] the Indians massacred an emigrant train at this point. The[illegible] represent the denuded feeder of an ancient volcano. The distribution and coarseness of the pyroclastic rocks from th[illegible] suggest that in comparison with similar less dissected cones in [illegible] regions, the original cone here may have been a thousand feet o[illegible] high and perhaps several miles in diameter. Its explosive pro[illegible] and flows were spread over more than 20 square miles. The pro[illegible] of this volcano, which are here named the "Massacre volca[illegible] are much older than the other basalts that now form the canyon [illegible] on the north side of the Snake River opposite the historic spot.

The volcano was mainly explosive during its history, for the b[illegible] ash, cinders, and bombs greatly predominate in quantity ov[illegible] lava flows. A few blocks of basalt, spherulitic obsidian, clay [illegible] limestone torn from the underlying basement are intermingled [illegible] these fire-fountain deposits. The beds are brown, red, or black [illegible] color depending upon the state of oxidation of the iron prese[illegible] them. They are all consolidated and readily distinguished from [illegible] underlying Eagle Rock tuff. In general they dip away from Mas[illegible] Rocks, but many of the beds have been tilted considerably by [illegible] sequent faulting. In the SW¼ sec. 21, T. 8 S., R. 30 E., a pe[illegible] bed of cinders crops out about 20 feet above the northwest bank o[illegible] Snake River. It contains numerous red concretionary balls of [illegible] tically pure calcite as much as 4 inches in diameter.

Beds belonging to the Massacre volcanics are exposed at inte[illegible] on both banks of the Snake River upstream from Massacre R[illegible] as far as Eagle Rock, a distance of about 11 miles. (See pl. 6.) [illegible] this place they are cut off by a fault. Downstream they are exp[illegible] to a point only 1½ miles from Massacre Rocks, where they are faul[illegible] down out of sight.

In the SW¼ sec. 22, T. 8 S., R. 30 E., on the south bank of [illegible] river, which there makes a right-angle turn to the northwest, [illegible] fire-fountain deposits are in contact with the underlying Eagle R[illegible] tuff. A similar contact can be seen on a neighboring island in [illegible] river. Here the deposits rest on 4 feet of loess soil containing ang[illegible] rock chips derived chiefly from the red felsitic tuff, which her[illegible] only 1 foot thick and lies on the spherulitic obsidian. This con[illegible] shows that sufficient time elapsed between the obsidian flow and [illegible] eruption of the Massacre volcanics to form deep soil and also that [illegible]

[49] Fenner, C. N., The origin and mode of emplacement of the great tuff deposit of the Valley of Ten Thou-sand Smokes: Nat. Geog. Soc., Contributed Tech. Papers, Katmai ser., no. 1, pp. 70-74, 1923.

[illegible] took place on dry land. In places thin layers of basalt, [illegible] was erupted from the Massacre Rocks volcano, cap the fire-[illegible] deposits and are interbedded with them. The prominent [illegible] rises about 500 feet above the Snake River in sec. 5, T. 9 S., [illegible]E., is capped with weathered porphyritic basalt that may have [illegible] from this vent.

[illegible]her flow from the Massacre Rocks vent makes a prominent [illegible] along the highway just northeast of the mouth of Rock Creek, [illegible]12, T. 9 S., R. 29 E. A few thin flows interspersed with the [illegible] have not been differentiated on plate 6. Although these [illegible] are thin where exposed, they are close to the source, where [illegible] lava was extremely liquid and was flowing down the cone slope. [illegible] they may represent the upper ends of originally extensive [illegible]

[illegible] the north bank of the Snake River near the foot of American [illegible] the soil above the obsidian is overlain by a fine-grained blue [illegible] flow 25 feet thick. This flow caps the rhyolitic tuffs for 5 miles [illegible]stream, except where it has been removed by erosion. As it [illegible] the same stratigraphic position as the Massacre volcanics, [illegible] have been erupted from the Massacre Rocks vent.

MIDDLE (?) PLIOCENE ROCKS

ROCKLAND VALLEY BASALT

On the west side of Rockland Valley even-bedded basalt flows [illegible] exposed in the deep, narrow canyon of Rock Creek. In sec. 8, [illegible] S., R. 30 E., about 250 feet of these lava flows is exposed. The [illegible] exhibit the usual columnar jointing and are all of the pahoehoe [illegible] They are considerably weathered, and their state of decom-[illegible]tion readily distinguishes them from the adjacent later basalts [illegible] cover the Snake River Plain. The uppermost flow near the [illegible] of Rock Creek is 40 feet thick and rests with apparent con-[illegible]ity on light-colored clay beds 15 feet thick, which in turn overlie [illegible]. Although the lavas do not exhibit subaqueous phases, [illegible] were evidently laid down at about the same time as the lake-bed [illegible]. These clays appear to be playa deposits, hence they may [illegible] been dry when the lava covered them. This suggestion receives [illegible] support from the fact that the clay beneath the 40-foot lava [illegible] is not baked red near the top by the basalt.

[illegible] the north end of Rockland Valley most of the lavas are buried [illegible] later deposits. The lavas extend toward Table Mountain, a high [illegible] to the south, and it is possible that the vents lie in that direction. [illegible]ese lavas appear to have been tilted gently to the northwest. Apparently the Massacre Rocks cone was too high to be covered by [illegible], for no remnants of them overlie the tuff; hence the cone was [illegible]bably a kipuka during the lava floods.

The total thickness of the Rockland Valley basalt may be exposed somewhere in the Rockland Valley. The driller of the Burley city well 5, about 40 miles west of the mouth of Rock Creek, reported at the bottom of the well 647 feet of basalt, which occupies the stratigraphic position of the Rockland Valley basalt. (See p. 50.) Because basalts are poured out over the land as semifluids, a flow may be 1,000 feet thick at an outcrop, where it fills an old canyon, but a mile away the same flow may be absent or be only a few feet thick. The notable variation in thickness of basalts from place to place, contrasted with the relatively uniform thickness of sedimentary deposits, may involve considerable errors in correlation and doubtless causes some of the great difference in the logs of wells drilled within a small area.

In spite of its extensive weathering, this basalt is fairly permeable and several domestic wells probably derive their supply from it.

RAFT LAKE BEDS

Lake beds, here named the "Raft lake beds" (pl. 6), extend westward from the mouth of Rock Creek along the south shore of Lake Walcott as far as the mouth of the Raft River. The beds in this formation appear to have uniform thickness when seen in any one exposure, but individual layers are traceable for only short distances. The beds are buff to pale yellow and consist of partly consolidated silt, sand, caliche, and gravel. At the mouth of Fall Creek lens-shaped beds of coarse gravel and hardpan are plentifully intercalated in them. Nodular concretions, as much as 10 inches in length, are characteristic of the beds, but tuffaceous beds are uncommon.

Near the mouth of Rock Creek the lake beds rest on the Rockland Valley basalt. A small outlier of them is seen in a depression in the Massacre volcanics a mile northeast of this creek, on the south side of the highway, and possibly another occurs beneath the Cedar Butte basalt on the north bank of the Snake River near Bonanza Bar, at the mouth of Lake Channel. In the Rockland Valley these beds form rounded hills covered with rich brown soil that is extensively dry-farmed. At the head of Fall Creek, in secs. 27 and 28, T. 9 S., R. 29 E., a basal conglomerate of the formation crops out and includes talus blocks from the adjacent Paleozoic limestone. The beds rest unconformably on ancient limestone in sec. 9, T. 10 S., R. 28 E.

The Raft lake beds are about 200 feet thick near Fall Creek, and there they also rise about 200 feet above the Lake Walcott Reservoir. At the Raft River, 8 miles to the west, they rise only about 50 feet above the reservoir. Their surface also rises gently toward the southeast and forms a plateau cut only by a few ephemeral streams. The plateau is capped here and there by gravel deposits, which probably are the alluvial fans deposited by similar ephemeral streams

tributary to the ancient lake. The whole formation has been tilted to the northwest, so that the beds dip in this direction about 5°. They form a precipitous bluff along the Lake Walcott Reservoir, and at one time they evidently extended much farther north into the Snake River Plain. Although these lake beds were possibly removed by the Snake River, they may be terminated on the north by an eastward-trending fault or series of faults.

The presence of several warm springs in sec. 19, T. 9 S., R. 28 E., issuing at the base of the bluff, suggests faulting as the cause of the escarpment, but similar bluffs have been carved by the Snake River in the Hagerman lake beds in many places. Furthermore, the underlying Massacre volcanics and possibly even the Raft lake beds crop out on the north bank of the Snake River, and if a fault terminated the lake beds the tuffs should have been carried down out of sight. The Raft lake beds end abruptly on the east side of the Raft River, beyond which they have been removed by erosion and replaced by recent basalts.

