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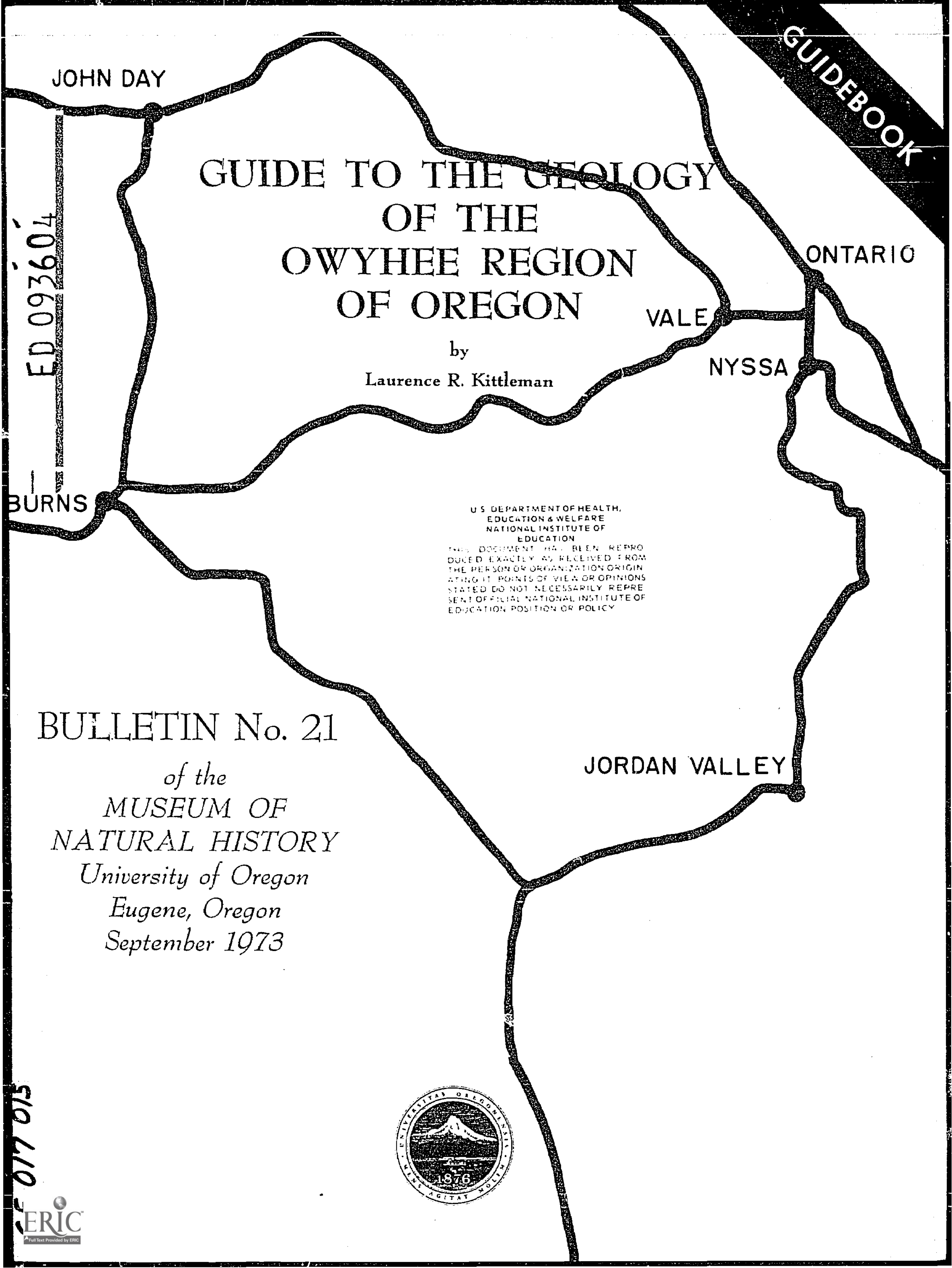
ABSTRACT

In this bulletin a detailed description of a geologic region in Oregon is presented with numerous illustrations, both plates and schematic diagrams. Maps of the region as well as maps of various excursions are included in the booklet. A geologic-time unit table is presented covering the Cenozoic Era. Three excursions with included side-trips are described in detail. Road logs give point by point instructions and explanations for the geologic excursions. The maps show routes, stops made, and important geographic details. Mileages are given to include accumulated mileage and distance between each station. A list of readings is presented as well as a listing of geologic words and meanings. The bulletin includes a list of publications of the Museum of Natural History at the University of Oregon. (EB)



GUIDEBOOK

GUIDE TO THE GEOLOGY OF THE OWYHEE REGION OF OREGON

by

Laurence R. Kittleman

BULLETIN No. 21

of the
MUSEUM OF NATURAL HISTORY
University of Oregon
Eugene, Oregon
September 1973

The *Bulletin* of the Museum of Natural History of the University of Oregon is published to increase the knowledge and understanding of the natural history of Oregon. Original articles in the fields of Archaeology, Botany, Ethnology, Geology, Paleontology, and Zoology appear irregularly in consecutively numbered issues. Contributions arise primarily from the research programs and collections of the Museum of Natural History and the Oregon State Museum of Anthropology. However, in keeping with the basic purpose of the publication, contributions are not restricted to these sources and are both technical and popular in character.

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Bulletin No. 21
Museum of Natural History
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Eugene, Oregon
September 1973

To

J. Arnold Shotwell, my teacher,
colleague, and friend.

CONTENTS

LIST OF ILLUSTRATIONS

MAPS

TABLE

Published with the financial assistance of
the Office of Scientific and Scholarly Research
in the Graduate School
of the University of Oregon

GUIDE TO THE GEOLOGY OF THE OWYHEE REGION OF OREGON

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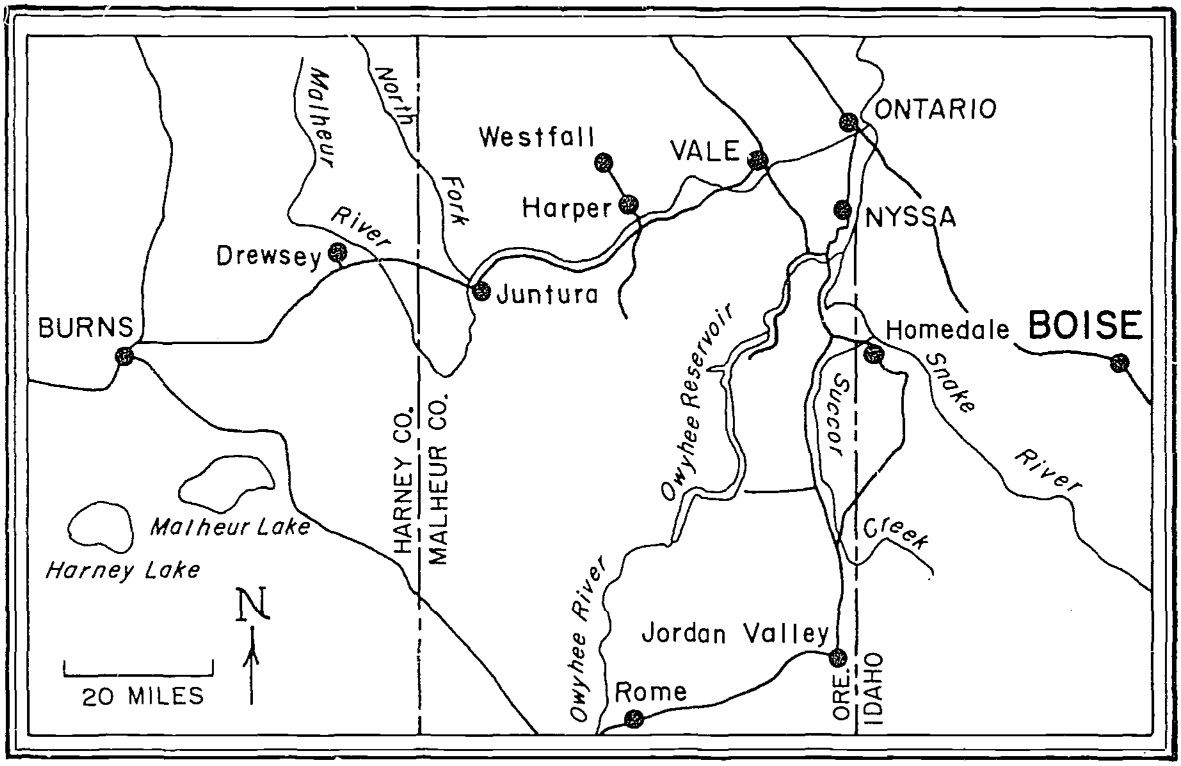
INTRODUCTION

The Owyhee region is an area of no exact boundaries in southeastern Oregon, within the drainage basins of the Malheur and Owyhee rivers, both tributaries of the Snake River, which forms part of the border between Oregon and Idaho (Map 1). The region is a land of plateaus cut by deep canyons. Elevations range from 2100 feet above sea-level, where the Malheur River enters the Snake, to 6500 feet, at the top of Mahogany Mountain (Map 3). Average yearly moisture is 10 inches of water, which falls mainly in the winter, and extremes of temperature range from about −30 degrees Fahrenheit on winter nights to 100°F or more on summer afternoons. This climate may seem harsh, but in ways it is a part of the attractiveness of the region. The air is dry and clear, and is filled by the smell of sun-baked sage. Many people enjoy the daily round of temperatures, which in summer may go from a brisk 40°F at dawn to a roasting 100°F at noon. From late June until October, sunshine is nearly unfailing, and the deep-blue sky, perhaps with perfect fluffy white clouds, invites color photography of the region's fine scenery. Climate is the main regulator of the vegetation that marks the region as a desert and contributes to its stark beauty.

The conspicuous plants of the Owyhee region are big sagebrush, cheat grass, and shadscale. Rabbitbrush grows in moist places, and juniper and mountain mahogany grow at higher elevations. The dominant form is sagebrush, the plant by which the habitat is known —the high sage desert.

On a summer day, the desert seems to be poor in animal life. Carrion-eating birds and birds of prey are seen in the sky, and there are flying insects, but on the ground only lizards and ground squirrels are active when the sun is high. The desolation is only apparent, for many inhabitants seek shelter during the heat of the day, because they depend solely on the water in their food, or else drink seldom from scarce sources of water. These animals escape drying or overheating by burrowing underground or by resting in the shade of plants. Those that live above ground are seen only when they are disturbed, as when a jackrabbit is flushed from its shady refuge or when a rattlesnake is made to buzz by a footstep too close to where it is coiled beneath a ledge. Animals of the desert are active during the cooler times of day, when they leave their hiding places to hunt or forage. Come twilight, bats and nighthawks feed on flying insects. Owls and rattlesnakes begin their hunt for rodents—the pocket mice, deer mice, jumping mice, harvest mice, and kangaroo rats. Travelers in the desert who make camp or occupy an abandoned building for the night may be visited, sometimes to their dismay, by skunks, wood rats, or racoons. The yapping of coyotes is a usual and pleasant sound of the night. Those who travel just after dawn are likely to be rewarded by the sight of a herd of pronghorns, surprised while grazing in a hol-



Map 1. *General map of the Owyhee region.*

low. These animals, capable of 50-miles-an-hour sprints, show their white rump patches to any human intruder and quickly disappear over the nearest ridge, sometimes pausing to look curiously back from the safety of a half-mile distance.

Any landscape is the product of a long period of geologic evolution culminating in present forms that are acted on by the present climate and covered by vegetation in harmony with that climate. The character of the land, in turn, influences human history, determining means of livelihood, routes of communication, and patterns of settlement. The history of a landscape can be read from clues in the rocks themselves, just as written history is pieced together from documents. Contrary to first impressions, the land is not just a jumble of stones and dirt, but an orderly assemblage of rocks and soils that have been formed in a particular sequence by ordinary processes. These processes go on continuously. They can be seen in action daily or can be reasonably understood from events that have been witnessed. There is no need to appeal to fantastic happenings, and the most spectacular events, volcanic eruptions, for example, are no less spectacular if their causes are understood.

Rocks that make up the land commonly are arranged in layers that can be interpreted according to the principle that lower layers are older than those which overlie them. There are exceptions. Sometimes layering can no longer be seen, or the layering is upside down, but the principle is a good one nevertheless. Each layer, whether it is a fraction of an inch or many feet thick, is formed by some process acting for a time under more or less constant conditions. When conditions change, or when some different process begins, a new layer forms on top of the old one. For example, a flow of basaltic lava may erupt from fissures, cover a wide area, cool, and form a layer of basalt. The basalt perhaps blocks previously existing streams, and new streams wander over the newly formed surface of basalt, depositing layers of sand and gravel, which will, in time, become layers of sandstone and conglomerate. Perhaps there follows a new flow of basaltic lava, which buries the sandy layers. Now there is, in imagination, a layer of basalt, the older, then layers of gravel and sand, then another layer of basalt, the younger. These three layers are a geologic record of the events that formed them. Each layer contains in its grains of minerals—their chemical compositions, forms, and arrangement—a record of the process responsible and the associated physical and chemical conditions. It is only necessary to learn to read such records, and that is what the business of geology is. Rocks hold the records of deposition in streams and lakes, of eruptions of lava, of plants and animals that leave parts of their bodies as fossils, of movements in the earth's crust that break or fold layers of rock, of weathering of rocks that forms soil and new sediment, and of erosion that carves out canyons and mountains.

The geologic record is made up of many different kinds of rock layers, some thick, some thin, some widespread, and some extending only a few feet. It is impossible and unnecessary to understand completely the relationships among all individual layers. Instead, geologists mentally gather layered rocks together into manageable units that are called formations. A formation may be a single thick layer or, more comomnly, a group of individual layers with more or less consistent characteristics which are recognizable throughout a wide area. The main requirements are that a formation be clear enough and thick enough that it can be told apart from other similar formations and be traced and plotted on a geologic map. Formations are given names that have two parts. The first part is taken from the name of some geographic feature near the place where the formation is well developed and readily seen at the surface. The second part is the name of the kind of rock most characteristic of the formation as a whole. For example, the Hunter Creek Basalt is a widespread flow of basalt which is well exposed on hillsides above Hunter Creek, near Juntura, Oregon(Map 2). If a formation contains a variety of different kinds of rocks, no rock-name is used, but the word formation is added to the geographic part of the name, for example, Deer Butte Formation.

There runs through the foregoing discussion the implication that layers of rock record not only series of events in the past, but also the passage of time. Only recently has it been possible to measure geologic time in terms of calendar years, using methods which depend upon natural radioactivity, for example, the disintegration of carbon-14. Before such methods were developed, the passage of geologic time was thought of only in terms of the rocks themselves. Through many years of painstaking work, geologists developed a system based upon the idea that the layers of rocks laid down during a particular period of time represent that time. Fossils which the rocks contain are indicators of the period of time represented by the rocks. With this system, it is not necessary to know the length of time in years. Instead, a number of named geologic-time units have been developed, and these units are used throughout the world, even though it is now possible to relate the geologic-time scale to time measured in years. The scale is made up of eras, each divided into several periods, each, in turn, divided into epochs. Rocks of the Owyhee region belong to the Cenozoic Era (Table 1), which began about 65 million years ago. Their geologic ages are found mainly from study of fossil mammals that they contain. Such studies in North America and elsewhere show that there are particular species of mammals whose fossils are found only in rocks of a particular epoch. It is from these special fossils that geologic age can be determined. For example, if a layer of rock contains fossils of mammals that lived only during Pliocene times, then it is said that the rocks belong to the Pliocene Epoch or that they are of Pliocene age.

In Table 1 the geologic-time scale is related to a scale of time in years obtained by the potas-

TABLE 1

Geologic-Time Units of the Cenozoic Era

		EPOCH	APPROXIMATE SCALE OF TIME IN YEARS BEFORE PRESENT
CENOZOIC ERA	QUATERNARY PERIOD	Holocene Epoch	10 thousand years
		Pleistocene Epoch	4 million years
	TERTIARY PERIOD	Pliocene Epoch	11 million years
		Miocene Epoch	26 million years
		Oligocene Epoch	40 million years
		Eocene Epoch	55 million years
		Paleocene Epoch	65 million years

sium-argon method of dating rocks. This method depends upon the radioactive breakdown of the chemical element potassium-40 to argon-40. The rocks that are dated have minerals in them which contain potassium-40. The breakdown happens at a known, unchanging rate, so, from the amounts of potassium-40 and argon-40 measured to be in a rock, the number of years since the rock was formed can be figured. Some rocks in the Owyhee region are 15 million years old, relatively young geologically, but about 3000 times the length of all written history. Such lengths of time are so enormous that no one can really imagine them. It is easier to think in terms of periods and epochs.

Geologic formations of the Owyhee region are shown in Figure 1, where they are arranged in order of age, with the oldest on the bottom. Geographic relations of the formations to each other are shown in a greatly simplified way in Figure 2. When these formations are mentioned later on, the illustrations can be looked at to get an idea how each formation is related to those above or below it or in other geographic areas.

Rocks that tell the story of the Owyhee region are exposed to view in canyons and plateaus that began to be carved into their present forms a few million years ago, near the beginning of Pleistocene time. Flow upon flow of basalts that make up the unnamed igneous complex are laid bare in the walls of Malheur Canyon (Fig. 9), and Jump Creek Rhyolite forms the rugged surface of the mesa above Succor Creek (Fig. 33). Leslie Gulch Tuff is carved into a maze of cliffs and spires in the narrow canyon of Leslie Gulch (Plate IV). Rocks of the Deer Butte Formation rise in forms like Mitchell Butte (Fig. 14).

The oldest rocks exposed in the region formed about 15 million years ago, late in the Miocene Epoch, a time of great volcanic activity throughout the American West. This volcanism is recorded by the rocks of the Sucker Creek Formation, the oldest known in the region. Much of this formation is volcanic ash that came from explosive volcanic eruptions somewhere outside the region and was carried in by winds. Most of the ash probably was washed from hillsides after it fell and carried to final places of deposition along streams or in lakes. One part of the formation, the Leslie Gulch Tuff, has a different origin, and it must have come from a nearby source, although that source has not yet been found. This deposit is an ash-flow tuff, which erupted from fissures or from a volcanic vent as molten froth filled with hot volcanic gases. Layered with the volcanic sediments of the Sucker Creek Formation are beds of sandstone and conglomerate with grains of quartz and feldspar and pebbles of granite. These were deposited by streams that got their loads of sediment from granitic lands to the southwest in what is now Idaho. During the time the Sucker Creek Formation was being laid down, local eruptions produced the flows called the basalt at Bishop's Ranch.

Building of the Sucker Creek Formation was followed by fissure eruptions of basaltic lava, forming the many layers of Owyhee Basalt. Farther to the west, other basaltic eruptions began at about the time rocks of the Sucker Creek Formation were being deposited and built up the thick accumulation of basalts that is the unnamed igneous complex.

In spite of continual volcanism during the Miocene, streams flowed, forests grew, and animals lived in them. Of course living things are destroyed or threatened when eruptions are actually happening, but at places where volcanism is temporarily inactive, plants and animals can live undisturbed. Probably there were periods when volcanic activity was no greater than it is in the region today. Conditions may have resembled those in modern Iceland, Central America, Hawaii, or Indonesia, all of which are inhabited, despite frequent volcanic outbursts. In the Miocene, living things did flourish in the Owyhee region, and they have left their shells, bones, or impressions, in testimony.

Fossil plants, the impressions of leaves and other parts preserved between layers of sedimentary rocks, show that there were forests of maple, birch, chestnut, walnut, laurel, sycamore, poplar, oak, willow, pine, and elm. Rushes of horsetail and cattail bordered bodies of water. These are not at all like the plants that grow in the region today. They are the vegetation of moist, temperate lowlands—less than 1000 feet in elevation—bordered by cooler highlands. Since the Miocene, the region has been uplifted thousands of feet by movement of the earth's crust, and the Cascade Range has risen, cutting off the flow of warm, moist air from the Pacific Ocean.

The plants of the Miocene are modern forms and would not seem strange to us. So too, the animals were not weird beasts, but the ancestors of modern species. There were dog-like animals, squirrels, and the ancestors of the mountain beaver that now lives only in the Coast Range. The horses were small and had two extra toes, and we would be surprised to notice rhinoceroses, peccaries, mastodons, camels, and some unfamiliar deer-like creatures.