From exposures near the mouth and from well records farther south, much of the Raft River Valley, under a cover of alluvium, seems to be filled with Raft lake beds. Warneke's well, in the NE¼SE¼ sec. 32, T. 13 S., R. 27 E., is reported to have penetrated 48 feet of gravel and then remained in fine-grained stream and lake deposits to its bottom, at a depth of 800 feet. A composite sample from the cutting dump shows that the last material drilled was arkosic sand.

In T. 15 S., R. 24 E., 6 miles due south of Almo and 5 rods from the Raft River, the Oasis Oil Co., of Burley, started a well for oil. According to the log furnished by A. T. Wilcox, of Almo, this well is 375 feet deep and below 5 feet of soil penetrated gravel and sand, with some clay.

The Raft lake beds are younger than those in the adjacent valley of Goose Creek, described by Piper [40], because they overlie instead of underlie the rhyolite, and they are quite different lithologically. According to Anderson [41], however, there are on both sides of the Raft River Valley sedimentary beds which are capped by and locally intercalated with rhyolitic flows. He maps these rocks only in the range east of the valley and in a small area south of Almo but notes their presence in small exposures in numerous other localities, particularly beneath the rhyolitic flows of the Malta Range.

City well 5 at Burley is 1,115 feet deep and between 255 and 468 feet below the surface penetrated 213 feet of lake beds with some basalt above them. The driller's description indicates that these beds are probably the Raft lake beds, because they occupy the proper strati-

[40] Piper, A. M., Geology and water resources of the Goose Creek Basin, Cassia County, Idaho: Idaho Bur. Mines and Geology Bull. 6, pp. 27-31, 1923.

[41] Anderson, A. L., Geology and mineral resources of eastern Cassia County, Idaho: Idaho Bur. Mines and Geology Bull. 14, pp. 35-44, 1931.

graphic position. Beneath the lake beds is 647 feet of basalt, v tions in which indicate that it may comprise nearly 50 separate f The surface of the lake beds slopes about 18 feet to the mile west from the mouth of Fall Creek to the mouth of the Raft River. Bu is about 30 miles due west of the Raft River. If this same gradie maintained these beds should lie about 550 feet below the surfac Burley instead of 255 feet. A fault on the west side of the Raft R is postulated on page 106. If this fault moved again subsequent to deposition of the lake beds it would account for this difference of feet.

The lithology of the Raft lake beds points rather conclusively shallow-water conditions during most of the lake's existence. I highly probable that these sediments were laid down behind a dam in a depression that was fed by mountain streams, which fi certain parts of it at different times during the year, and that the w escaped through the dam or was evaporated. That is, the beds formed in a playa rather than a lake, although in exceptionally years a temporary lake may have existed. Many of the fine-gra sedimentary beds that have accumulated in different places in south Idaho were formed under similar conditions.

The Raft lake beds are, as a whole, poor water bearers. perennial springs except the warm springs mentioned above are kno to issue from them. However, wells drilled about 200 feet into th have obtained domestic supplies. The beds in the Burley well supposed to belong to this formation did not yield appreciable amou of water.

UPPER PLIOCENE ROCKS

BANBURY VOLCANICS

Flows.—The Banbury volcanics, named from the thick expos near Banbury Hot Springs, in sec. 33, T. 8 S., R. 14 E. (see pl. extend from the Perrine ranch, in sec. 28, T. 9 S., R. 17 E., at an al tude of 3,250 feet above sea level, down the Snake River 63 miles the vicinity of King Hill, at an altitude of 2,500 feet. They crop o fairly continuously as a series of even-bedded massive basalt flows o 300 feet thick. Basalt belonging to this formation extends up Salm Falls Creek also.

The basalt of this formation, wherever it is exposed, weathers to dark brown, often with a greenish cast. By this color and its relativ softness it is readily distinguished from the younger hard blue basalts that locally lie in juxtaposition with it. A fossil bone (specimen E-15) collected from a bed of gravel and sand 30 feet thick and of fluviatile origin, halfway below the rim of the south canyon wall of the Snake River in the SW¼NE¼ sec. 9, T. 9 S., R. 15 E., and interstratified with the Banbury volcanics, was identified by J. W. Gidley as the tibia of a large camel of either Pleistocene or Pliocene age. Because these

lavas are intimately associated with the overlying lake beds, which contain late Pliocene fossils, their age is fixed with considerable certainty. The bottom of the basalt series was not observed. The fact that the basalts crop out at a higher altitude to the east than to the west may be due to their being gently downwarped toward the west or to their having accumulated in a greater thickness in one end of the basin than in the other. That these lavas were not spread uniformly over the entire basin is attested by the local variations in them.

Near the crossing of Salmon Falls Creek known as "Castleford" the Banbury volcanics rest on and are back-filled against an abrupt face of Miocene (?) lava, probably andesite. The Banbury volcanics are again exposed about three-quarters of a mile south of a hot spring in sec. 31, T. 8 S., R. 14 E., and continue to a point a few yards north of the spring, where they are abruptly terminated apparently by a fault and brought into contact with the upper part of the Hagerman lake beds.

The flows of this formation are massive, and such openings as exist are largely filled with soil as a result of weathering. Consequently they are less permeable than most other basalts, and only small supplies of water have been obtained from the formation. One exception occurs on the Twin Falls project, where a drainage tunnel about 100 yards long in this formation developed about 1 second-foot of water.

Riverside Ferry cone.—On both sides of Snake River at the old Riverside Ferry in secs. 20 and 29, T. 8 S., R. 14 E., are cliffs 125 feet high exposing steeply dipping bedded dark-gray and reddish-black cinders and thin layers of weathered brown basalt typical of a dissected cone. It is cut through by the Snake River, but erosion has not yet bared the feeder, as at Massacre Rocks. The gravel, older basalt blocks, and porcelain-like fragments of baked clay hurled out during the eruption and deposited with the cinders indicate that these rocks underlie the cone. The tuff exposed at Thousand Springs, 1¼ miles downstream, is probably from this cone. Some of the flows in the adjacent Banbury basalt appear to have originated at this vent. The cone deposits are cut off by a steep erosional unconformity on the north side of the river and overlain by the Sand Springs basalt. On the south side of the river the cinders are in juxtaposition with lake sediments possibly as a result of faulting. They are not exposed on the east bank of Snake River south of Box Canyon.

Because the deposits from Riverside vent form an integral part of the Banbury volcanics there can be little doubt that individual cones were the source of part, if not all, of the Banbury basalt. The character of the deposits from this cone suggests that it formed beneath the waters of a lake. The tuffs from this cone are not differentiated on plate 5 from the Banbury basalt, but the cone is shown by a separate

HAGERMAN LAKE BEDS

The Hagerman lake beds rest on the Banbury volcani prominent bluffs along the Snake River in Hagerman Vall in plate 10, *A*. They comprise a series of white to buff solidated clays and silts, and are named from the fine exp valley. Intercalated with the fine sediments are a few gr and basic tuffs and flows. Some of the clay beds are gyp near the mouth of Salmon Falls Creek a 20-foot bed occurs in the series. A gravel bed 20 feet thick, laid down was drained, forms the capping member. The beds are zontal, and dips of only 2° to 3° were recorded except in the beds had been disturbed by landslides. They are ex Melon Valley, north of Buhl, for many miles to the west and only a small part of them is included in the area mapp

The top of the Hagerman lake beds reach an altitude of feet, and because of the practically undisturbed condition it is judged that this altitude represents approximately shore line of the lake. The types of sediments indicate tha was more persistent than the playa lake in which the Raft were deposited. Nevertheless, the character of the vertebr and of the beds containing them, described below, shows that was not submerged by a lake throughout the time during wh Hagerman beds were accumulating. Some of the beds are laid, and others appear to have been formed in a swamp, but th almost exclusively in the upper part of the section. Only four lava flows were intercalated in these sediments in this are the long time in which they were being laid down.

A flowing well that was drilled to obtain hot water for a nat on the north side of the highway near the center of sec. 7, T. 11 E., about half a mile east of King Hill, penetrated 970 feet in beds, and the log is given below.

Driller's log of well at King Hill

[F. B. Hughes, driller. Altitude 2,550 feet]

	Thick (feet)
Boulders and sand (first surface water at 70 feet)	70
Clay	80
Hard rock	130
Clay	70
Clay and sandrock (small flow of about 15 gallons a minute[1] over casing at 350-360 feet; temperature 72° F.)	100
Sandrock (large flow of about 100 gallons a minute[1] at 450-480 feet; temperature 78° F.)	140
Hard rock	40
Soft sandrock (flow of about 200 gallons a minute[1] at 680-690 feet; temperature 83° F.)	60
Boulders and shale	110
Clay and boulders (last water at 820-840 feet; flow of about 300 gallons a minute;[1] temperature 92° F.)	170

[1] Driller's estimates of flow all believed to be too great.

EXPOSURE IN THE HAGERMAN LAKE BEDS ON THE WEST SIDE OF SNAKE RIVER IN HAGERMAN VALLEY.

BASALT CONTAINING TALUS BLOCKS OF A FORMER CLIFF (a) AND OVERLAIN BY VITREOUS VOLCANIC SAND (b) AND OLDER ALLUVIUM (c).

well started in alluvium, and the hard rock struck at 150 feet probably intercalated basalt. The basalt at the mouth of Clover Creek shown in plate 5 is evidently eroded completely away at the well site. The bed of hard rock 40 feet thick that is reported at 590 feet, presumably basalt, is the only other interstratified lava to a depth of 970 feet. The mouth of the well is about 2,550 feet above sea level; hence the drill penetrated to an altitude of 1,580 feet. It is evident from the log that sediments similar to the Hagerman lake beds were encountered to a depth of 690 feet, but the boulders and clay for the remaining 280 feet are difficult to interpret. The log of this well indicates a greater thickness of lake beds at King Hill than is exposed in Hagerman Valley.

An upper Pliocene age for the Hagerman lake beds is indicated by the fossil vertebrates that have been found in the bluffs along the west side of the Snake River near the town of Hagerman. Stearns while hunting for fossils heard that Elmer Cook, a farmer living in Hagerman, had some fossils in his yard and was shown the source by Mr. Cook. Recognizing the importance of this rich fossil deposit, Stearns excavated several hundred pounds and sent a representative collection to the National Museum in 1928. He suggested that someone be sent to make further excavations. Parties from the Smithsonian Institution under Dr. Gidley in the next two summers and under N. H. Boss in 1931 obtained a large quantity of fossil material from this locality. The great bulk of the collection consisted of horse remains and was uncovered in a quarry located on a hill in the NW¼ sec. 16, T. 7 S., R. 13 E., about 30 feet below the top of the lake series. The equid material has been described by Dr. Gidley as *Plesippus shoshonensis* [42] and includes a large number of skulls, lower jaws, and other skeletal parts. Much of the material was disarticulated, but several nearly complete articulated skeletons are included in the collection, and also some articulated limb and vertebral portions. *P. shoshonensis* represents a stage between that of the typical Pliocene *Pliohippus* and Pleistocene *Equus*. The Idaho form was noted by Dr. Gidley to be more advanced than the *P. simplicidens of* the Blanco formation of Tesas and *P. proversus* of the upper part of the Etchegoin of California, suggesting a closer relationship to *Equus*.

The environmental conditions indicated by the fauna from the *Plesippus* quarry are described in the following quotations from Gidley's second report [43] on his explorations in Idaho:

> It [the quarry deposit] is evidently the remnant of a stream-channel deposit made up of cross-bedded layers of coarse and fine sand with occasional pebbles and here and there patches and lenses of almost pure clay, forming a part of the horizontally laminated beds of the Idaho formation [Hagerman lake beds of this

[42] Gidley, J. W., A new Pliocene horse from Idaho: Jour. Mammalogy, vol. 11, no. 3, pp. 300-303, 1930.
[43] Gidley, J. W., Continuation of the fossil horse round-up on the Old Oregon Trail: Explorations and Field Work Smithsonian Inst. in 1930, pp. 33-40, 1931.

report]. The bone deposit was evidently at the time of its formation a boggy springy terrane, perhaps a drinking place for wild animals in a semiarid country where water holes were not abundant. * * * Springs and swampy conditions are indicated from the fact that there are in the deposits the remains of frogs, fish, swamp turtles, beavers, and other water-loving animals, and also abundant evidence of vegetation, as shown by remnants of coarse grass stems, leaves, and even small pieces of wood. * * * In the lower stratum of the deposit the sand is heavily stained, and many of the fossil bones are encrusted and stained with light accumulations of bog iron.

The bed that yielded the fossils is a light-yellow partly consolidated cross-bedded sandstone, capped with a layer of clean gravel. Locally the sand is tightly cemented in large irregular lumps by either calcareous or limonitic cement. The limonite points to boggy conditions, suggestive of swampy water holes and shallow ground water. The conglomerate contains mostly water-worn gravel of red and other dark colors derived chiefly from the silicic extrusive rocks that crop out in the mountains to the south. Most of the pebbles in the gravel are less than 3 inches in diameter.

The hill in which the fossils occur has been subjected to erosion, but 30 feet of light-yellow loess, which has accumulated since the lake was drained, caps the gravel on the adjacent plateau.

In addition to the forms mentioned above as obtained from the quarry, this and other localities in the vicinity of Hagerman have yielded remains of mastodon, camel, peccary, sloth, cat, otter, hares,[44] aquatic birds,[45] and a rodent of the muskrat group. The presence of the otter, the muskratlike rodent, and aquatic birds adds materially to the evidence indicating the environment suggested by Gidley.

Considerable silicified wood has been found along Clover Creek near King Hill in these same lake beds. The following invertebrate fossils, identified by W. C. Mansfield, of the United States Geological Survey, were collected by Stearns from a highly fossiliferous sandstone member of the Hagerman lake beds along the King Hill canal at a large siphon about 5 miles upstream from King Hill:

Goniobasis taylori (Gabb)
Lithasia antiqua Gabb
Latia dalii White
Sphaerium sp.

Besides these fossil shells, large fresh-water clam shells that evidently belong to the *Unio* family were noted along the canal road farther upstream. All these fossils indicate that these beds were laid down in fresh water.

The interstratified basalt members of the Hagerman sediments are shown in plate 5. They occur as relatively thin basalt flows of remarkable continuity, indicating extreme fluidity at the time of extrusion. The lower contact zone is commonly stained yellow to

[44] Gazin, C. L., Fossil hares from the late Pliocene of southern Idaho: U. S. Nat. Mus. Proc., vol. 83, no. 2976, pp. 112–121, 1934.

[45] Wetmore, Alexander, Pliocene bird remains from Idaho: Smithsonian Misc. Coll., vol. 87, no. 20 (Pub. 3228), pp. 1–12, 1933.

reddish brown and usually consists of comminuted and fragmental glassy lava. The flows are considerably jointed and in a few places change into "pillow" lava, or balls of lava surrounded by a vitreous glass, a common feature of subaqueous basic flows. In places these intercalated volcanic beds are tuffaceous, especially near the mouth of Salmon Falls Creek and near Bliss. Both lava and tuff occur sparingly in the Hagerman lake beds, indicating that the tranquil waters of this lake were not often disturbed by volcanic eruptions.

The upper basalt layer in the Hagerman lake beds in the NW¼ sec. 18, T. 6 S., R. 13 E. (pl. 5), consists of 30 feet of columnar-jointed deeply weathered pahoehoe with the upper part showing the usual horizontal parting planes and vesicles. Nothing is present to indicate a subaqueous origin. About half a mile to the southeast the basalt is only 10 feet thick and rests on 12 feet of horizontal thin bedded basaltic tuff. Some layers of the tuff contain lapilli and others sand-sized particles, but foreign ejecta are scarce. This tuff is similar to that in the tuff craters of Oahu, Hawaii, and may have resulted from phreato-magmatic blasts.[46] The basalt pinches out a short distance southeast of this point and the tuff gets thicker. This tuff and lava indicates a vent not far away.

A deposit perhaps indicating a vent is exposed in the SE¼ sec. 20, T. 6 S., R. 13 E., but it is certainly unlike any volcanic deposit either at a vent or elsewhere known to Stearns. It crops out along the ditch road in the south side of the river in an exposure about 200 feet high. It is a decomposed dark-brown crumbly mass containing streaks and small balls of dense hard basalt intermixed with chunks of clay and streaks of agglomerate. The latter consists chiefly of weathered older basalts, and no andesite or quartzite fragments were noted. The whole deposit is overlain by 6 feet of laminated buff clay, which is distorted and so badly jumbled that its significance could not be determined. The whole mass dips to the northwest. To the southeast is another great mixture of rocks mapped as a landslide (pl. 5). Perhaps both have the same origin.