Following deposition of the Owyhee Basalt and the unnamed igneous complex, there was a period during which erosion dominated, accompanied by faulting and tilting of the rocks to form low mountains. Lavas of a new episode of volcanism flowed out on this landscape, forming layers now called Dinner Creek Ash-Flow Tuff, Hunter Creek Basalt, and Littlefield Rhyolite. The Dinner Creek Tuff was formed

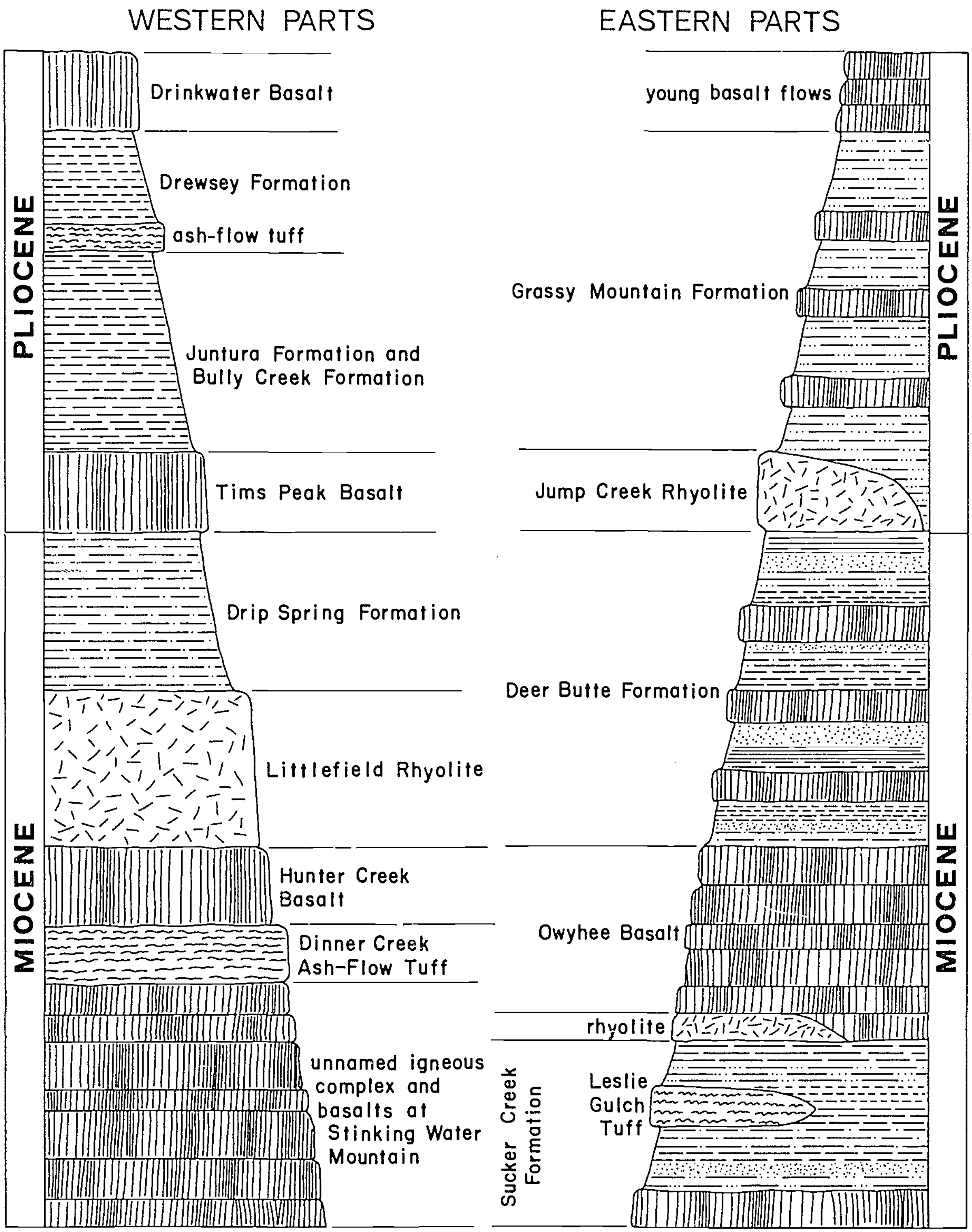


Figure 1. *Sequence of layered rocks in the Owyhee region.*

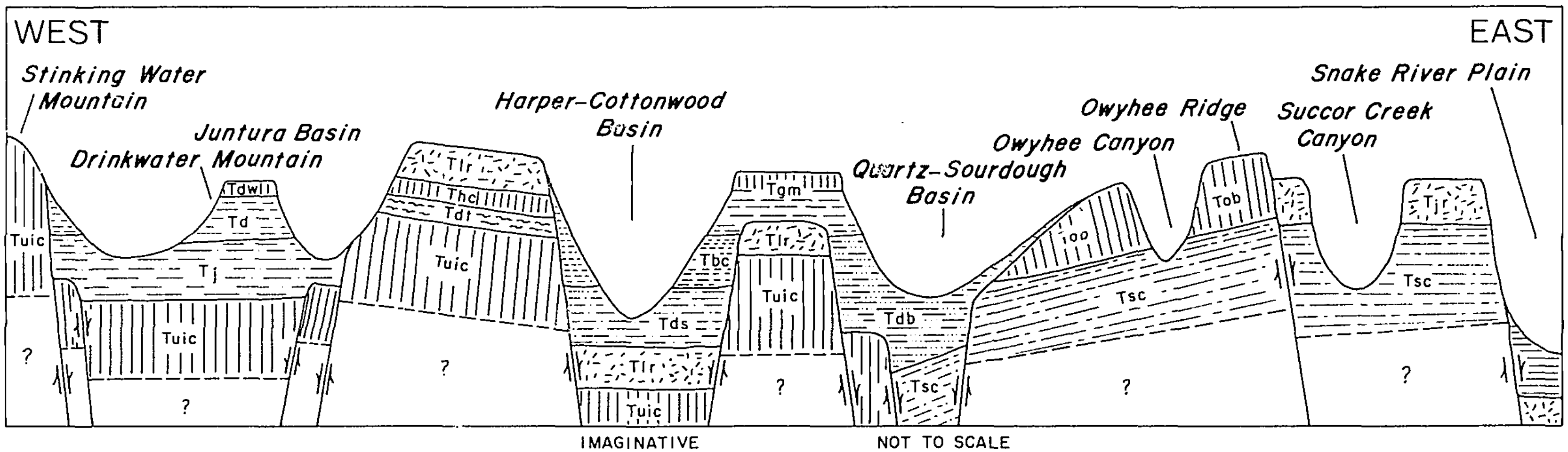


Figure 2. *Relations among formations of the Owyhee region.*
Symbols—**Tdw,** Drinkwater Basalt; **Td,** Drewsey Formation; **Tj,** Juntura Formation; **Tuic,** unnamed igneous complex; **Tlr,** Littlefield Rhyolite; **Thc,** Hunter Creek Basalt; **Tdt,** Dinner Creek Ash-Flow Tuff; **Tgm,** Grassy Mountain Formation; **Tdb,** Deer Butte Formation; **Tbc,** Bully Creek Formation; **Tds,** Drip Spring Formation; **Tob,** Owyhee Basalt; **Tsc,** Sucker Creek Formation; **Tjr,** Jump Creek Rhyolite

by an eruption of at least 20 cubic miles of molten froth that covered more than 1000 square miles. Nothing like it has ever been witnessed, but similar, though much smaller, eruptions have happened in modern times at Bezymianny volcano, in Kamchatka, eastern Siberia, and at Mount Katmai volcano, Alaska. These eruptions spewed out great masses of hot volcanic ash and gas that blanketed the land and exhaled jets of steam and gases for months afterwards.

In contrast, the Hunter Creek Basalt must have erupted rather quietly, probably from fissures. Its thinness and wide extent suggest that it flowed easily over great distances.

The Littlefield Rhyolite must have oozed out of many closely spaced fissures, which all opened at about the same time. It is about 500 feet thick in places, and contains many thin laminations that indicate flowage, churning, and folding of stiff masses of rhyolitic lava. The rhyolite cooled. The landscape created was inhabited by plants and animals, and it received showers of volcanic ash that was redistributed by streams, but the region was shortly disturbed by vertical movements of the earth's crust, perhaps caused by earlier withdrawal of great amounts of rhyolitic lava from deep reservoirs. The land broke along faults—straight, nearly vertical cracks, miles long—which ran in a northerly direction. In places, great blocks of rock between faults sank, forming narrow troughs that are known today by names like Harper Basin and Juntura Basin. This sinking did not happen all at once during a single catastrophic earthquake, but slowly over many thousands of years, probably accompanied by countless small and large earthquakes. Keep in mind that if the fault-blocks sank only as fast as one-half inch a year, then they could sink 3000 feet in about 100 thousand years. In the sinking troughs, sediment and lava flows accumulated—stream gravels, volcanic ash, basalts, and lake-bottom oozes. These accumulations spanned the boundary between Miocene and Pliocene times and produced deposits called by the names Drip Spring Formation, Deer Butte Formation, Tims Peak Basalt, Bully Creek Formation, Juntura Formation, Grassy Mountain Formation, and Drewsey Formation.

Accumulating sediments entombed the bones of animals that lived in a variety of habitats, from the banks of ponds and streams to drier uplands. A fascinating assemblage of fossil Miocene mammals has been found, representing tiny animals with microscopic skeletal parts to elephant-like mastodons. There were shrews and moles; rabbits; chipmunks, squirrels, and beavers; dogs, weasels, and martens; several kinds of small, three-toed horses; rhinoceroses; and a variety of antelope-like creatures.

By Pliocene times, the climate of the Owyhee region had become drier, as the rising Cascade Range increasingly blocked inland flow of air from the Pacific. Changing climate caused changes in communities of animals, as the environments of the Miocene gave way to new ones, which could be exploited by new groups of animals evolving from the old. Several different animal communities can be recognized from fossils, each with its characteristic inhabitants. A savanna community of open grasslands with scattered groves of trees included camels, horses, mammoths, rhinoceroses, and peccaries. A pond-bank community had shrews, moles, rabbits, beavers, ground squirrels, and foxes. A grassland community contained horses, antelopes, and dogs.

Near the end of Pliocene times, perhaps 5 million years ago, the basins of the Owyhee region had filled in with sediments and lava. Even ridges bordering basins were overtopped, and a few late flows of basaltic lava—the Drinkwater Basalt is an example—spread across what must have been a fairly flat landscape. The whole region then began to rise toward its present elevation around 4000 feet above sea level. As it did so, ancestors of the modern Malheur and Owyhee rivers, which had already established winding courses, kept pace, cutting twisting canyons deeper and deeper into stacked layers of rock, while countless rains eroded hillsides and supplied water and sediment to streams. The products are the canyons, plateaus, buttes, and mesas of the modern landscape, lying under the sun of the Oregon desert, inhabited by modern plants and animals, and by humans, who have been there only about one one-hundred thousandths of the time since the history of the Owyhee landscape began.

ROAD-LOGS

INTRODUCTION

The material that follows gives point by point instructions and explanations for geologic excursions in the Owyhee region. There are accompanying maps that show routes, stops to be made, and important geographic features. The region traveled is shown on the Burns and Boise quadrangles (scale, one-fourth inch equals one mile), published by the U.S. Geological Survey. Three geologic maps of the region have been published also:

Geology of the Mitchell Butte Quadrangle, Oregon (1:125,000), by R. E. Corcoran and others: Oregon Department of Geology and Mineral Industries, Geological Map Series, GMS-2 (1962)

Geologic Map of the Burns Quadrangle, Oregon (1:250,000), by R. C. Greene and others: U.S. Geological Survey, Miscellaneous Geologic Investigations, Map I-680 (1972)

Geologic Map of the Owyhee Region, Malheur County, Oregon (1:125,000), by L. R. Kittleman and others: University of Oregon Museum of Natural History, Bulletin No. 8 (1967)

Road-logs are arranged as three excursions, Excursion A from Burns to Vale, Excursion B to Owyhee Reservoir, and Excursion C to Succor Creek Canyon. Included are optional side-trips off the main route. Although each excursion might be completed in only one day, two days would be more pleasant.

Mileages are given in the two columns at the left. The first column is accumulated mileage from the beginning of the excursion, not including side-trips. The second column is the distance from the preceding station. These distances were measured with the mileage dial of an ordinary automobile speedometer, so some variation from one car to another is to be expected. Generally the distances should check within about 0.2 mile, barring changes in the roads themselves.

Instructions and important notations are printed in **BOLD** type. Stations where it is worthwhile to linger are called Stops. They are individually numbered and are shown on the accompanying Maps 2 and 3. Names of geographic features are printed in *italic* type, and names of geologic formations are printed in SMALL CAPITALS. Historical notes are set off from the rest of the text by a different style of type.

Technical words are avoided, but they cannot be eliminated completely. Many of those that must be used are explained immediately in the text, and the rest are defined in the accompanying list, Meanings of Geologic Words.

EXCURSION A. BURNS TO VALE
187 MILES
WITH SIDE-TRIPS TO DREWSEY, HARPER BASIN, AND COTTONWOOD BASIN

MAP 2

MILEAGES

0.0 0.0 **BEGIN EXCURSION** in *Burns*, at the Visitors' Center on the northeastern edge of town. Take Highway 20-395 northeastward. The geology of the region traveled for the next 66 miles is shown on Map I-680, mentioned in the Introduction to this section.

2.2 2.2 **JUNCTION. KEEP RIGHT on Highway 20.**

13.0 10.8 **STOP 1. HARNEY JUNCTION. PULL OFF and stop** on the right (south) near the Historical Marker for *Fort Harney*. The former site of the fort is a few miles north (left) of the highway along the dirt road (Fig. 3).

FORT HARNEY

A military post called Camp Steel was established here in 1867, and the name was changed to Fort Harney in 1879. The post was abandoned in 1880. Nothing now remains of the buildings.

CONTINUE EASTWARD ON HIGHWAY 20. The roadway is built upon sediment of a lake that occupied *Harney Basin* during the moister climate of Pleistocene time. *Harney Lake* and *Malheur Lake* south (right) of the highway (Map 2) are present-day remnants. The bluffs on the left (north) are ash-flow tuffs and tuffaceous sedimentary rocks of Pliocene age.

24.4 11.4 **BUCHANAN.** Begin *Stinking Water Pass.* Ahead, the western escarpment of *Stinking Water Mountain* is made of unnamed andesites, basalts, rhyodacites, and ash-flow tuffs of Miocene and Pliocene age. North-trending faults, downthrown on the west, helped to create the depression, now called *Harney Basin.* The rock in the prominent roadcut just east of *Buchanan* is Miocene rhyodacite.

ENROUTE. Rocks in roadcuts on both sides of the highway are unnamed basalts and andesites of Miocene age. They are cut by northeast-trending faults.

30.6 6.2 **SUMMIT** of *Stinking Water Pass* (elevation, 4848 feet). Enter western *Juntura Basin.*

This pass and Stinking Water Creek, a north-flowing tributary of Malheur River just east of Stinking Water Mountain, take their names from smelly hot springs nearby.

32.4 1.8 **STOP 2. EASTERN SLOPE OF STINKING WATER PASS. Pull off and park** at the right (south) side of the highway. Flows of coarse-grained, brown-weathering, crudely columnar basalt (Miocene) are exposed in the gulch south of the highway. The brown color comes from decomposition and weathering of iron- and magnesium-bearing minerals in the basalt. Here there is a view of the western *Juntura Basin* and *Drinkwater Mountain* (elevation, 4610 feet) beyond (Fig. 4). *Castle Rock* (elevation, 6780 feet) is a volcanic neck, and is believed to be the source of the DINNER CREEK ASH-FLOW TUFF (Miocene). *Drinkwater Mountain* is a mesa capped by DRINKWATER BASALT (Pliocene). Beneath the basalt lie tuffaceous and diatomaceous sedimentary rocks of the JUNTURA FORMATION (early Pliocene), which together occupy most of *Juntura Basin.* All rest upon a foundation of basalts and andesites like those exposed in *Stinking Water Mountain. Stinking Water Mountain* is bounded on the east by northwest-trending faults, downthrown on the east, which contributed to formation of *Juntura Basin.*

STINKING WATER PASS

36.7 4.3 **SITZ RANCH.** Seasonal ponds to the right (south) of the highway.

36.9 0.2 **BASALT FLOW IN JUNTURA FORMATION** (early Pliocene) in roadcut. On the left (north) in the distance is *Table Mountain,* capped by DRINKWATER BASALT. Ahead is *Deer Butte,* which is made of the same basalts as those seen on *Stinking Water Mountain.* On the right, *Bartlett Mountain* also is capped by DRINKWATER BASALT.

37.8 0.9 **STINKING WATER CREEK,** a north-flowing tributary of the *Malheur River.* On the right (south), the olive-drab bluffs in the middle distance are DREWSEY FORMATION (middle Pliocene)

Figure 3. Site of Fort Harney, *a U.S. military post between 1867 and 1880. The fort was at the break in the line of bluffs, where Rattlesnake Creek enters Harney Basin.*

ENROUTE. JUNTURA FORMATION (early Pliocene) in roadcuts.

39.0 1.2 **ROADCUT IN DREWSEY FORMATION.** In the western *Juntura Basin*, the ash-flow tuff at the base of the DREWSEY FORMATION is missing, and the DREWSEY is not easily distinguished from the underlying JUNTURA FORMATION, because their appearances are similar. They can be told apart by means of the fossil mammals both contain.

39.2 0.2 **EXPOSURES** near the highway on the left (north) are DREWSEY FORMATION.

41.4 2.2 **ON THE LEFT** (north) is *Deer Butte*. The workings to the right of the highway probably are prospect holes dug in search of commercially valuable deposits of diatomite.

43.7 2.3 **DREWSEY JUNCTION.** Begin side-trip A_1 to Drewsey.

Side-Trip A_1 to Drewsey
5 miles, round-trip

0.0 0.0 **DREWSEY JUNCTION. TURN LEFT** (north).

2.4 2.4 **STOP 3. DREWSEY.** The town is on the *Middle Fork* of the *Malheur River*. *Table Mountain*, north of town (Fig. 5), is made of tuffaceous sedimentary rocks of the DREWSEY FORMATION (middle Pliocene), which is named for the exposures here. It is capped by DRINKWATER

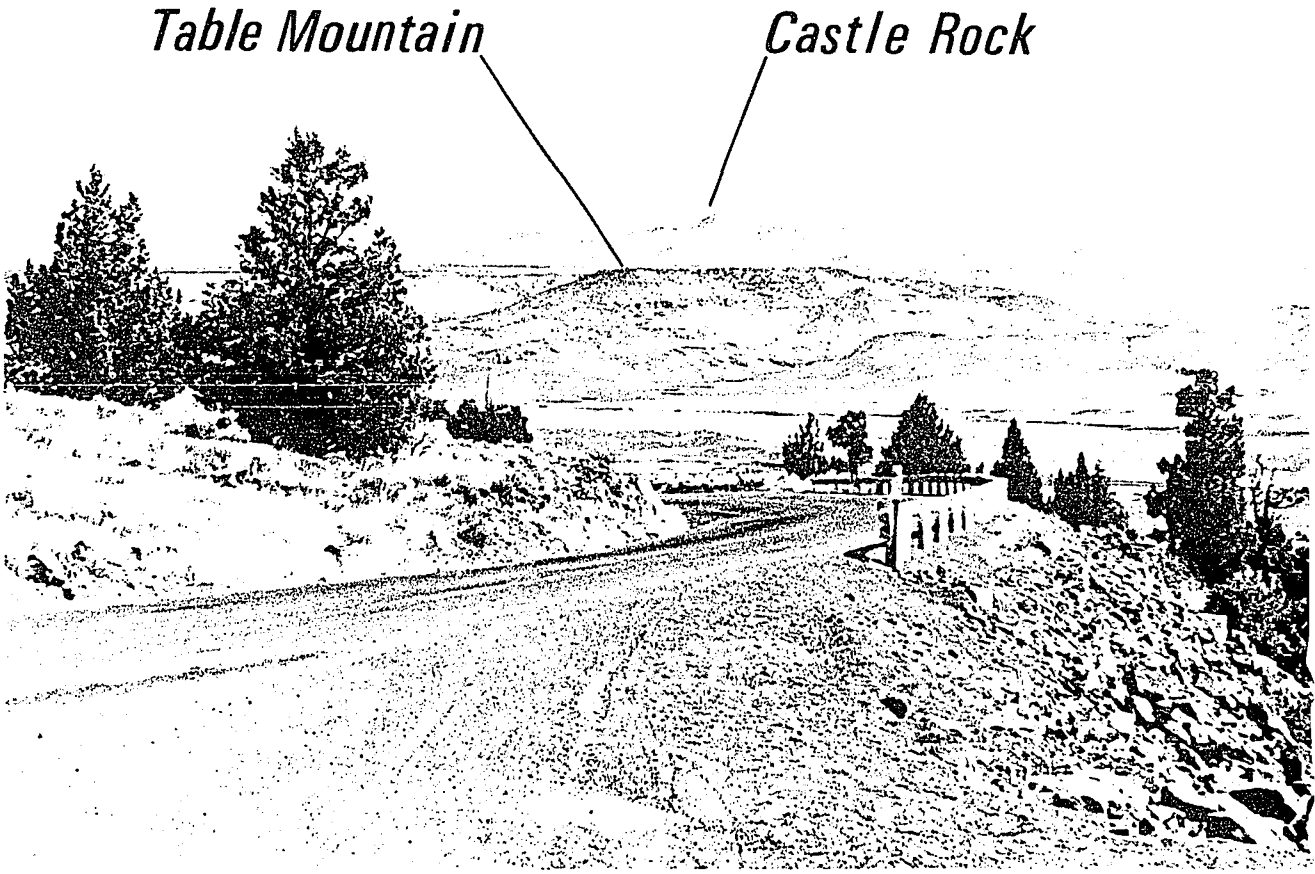


Figure 4. Western Juntura Basin *seen from Stinking Water Mountain. Castle Rock is thought to have been the source of the Dinner Creek Ash-Flow Tuff.*

BASALT. The DREWSEY FORMATION consists of sandstones, tuffaceous sandstones, tuffs, volcanic breccias, and diatomites. At the base in some places is a layer of ash-flow tuff.