The Hagerman lake beds are in general so impermeable, because of their fine texture, that water occurs only sparingly in them. Most of this formation is traversed by canyons, hence precipitation falling on its outcrop appears as surface run-off. Perennial springs discharging over a few gallons a day do not occur, and small perennial seeps are few and far between. At the west end of the Twin Falls South Side tract these beds are saturated with irrigation water and yield water rather high in mineral content. The Banbury hot well, described on page 167, obtains its water from tuff and basaltic flows, intercalated with the lake beds. Wells penetrating the Hagerman

[46] Stearns, H. T., and Vaksvik, K. N., Geology and ground-water resources of the island of Oahu, Hawaii: Hawaii Dept. Public Lands, Div. Hydrography, Bull. 1, pp. 16–17, 1935.

lake beds will be unsuccessful for the most part, but if drilled deep enough they will probably find sufficient supplies from the sandy members or the interstratified basic tuffs and lavas. One of the wells of the Oregon Short Line Railroad at Bliss, after penetrating 56 feet of Pleistocene lava and clay, entered the Hagerman lake beds and obtained a good supply of water at 517 feet. At 235 feet enough water was struck in the clay for drilling, but the main supply was obtained from sandy layers between 456 and 470 feet. The water rose to a level 350 feet below the top of the well. The well is cased to 422 feet and on October 17 and 18, 1917, was tested with a steam pump and yielded 80 to 100 gallons a minute. The draw-down during this test is not known.

PLEISTOCENE ROCKS

OCCURRENCE AND CHARACTER

All the volcanic and sedimentary materials that were laid down on the Snake River Plain from the end of the Hagerman epoch to the end of the deposition of the older alluvium are assigned to the Pleistocene epoch. (See table, pp. 27–32, and pl. 4.) The lava flows, which make up by far the greater part of the Pleistocene rocks, might be further subdivided roughly into early and later groups, each group comprising the products of numerous eruptions. Available data do not permit differentiation of the flows in the greater part of the plain, partly because, in the absence of dissection, the youngest flows in each locality tend to conceal those previously erupted. The comparatively excellent exposures along the canyon of the Snake River between Blackfoot and King Hill have permitted the distinction of 11 local Pleistocene formations which for the most part correspond in age with the younger group of basalts. These are, named in order of decreasing age, Cedar Butte basalt, American Falls lake beds and intercalated basalt, Madson basalt, Malad basalt, Thousand Springs basalt, McKinney basalt, Bliss basalt, Sand Springs basalt, Burley lake beds, Minidoka basalt, and Wendell Grade basalt. Their distribution is shown in plates 5 and 6. Similar local subdivisions of the Pleistocene sequence have been made in the Mud Lake region and elsewhere.

SOURCES OF THE ERUPTIONS

The principal vents from which the Pleistocene and later basalts issued are shown on plate 4. Altogether about 300 vents are mapped, and probably about 400 occur in the entire plain. Most of the vents not shown lie in the desert between Idaho Falls and Kimama, and reconnaissance through this area on the few existing roads indicates that only about a third were mapped. Except for the cluster in the Craters of the Moon and the group north of St. Anthony, the vents are rather evenly distributed. No definite rift pattern is discernible,

although here and there short cone chains occur. The vents that supplied the recent black lavas have not been differentiated by a separate symbol on plate 4 because generally their close relation to the lavas is evident from their position. However, a few of the cones are older and stand like islands in the areas of black lavas. About [illegible] of the Recent cones are shown on plate 4.

Near the foothills along the north side of the Snake River Plain, cinder cones 50 to 200 feet high predominate. Over most of the plain the greater number of the vents are broad lava domes, each usually about 100 feet high and with the related flows covering an area of about 30 square miles. The broad dome is capped by a smaller dome which has slightly steeper slopes and is generally about 50 feet high. Deep craters in the domes are usually absent, and in many places only a suggestion of a crater rim was left when activity ceased. Small spatter cones 10 to 50 feet high occur in some places, but beds of basaltic tuff indicative of explosive eruptions are rare. The lava rose to the surface through fissures or tubular vents and welled out quietly and profusely. Unlike most volcanic cones of the central-vent type, nearly all these cones had only one period of activity. When volcanic activity was resumed in the neighborhood of one of these cones a new opening poured out lava, usually only a short distance away.

It is obvious that the copious flows in the region must have interfered with drainage greatly and intermittently through a long period of time. Several examples of such interference are described in subsequent parts of this paper. The present channel of the Snake River through most of the region here considered lies close to the southeastern and southern margin of the plain, a position which leads to the inference that many of the Pleistocene vents were so situated that eruptions from them forced the river to shift in this direction instead of remaining more nearly in the median portion of the plain, where presumably it originally flowed. The fact that many of the early Pleistocene flows now recognizable lie in the southern part of the plain supports the concept that later lava came largely from vents farther north and thus covered the older flows there. The early lava along the Snake River west of the Minidoka Dam issued in large part from cones on the south side of the river and from buttes near Eden, a short distance north of the canyon. The fact that the streams which reach the plain from the north now have no channelways connecting them with Snake River also constitutes evidence in favor of this concept. It would seem that when the major drainage pattern of the region was originally established these streams must have been directly tributary to the Snake River.

There is direct evidence that flows from cones to the south tended locally to shift the channel northward also. Examples are known near

Yale, in the Raft River Valley, and also in the South Side Twin Falls tract.

WATER IN THE PLEISTOCENE BASALT

The basalts of the Snake River Plain are in general very permeable, and their usefulness as aquifers is indicated by the large amount of water discharged from them in the form of springs between King Hill and Milner. In 1902 these springs discharged about 3,900 second-feet, and in 1918, as a result of irrigation, they had increased to about 5,100 second-feet. Wells that have penetrated the water table in these basaltic areas, almost without exception, yield abundant supplies of water for domestic and municipal use, with but slight draw-down. Yields of more than 50 gallons a minute for each foot of draw-down are not uncommon, and yields of more than 500 gallons a minute for each foot of draw-down are recorded. The Ralph Raumaker well, near Hamer, is about 50 feet deep, and the draw-down is only a few inches when the well is pumped with a 5-inch centrifugal pump that discharges about 450 gallons a minute. The Pleistocene basalts are fresh, and the cavities in them are as a rule open. The openings that allow ground water to move through the lavas are the clinkery contacts of one flow with another and the vertical joints or shrinkage cracks that characterize these flows. The open spaces in extrusive basalt through which water can move, exclusive of those due to later disturbances of the rocks, are listed in approximate order of usefulness 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 openings in cinders, aa, and subaqueous lava formed during deposition.
3 —Open spaces in joints formed by shrinkage of the basalt in cooling.
4 —Tunnels and caves produced by liquid lava flowing out from under a hardened crust.
5 —Vesicles and cavities due to the expansion of gases during the cooling of the lava.
6 —Tree molds, resulting from lava surrounding a tree and solidifying before the tree has burned away.

The upper crust of a lava is generally rough and broken because of movement within the flow after the crust has formed. Inundation by another lava flow never completely fills these irregularities. Consequently many openings, some of which are extensive and capable of holding or transmitting large quantities of water, occur between successive beds. Beds of cinders are not extensive in the Snake River Plain and occur chiefly as buried cones. Drillers often report red cinders in drilling, but generally they refer to beds of red doughy masses that lie at the bottom of a lava flow or to the fragmental part of aa lava. Aa lava flows are the most permeable of the lava beds. This brecciated rock produced by granulation of the lava stream while in motion is, prior to weathering, probably the most permeable rock formation on the face of the earth. The blocks are rough and angular and resemble talus. They cover an appreciable area of the Snake River Plain, and drillers report the aa clinkery lava in wells.

Subaqueous lava, of which the Bliss basalt is typical, differs considerably from aa but is also brecciated and permeable. In many places where lava flows rest on older sediments they exhibit a subaqueous phase at the contact. Thousand Springs and most of the other large springs in the Snake River Canyon issue from basalt of this type. Cinders, aa, and subaqueous basalts, because of their fragmental character, yield readily to weathering and hence are commonly the first to become watertight with age.

Lava tubes are common in the Snake River Plain, and it is through a system of ramifying tubes that the pahoehoe type of lava was distributed from the vents. On relatively steep slopes these tubes are left open after the flow stops, and the lava drains out of them. Some of these tubes are as much as 50 feet in diameter and several thousand feet long. The Sand Springs basalt, which is about 300 feet thick near Thousand Springs, contains many open tubes. Lava tubes are sometimes encountered in drilling. Stearns was lowered on the drilling cable into the new Idaho Falls city well, near the mouth of Willow Creek to examine a cavity about 8 feet in diameter that was struck about 100 feet below the surface. In the J. A. Melton well, west of Mud Lake, a lava tube full of water was encountered. Large tubes full of water were also encountered in the Wilkinson and Cox drainage tunnels on the South Side Twin Falls tract.

Joint cracks due to shrinkage of the basalt at the time of cooling range from a fraction of an inch to several feet in width and in general are nearly vertical. They are useful in the transmission of water from one lava flow to another one below and doubtless are the means by which irrigation water in many places percolates readily downward to great depths. The Goyne sump, in sec. 10, T. 9 S., R. 23 E., serves as an outlet for drainage water on the North Side Minidoka project. It is about 100 feet deep and 8 feet in diameter, and all except the upper few feet is in basalt. About 22 second-feet of water will sink continuously in this pit, but when 25 second-feet is allowed to enter, the pit fills up, because its transmission capacity has been reached. Wells drilled into the lava on this project and near Roberts have been used successfully for drainage. The fact that many of the wells drilled in basalt blow and suck air with changes in barometric pressure is further evidence of the connected systems of cracks and caverns that occur in these lavas.

Vesicles and cavities caused by the expansion of gases during the cooling of the lava are usually disconnected, and hence water cannot move readily through them. Near the top of a lava flow these vesicles are commonly so numerous as to give the crust a spongy app[illegible] and this part is generally more permeable than the main mass [illegible] flow. Drillers frequently state that this spongy lava yield[illegible] volumes of water. The spongy or vesicular lava is in fact com[illegible] not the source of these large yields, however, but its presence ind[illegible] that the drill has passed from one flow to the top of another [illegible] water is obtained largely from the open spaces at the contact [illegible] lava beds or from the numerous joint cracks which occur at [illegible] of the flow rather than from the vesicles.

In places where lava flows have entered forests tree molds ar[illegible] mon and form an appreciable amount of the voids in the lava. [illegible] Craters of the Moon National Monument there are certain [illegible] areas where tree molds are plentiful, and molds full of water hav[illegible] encountered in drainage tunnels on the Twin Falls tract. Ho[illegible] if the Snake River Plain was nearly treeless during the accum[illegible] of the lava flows, as it is at present, it is not likely that tree m[illegible] sufficiently numerous to be very useful in the movement of [illegible] water.

In small areas in the valley water in the basalts is con[illegible] impermeable beds of clay and loess, of sufficient extent to [illegible] slight artesian heads. This condition occurs in the vicinity [illegible] Lake, where there are flowing wells with large discharge and [illegible] specific capacity.

A somewhat similar artesian condition has been developed in [illegible] areas in the Aberdeen-Springfield and Twin Falls South Side [illegible] as a result of irrigation. In the Twin Falls South Side tract [illegible] wells have proved effective in the drainage of swampy land. [illegible] wells, like those at Hamer, have low head but yield abundantly.

Dike systems and sills have not been recognized in any of th[illegible] developments except at Bliss Spring, although they must exist in [illegible] parts of the Snake River Plain. From the wide distribution [illegible] vents and the absence of dikes in the walls of the Snake River C[illegible] they are probably too scattered to affect the circulation of water [illegible] locally.

The rate of flow of the water through the basalt is depend[illegible] the geologic structure. Thus in the Twin Falls South Side [illegible] which lies from 50 to 300 feet above the Snake River, on [illegible] bordering the Snake River Canyon, swampy tracts have [illegible] through irrigation, whereas on the opposite side of the canyon [illegible] also irrigation water is applied in large amounts, there are [illegible] no seeped areas and the water table lies far below the surface. [illegible] condition is interpreted as being caused by loess beds on th[illegible] side, which are intercalated with the lava flows and which [illegible] artesian wedges, whereas on the north side these loess beds ha[illegible] cut through by former channels of the Snake River. These [illegible]

[illegible] were later filled with permeable basalt and now form [illegible] wedges in which no loess occurs. The Sand Springs basalt [illegible] such a canyon, and from it issue many of the largest springs. [illegible] north side is favored with natural drainage channels, but [illegible] River has never cut a channel farther south than the present [illegible] vicinity of Twin Falls. This means that the South Side [illegible] none of these lava-filled canyons through which ground water [illegible] rapidly away from the project. Furthermore, a study of [illegible] and water table indicated that the greater part of the [illegible] River Plain from Big Bend Ridge, near Ashton, to King Hill [illegible] these ancient canyons through which the ground water [illegible] freely.

[illegible] at which the water moves through the basalt is difficult [illegible] because it varies from place to place according to the [illegible] of the lava, the geologic structure, and the hydraulic [illegible] The daily records of the flow of Blue Lakes Spring in sec. 28, [illegible] 17 E., from 1917 to 1920 afford a basis for estimating the [illegible] movement of the ground water tributary to it. The contour [illegible] water table (pl. 19) shows that the water that supplies [illegible] passes under Wilson Lake and the First Segregation of [illegible] Side tract at Hazelton. There is no irrigated area between [illegible] Segregation and Blue Lakes, and therefore a time interval [illegible] underground travel between the two points can be determined by [illegible] the observed flow of Blue Lakes Spring with fluctuations [illegible] and hence the seepage loss of water on the North Side [illegible] and the amounts of water in Wilson Lake, which loses at a [illegible] when containing much storage water.[47] The records of [illegible] diversions and of storage in Wilson Lake are plotted by 15-day [illegible] in plate 11. During the early part of each irrigation season [illegible] lake drops rapidly, with corresponding decreases in percola- [illegible] On the other hand, there is an increase in losses during [illegible] period from increased irrigation diversions. Records are [illegible] able for Wilson Lake during the winter.

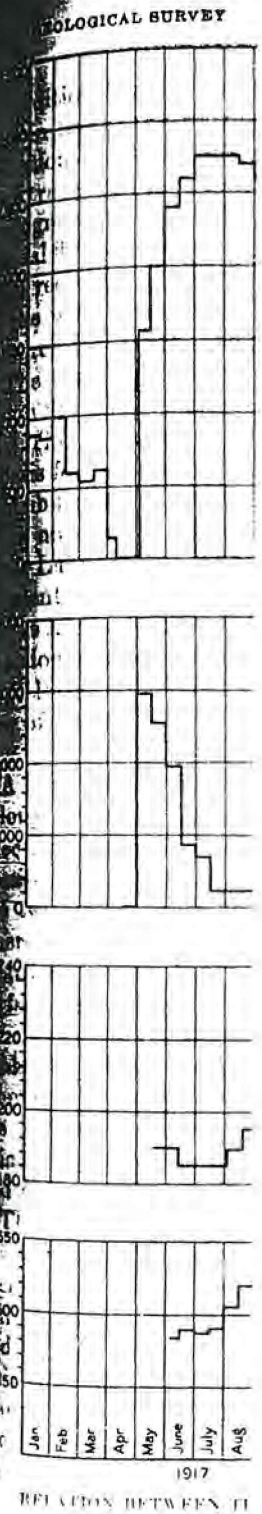
[illegible] sudden increase in diversions and lake storage during the [illegible] of May 1917 is clearly reflected by the increased discharge [illegible] Lakes Spring during the first part of August, 3 months later, [illegible] in plate 11. The time between the average of the summer [illegible] diversions in that year and the corresponding peak in the [illegible] Blue Lakes Spring in 1917 was about 3½ months. A similar [illegible] occurred in 1918. In 1919 the time between the seasonal [illegible] only 2 months. That year, however, was one of deficient [illegible] supply, causing deliveries to the First Segregation to be less [illegible] the average in normal years, hence contributions to the

[illegible] T., Success and failure of reservoirs in basalt: Am. Inst. Min. Met. Eng. Tech. Pub. 215, water table from irrigated lands were very small. The seasonal flow of Blue Lakes Spring in 1919 was about 3 to 3½ months than the peak at Wilson Lake, and probably the fluctuations in year reflected the ground-water contributions from Wilson Lake much greater extent than the contributions from irrigated lands.

The large amount of water diverted through the canal la October 1919, after the canal had been dry for a month, clearly ca the increased flow at Blue Lakes Spring 3 months later. (See pl The time between the peak diversions in 1920 and the maximum of the spring was about 3½ months, although the period when canal was dry in the later part of September 1920 could be det only 3 months later at Blue Lakes Spring.

It thus appears that the time interval between seasonal peak about 3½ months but that sudden large increases in the contribu to the water supply require only about 3 months to travel Wilson Lake and the First Segregation to Blue Lakes Spring point half a mile south and 1½ miles west from Hazelton is about center of ground-water contributions from the First Segregation the Wilson Lake region. This point is 15 miles east of Blue L Spring. Thus about 3½ months is required for the ground water move 15 miles. The average seasonal rate of movement of grou water between the two points is therefore about 750 feet a d whereas under certain conditions it apparently travels about 850 f a day through the same permeable basalts underlying this area.