DREWSEY

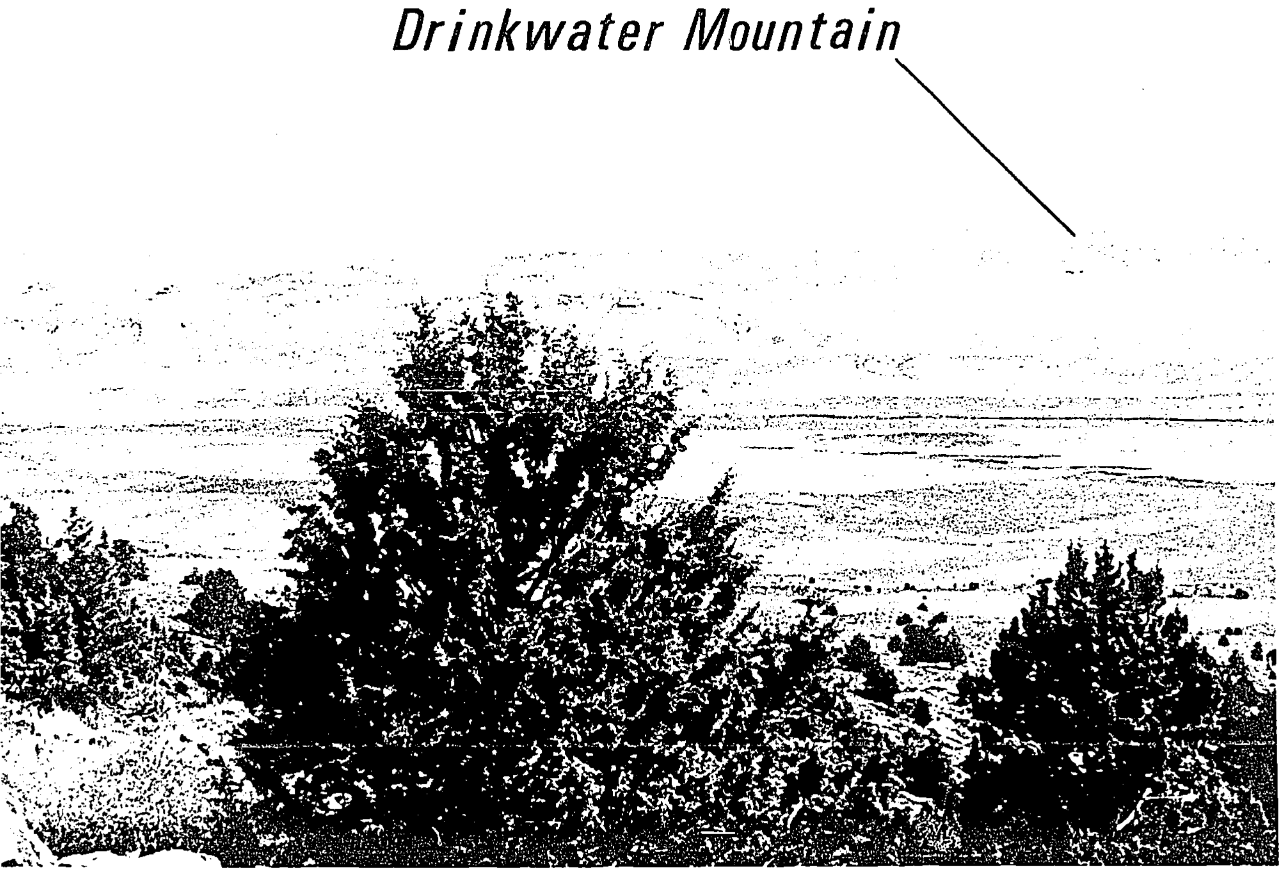
The town established here in 1883 first was called Gouge Eye, but when a Post Office was opened, authorities refused to accept that name, apparently thinking it crude, so the name was changed to Drewsey, after the postmaster's daughter.

TURN AROUND and return to Highway 20.

4.8 2.4 **DREWSEY JUNCTION. END of side-trip A_1 TURN LEFT** (east) to resume excursion A.

Resume Excursion A

43.7 .... **DREWSEY JUNCTION. CONTINUE EASTWARD** on Highway 20.



45.1 1.4 **MIDDLE FORK OF THE MALHEUR RIVER.** Begin ascent of *Drinkwater Pass.*

ENROUTE. Rocks of the DREWSEY and JUNTURA formations are exposed in roadcuts. The exact location of the boundary between these two formations is not known in this area.

47.7 2.6 **STOP 4. DIATOMITES** of the JUNTURA FORMTION (early Pliocene). Diatomite is a sedimentary rock made almost wholly of the microscopic shells of single-celled plants called diatoms that live in lakes or in the ocean. The shells are made of opaline silica, a form of the chemical compound, silicon dioxide, which living diatoms extract from the water around them. Individual diatoms are only about two thousandths of an inch in size, and high magnification is necessary to see them well. They live inside beautiful, perforated and finely sculptured opaline shells that resemble little round or oval pill boxes, each with a bottom and a lid. When the plant-cell inside dies, the shell survives and eventually sinks to the bottom. Countless millions of these shells accumulate on the bottom of a body of water, sometimes with other sediment, to form a diatomaceous ooze that eventually will become diatomite rock. The

DRINKWATER PASS

rock is white—blindingly so on sunny days—soft, light in weight, and it has a distinctive abrasive feel. This diatomite now high on *Drinkwater Pass*, was at the bottom of a lake that was here in early Pliocene time. The diatomite, of various degrees of purity, commonly is mixed with clay formed through decomposition of volcanic ash. There are also distinct beds of silvery-gray vitric volcanic ash. The association is not accidental, because the diatoms, which build siliceous bodies for themselves, were nourished by silica from the volcanic ash dissolved in the lake water. The rock is cut by many small faults, shows signs of flowage, and contains entrapped cobbles and boulders. These features formed shortly after the diatomaceous ooze was laid down, while it was still saturated with water and capable of flowing, sliding, and settling on the lakebottom. Only gradually did it become consolidated into the diatomite rock now seen. The most pure diatomite has been mined commercially near the town of *Westfall*. It is used for insulation, as an abrasive, and for filtering.

48.2 0.5 **STOP 5. SUMMIT OF DRINKWATER PASS** (elevation, 4212 feet). Here, bedded rocks of the JUNTURA FORMATION (early Pliocene) are cut by many small faults (Fig. 6). Enter eastern *Juntura Basin*.

48.4 0.2 **STOP 6. EXPOSURES of several formations** in the rim of *Drinkwater Mountain*. Rocks of the JUNTURA FORMATION are near the level of the highway. A short distance to the west, near the top of the gulch, is rim-rock of DRINKWATER BASALT underlain by ash-flow tuff of the DREWSEY FORMATION (middle Pliocene). The ash-flow tuff is composed mainly of glass-shards, along with scarce crystals of sanidine. It is not welded at this locality. The rock is soft, but it has a harsh fell caused by countless tiny, sharp glass-shards. These shards can be seen individually with a low-power magnifier. They are fragments of shattered, glassy froth, formed when the substance first erupted as molten rock. DRINKWATER BASALT is an open-textured, fresh-appearing basalt that contains labradorite, clinopyroxene, magnetite, and olivine, all surrounded by a matrix of dark-colored glass. On a freshly broken surface, greenish, glassy grains of olivine can be seen with a magnifier. Commonly, they have a coating of brownish-red iddingsite that formed by decomposition of the olivine while the lava was cooling.

49.2 0.8 **EXPOSURES OF JUNTURA FORMATION.**

51.2 2.0 **ENTER MALHEUR COUNTY.** On the right (south), in the distance, is *Black Butte* (elevation, 5550 feet), a dome of rhyolite or rhyodacite that probably marks a former volcanic vent. On the left (northeast) are basalts of the UNNAMED IGNEOUS COMPLEX (middle or late Miocene).

52.2 1.0 **UNNAMED IGNEOUS COMPLEX** in roadcuts.

53.4 1.2 **ENTER KINGSBURY GULCH.**

55.6 2.2 **TIMS PEAK BASALT** (early Pliocene) in roadcuts. Sedimentary rocks near the road belong to the JUNTURA FORMATION (early Pliocene).

57.2 1.6 **EMERGE FROM KINGSBURY GULCH.**

57.6 0.4 **LEDGE OF ASH-FLOW TUFF on the left (north).** This is the ash-flow tuff member of the DREWSEY FORMATION (middle Pliocene), which here has a zone of dense welding, marked by a glassy layer near the bottom of the ledge. The escarpment ahead (northeast) reveals a thick sequence of UNNAMED IGNEOUS COMPLEX at the base, overlain in turn by DINNER CREEK ASH-FLOW TUFF, which forms the prominent, dark-colored ledge, then HUNTER CREEK BASALT (late Miocene) and TIMS PEAK BASALT (early Pliocene).

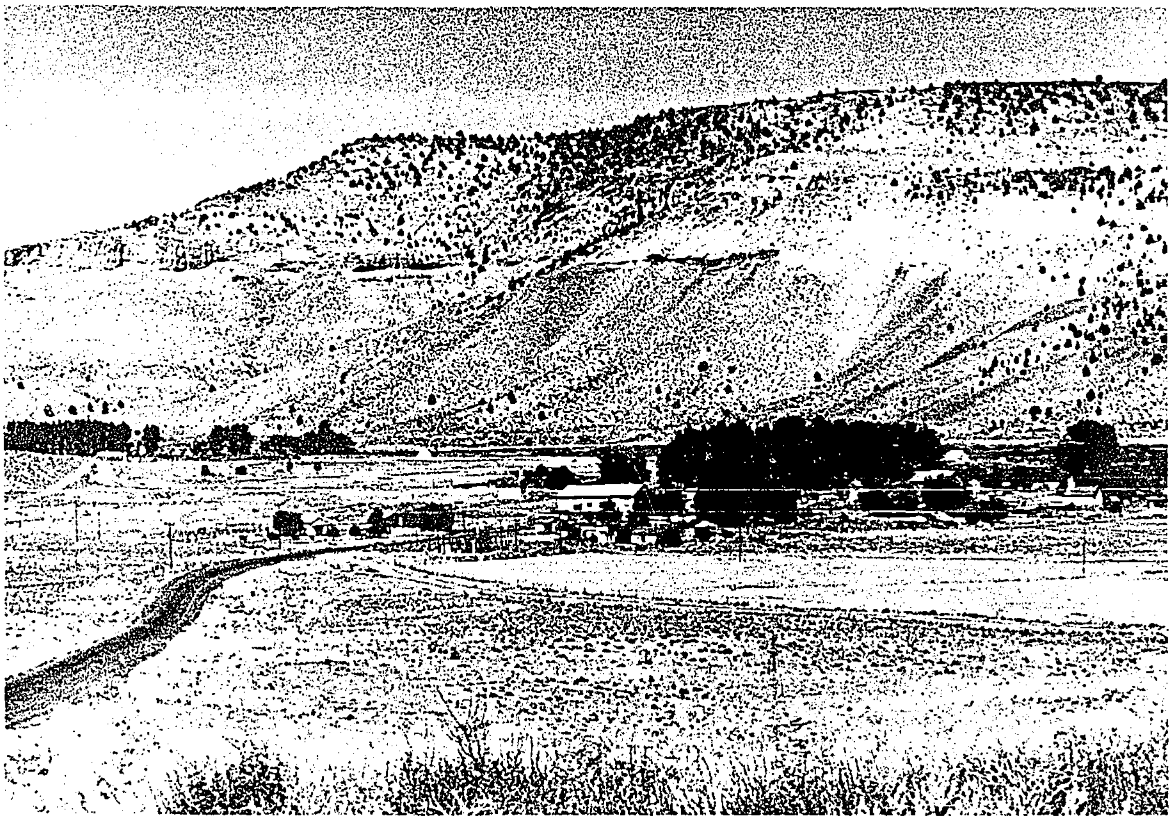


Figure 5. Town of Drewsey. *Table Mountain beyond is made of Drewsey Formation, named for the town.*

60.7 3.1 **JUNTURA** (elevation, 2953 feet). The town is at the junction of the *North Fork* of the *Malheur River* with the main stem.

JUNTURA

The name Juntura is a Spanish word that means junction, pronounced hun-too-ra in the original language, but Americanized to jun-tur-a. Juntura, founded in 1882, was once an important place. In the early days, Malheur Canyon east of town was impassable to wagons, and travel to places east and north was by way of Beulah and Westfall (Map 2). The Union Pacific Railroad, building westward through Malheur Canyon from Boise, Idaho, reached Juntura in 1913 , and the town became a railhead for livestock shipping for a vast ranching country in Malheur and Harney counties. A number of stores and even a substantial stone-masonry bank were built, but prosperity lasted only until 1924, when the rails reached onward to Burns.

62.2 1.5 **STOP 7. PETER SKENE OGDEN HISTORICAL MARKER on right** (south) overlooking the *Malheur River* (Fig. 7).

Peter Skene Ogden, a trapper, explorer, and leader of men for the Hudson's Bay Company, gave the Malheur River its name. The French word, malheure, means evil hour or misfortune. On 14 February 1826, Ogden camped at the confluence of the Malheur and Snake rivers (Map 1). He wrote in his journal, ". . . we encamped on River au Malheure (unfortunate River) so called on account of property and Furs having been hid here formerly discovered and

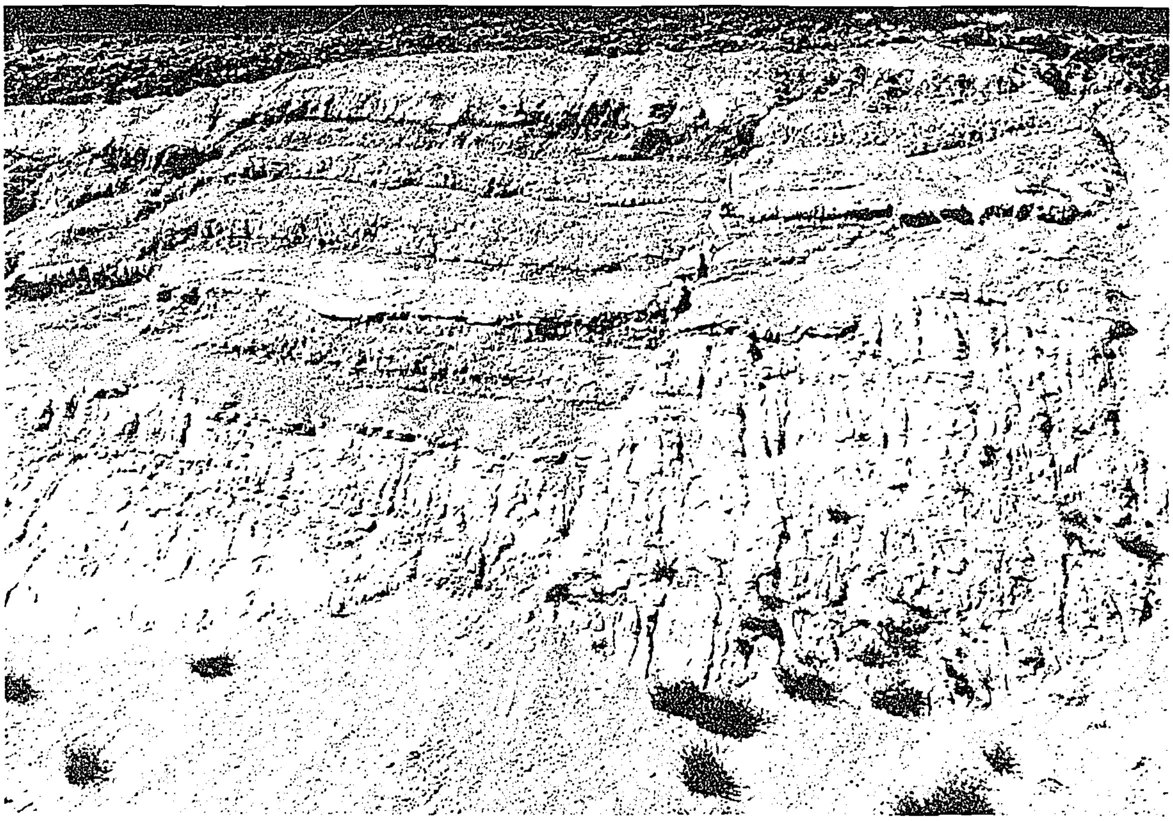
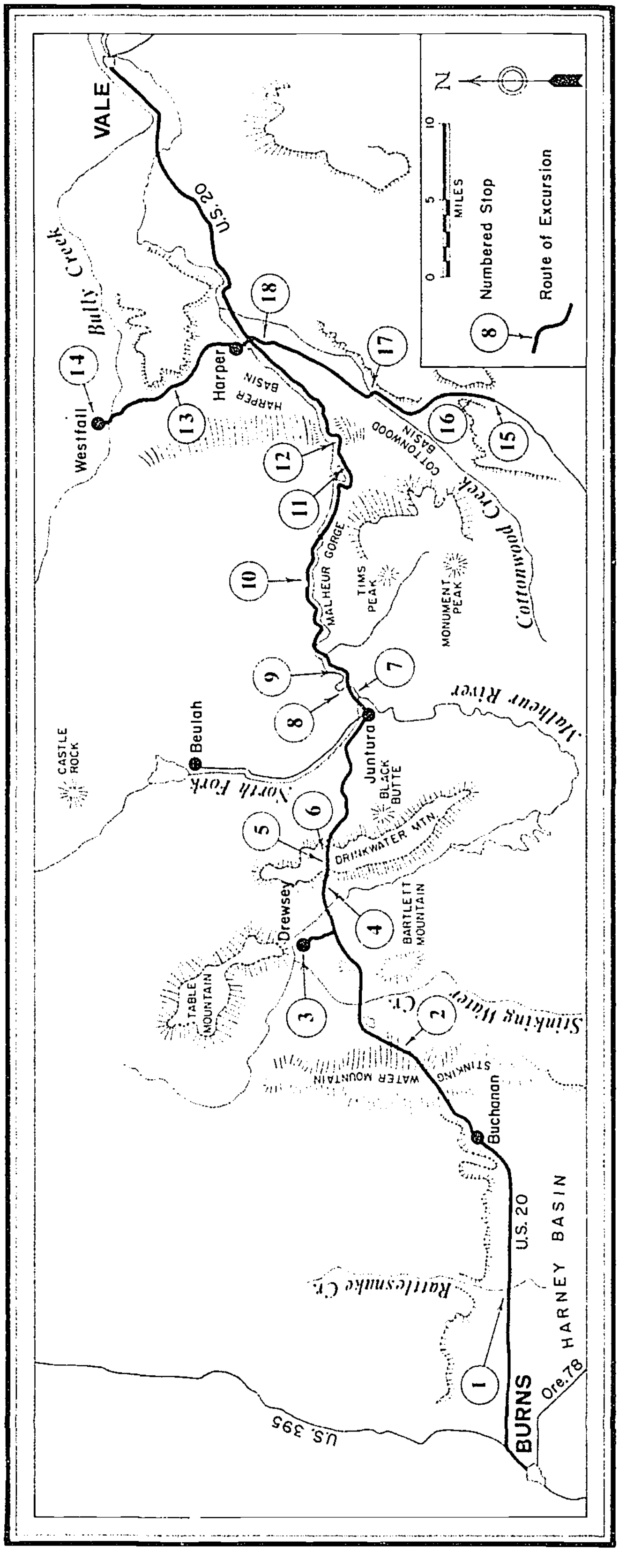


Figure 6. A minor fault *in the Juntura Formation at Drinkwater Pass. The layers on the left have moved down in relation to those on the right.*

Stolen by the Natives—this is a fine stream about 1/16 of a mile in width and well lined with willows we encamped at its discharge in the South Branch [Ogden's name for the Snake River]—all my Trappers are in the upper part of this River and here I must wait their arrival. . . ." Ogden visited the valley of the Malheur River again in October of 1828, this time striking the river somewhere near this Historical Marker.

63.2 1.0 **STOP 8. MALHEUR BRIDGE. TURN LEFT (north) at the near (west) end of the bridge** onto the old road and stop before crossing the old bridge. The conspicuous ledge of basalt just above the *Malheur River* belongs to the UNNAMED IGNEOUS COMPLEX (middle or late Miocene). The rock is a lava flow that came from fissures now concealed beneath the flows. It contains plagioclase, clinopyroxene, and magnetite,, but olivine is rare or absent. The brown material that gives the rock its characteristic color is formed by decomposition of iron- and magnesium-rich minerals like clinopyroxene. Decomposition probably occurred while the rock was still hot, just after it solidified from a liquid. The tall, five- or six-sided columns prominent in this flow also formed while the rock was cooling. This feature, called columnar structure, is formed by intersecting vertical fractures caused by shrinkage of the rock during cooling. Above the basalt flow, south of the highway, is a reddish, vertical-faced ledge of DINNER CREEK ASH-FLOW TUFF (late Miocene).