The altitude of the water surface in the town well at Hazelton 3,836.2 feet on July 2, 1917, whereas that of the outlet of the spr that supplies Blue Lakes is about 3,300 feet. The difference in water surface between the two points, 16½ miles apart, is theref 536 feet, and the average slope is 32.5 feet to the mile. It appe from the ground-water contours of this section on plate 19, howe that the water table from Hazelton toward Blue Lakes has an aver fall of only about 20 feet to the mile, which in 16½ miles would amo to 330 feet, or about 206 feet less than the total difference in altitu between the water table at Hazelton and that at Blue Lakes. Th drop in the water table of 206 feet is probably concentrated in a sh distance above the springs. The springs are about 160 feet hig than the Snake River and about three-quarters of a mile from making an average fall from the spring outlet to the river of 214 f to the mile. If the ground-water cascade of which Blue Lakes Spr is the outlet continues on this gradient it would thus extend for abo a mile in an easterly or northeasterly direction before reaching t main underground flow, which is moving westward under the pla north of the Snake River.



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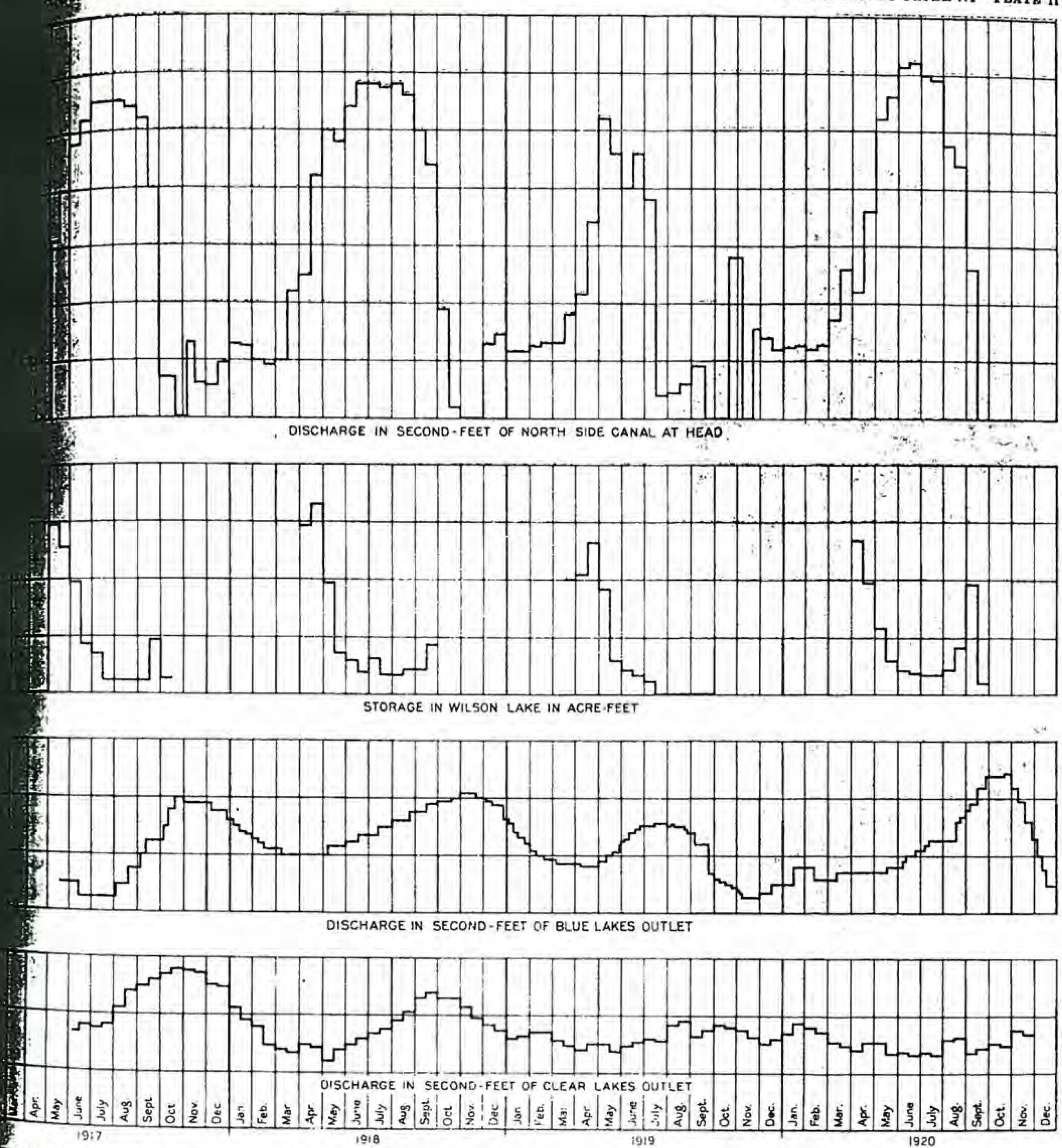

LATION BETWEEN THE USE OF IRRIGATION WATER ON THE TWIN FALLS NORTH SIDE TRACT AND THE FLOW OF BLUE LAKES AND CLEAR

...vidence of the relatively rapid rate of ground-water ...ion is afforded by the fact that the ground-water con... more than 600,000 acre-feet annually from the North ...ppear each year as underground run-off without causing ...ise in the water table under the project. The average ...tion in the water table amounts to about 6 feet, resulting ...from irrigation water, but each year the water surface ...turns to practically its former level, which is several ...below the ground surface.

...ge of Clear Lake outlet, the only spring beside Blue ...for which daily records are available, is shown by plate ...uations recorded at the Clear Lake gage do not afford ...ulating the rate of flow, because the irrigated area that ...the water that emerges at this point extends for many ...t and is not localized enough to indicate the source of ...ter. The low flow of this spring in 1919 was caused by a ...r supply for irrigation, but the failure of the spring to ...in 1920 as it was in 1917 and 1918 is probably due to the ...t of the Jerome Reservoir in the fall of 1919, part of the ...from that reservoir evidently having contributed to the ...r Lake.

UNDIFFERENTIATED BASALT

...proportion of the flows throughout the Snake River Plain ...the early Pleistocene group, but in many areas these are ...concealed beneath later deposits, and in others it is im... ...ith the available data, to distinguish definitely between ...roups. In the Mud Lake region, and to some extent else... ...relations to glacial and other deposits and the degree of ...show that most of the flows in the vicinity of the present ...(exclusive of those grouped as Recent black lava) are as ...ate Pleistocene, and some are possibly Recent. Along the ...ver between the Minidoka Dam and King Hill the flows ...s "undifferentiated basalt" on plates 4 and 5 are older than ...ocene flows described individually. Upstream from the ...Dam the basalt thus grouped includes flows both younger ...than those downstream.

...eistocene flows in general are readily distinguished from the ...alts by their comparative freshness. In most outcrops of ...ene basalt weathering has penetrated less than an inch. ...salt is commonly gray to black, fine-grained, and vesicular, ...many exposures has small feldspar and olivine phenocrysts ...o the unaided eye. Most of the flows are pahoehoe, whereas ...f the Recent black lavas are aa. One of the few aa flows in ...ies overlies the American Falls lake beds north of American ...and thus belongs to the later Pleistocene flows. Samples of

drill cuttings taken at intervals of 1 to 5 feet in the Y
dry hole north of Minidoka, were examined by H. T.
the results given below. Drillers' logs of other wells
the region show broadly similar variations in the charact

Log of Yarnell well, north of Minidoka

Soil consisting of loess and wind-blown quartz sand
Blue basalt, red at base, containing olivine crystals 1 to 3 millimeters in diameter. Vesicular at top and base of flow
Loess soil
Blue basalt flow with phenocrysts of olivine and feldspar. The uppermost and lowermost 3 feet are composed of red vesicular lava
Loess soil, baked red
Reddish-brown basalt, changing downward into extremely dense basalt except at 68 and 72 feet and at the base of the flow, which is vesicular
Blue-black basalt flow, with vesicular rock at 88 to 94 feet. Number of olivine grains greatly increases in densest part of flow, which is at 98 feet
Wind-blown soil
Blue basalt containing small amount of olivine and extremely dense at 110 feet
Wind-blown soil
Olivine basalt
Wind-blown soil
Brownish-blue basalt, with abundant olivine discolored by weathering
Wind-blown soil
Reddish vesicular olivine basalt except for dense rock at 173 feet
Wind-blown soil
Gray-blue basalt, with olivine and clear feldspar crystals in abundance and a dense streak at 182 to 194 feet. At 197 feet the cuttings change to red vesicular rock, indicative of base of flow
Olivine basalt with only a thin vesicular band at top and bottom
Wind-blown sand
Blue basalt, extremely dense in lower 15 feet; evidently bottom of hole is near the bottom of the flow but not quite through it

This well, if continued deeper, will encounter water,
drilled to discover gold ore, which, of course, does not
bedded with the basalts as the driller believed.