MALHEUR RIVER



Map 2. *Route-map for Excursion A—Burns to Vale.*

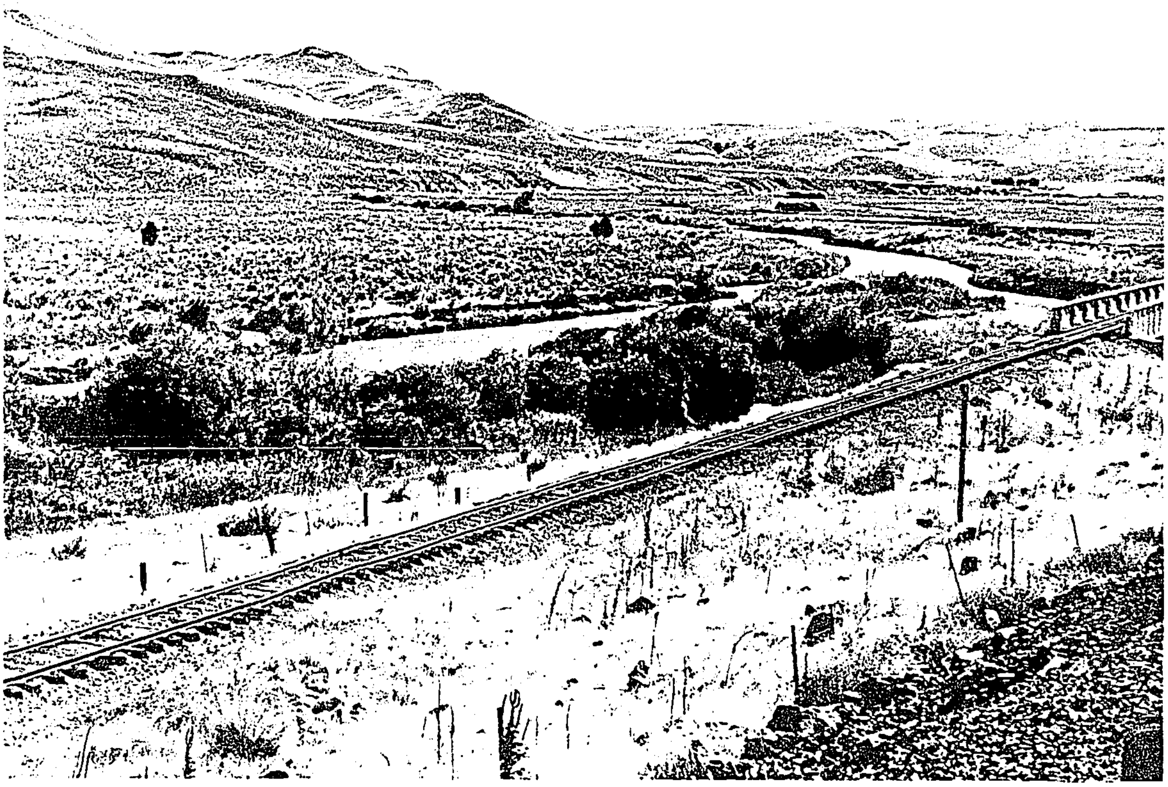


Figure 7. Malheur Valley *near Juntura. The explorer, Peter Skene Ogden, crossed the Malheur near here in 1828 on his way southward.*

RETURN TO THE HIGHWAY.

63.4 0.2 **DINNER CREEK ASH-FLOW TUFF** appears near the level of the road on the right (south).

64.6 1.2 **STOP 9. DINNER CREEK ASH-FLOW TUFF. PULL OFF** and stop just before you reach the ledge on the right. In this part of the canyon, the prominent, reddish ledge of DINNER CREEK ASH-FLOW TUFF sandwiched between the underlying UNNAMED IGNEOUS COMPLEX and overlying HUNTER CREEK BASALT, is tilted in various directions and broken by many faults. Up-and-down motion along these faults has moved the layer of DINNER CREEK TUFF up or down to different elevations, and later erosion of the canyon has bared the rocks in steep slopes so that the effects of the faulting can be seen. The DINNER CREEK TUFF acts as a marker, recording the faulting. In one place it appears high on the walls of the canyon, and in another, shifted downward by a fault, it appears near the level of the highway and, being tilted, slopes up-upward to a high elevation once again. The DINNER CREEK ASH-FLOW TUFF is an unusual formation. It probably erupted, in late Miocene time, from *Castle Rock* (Map 2), where it gushed out of the ground as a glowing froth of molten rock and hot gases that flowed southward and eastward, covering many hundreds of square miles, and of course destroying every living thing in its path. When the flow finally came to rest, the gases were expelled, and the glassy fragments of froth that

Figure 8. Dinner Creek Ash-Flow Tuff *forms the dark ledge on the distant hill. Above is a rounded cap of Hunter Creek Basalt with its characteristic stone-stripes.*

remained, still partly molten, settled, compacted, and welded together. Near the bottom of the flow, where the weight of overlying lava and degree of entrapped heat were greatest, the froth was compressed into a dense, glassy layer that resembles obsidian. Evidence of these events can be seen here. At the bottom of the ledge is a gray, glassy layer that was the zone of greatest compression and welding. Above, the grayish-red rock is less densely welded and contains irregularly shaped cavities, as much as several inches across, that represent bubbles made by gases escaping from the still-molten lava. If the rock is broken across its grain and the broken surface moistened and examined with a magnifier, very fine, thread-like, flattened objects can be seen throughout the rock. These are compressed, welded fragments of the glassy froth which the rock formed. Eruptions of exactly the same sort as recorded by the DINNER CREEK TUFF have never been seen in historic times, but their characteristics have been worked out by examining the rocks that they form. Similar eruptions have been seen, however. One of these happened in 1903 on the island of Martinique, French West Indies. There, the volcano Mount Pelee suddenly ejected a glowing cloud of hot gases and volcanic ash, which rushed down the slope of the mountain at more than 100 miles an hour and swept into the town of Saint Pierre at its foot. At least 30,000 people died instantly.

66.9 2.3 **ENTER AREA OF OWYHEE REGION GEOLOGIC MAP** (Kittleman and others, 1967).

70.7 3.8 **POLE CREEK RANCH ON THE LEFT.** To the rear (west), the ledge of DINNER CREEK ASH-FLOW TUFF is clearly exposed in the walls of the canyon (Fig. 8). Beneath the ledge are numerous basalt flows of the UNNAMED IGNEOUS COMPLEX layered one on top of another, and above is the HUNTER CREEK BASALT (late Miocene), a dense, dark-colored, fine-grained basalt. From a distance, the HUNTER CREEK characteristically appears as broad, rounded hills perched upon the ledge of DINER CREEK TUFF, and it is usually marked by long, dark stripes of rubbly basalt stones that appear to stream down the slope (Fig. 8). These are called stone-stripes or patterned ground, and they are believed to have been formed during the ice age by slow churning and sorting motions given to stones on and within permanently frozen soil by repeated expansion and contraction of ice.

MALHEUR CANYON

71.5 0.8 **STOP 10. ESCARPMENT OF UNNAMED IGNEOUS COMPLEX,** ahead, is capped by DINNER CREEK ASH-FLOW TUFF and HUNTER CREEK BASALT (Fig. 9). This escarpment is more than 2500 feet high. A major fault runs westerly along the base of the steepest part of the slope. Rocks on the north (far) side of the fault have moved upward, carrying the ledge of DINNER CREEK TUFF to an elevation of 5000 feet, about 2000 feet higher than the same formation south of the fault. The lower, gentler slopes are remnants of a former valley-floor of the *Malheur River*. The river and its tributaries are now dissecting this former valley and continuing downward erosion.

72.7 1.2 **JONESBORO.**

74.4 1.7 **DINNER CREEK ASH-FLOW TUFF ON THE RIGHT** (south) near the level of the *Malheur River*. Here HUNTER CREEK BASALT, underlain by DINNER CREEK TUFF, is exposed across the river south (right) of the highway. Rocks of the UNNAMED IGNEOUS COMPLEX are exposed in the cliffs north (left) of the highway on the other side of the major west-trending fault, upthrown on the north.

76.6 2.2 **UNNAMED IGNEOUS COMPLEX.** The highway has entered a gorge formed by cutting of the *Malheur River* into basalts of the UNNAMED IGNEOUS COMPLEX, which are exposed on both sides of the highway. High on the north (left) wall of the canyon, these rocks are capped by DINNER CREEEK TUFF, overlain, in turn, by HUNTER CREEK BASALT. With progressive eastward travel, cliffs of LITTLEFIELD RHYOLITE (late Miocene) occasionally can be seen on the highest skyline.

84.6 8.0 **STOP 11. ROADSIDE SPRING. Pull off and stop on the right** (south) side of the highway. The cliff next to the highway in a dense, fine-grained basalt of the UNNAMED IGNEOUS COMPLEX. This part of the *Malheur River* follows a winding course in a deep, narrow canyon. The size of the bends in the river—some more than a mile across—seem to be out of proportion to the present width of the stream. How can such a winding course have been cut so deeply into solid rock? Probably, the course was established, perhaps near the beginning of Pleistocene time, in softer rock on what was then a plateau far above the present position of the riverbed, at a time when the river carried more water than it does now. The size of the bends in the river was adjusted to the greater flow that then prevailed. During the Pleistocene, the land was slowly uplifted, and cutting of the river kept pace, while the same winding course was maintained. Thus the present form of the channel is inherited from an earlier time.

The deep, narrow gorge of the Malheur River was long an obstacle to travel. Stagecoach routes from Ontario and Vale to Burns swung northward through Westfall, Beulah, Drewsey and Harney (Map 2), avoiding Malheur Canyon entirely. About 1884, a stagecoach operated daily between Ontario and Burns. The trip took 36 hours and cost ten dollars. It was not until 1913, when a branch of the Union Pacific Railroad was extended to Juntura, that Malheur Canyon was used for through travel. A narrow trail through the canyon for horses, and perhaps wagons, was opened about 1928, but there was no practical route for automobiles until the Central Oregon Highway was completed in 1939.

SIMMONS GULCH

85.2 0.6 **SIMMONS GULCH.** In the area around *Malheur Canyon*, the layers of rock through which the canyon is cut generally are tilted eastward, so that younger and younger rocks are encountered as one travels eastward. As has been seen, the oldest in this sequence of rocks is the UNNAMED IGNEOUS COMPLEX (Fig. 1), overlain, in turn, by DINNER CREEK ASH-FLOW TUFF, and HUNTER CREEK BASALT. Here at *Simmons Gulch*, the canyon is cut into a still younger layer, the LITTLEFIELD RHYOLITE (late Miocene). It forms rugged cliffs, somewhat less ledgy than older rocks, with growths of green lichen, which, for some reason, prefer the rhyolite to the basalt.

87.1 1.9 **STOP 12. LITTLEFIELD RHYOLITE. TURN RIGHT at the far (east) end of the bridge** and drive cautiously along the loop of old highway for about half a mile. The cliffs and rubble on the left (south) are LITTLEFIELD RHYOLITE (late Miocene), a very fine-grained, grayish-red to dark-gray rock with scattered crystalline grains of plagioclase and pyroxene. Here the rhyolite is mostly dark gray on freshly broken surfaces, but dusky red on weathered surfaces. With a magnifier can be seen bright, mirror-like reflections from tiny, oblong cleaved grains of plagioclase. The LITTLEFIELD RHYOLITE extends for many miles northward and southward. The lava from which it formed evidently oozed out of the ground from many closely spaced fractures and spread out sideways. Rhyolitic lava, even through its temperature at the time of eruption is about 1600 degrees Fahrenheit, is very stiff and flows sluggishly. As it flows, it tends to form thin sheets, which slide over one another as the flow advances. These sheets are preserved when the lava solidifies, and they cause the rock to have a laminated appearance and to break into flat plates, many of which can be seen among the rubble next to the road.

TURN AROUND CAREFULLY, RETURN TO THE HIGHWAY AND TURN right (east).

89.1 2.0 **ENTER HARPER BASIN.** Here the *Malheur River* emerges from the northwest-trending ridge of LITTLEFIELD RHYOLITE that bounds *Harper Basin* on the west and enters the broad depression of *Harper Basin*, formed in soft, easily eroded sedimentary rocks. Generally, the rocks on the left (north) of the highway belong to the BULLY CREEK FORMATION (Pliocene), and those on the right (south) to the DRIP SPRING FORMATION (late Miocene). To the rear, the ridge of LITTLEFIELD RHYOLITE can be seen angling away in both directions. The floor of the basin is 2000 feet below the top of the western ridge.

96.3 7.2 **HARPER JUNCTION** (elevation, 2500 feet). Begin Side-Trips A_{II} to *Westfall* and A_{III} to *Cottonwood Basin*.

Side-Trip A_{II} to Harper Basin and Westfall
27 miles, round-trip

0.0 0.0 **HARPER JUNCTION. TURN LEFT** (northwest) and cross the *Malheur River*.

0.7 0.7 **HARPER. CONTINUE THROUGH TOWN on the paved road.** There is no place to buy gasoline beyond this point.

ENROUTE. The road skirts the eastern edge of *Harper Basin*, crossing diatomites, tuffs, and tuffaceous sandstones of the BULLY CREEK FORMATION (early Pliocene). The plateau on the right (east) is capped by basalts of the GRASSY MOUNTAIN FORMATION (middle Pliocene). The ridge in the distance on the left (west) is made of LITTLEFIELD RHYOLITE.

HARPER BASIN

6.9 6.2 **STOP 13. EXPOSURES OF BULLY CREEK FORMATION** on the right (east). It is possible to approach the bluffs more closely by driving up the side-road on the right, but it is easy to get stuck in the soft diatomite, it is very dusty, and it is difficult to turn around. The brown and gray bluff just above the road (Fig. 10) is a layer of vitric tuff in the BULLY CREEK FORMATION, made almost wholly of glass-shards. The white bands at the base of the bluff are diatomite. The diatomite is made entirely of tiny, siliceous shells of diatoms, the microscopic plants that in early Pliocene time flourished in the fresh-water lake centered about where *Harper Basin* is now. The layer of vitric tuff was formed when volcanic ash from a distant volcano fell into the lake.

13.4 6.5 **STOP 14. WESTFALL.** The town is on the north bank of *Bully Creek*, the stream from which the BULLY CREEK FORMATION takes its name. The road leading into the town from the south descends gravelly terraces built by the stream.

In the 1880's, Westfall was on the stage route between Ontario (Map 1) and Burns. At one time, the town had about 300 homes, three stores, a bank, two saloons, two livery barns, and a blacksmith shop. Most of Westfall—people, buildings, and business activity—moved to Harper when the railroad reached there in 1909.

TURN AROUND and return to *Harper Junction*.

26.8 13.4 **HARPER JUNCTION. END of Side-Trip A_{II}. TURN LEFT** (east) on Highway 20 to resume Excursion A, **or GO SOUTH** across Highway 20 to begin Side-Trip A_{III}.

Side-Trip A_{III} to Cottonwood Basin
38 miles, round-trip

0.0 0.0 **HARPER JUNCTION. TAKE THE DIRT ROAD SOUTHWARD** (right, if you are turning from Highway 20). **THIS SIDE TRIP IS NOT RECOMMENDED IF YOU ARE NOT USED TO DRIVING ON DESOLATE, UNIMPROVED ROADS.** There is no place to buy gasoline beyond this point. The road is unpaved, but in good weather it is usually easily passable to passenger cars if reasonable caution is used. In early spring or in rainy weather it may be impassable.

ENROUTE. The road passes among hills of DRIP SPRING FORMATION

Plate I. Owyhee Reservoir *near the dam. The prominent ledge is rhyolite, and the canyon wall in the background is Owyhee Basalt.*

(late Miocene). The formation contains various tuffs, volcanic conglomerates, diatomites, siliceous diatomites, and sandstones.

10.2 10.2 **COTTONWOOD CREEK CROSSING.**

12.1 1.9 **COTTONWOOD BASIN.** *Cottonwood Creek* is on the right (west). The dark, brownish patches near the creek on the right are exposed parts of peperite intrusions. These are bodies of basalt lava that have been squeezed upward from fissures into waterlogged sediments. Contact of the lava with water generated steam and also suddenly cooled and shattered the hot rock, forming a pulverized mixture of sediment, glassy basalt, and clay-like compounds that are formed by chemical decomposition of the basalt by steam. The resulting fragmented mixture is called peperite.

12.9 0.8 **JUNCTION WITH SHEARING PLANT ROAD. STAY LEFT.**

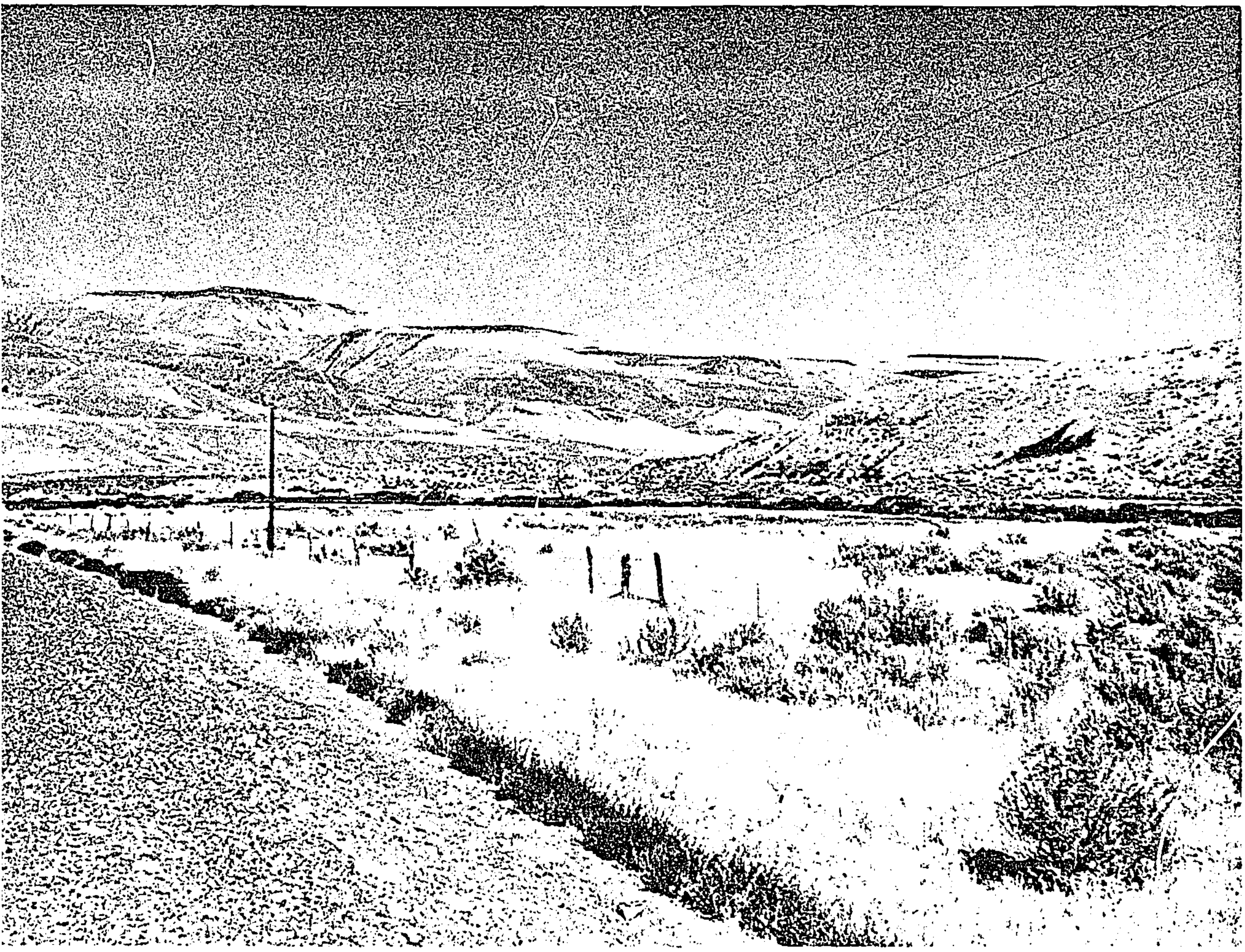
19.0 6.1 **STOP 15. TURN AROUND at the crest of the ridge** (elevation, 4500 feet). The road has climbed from *Cottonwood Creek* up through rocks of the DRIP SPRING FORMATION and over a rimrock of basalt flows that belong to the GRASSY MOUNTAIN FORMATION (middle Pliocene). This road continues 35 miles to *Crowley Ranch* and eventually to Highway 78, but it is not recommended to inexperienced travellers. Southward, the nearest sure place to buy gasoline is at *Rome*, about 100 miles from here.

CONTINUE BACK NORTHWARD TOWARD HARPER.

Figure 9. Malheur Canyon *near Jonesboro. Most of the steep canyon wall is basaltic flows in the unnamed igneous complex.*

20.5 1.5 **STOP 16. VIEW OF COTTONWOOD BASIN.** On the far left (west), the highest point on the skyline is *Monument Peak* (elevation, 5760 feet), composed of LITTLEFIELD RHYOLITE. A bit to the north of that, the pointed top of *Tim Peak* (elevation, 5500 feet) is just visible above the surrounding plateau. The peak is made of upturned layers of basalts in the UNNAMED IGNEOUS COMPLEX. Below the peak is a broad plateau, capped by a flow of the TIMS PEAK BASALT (early Pliocene) and underlain by LITTLEFIELD RHYOLITE (late Miocene). On the distant skyline to the northwest are plateaus of UNNAMED IGNEOUS COMPLEX, DINNER CREEK ASH-FLOW TUFF, HUNTER CREEK BASALT, and LITTLEFIELD RHYOLITE that rise above *Malheur Canyon*. To the north is a long red ridge of LITTLEFIELD RHYOLITE that lies west of *Harper Basin*. On the east (right) nearby and in the middle distance are plateaus and rimrock of basalts in the GRASSY MOUNTAIN FORMATION (middle Pliocene). *Cottonwood Basin*, below this viewpoint, is a southward extension of *Harper Basin* (see Side-Trip A_{II}). Both contain upper Miocene and Pliocene sedimentary rocks and are bounded by ridges of older rocks capped in places by Pliocene basalts. Thus *Cottonwood Basin* has pla-

COTTONWOOD BASIN



teaus of TIMS PEAK BASALT on the west and of GRASSY MOUNTAIN FORMATION on the east, both underlain by LITTLEFIELD RHYOLITE (Fig. 11). In the center of the basin, the foundation of LITTLEFIELD RHYOLITE sank down along northwesterly faults along side the ridge at each edge of the basin. The resulting depression then received the tuffs, sandstones, and diatomites of the DRIP SPRING FORMATION and the BULLY CREEK FORMATION. This pattern of landscape development is repeated throughout the Owyhee region in the *Juntura*, *Harper-Cottonwood*, and *Quartz-Sourdough* basins, all of which have similar features.

24.6 4.1 **JUNCTION WITH SHEARING PLANT ROAD. STAY RIGHT.**

27.3 2.7 **STOP 17. COTTONWOOD CREEK CROSSING.** On the right (east), is rimrock basalt of the GRASSY MOUNTAIN FORMATION (middle Pliocene), which overlies the DRIP SPRING FORMATION (late Miocene). To the north (ahead) is a contact between Pliocene and Miocene rocks (Fig. 12). Basalts of the GRASSY MOUNTAIN FORMATION on the right lap against what was a hill of DRIP SPRING FORMATION at the time the basalt flows erupted. This indicates that a rugged landscape had been

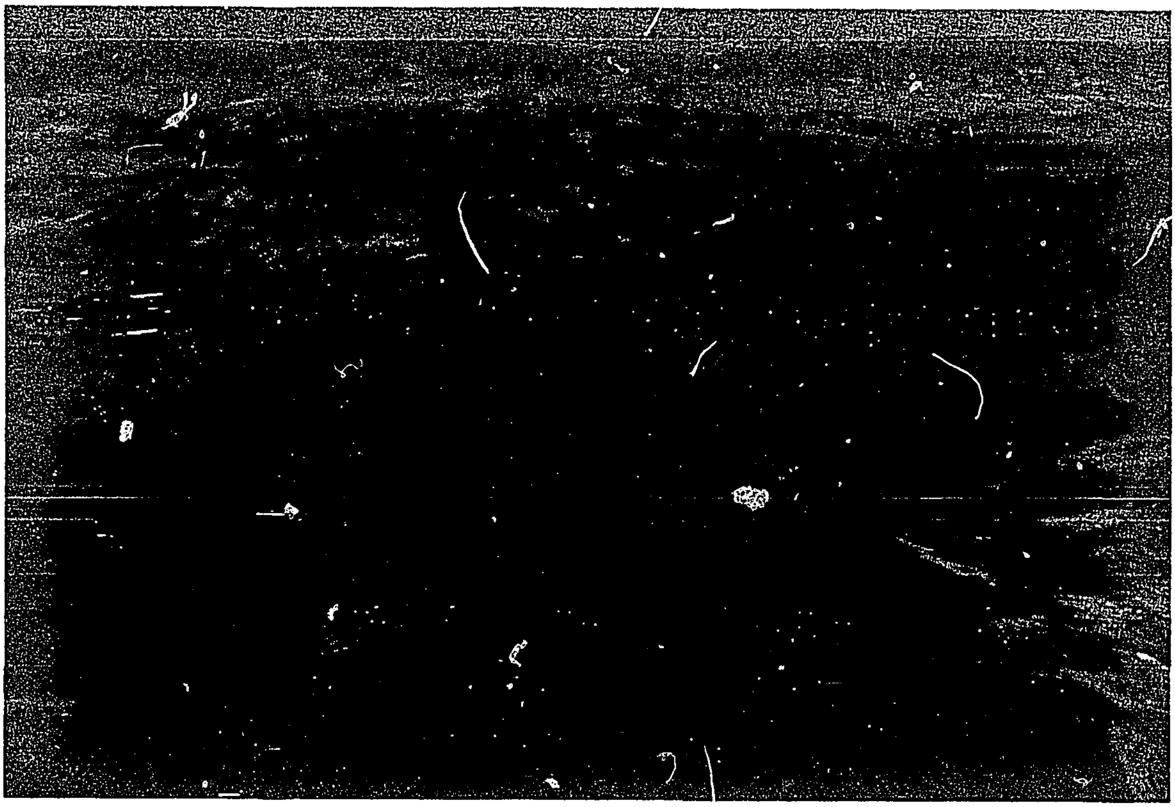


Plate II. Elbow Gulch and Owyhee Reservoir *from the air. The buttes in the foreground are volcanic necks. Grassy Mountain is on the distant skyline.*

formed in the rocks of the DRIP SPRING FORMATION by middle Pliocene time, and the GRASSY MOUNTAIN basalts flowed out upon it.

36.6 9.3 **STOP 18. VIEW OF HARPER BASIN.** On the right (east), in the distance, dark-colored flows of basalt in the GRASSY MOUNTAIN FORMATION overlie brilliant white diatomites of the BULLY CREEK FORMATION (early Pliocene). BULLY CREEK rocks occupy the center of the basin, and, on the far left (west), they overlie LITTLEFIELD RHYOLITE, which forms the ridge on the western skyline.

37.5 0.9 **HARPER JUNCTION. END of Side-Trip A_{III}. TURN RIGHT** (east) to resume excursion A.

Resume Excursion A

96.3 .... **HARPER JUNCTION. CONTINUE EASTWARD** on Highway 20.

100.5 4.2 **ON THE LEFT, BASALT OF THE GRASSY MOUNTAIN FORMATION** overlies diatomite of the BULLY CREEK FORMATION in a canal-cut.

101.1 0.6 **BASALTS OF THE GRASSY MOUNTAIN FORMATION.** East of the exposure at mile 100.5, the GRASSY MOUNTAIN FORMATION no longer rests upon diatomites, but upon sandy and gravelly sediment. The route has left the former lake-basin in which the diatomites accumulated.

Figure 10. Bully Creek Formation *in Harper Basin. Light-colored rocks are diatomites and tuffs. The gray ledge is a layer of vitric tuff.*

ENROUTE the highway crosses unnamed gravelly, sandy, and tuffaceous sedimentary rocks within or upon the GRASSY MOUNTAIN FORMATION. Some of the sedimentary rock is as young as Pleistocene.

VINES HILL

107.3 6.2 **VINES HILL.** The roadcuts are made in unnamed conglomerates and sandstones that may be late Pliocene or early Pleistocene in age. The sediment was deposited in stream channels as bars, and the complex oblique bedding, called cross-stratification, is characteristic of such an environment.

119.3 12.0 **VALE** (elevation, 2250 feet).

VALE

The site of Vale has been a habitation for settlers for many years. A man named John Reed had a dwelling near the hot springs east of town as early as 1813, but the place was later abandoned. In the 1840's and 1850's the site was a way-station on the Oregon Trail, people evidently being attracted by shade along the Malheur River, good water, and the hot springs. Jonathan Keeney built a small log house on the south side of the river in 1863, and it was used as a tavern and inn. In 1872 Louis B. Rinehart built a stone house here. It was used as a hotel, and later, in 1878, as a stage station on the line between Boise and Canyon City. This building, which became known as the Stone House, still stands near the corner of C and Main streets in the southeastern part of town (Fig. 13). It is now used as a historical museum. The settlement here was long known as Stone

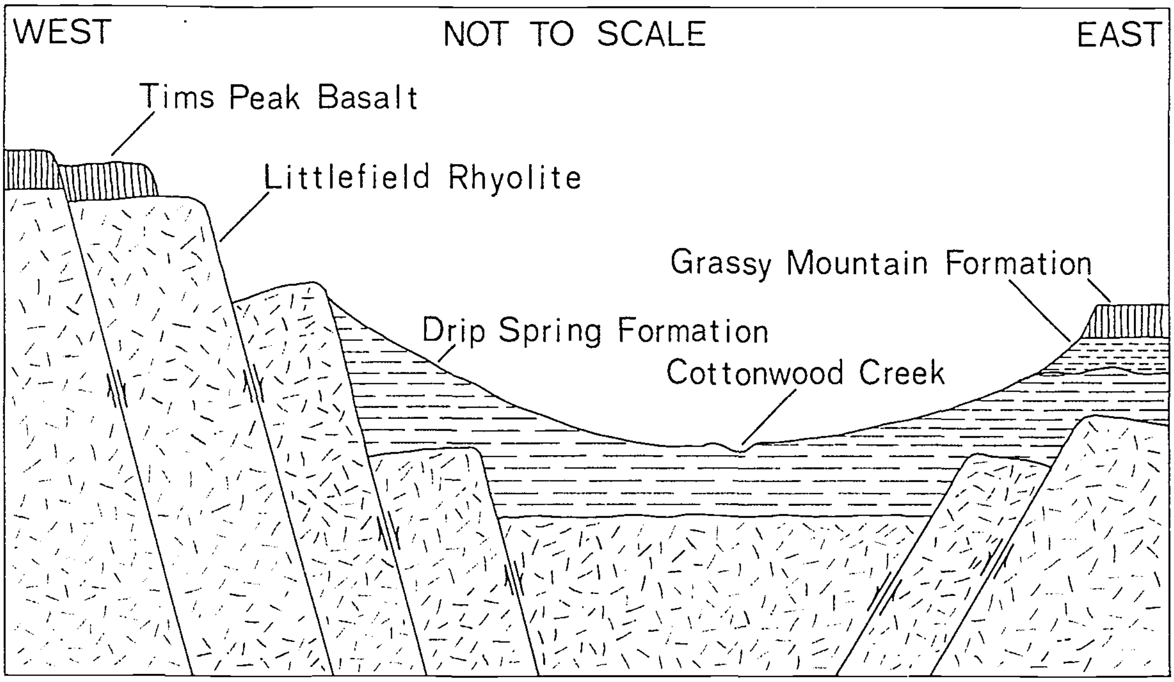


Figure 11. *Sketch of structural relations of rocks in Cottonwood Basin.*

Figure 12. Grassy Mountain and Drip Spring formations *in Cottonwood Basin. Basalts of the Grassy Mountain Formation, on the right, lap against a hill of Drip Spring Formation that was there when the basalt erupted.*

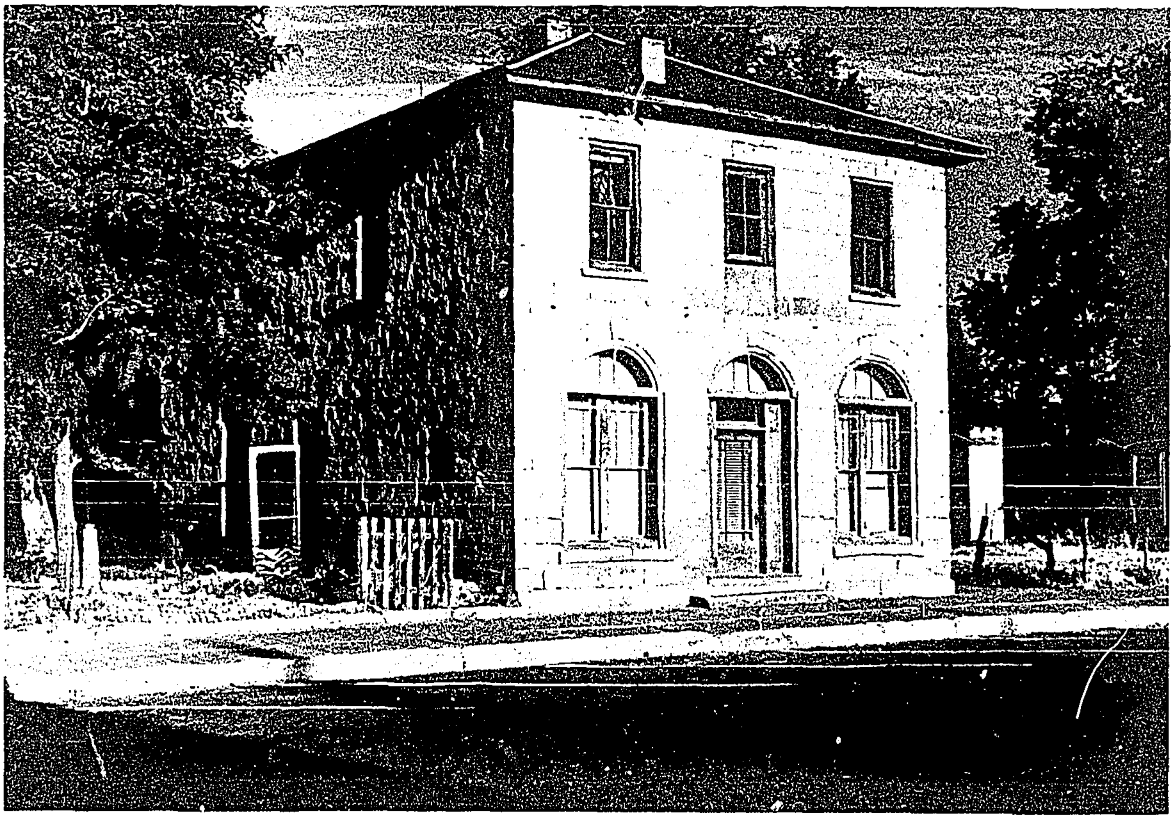


Figure 13. Stone House in Vale. *The building was put up in 1872 and used as a hotel and as a stage station.*

House, but the name was changed to Vale when a post office was established in 1883

END OF EXCURSION A.

EXCURSION B. OWYHEE RESERVOIR
82 MILES, ROUND-TRIP
WITH A SIDE-TRIP TO TUNNEL CANYON
MAP 3

MILEAGES

0.0 0.0 **BEGIN EXCURSION IN VALE,** at the corner of *B* and *Glenn* streets. From *B* **TURN RIGHT** (south) onto Glenn, cross the *Malheur River*, and take the paved road, *Lytle Boulevard*. The region traveled is covered by geologic maps of the Mitchell Butte quadrangle and of the Owyhee Region mentioned in the Introduction to this section.

1.0 1.0 **VALE BUTTE ON THE LEFT** (east) (elevation, 3171 feet) is made of sandstones and conglomerates of the DEER BUTTE FORMATION (late Miocene) firmly cemented by silica. The intense cementation here is thought to be related to the flow of silica-bearing water from hot springs that are still active at the eastern base of the butte.

3.3 2.3 **ENROUTE** the road passes through low sandstone ledges that may belong to the DEER BUTTE FORMATION or to the CHALK BUTTE FORMATION (Pliocene).

6.5 3.2 **SUMMIT** (elevation, 2900 feet). **ENTER COW HOLLOW.**

This road, Lytle Boulevard, approximately follows the route of the Oregon Trail, used by immigrants during the middle 1800's. This part of the trail was the connection between the crossing at the Snake River and Vale, then known as Stone House.

14.8 8.3 **CROSSROADS. TURN RIGHT** (west).

14.9 0.1 **CROSSROADS. TURN LEFT** (south).

15.5 0.6 **CROSSROADS. TURN RIGHT** (west) onto *Klamath Avenue*. The hill ahead is *Chalk Butte* (elevation, 3215 feet), composed of DEER BUTTE FORMATION.

16.6 1.1 **CROSSROADS. TURN LEFT** (south). The hill on the right (west) is *Mitchell Butte*, composed of DEER BUTTE FORMATION.

17.6 1.0 **CROSSROADS. TURN RIGHT** (west) onto *Owyhee Avenue*. **THEN IMMEDIATELY TURN LEFT** (south) onto the first road (about one-half block).

19.9 2.3 **CONGLOMERATES AND SANDSTONES** of the DEER BUTTE FORMATION in the roadcut. On the left (east) is the *Owyhee River*.

MITCHELL BUTTE

20.9 1.0 **STOP 1. ON THE RIGHT** (west), the closer hill is *Mitchell Butte* (elevation, 3500 feet) (Fig. 14), and the southerly, more distant promontory is *Deer Butte*. Both are made of the DEER BUTTE FORMATION (late Miocene). On the left (east) on the other side of the *Owyhee River*, are sculptured bluffs of DEER BUTTE FORMATION (late Miocene). Ahead is a high ridge of OWYHEE BASALT (late Miocene), with an irrigation ditch cutting across its face at a high level. Prominent in *Mitchell Butte* are dark-brown ledges of conglomerate and sandstone, which are layered between beds of tuff and tuffaceous sandstone. The ledges grow thicker toward the right (east) and merge into a thick layer of conglomerate and sandstone at the eastern end of the butte. Exposures of the same rock continue on the east side of the *Owyhee River*. The conglomerates and sandstones were deposited in the channel and on the floodplain of a north-flowing stream during late-Miocene time. The center of the channel at this point must have been near what is now the eastern end of *Mitchell Butte*, where the sandy, gravelly filling of the channel is exposed in cross-section. The closeness of the modern *Owyhee River* is only accidental.

OWYHEE GORGE

23.0 2.1 **ENTER OWYHEE GORGE.** This is the mouth of the canyon of the *Owyhee River*. The great cliffs on either side are made of flow upon flow of OWYHEE BASALT (late Miocene). They rise 1000 feet above the river. The *Owyhee River*, like the *Malheur River* that was seen during Excursion A, keeps a winding course through resistant rocks, and that course must have been started first in softer rocks when the river was flowing at a higher level, above the resistant basalt. The great pipe (Fig. 15) that here descends one wall of the canyon and ascends the other is a siphon that carries irrigation water from *Owyhee Reservoir* to farmlands to the north.

The Owyhee River, a tributary of the Snake (Map 3), has lent its name to a dam, a reservoir, a mountain range, a geological formation, and to a whole region. The name, like so many others here-

Plate III. Succor Creek Gorge *from the north. Lower cliffs are Leslie Gulch Tuff. The upper cliffs on the right and the distant mesa are Jump Creek Rhyolite.*

about, was given by Peter Skene Ogden, of the Hudson's Bay Company. Ogden camped at the mouth of this river on a cold day, 18 February 1826. He wrote in his journal, "Course South four miles when we reach sandwich Island River so called owing to two of them having been killed by snake Indians in 1819 this is from appearance a fine large River and from the upper parts not having been visited is worthy of examination. . . ." Evidently an earlier expedition had included as members some natives of the Sandwich Islands, two of whom were killed by Snake Indians. Another name for the Sandwich Islands is Hawaii, which, in Ogden's day was spelled Owyhee. Ogden uses the names Sandwich Islands and Owyhee interchangeably.

24.5 1.5 **STOP 2. DEER BUTTE HOT SPRINGS.** The hot springs to the left (east) of the road are evidence of volcanic heat below the earth's surface. Water that comes from the springs is not itself of volcanic origin. It is ordinary rainwater that seeps into fractures in the rock, circulates as groundwater, and comes to the surface again at favorable places. While circulating underground, this water comes into contact with hot rock left from past volcanic activity and is heated before it rises to the surface again. Everywhere on earth, the temperature becomes higher at greater depth, as can be found out by making measurements of temperature in mines or bore-holes. In presently or recently active volcanic regions, the rate of increase in temperature with depth is especially fast: that is, hot rock is unusually close to the surface. This ac-

DEER BUTTE

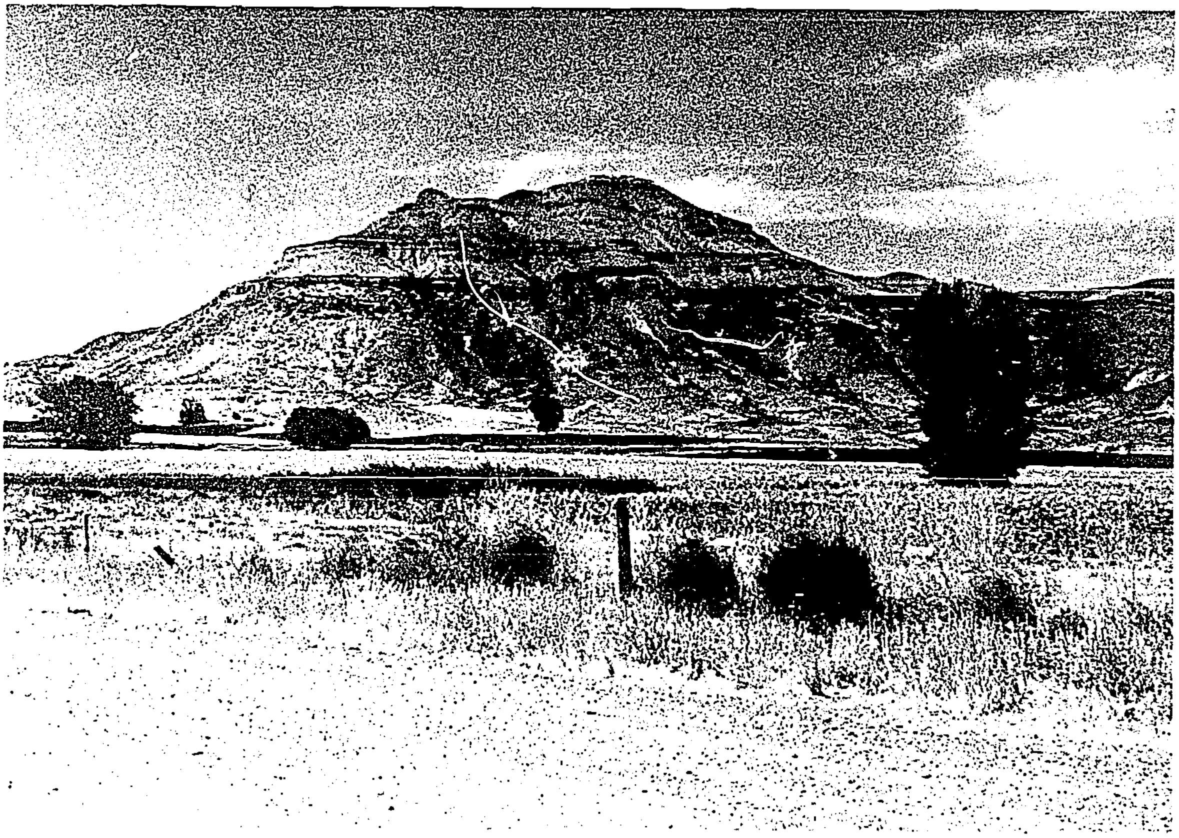


Figure 14. Mitchell Butte, *south of Vale, contains rocks of the Deer Butte Formation. The dark ledges are layers of sandstone.*

counts for the abundance of such things as hot springs, geysers, boiling mud-pots, and steam-vents in volcanic areas. In the Owyhee region, the rise in temperature with depth is in places as much as 13 degrees Fahrenheit per 100 feet, which means that the boiling point of water could be reached at a depth of 1100 feet.