Individual flows are commonly 10 to 75 feet thick, bu
flow piles up in a preexisting drainage channel its thick
abruptly increase. In the early lavas exposed in the wa
canyon beyond the Minidoka Dam local thickenings resul
such fills are relatively small. The aggregate thickness of
flows exposed in this vicinity is 600 feet. Northwest of St
a well 1,050 feet deep failed to reach rock recognizable as p
cene. In Laidlow Park, a short distance south of the Crat
Moon National Monument, a well penetrated 918 feet
before reaching the older silicic lava. It is probable that o
of the central part of the Snake River Plain the Pleistoc
aggregate fully 1,000 feet in thickness.

SEDIMENTARY BEDS IN THE LAVA

Loess and clay are intercalated in the Pleistocene flows.
places, as near Trail Springs, there is also some gravel.
canyon of the Snake River these materials are especially
near the new Twin Falls bridge. The sedimentary beds ar
where thin as compared to the basalt. Some are thick eno

tervals of quiescence of considerable length between
The products of any single eruption covered only a small
plain, and meanwhile soil accumulation continued undis-
where. The thickness of an individual loess bed depends
nearness to a source of supply than on the time interval
uptions. For example, only a short distance west of the
area extensive outcrops of incoherent lake beds have long
d to the wind. During the time required to accumulate
oess on lava in this vicinity only an inch or two will prob-
eposited on the basalt 50 miles to the northeast. In spite
factors of this sort it appears to be broadly true that the
uniformity of cover of loess soil on a given area of basalt
f the age of the flows. On this basis it is postulated, for
t the basalt south of the river near Twin Falls, which is
where covered by deep soil, is materially older than that
river in the same locality, where numerous areas of
osed and most of the soil is comparatively thin.
places masses of sedimentary material, so thick or exten-
hey can be separately mapped, are associated with the
flows. Each of these masses that has so far been recog-
escribed on succeeding pages.

PLEISTOCENE FORMATIONS ABOVE THE CANYON OF SNAKE RIVER

LAVA FILLS

umerous displacements of the Snake River and its tributaries
ows have caused it to aggrade behind the dams thus caused,
own through these dams, and to build accumulations of
hort distances beyond them. The local formations dis-
ed along the present canyon of the river and described
(pp. 65–84) have all resulted more or less directly from such

ake River before displacement by the Sand Springs basalt,
mple, was flowing in a basaltic canyon 500 feet deep with
rtical walls. The inflowing lava was pahoehoe basalt that
great volume from a cone on the north side of the river.
a had first spread laterally on the plain above, but when
it reached the north rim and cascaded into the canyon it
rarily built up a lava delta. The sudden change in grade of
ace on which the lava flowed accelerated the draining of the
tube leading from the vent and tended to make this the
drain. Thus, from the time the lava began cascading into
yon the flow tended to cease spreading laterally, and most
lava flowed toward the canyon.
ough canyon lava fills in this area are impressive because of
ngth and thickness they do not ordinarily represent greater

outpourings than occurred elsewhere on the plain. Instead of sheets, V-shaped lava fills were formed.

As some of these lava fills are 50 miles long and 300 to 500 feet thick, it is obvious that they must have retained much heat. Here as elsewhere [48] this was doubtless accomplished by movement of the lavas through tubes of its own construction beneath an insulating crust. In all localities where the Snake River was displaced the flow filled the canyon at the original point of entry and then because of topographic control spread along it, chiefly but not exclusively downstream. The lava rarely extends more than a fraction of a mile on the south side of the canyon, except where it fills tributary valleys owing to the easier escape down the canyon.

In all places studied in detail the lava had completely obliterated the preexisting canyon for several miles. Then it had become confined between the walls of the canyon for a few miles and stopped. The Sand Springs flow, for example, obliterated the Snake River Canyon for 50 miles downstream beyond its point of entry and stopped 10 miles farther down. The ends of the flows are not now exposed except where they are cut through by the Snake River. They are generally about 20 feet high, or the same height as if the flow had spread out on the plains, even though the lava fill upstream may be 500 feet thick.

During such an accumulation of lava in the canyon, especially in the early phases of an eruption, the margin of a flow advancing upstream was continually entering ponded waters and producing local steam explosions. One such explosion is definitely known to have formed a cinder and ash cone more than 200 feet high. Most of the products of these explosions were later buried by the sediments deposited behind the lava dam; hence they are seldom found.

It is not unusual to find lava several miles upstream from the point where the flow entered the canyon. The downstream advance of such a flow was accompanied by many activities and changes. The following hypothesis is offered to account for the pillow lava and glassy brecciated pahoehoe at the base of the lava fills.[49] Where the stream bed was underlain by saturated gravel or other permeable materials the lava that flowed over such wet ground was comminuted or brecciated by steam explosions. This extremely permeable phase of the pahoehoe made the dam start leaking at the outset. The leakage was continually available for minor explosions and for the formation of pillow lava at the downstream margin. To a less extent the same permeable material is found at the contact of the lava with the canyon wall, apparently because steam rising in most places along

[48] Stearns, H. T., Geology and water resources of the middle Deschutes River basin, Oreg.: U. S. Geol. Survey Water-Supply Paper 637, pp. 145–146, 1931.

[49] Stearns, H. T., Origin of the large springs and their alcoves along the Snake River in southern Idaho:

the contact was available for the disruption of the lava. As the hydraulic gradient of the water moving through the lava dam was probably somewhat steepened by the damming effect of the debris caused by the steam explosions at the downstream margin and by the progressive widening of the dam, the water table in the lava dam may have risen simultaneously with the accumulation and cooling of the lava, so that it may have been fairly close to the hot lava at all times.

Because of the narrowness of the canyon, the newly created lake had small storage capacity, hence it may have overflowed even while the eruption was in progress, unless leakage through the dam with the added effect of steam explosion was sufficient to dissipate the inflow. These agencies, however, could not have sufficed to dispose of the inflow of so large a river as the Snake during prolonged eruptions. In fact, a dam 50 miles wide and only a mile across would be entirely different from any known engineering structure. As the dam was permeable, the seepage, instead of following a few well-defined crevices, must have built up a water table with a fairly uniform slope from the surface of the impounded lake to the toe of the dam.

At the moment of overflow the great volume of water in the Snake River was sufficient to establish a course along the southern margin of the new lava flow until it reached the point where the lava no longer filled the canyon. At this point the water tumbled back into its former course and formed a cascade on the surface of the lava fill until the end of the flow was reached, where it again returned to normal grade in its prelava channel. The river was influenced by topographic irregularities near the margin of the lava and at some places did not follow that margin very closely. For example, it established a course half a mile to 5 miles south of the Sand Springs lava fill from the lake it created near Burley to Shoshone Falls. Here it again returned to the edge of the lava, which it followed to Salmon Falls Creek and then reentered its former canyon.

On the irregular surface of the lava fill the river took a meandering course that soon became established. As the downcutting proceeded remnants of the fill were left first on one side of the river channel and then on the other as detached benches. While the new channel was being established there was doubtless considerable leakage into the lava. In at least one place this leakage was sufficient to give rise to large springs at the toe of the dam.

When the Snake River was displaced by lava flows and had taken its new course it faced the great task of draining the lakes so formed and of resuming its former grade. While the outlets of the lakes were being cut down the debris carried by the river was settling in the quiet waters behind the lava dams. In some of the lakes this process of sedimentation was more rapid than the cutting, so that the lakes filled with silt before the outlets were appreciably reduced. In others, where the new course was in relatively weak lake beds and one abutment of the newly formed lava dam was in lake beds also, the outlet was reduced so rapidly that there was time for only a thin veneer of gravel to form in the lake bottom. Thus, the texture of the lake sediments would be dependent in some measure upon the size of the lake and the weakness of the dam.