To the right (west) of the road here, the hill at the head of the gulch is *Deer Butte* (elevation, 3600 feet), which gave its name to the DEER BUTTE FORMATION. High on the butte, the dark-brown ledges are layers of sandstone and conglomerate bedded amongst softer tuffs and other volcanic sedimentary rocks. Lower down, the dark-colored ledges are flows of basalt. The rocks in the butte include layers of conglomerate that contain cobblestones made of granite. Many such cobbles can be seen in the bed of the gulch that crosses the road here. They are not from local sources, but were brought here from granitic mountains in what is now southwestern Idaho by swiftly flowing streams that deposited the sands and gravels of the DEER BUTTE FORMATION about 15 million years ago.

27.4 2.9 **OWYHE RIVER BRIDGE.** Spectacular cliffs of OWYHEE BASALT (Figs. 16 and 17) bound the narrow canyon of the *Owyhee River*.

28.8 1.4 **MOUTH OF TUNNEL CANYON.** Begin Side-Trip B_1.

Figure 15. An irrigation siphon *carries water across Owyhee Canyon to farmlands around Vale. The water comes from Owyhee Reservoir, 15 miles upstream.*

Side-Trip B_1 to Tunnel Canyon
2.4 miles, round-trip

TUNNEL CANYON

0.0 0.0 **MOUTH OF TUNNEL CANYON. TURN LEFT** (east) across the cattleguard. The dirt road is steep and narrow, but it is usually easily passable to passenger cars. The road climbs through cliffs of OWYHEE BASALT. There are a variety of different kinds. Generally, lower flows are darker in color and break into chunks. Upper flows are lighter in color, are more like andesite, and break into flat slabs. All kinds contain the minerals plagioclase, pyroxene, and magnetite, but the lower flows may contain some olivine, and the upper flows are especially rich in plagioclase. Most of the rock is fine-grained or even nearly glassy, so that individual grains of minerals usually cannot be seen without a magnifier. The differences between flows from bottom to top in the cliffs are a reflection of progressive changes in the chemical composition of the lava as one eruption followed upon another.

0.9 0.9 **TURN HARD RIGHT at the head of the gulch** and continue **CAUTIOUSLY** up the short, steep pitch. Be prepared to **TURN RIGHT** at the top.

1.0 0.1 **IRRIGATION CANAL.** The light-colored sedimentary rocks hereabout probably belong to the DEER BUTTE FORMATION and were deposited in late Miocene time in depressions eroded in a landscape of OWYHEE BASALT.

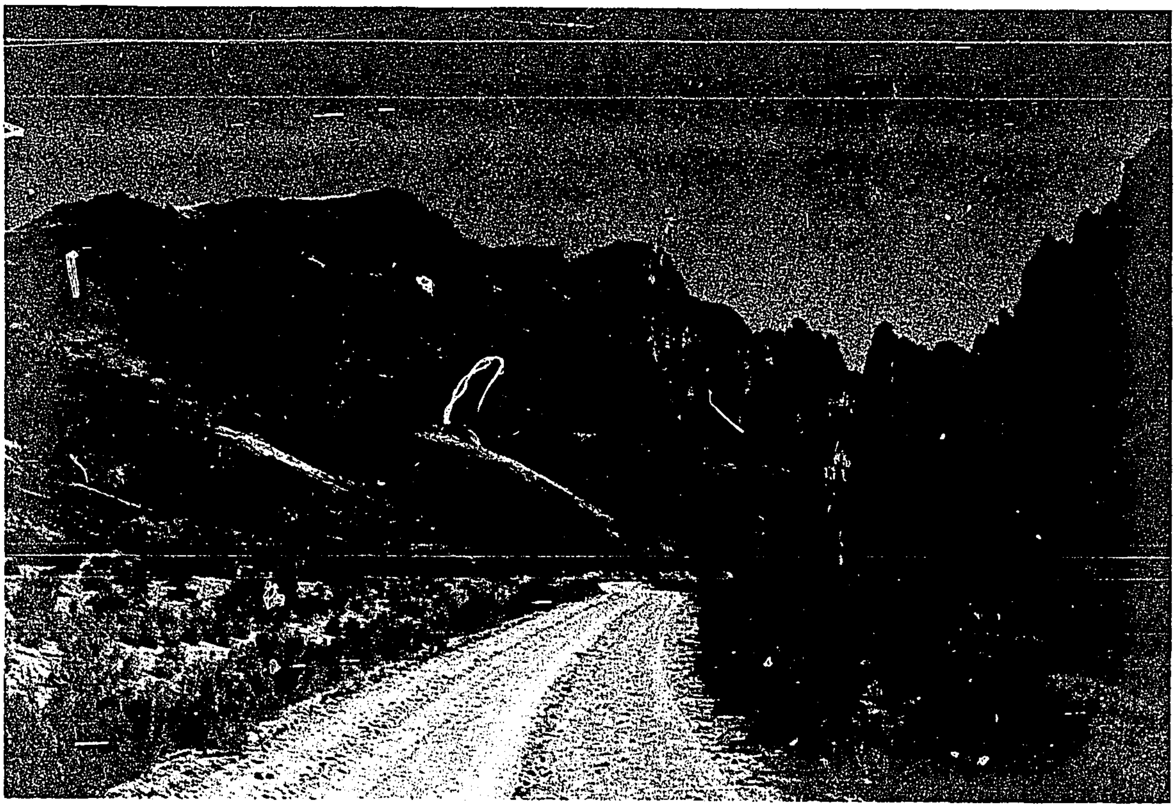


Plate IV. Leslie Gulch. *The jagged forms and pinnacles on the wall of the canyon are Leslie Gulch Ash-Flow Tuff*

1.2 0.2 **STOP 3. PORTALS OF THE OWYHEE WATER TUNNEL.** The works here are part of the Owyhee Irrigation System. Water is carried in a tunnel from an inlet near the base of *Owyhee Dam* and comes out the portal on the right. Some is diverted into the creek in *Tunnel Canyon*, part is sent into the canal to serve farmlands around *Vale* and *Nyssa*, and the rest enters another tunnel, on the left, and is carried through *Owyhee Ridge* (Map 3) to the area of *Homedale, Idaho.*

TURN AROUND and return to the paved road.

2.4 1.2 **MOUTH OF TUNNEL CANYON. END** of **Side-Trip B_1. TURN LEFT.**

Resume Excursion B

28.8 .... **MOUTH OF TUNNEL CANYON. CONTINUE southward** on the paved road.

32.1 3.3 **OLD RAILROAD TUNNEL.** The road through *Owyhee Canyon* follows the line of a railway that was built in the late 1920's to haul construction material for *Owyhee Dam*. The tracks were torn up after the dam was finished, and later the present county road was built. This is the only remaining tunnel on the route. It goes through dense, dark-colored OWYHEE BASALT (Fig. 18).

36.3 4.2 **OWYHEE DAM JUNCTION. TURN RIGHT (west) onto the dirt road** and cross the *Owyhee River*.

Figure 16. Owyhee Canyon *at the steel bridge. The towering cliffs are Owyhee Basalt.*

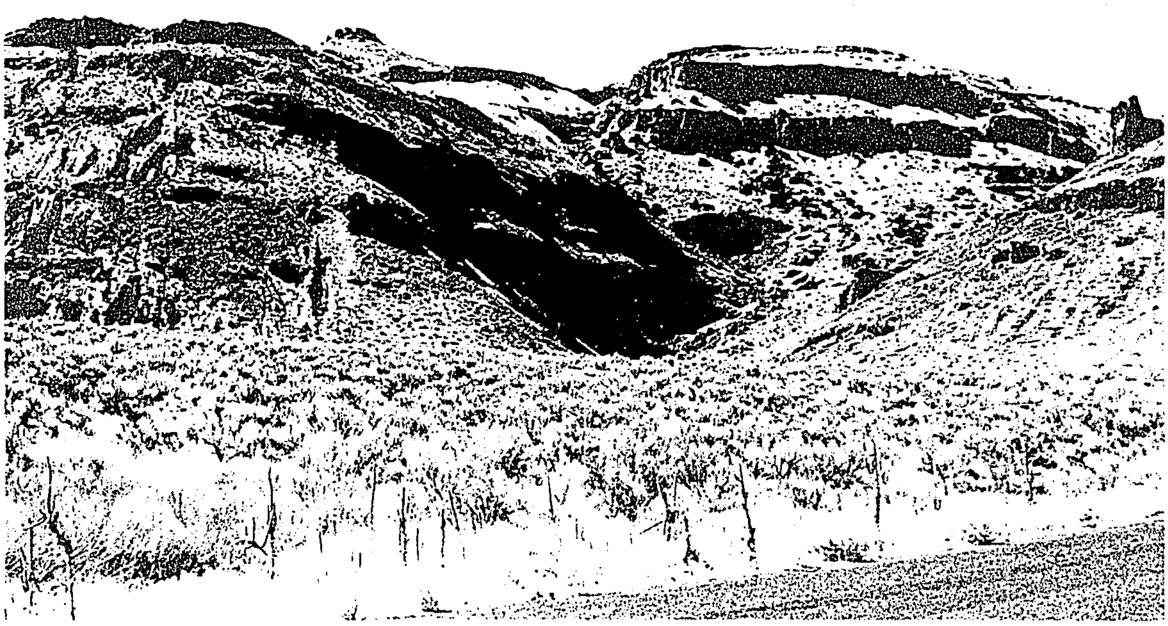


Figure 17. Owyhee Basalt *forms the cliffs along Owyhee Canyon. Red color in the rock comes from iron oxides in the rock similar to rust.*

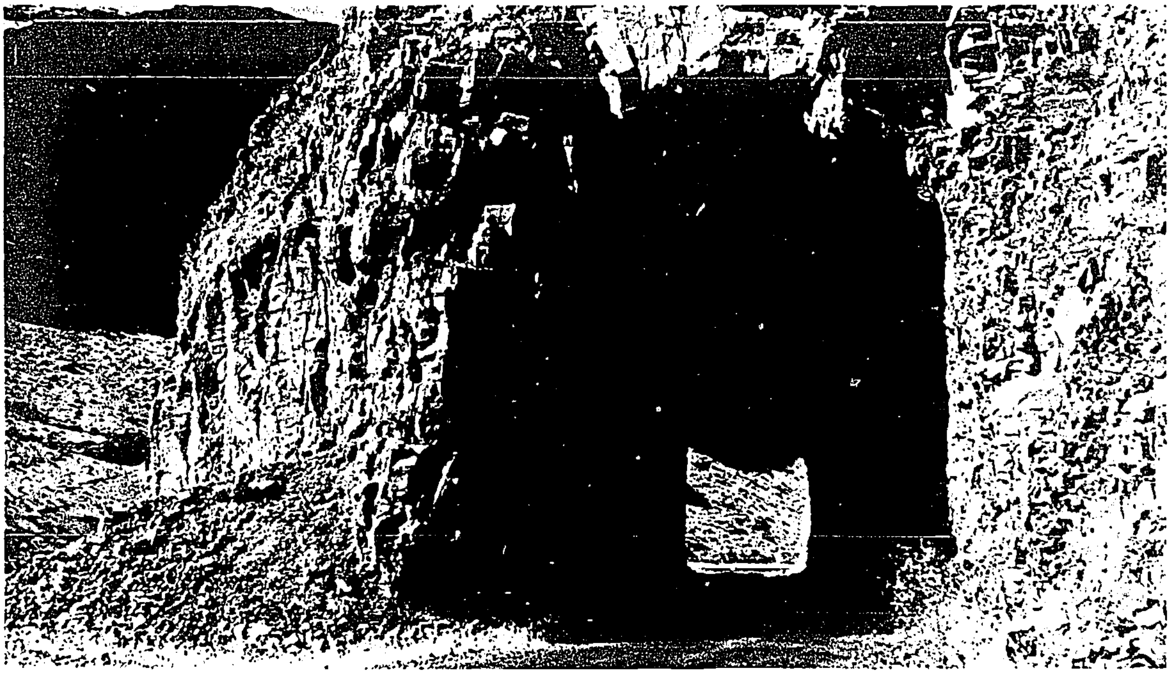


Figure 18. Abandoned railway tunnel *in Owyhee Canyon now serves the automobile road. The rock at the tunnel is Owyhee Basalt.*

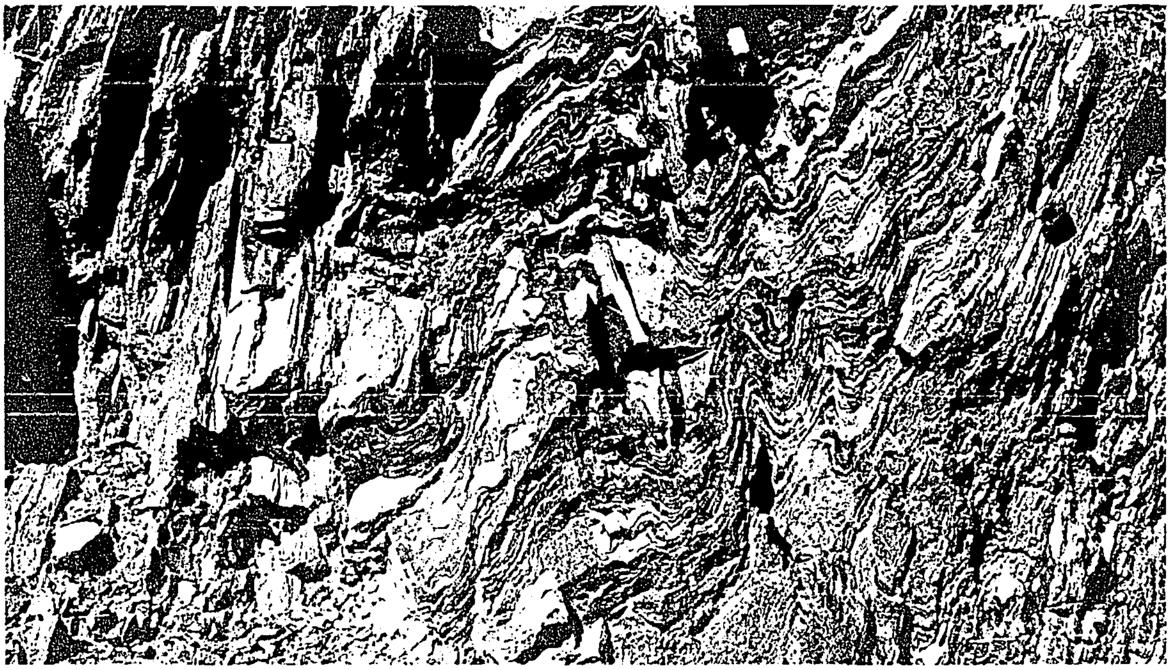


Figure 19. The Eggbeater, *a structure of contorted, flow-layered rhyolite near Owyhee Dam.*

Figure 20. Vertical flow-layering *in rhyolite near the right abutment of Owyhee Dam suggests that this is part of the pipe through which the molten rock rose.*

OWYHEE DAM

36.5 0.2 **STOP 4. PICNIC AND CAMP GROUNDS.** The buildings here were built during construction of *Owyhee Dam* as engineering offices and homes for the resident engineers. **CONTINUE** on the dirt road and go through the gate in the stone wall. **BEAR RIGHT** and start up the grade on the wall of the canyon.

36.9 0.4 **STOP 5. THE EGGBEATER. CAREFULLY PULL OVER** to the side of the road and stop. The rock outcrop on the right (southwest) is the rhyolite into which the *Owyhee River* has cut a deep cleft called *The Hole in the Ground.* Erosion has here exposed what was once the pipe or conduit through which molten rhyolite reached the surface. The pipe is still filled with rhyolite which solidified when eruptions stopped. Molten rhyolite, though very hot, is stiff, and here is squeezed up from the ground much like toothpaste from a tube. As it flowed, the taffy-like lava formed thin sheets that themselves became twisted, folded, and churned up as the flow progressed. The result of this process is exposed in the bank to the right (southeast) of the road (Fig. 19), where the crumpled and folded sheets are frozen into solid rock. The structure is called flow-layering. Geologists jokingly call this startling exposure The Eggbeater because of its churned appearance.

37.6 0.7 **STOP 6. LEFT ABUTMENT OF OWYHEE DAM** (elevation, 2675 feet). Both abutments of *Owyhee Dam* rest upon flow-layered, grayish-red rhyolite, seen here at the right side of the road next to the parapet of the dam. The layering is vertical (Fig. 20), an indication that here,

Figure 21. Owyhee Dam *from the air. The abutments are against a body of rhyolite which has caused narrowing of the canyon here, creating an ideal place for a dam. The ring-like object is the gloryhole spillway.*

as at Stop 5, we are standing in the area of the former vent from which the rhyolite came. The cliffs above are OWYHEE BASALT (late Miocene), which erupted flow upon flow after the rhyolite cooled. The turret on the parapet of the dam is an entryway, from which a spiral staircase leads to galleries and controls inside the dam.

DRIVE ON ACROSS THE CREST OF THE DAM AND TURN RIGHT into the parking area.

37.9 0.3 **STOP 7. RIGHT (NORTHEAST) ABUTMENT. PULL OFF AND STOP in the parking area.** *Owyhee Dam* (Figs. 21 and 22) was put here because this spot is a fine place for a dam. There is a narrow place in a deep canyon, so a great depth of water can be held by a dam that is relatively short across the crest. The abutments are firmly founded on strong rock that can bear the thrust of the water brought against the sides of the canyon by the arch-like structure of the dam. Tuffaceous rocks of the SUCKER CREEK and DEER BUTTE formations upstream from the dam are rich in clay and so form a good seal against leakage of water from the reservoir.

Owyhee Reservoir stores water for irrigation of 92,000 acres of farmland in the neighborhoods of Vale, Oregon, and Homedale, Idaho. It is 52 miles long and holds roughly one million acre-feet (360 billion gallons) of water, of which about 60 percent can be

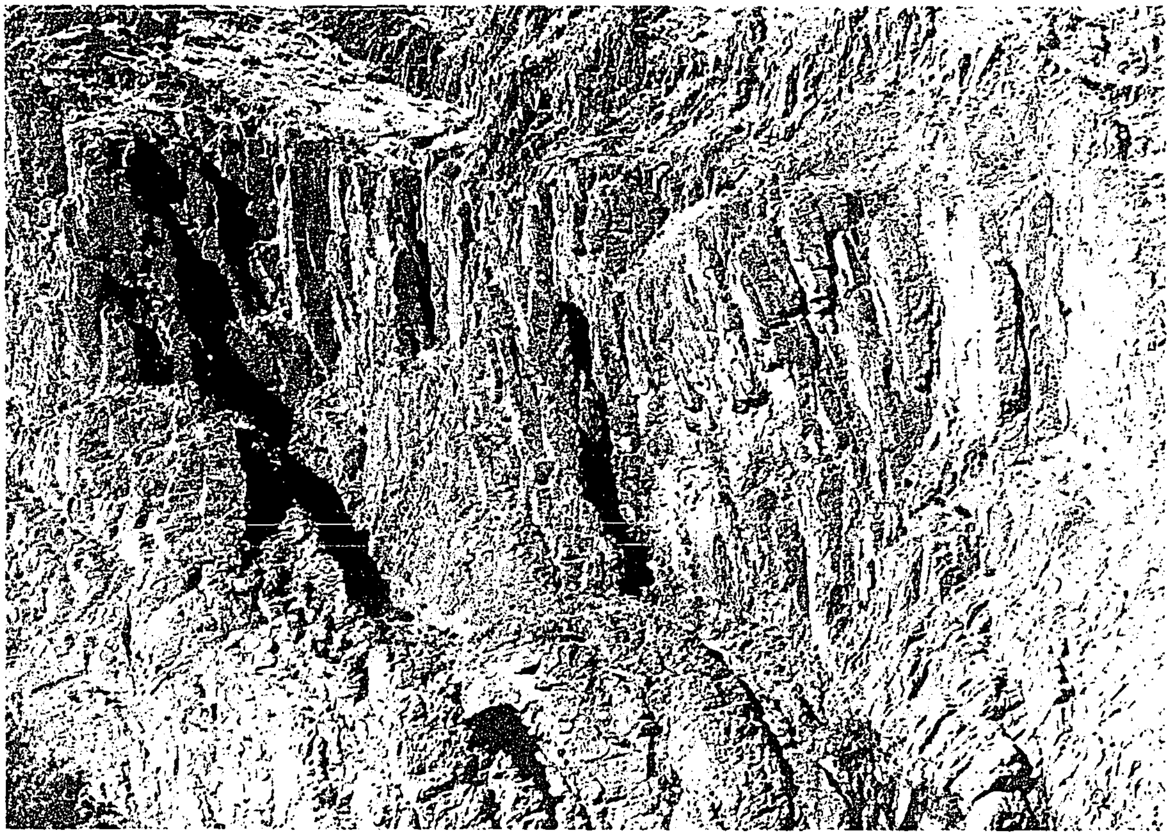


Figure 22. Massive flow-layering *in the cliff opposite Owyhee Dam indicates that the lava was rising vertically here.*

withdrawn for irrigation. Owyhee Dam, built by the U.S. Bureau of Reclamation, was the tallest in the world at the time of its completion. Construction began in 1928 and was finished in 1932. The top of the dam is 417 feet above the foundation, and the crest is 810 feet long. Five-hundred and forty-thousand cubic yards of concrete was used in the construction. About half-way down the face of the dam, near the left abutment, are three 48-inch valves, through which water can be let into the Owyhee River. Just upstream from the right (northeast) abutment is a gloryhole spillway (Fig. 23), which acts like a huge bathtub drain when the reservoir is full. The spillway is 60 feet across and is connected by a 235-foot vertical shaft to a tunnel that empties the water into the river just below the dam. It can drain water from the reservoir at a rate of 300,000 gallons per second.

Near the right (northeast) abutment along the road are outcrops of gray, banded, glassy rock that is a part of the rhyolite at the abutments (mile 36.9, mile 37.6). This rhyolite is exposed by an accident of erosion in cliffs here at *Hole in the Ground*, where it is possible to look at the rock closely and work out its history. It seems that the molten rhyolitic lava oozed from the ground through a roughly circular, nearly vertical pipe perhaps a thousand feet in diameter. Evidence of vertical movement of the lava can be seen at Stop 6 (Fig. 20, mile 37.6) and in the cliff downstream across from the dam (Fig. 22). The lava flowed

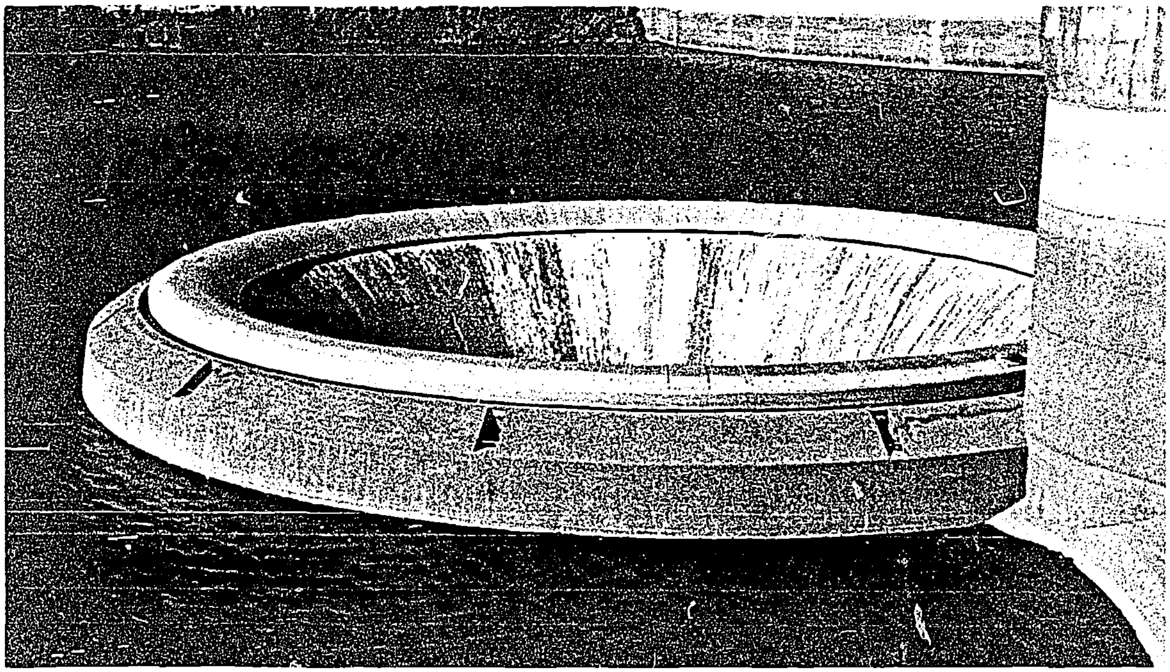


Figure 23. Gloryhole spillway *of Owyhee Dam acts like a huge drain when the reservoir is full. It can handle 300 thousand gallons per second.*

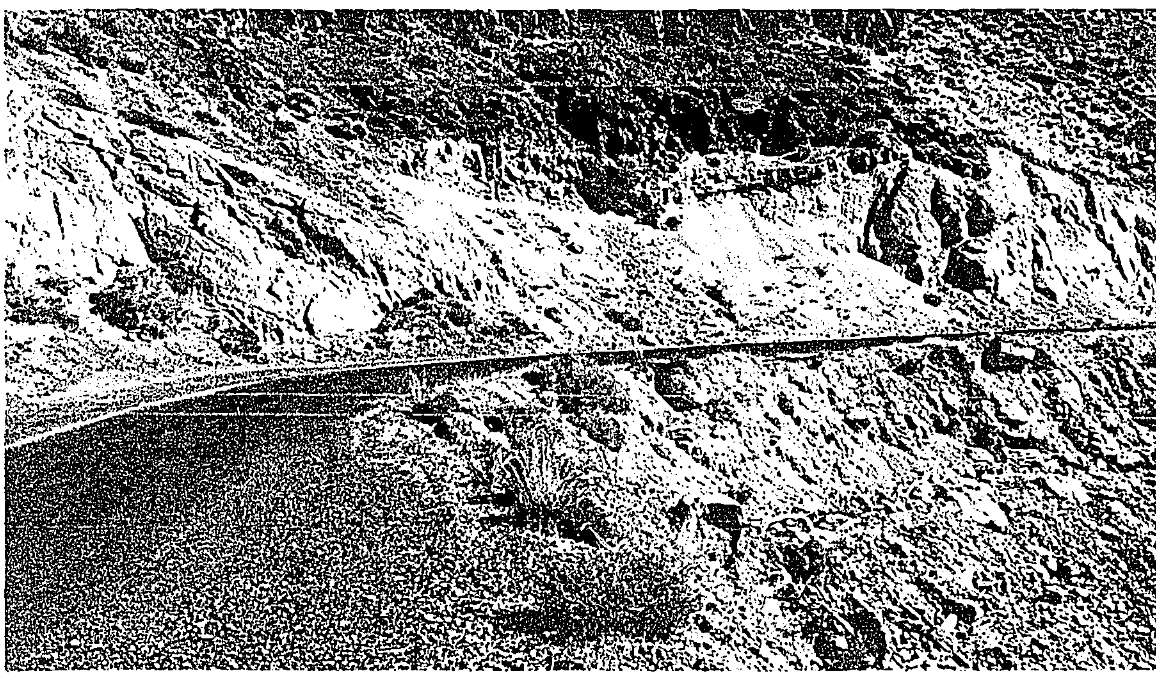


Figure 24. Owyhee Basalt *overlies Sucker Creek Formation near Owyhee Dam. The distinct line of contact between the two formations is seen here just above the road.*

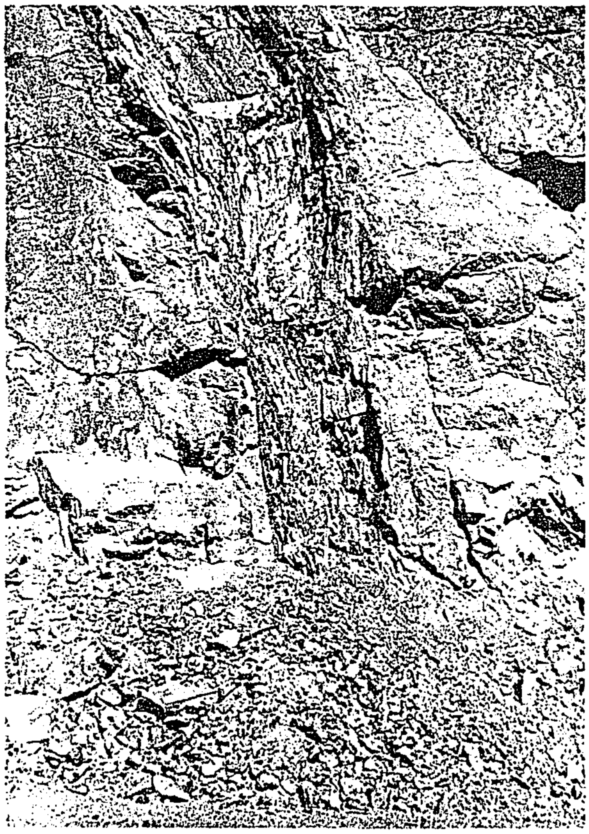


Figure 25. Basaltic dike *within the Sucker Creek Formation near Owyhee Dam. The exposure here is a cross-section of a fissure that fed lava to flows above.*

out onto a landscape made of SUCKER CREEK FORMATION, just then in the process of being laid down, and flowed southwestward for several miles, in places penetrating or plowing up fresh sediments of SUCKER CREEK FORMATION. The flow of rhyolite can be seen on the far shore of the reservoir as a reddish, flat-topped ledge at or just above the level of the water (Plate I). The rhyolitic lava was in contact with the ground at the bottom and with the air at the top and sides. At these places, the molten rock cooled quickly, forming a glassy rind. The upper rind is seen on the other side of the reservoir as a gray band between the rhyolite ledge below and the nearly black OWYHEE BASALT above. Here at the parking area, grayish-red, layered rhyolite on the bank of the reservoir just below the road grades upward into the banded, gray, glassy rock beside the road on the northeast. This glassy rind can be followed along about one-fourth mile up the road. It becomes increasingly crumbled into individual blocks that were formed when the molten inner parts of the flow continued to move and broke up the rind, which had already solidified into brittle rock. At the very edge of the flow, the rind is in contact with bedded tuffaceous rocks of the SUCKER CREEK FORMATION. The rhyolite flow did not go very far eastward, so a little farther up the road the OWYHEE BASALT overlies the SUCKER CREEK FORMATION with no rhyolite between them (Fig. 24).

CONTINUE UP THE ROAD BY CAR.

38.4 0.5 **STOP 8. SHAFT-HOUSE.** The structure stands over a service shaft which descends 90 feet to gates that control the release of water through

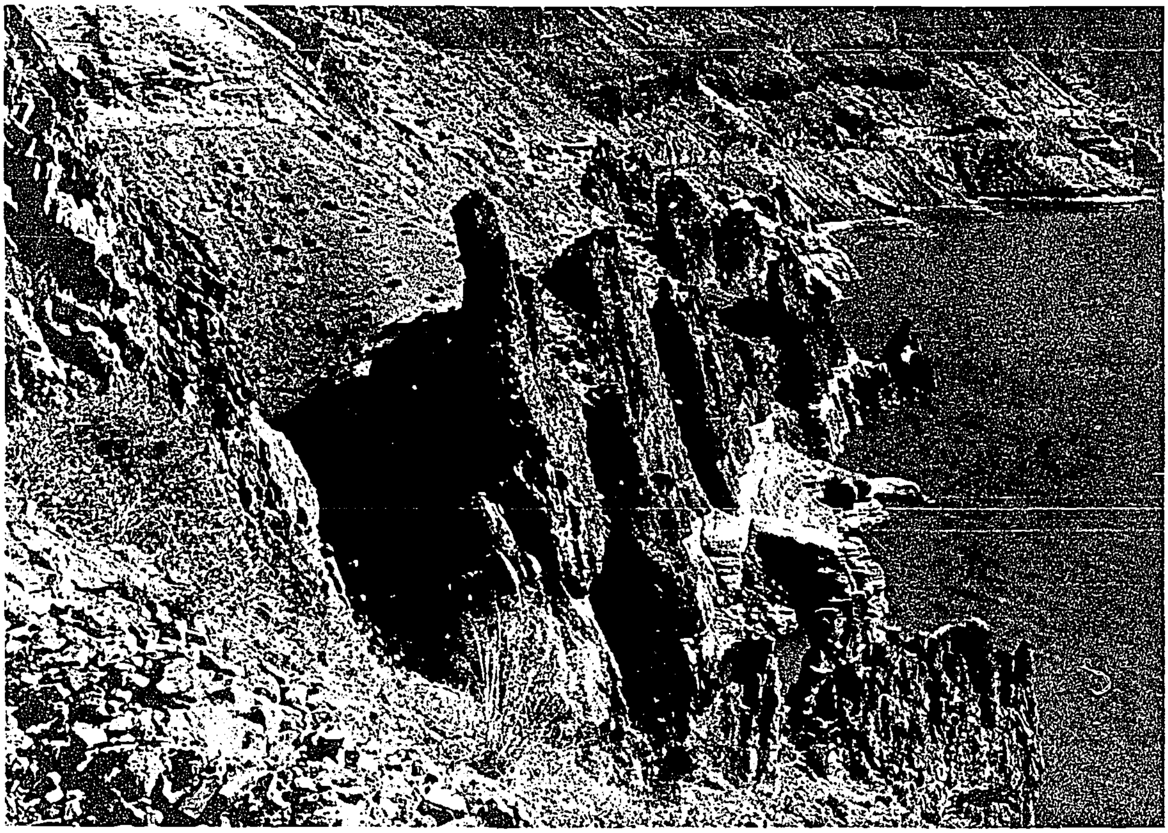


Figure 26. Basaltic dikes *along the shore of Owyhee Reservoir remain as standing slabs after surrounding softer rock has eroded away.*

a tunnel into the Owyhee Irrigation System. The other portal of the tunnel is at *Tunnel Canyon*, at Stop 3 (mile 1.2, Side-Trip B_I). The notch in the cliff where the shaft-house stands is cut into rocks of the SUCKER CREEK FORMATION, which here consists of yellowish-brown tuffs, volcanic breccias, and volcanic sandstones that contain fragments of basalt and rhyolite as much as one foot across. The rocks are layered or bedded and are tilted gently. The tilt (what geologists call the dip) is 5 degrees northwest, and an imaginary horizontal line on the surface of one of the layers would point north, 65 degrees east (the strike).

In the neighborhood of the shaft-house are a number of dikes, which appear in cross-section in roadcuts (Fig. 25) and as standing slabs (Fig. 26). Dikes are the fillings of fissures through which molten lava once rose to the surface. The fissures here, and many others like them, probably erupted lava that formed the many flows of OWYHEE BASALT in the walls of the canyon above the reservoir. The lava that was left in the fissures when the eruptions stopped solidified right there, forming dikes. In cross-sections (Fig. 25), rock at the sides of the fissure looks somewhat like fired pottery, where it was baked by the molten lava within the fissure, and the edges of the dike itself are glassy, where the lava was quickly chilled by contact with the walls of the fissure. The free-standing slabs (Fig. 26) are dikes from which surrounding softer rock has been stripped by weathering and erosion.

CONTINUE UP THE ROAD.

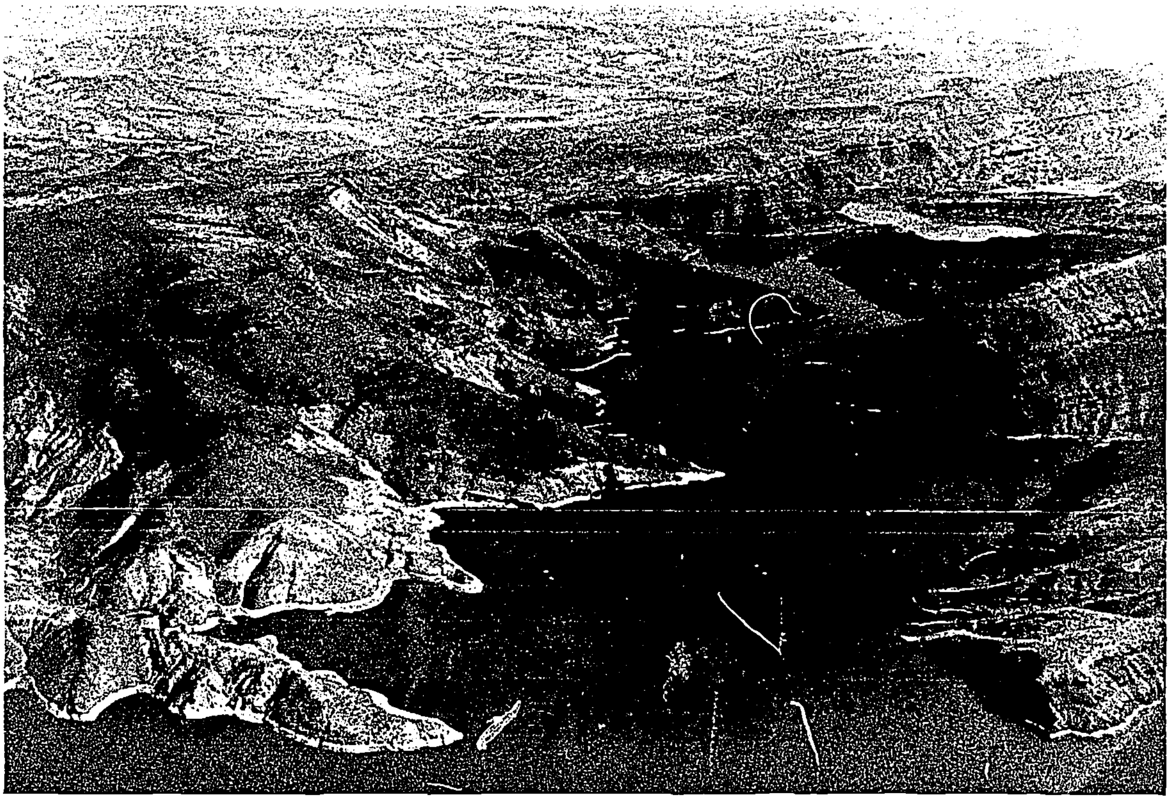


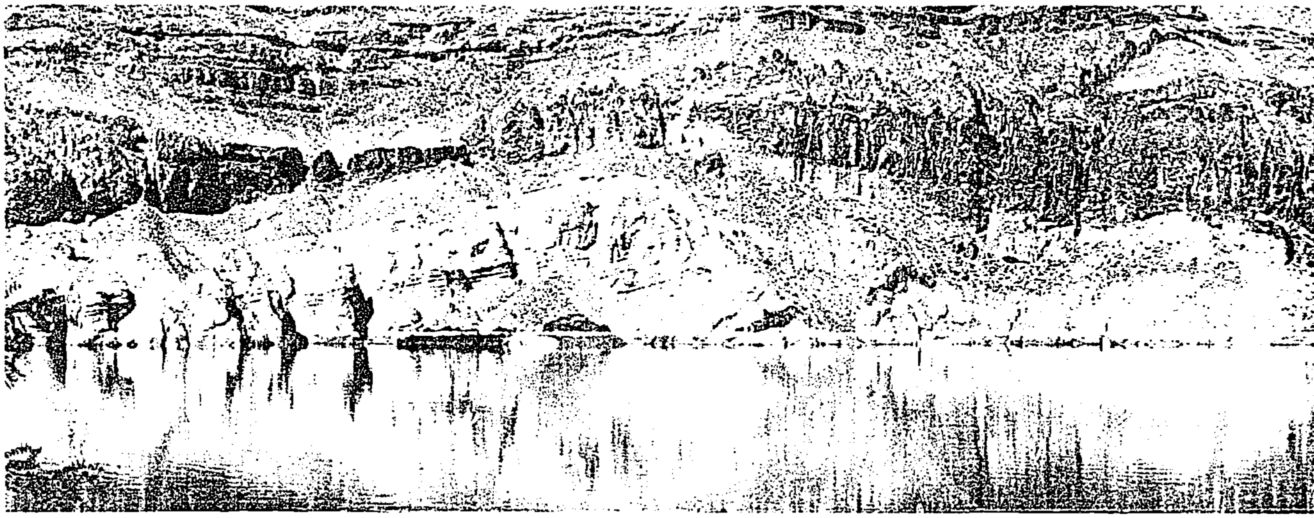
Figure 27. Owyhee Reservoir *from the air. This view northwestward toward Grassy Mountain shows tilted layers of Owyhee Basalt that slope toward the left and under the Deer Butte Formation.*

40.3 1.9 **GORDON GULCH STATE PARK.**

GORDON GULCH

ENROUTE. This road along the shore of *Owyhee Reservoir* crosses variously colored tuffaceous rocks of the SUCKER CREEK FORMATION. As one goes along, the bottom of the OWYHEE BASALT appears higher and higher on the canyon walls, because the basalt flows art tilted (dip) southwestward and the direction of travel is southward and southeastward. It is difficult, while winding along in a canyon, to keep in mind how the several layers of rock are arranged in the surrounding region, and it is helpful to be able to see things from the air. Figure 27, taken from a small plane, shows a large area around the lower end of *Owyhee Reservoir*. The view is northwestward, and *Owyhee Dam* is just beyond the upper right-hand corner of the picture. On the right are outlying spurs of Owyhee Ridge (Map 3), made of OWYHEE BASALT. The basalt is tilted to the left, and, on the left (west) side of the reservoir, it goes beneath layered sandstones, tuffs and basalts of the DEER BUTTE FORMATION (late Miocene), outcrops of which appear in the left foreground and swing around toward the top of the picture, above the OWYHEE BASALT. In the distance, at the upper left, is *Grassy Mountain*, a mesa made of GRASSY MOUNTAIN FORMATION (middle Pliocene).