While a lava-dammed lake was being filled with sediment and its outlet lowered, the Snake River actively aggraded its bed at the toe of the dam. The river cascading down the dam with a gradient in some places as much as 150 feet to the mile, loosened huge blocks of lava and rolled them to the toe, where the sudden flattening of the grade made them drop. The jointing in basalt permitted ready plucking, so that water-worn boulders 5 to 12 feet in diameter are common. During the early stages the debris accumulated rapidly enough to form a steep fan overlapping the toe of the dam and extending a mile or more downstream. With the flattening of its gradient and the subsequent reduction in quantity of debris supplied, the river ceased to build its fan and began to destroy it. The decreased velocity of the river at this stage permitted only the smaller material to be removed, and the large boulders are left as a residual concentrate much like that seen at hydraulic placer mines. Spectacular groups of boulders formed in this way can be seen in Hagerman Valley and near King Hill. They resemble the coarsest of morainal deposits. The alluvial fan near King Hill was only partly reworked by the river and now forms steeply sloping alluvial terraces that border the river. Boulder deposits of this type served as valuable field criteria in determining the location and number of the places where the Snake River had been ousted from its channel by lava. Such groups of boulders occur at the mouth of Rock Creek in connection with the lava dam at American Falls, and there are several similar occurrences in Hagerman Valley (pl. 12, *A*) and near King Hill.

Where a lava fill, such as those described above, has been largely removed through reexcavation of the canyon, its former presence is commonly recorded by benches composed of residual masses of the fill clinging to the canyon walls. Similar topographic forms, however, can be produced in other ways. Where a series of essentially flat beds of different degrees of resistance to erosion is cut into by a stream, a bench of somewhat similar appearance commonly results. Where the canyon of the Snake River is cut in basalt alone, the flows are of such nearly equal resistance that only a single conspicuous example of this type of bench was noted. This bench commences near Milner Dam, where it is so small as to be hardly noticeable. It increases in size in a short distance downstream, and between Murtaugh and Shoshone Falls is a conspicuous topographic feature on both sides of the river. (See pl. 9.) The part of this bench above Shoshone Falls lacks the billowy surface commonly characteristic of a youthful intracanyon flow. Good exposures near Twin Falls seem to show that the bench was formed because of the resistance of a massive layer of basalt at a time when a temporary base level was established by the resistant andesite now exposed at Shoshone Falls. Benches of this kind can be distinguished from remnants of intracanyon fills by the absence of any unconformity at the junction of bench and canyon wall.

CEDAR BUTTE BASALT

In secs. 22, 23, 26, and 27, T. 8 S., R. 29 E., there are two buttes, one of them known as "Cedar Butte" (pl. 6), which are former vents of a large basaltic dome. Like most of the great lava producers of the Snake River Plain both of them lack well-formed craters. The basalt spread southward from the cones as massive pahoehoe, with lesser amounts of aa. The lava is an aphanitic blue basalt containing phenocrysts of fresh green olivine as much as 3 millimeters in diameter. On the eastern knob of the northern butte there are a few cinders.

Prior to the eruption of the Cedar Butte basalt, the Snake River occupied a course roughly parallel to the present one but a few miles north of it, between a point near Blackfoot and the mouth of the Raft River. The Cedar Butte eruption filled at least 20 miles of this channel, damming the river and forming a lake about 40 miles long and 12 miles wide, which extended from Massacre Rocks nearly to Blackfoot (pl. 4).

AMERICAN FALLS LAKE BEDS

Sedimentary beds.—Along the Snake River from Springfield nearly to Massacre Rocks stretches a series of yellowish-white to buff lake beds, which are regarded as produced by sedimentation back of the dam described above. (See pls. 4, 6.) They form steep bluffs about 100 feet high along the north bank of the river from the American Falls Dam to the Narrows, a distance of about 5 miles. They consist of even-bedded, partly consolidated silt, clay, and sand, with local pebbly lenses near the top and a 6-foot bed of laminated basic tuff 30 feet below the top of the series southwest of American Falls. Large parts of them have been removed by erosion from the south bank of the Snake River below the dam. Along the north side of American Falls Reservoir just at the shore line, or about 100 feet below the highest deposits of the lake, basalt is interstratified with the sedimentary beds.

Although the precise stratigraphic relations between the tuff and basalt were not established because of the lack of adequate topographic maps and the distance between their outcrops, it seems likely that the tuff resulted from explosions caused by the basalt entering water.

The absence of tuff cones in the adjacent area supports the idea of a local origin.

Near the junction of the Low Line and High Line canals on the Aberdeen-Springfield project large basalt blocks lie scattered over the surface of the lake beds 100 feet or more from their parent outcrop. These blocks were presumably plucked from the basalt along the shore of the ancient American Falls lake and rafted away on ice cakes. The altitude of this place of plucking is 4,450 feet, which tends to establish the altitude of the shore line of the ancient lake. In some places a definite shore line exists near the High Line canal of the Springfield-Aberdeen project, but in others the lake beds grade imperceptibly into the loess covering the basalt of the plains. A well 178 feet deep in sec. 7, T. 4 S., R. 31 E., did not penetrate any sedimentary beds, hence the lake did not extend this far to the northwest. The exposure of the sedimentary rocks farthest downstream is in sec. 9, T. 8 S., R. 30 E., about 2½ miles above the point where the Cedar Butte basalt crosses the present canyon of the Snake River at Massacre Rocks. Remnants of the basalt crop out about 170 feet above the river on both sides a quarter of a mile below this point.

The completion of the American Falls Reservoir has caused the submergence of the lower part of the lake beds upstream from American Falls, but wave action has undermined the banks, exposing the upper beds. From American Falls to the mouth of the Portneuf River, along the southeast side of the reservoir, the top layer becomes progressively coarser and grades from fine shot-sized gravel through all sizes to huge boulders near the mouth of the Portneuf River. Red and white quartzite gravel predominates, suggesting that most of the gravel was derived from the Portneuf and adjacent tributary streams rather than from the Snake River. From the Portneuf River around the head of the reservoir to a point south of Springfield younger gravel at or slightly above the reservoir level obscures the lake beds if they are present. The upper surface of the lake beds on the south side of the Snake River, with its veneer of later gravel, corresponds to the Gibson terrace described by Mansfield.[50]

A flowing well in the center of sec. 15, T. 4 S., R. 32 E., is reported by the driller to have encountered 265 feet of clay and silt with some beds of colored gravel. A 36-inch log of redwood was drilled through at 190 feet. One piece of bone, too small to be identified, was found in the lake beds. It was not fossilized like those from the Hagerman lake beds. Leo Lee, of Aberdeen, obtained several bones and teeth which he states were removed from these beds during the excavation of the west abutment of the American Falls Dam. They have been identified by J. W. Gidley, of the Smithsonian Institution, as being bones of *Elephas* sp., of Pleistocene age, probably late Pleistocene. These beds rest on the eroded and deformed Eagle Rock tuff and Massacre volcanics and are unconformable on some of the basalt of the plains. In a general way they resemble the Hagerman lake beds in their lithology and undisturbed condition, but their shore line is 4,500 feet above sea level, or about 1,050 feet higher than that of the Hagerman beds.

[50] Mansfield, G. R., Geography, geology, and mineral resources of the Fort Hall Indian Reservation, Idaho: U. S. Geol. Survey Bull. 713, pp. 16-17, 1920.

The American Falls lake beds are generally so fine grained as to be poor water bearers, but in the vicinity of the reservoir the more sandy members carry sufficient water for domestic use.

Basalt member.—Gibson Butte rises several hundred feet above the Snake River in sec. 32, T. 3 S., R. 32 E., and is among the largest and most prominent basalt domes on the Snake River Plain. Its surface is heavily veneered with loess, but the character of the butte is shown by a few small outcrops of scoriaceous aphanitic gray basalt and a broad, shallow crater on its summit.

Young alluvium mantles the south and west sides of the butte, but on the southeast and east it abuts against the ancient alluvium of the Gibson terrace, which corresponds to the upper part of the American Falls lake beds. Across the Snake River and practically at the foot of the butte occurs a basalt flow whose sparse soil cover indicates youth. This condition and the fact that it seems to have come from the north indicates that it had no connection with the eruptions from Gibson Butte. Farther downstream much basalt is definitely intercalated with the American Falls lake beds. Other patches of basalt similar in character and stratigraphic position extend as far downstream as American Falls. The most southwesterly of these outcrops differs from the rest in that it contains tiny phenocrysts of olivine. Although this difference by itself does not prove that this basalt had a different origin from the rest, such an assumption is strengthened by the fact that there is some evidence that the basalt fills a depression cut in the lake beds instead of being merely intercalated in them.

So far as can be judged, the basaltic member lies at an average depth of 100 feet below the top of the lake beds. The basalt thickens northeastward toward Gibson Butte, with corresponding thinning of the overlying sediments suggesting that Gibson Butte is the source of this lava. Near the old shore line the basalt is only 1 to 10 feet thick and locally has the characteristics of lava that flowed under water. As much of the basalt does not have these characteristics, the lake may have been shallow at the time of eruption.

The basalt was, at least in part, buried under lake beds and alluvium at the time the lake was tapped by the Snake River, and therefore it had no effect on the original position of the channel cut by the river. The river started to cut down along the north shore of the former lake,