41.6 1.3 **STOP 9. McCORMACK STATE PARK. GO IN, STOP, and walk to the shore of the reservoir.** Directly across the lake, at the waterline, is an exposure of SUCKER CREEK FORMATION, overlain by a red ledge of rhyolite, in turn overlain by flows of OWYHEE BASALT that



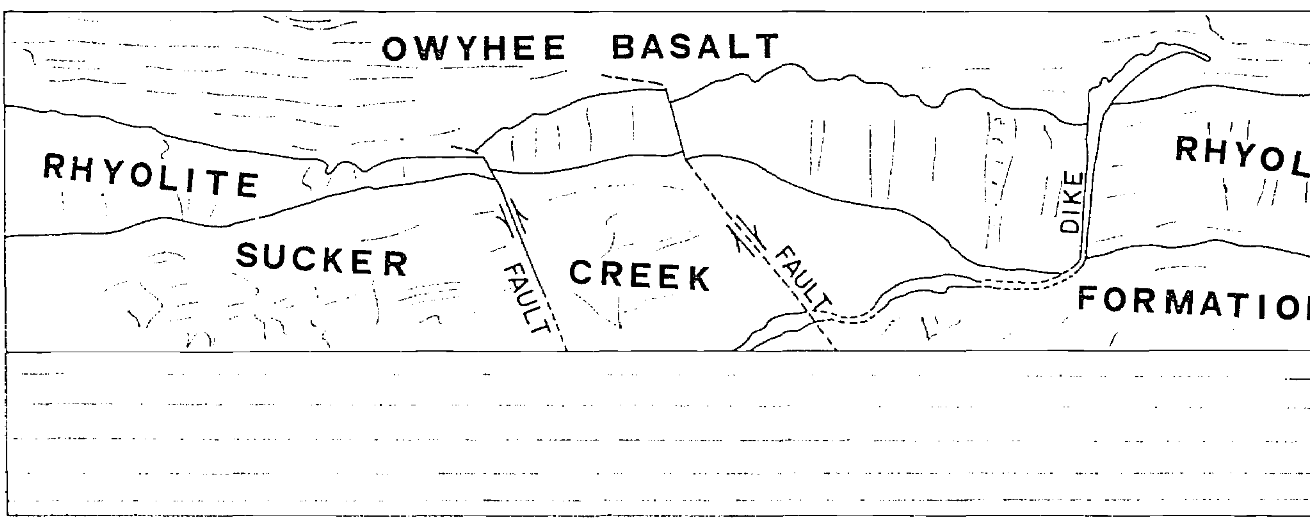
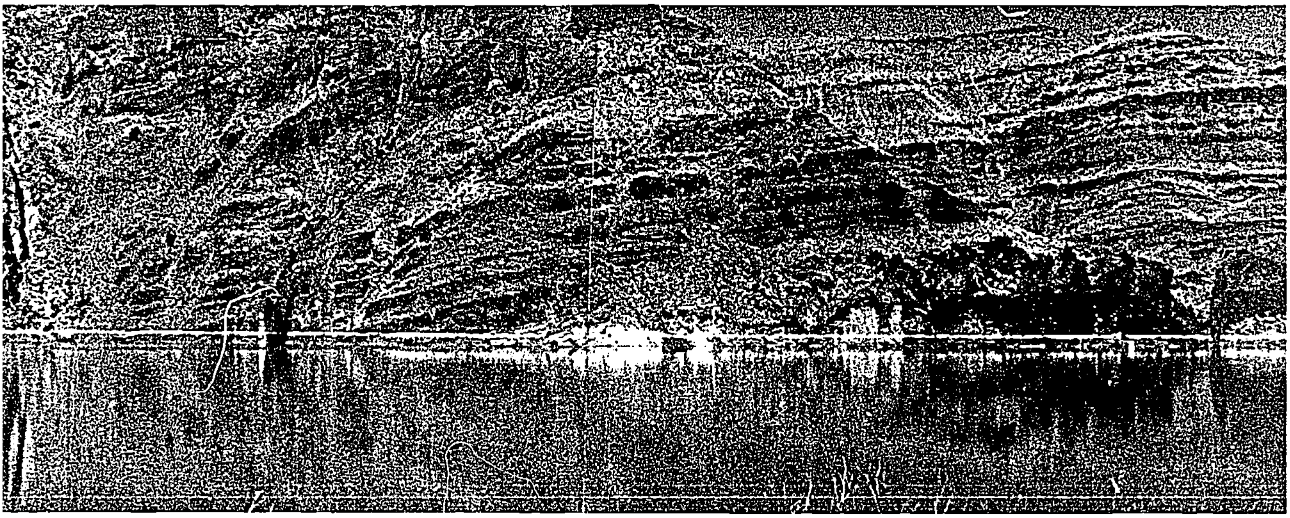
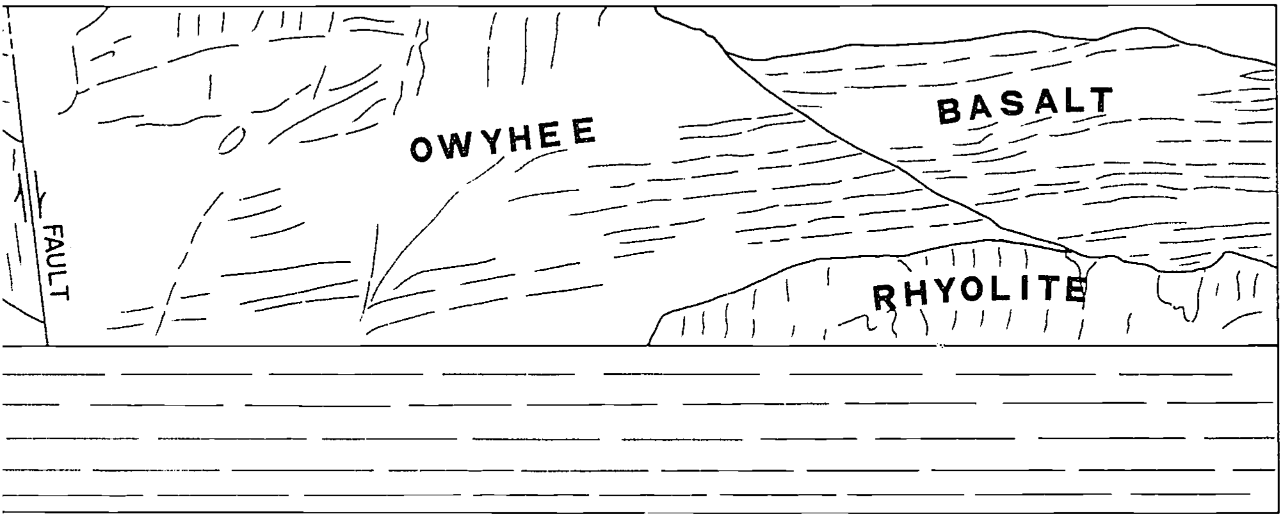


Figure 28. Ledge of rhyolite *across from McCormack State Park is cut by a fault that moved it downward on the right. The structure is interpreted in the accompanying diagram.*

form the cliffs above the reservoir (Fig. 28). The rhyolite is the same as that seen at Stop 6 (mile 37.6) and illustrated in Plate I. This seems to be a place where the flow of rhyolite overtopped a low hill of SUCKER CREEK FORMATION. The rhyolite is thinnest above the high part of the SUCKER CREEK outcrop. A diagram of these exposures is shown on Figure 28. On the left, layering in the SUCKER CREEK FORMATION slants southwestward (left), yet the top of the rhyolite flow and the flows of OWYHEE BASALT are approximately level, indicating that the SUCKER CREEK beds were tilted before the lava flows were laid down. Two faults, in the left-hand part of the diagram, cut the rock but cause little shifting of the layers. There is a dike, which stands as a rib of rock on the slope above the rhyolite, but which makes a cleft when it cuts the rhyolite. A third fault, near the middle of the diagram, caused significant shift of the layers. Rock to the right of the fault moved downward and tilted, so that the layers of basalt slant downward toward the left.





The ledge of rhyolite is cut off, and rhyolite abuts against basalt at the fault. Right of the fault individual layers of basalt rise higher and higher on the cliff, so that, far to the right, the bottom-most layers of OWYHEE BASALT and, below them, the ledge of rhyolite again appear above the waterline.

43.3 1.7 **OWYHEE LAKE RESORT. The shore road ends here.** The reservoir extends about 40 miles farther and can be approached by car at only a few places (One is at *Leslie Gulch*, described under Side-Trip C_1 of Excursion C.). Scenery along the upper reaches of the reservoir is spectacular. An aerial view is shown in Plate II. The picture was taken from a plane flying near *Watson Island* (Map 3), about 10 miles up the reservoir from here. The butte in the foreground is a volcanic neck, a vertical conduit that was once the vent of a small volcano. After eruptions stopped, basaltic lava left in the conduit solidified. Later, the rocks around the conduit were stripped away by

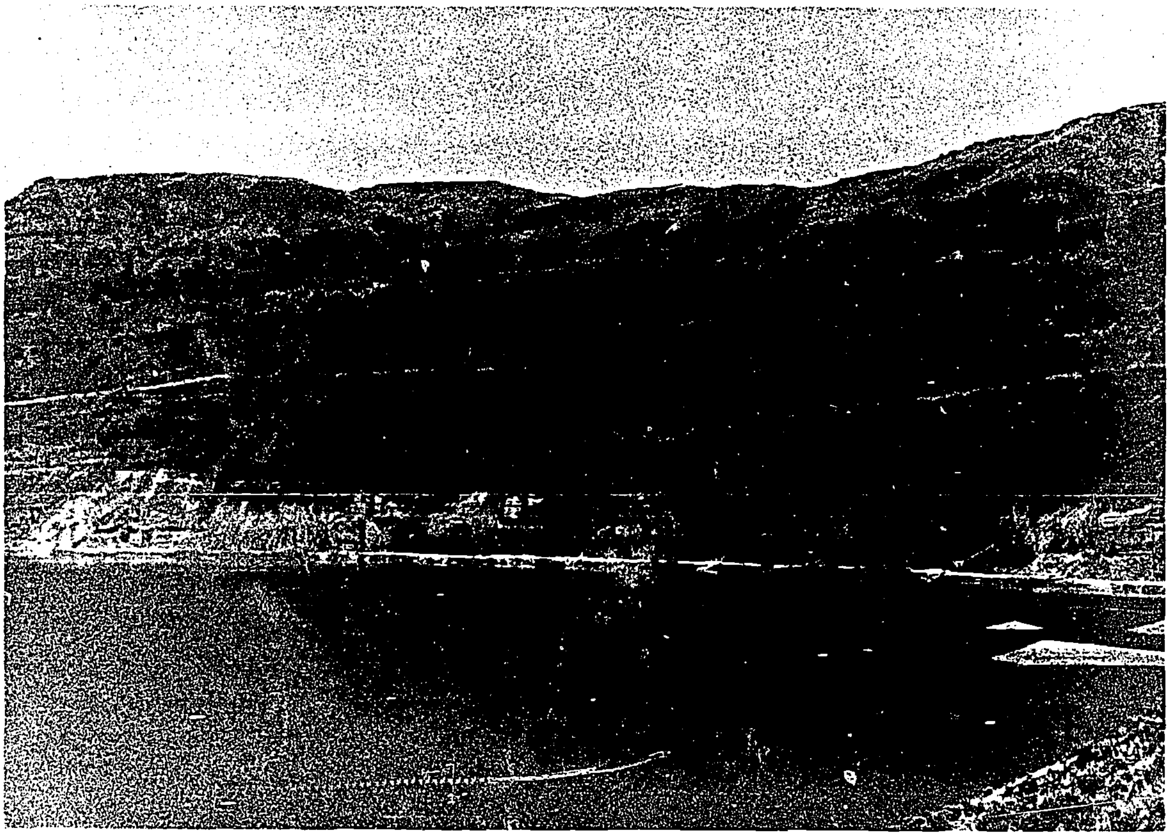


Figure 29. Cliff of Owyhee Basalt *near Owyhee Dam. The thin, white layer about half-way up shows how rocks have shifted along the fault that runs diagonally through the cliff.*

erosion, leaving the more resistant basaltic filling standing as a butte. In the middle distance is a second volcanic neck, and between the two is *Elbow Gulch*. Rocks in the middle distance on the right belong to the SUCKER CREEK FORMATION, which forms sculptured cliffs and slopes. Above them is the OWYHEE BASALT. In the distance is the DEER BUTTE FORMATION, above the OWYHEE BASALT, and at the top of the picture, on the horizon, are rocks of the GRASSY MOUNTAIN FORMATION, that make *Grassy Mountain*.

The Owyhee Valley above The Hole in the Ground, where the dam now stands, was settled about 1890, and a town called Watson was established in 1898 near the base of a butte in the canyon. The site of the town was flooded when Owyhee Reservoir filled in 1936, but the top of nearby Watson Butte sticks up above the water and is called Watson Island. It is about 12 miles above the dam, just north of Elbow Gulch.

TURN AROUND at the resort and head back toward *Owyhee Dam*.

ENROUTE, the great cliff of OWYHEE BASALT above the eastern (right) shore of the reservoir can be seen from the road. The cliff is nearly 1000 feet high. It is cut from top to bottom by a fault (Fig. 29), along which rocks on the right have shifted downward in relation to rocks on the left. The thin, white band interrupted by the fault is a layer of pumice in the midst of the basalt flows. It acts as a marker that shows how much rocks on opposite sides of the fault have shifted.

48.0 4.7 **OWYHEE DAM, RIGHT ABUTMENT. STAY RIGHT** (northeast) and go down the road on the right side of the canyon.
ENROUTE the road passes downward from OWYHEE BASALT into the underlying SUCKER CREEK FORMATION. At the contact between them, the SUCKER CREEK sediments were baked to a bright-red color by the hot lava that flowed across them.

48.3 0.3 **JUNCTION** to *Owyhee Dam* picnic area. **STAY RIGHT.**

67.1 18.8 **JUNCTION** with *Owyhee Avenue*. **TURN RIGHT** (east).

71.3 4.2 **JUNCTION** with Highway 201. **TURN LEFT** (north).

79.9 8.6 **NYSSA.**

END OF EXCURSION B.

EXCURSION C. SUCCOR CREEK CANYON
152 MILES, ROUND-TRIP
WITH A SIDE-TRIP TO LESLIE GULCH

MAP 3

MILEAGES

0.0 0.0 **BEGIN EXCURSION** at the western edge of *Nyssa* on Highway 201, at the school. **TAKE HIGHWAY 201 SOUTHWESTWARD.** The region traveled is covered by geologic maps of the Mitchell Butte quadrangle and of the Owyhee region mentioned in the Introduction to this section.

12.4 12.4 **ADRIAN. CONTINUE** on Highway 201. The bluffs on the right (west) are made of the DEER BUTTE FORMATION (late Miocene)

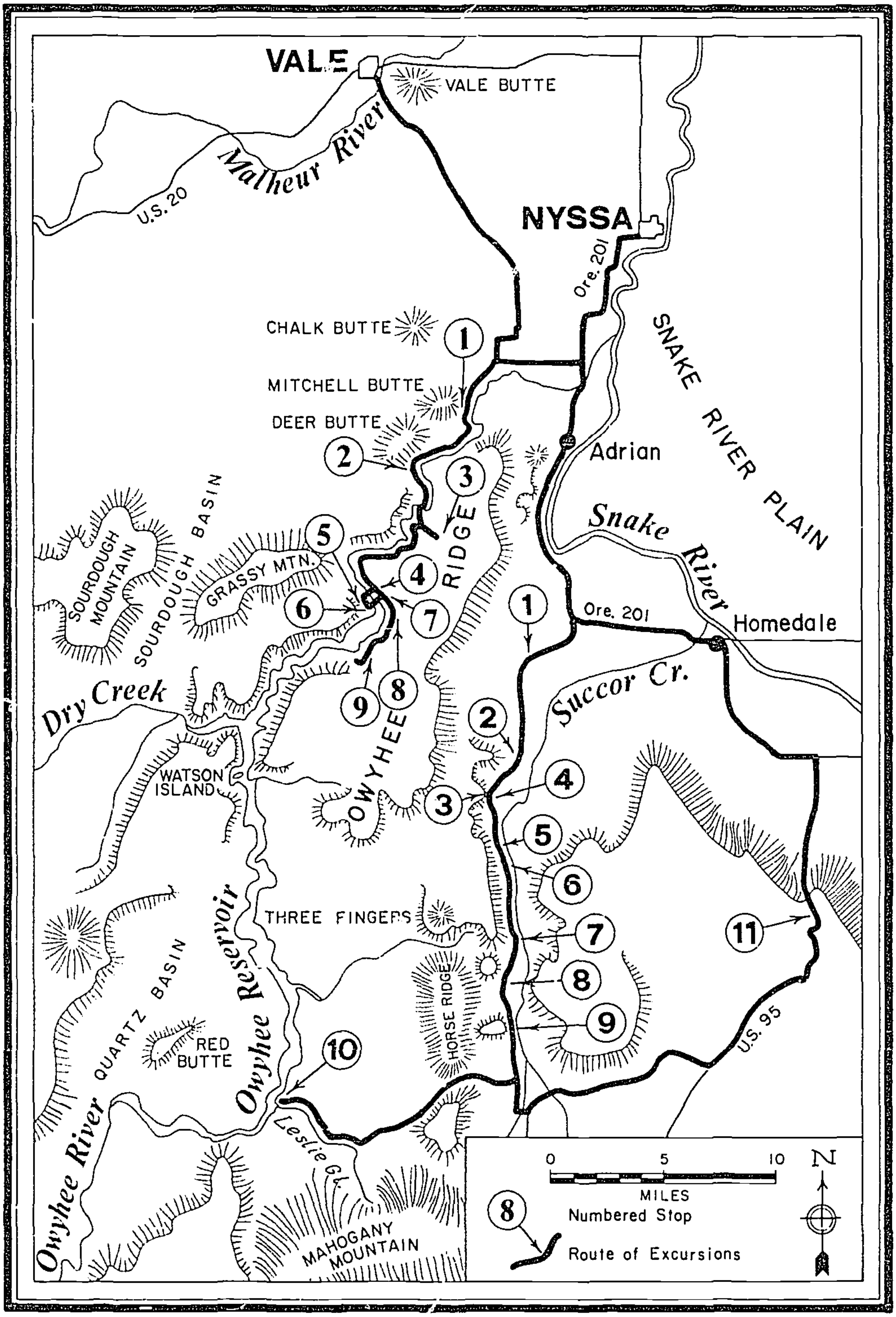
13.7 1.3 **SNAKE RIVER on the left (east).**

BROWN BUTTE

16.0 2.3 **BROWN BUTTE, on the right** (west), is made of rocks in the DEER BUTTE FORMATION. The conspicuous brown ledges are layers of sandstone rich in quartz and feldspar. Other layers are tuffs and vitric tuffs rich in fragments of volcanic glass. These outcrops resemble the ones on *Mitchell Butte* (Excursion B, mile 20.9), which also belong to the DEER BUTTE FORMATION. In both places the deposits were formed in the channels and on the floodplains of streams.

21.4 5.4 **SUCCOR CREEK JUNCTION** (elevation, 2512 feet). **TURN RIGHT** from Highway 201. The **NEXT PLACE TO GET GASOLINE** is at *Homedale, Idaho,* 100 miles farther along the route of the excursion. The Succor Creek Road, though unpaved, usually is suitable for passenger cars, but it may be impassable during rainy weather. **BE CAREFUL.**

23.7 2.3 **STOP 1. OWYHEE RIDGE AHEAD on the skyline** (elevation 4500 feet) is made mostly of OWYHEE BASALT (late Miocene). It is bounded on the east by north-trending faults downthrown on the east. Beneath the OWYHEE BASALT are rocks of the SUCKER CREEK FORMATION (late Miocene), which are mainly easily eroded sandstones, tuffaceous sandstones, and tuffs, into which *Succor Creek* has carved a broad valley. On the right (northwest) is *Blackjack Butte* (elevation, 3500 feet), a hill made of DEER BUTTE FORMATION perched on a ridge of OWYHEE BASALT. The brown and red hills low in the middle distance are made of SUCKER CREEK FORMATION. The low bluffs nearby on the right are



Map 3. *Route map for Excursion B to Owyhee Reservoir and Excursion C to Succor Creek Canyon.*

made of DEER BUTTE FORMATION. Generally the order in which the formations are layered is DEER BUTTE FORMATION on top, OWYHEE BASALT next, and SUCKER CREEK FORMATION below. Here the OWYHEE BASALT is missing, either because the flows never came this far east, or because they were here once but were later eroded away. Whatever has happened, the DEER BUTTE FORMATION here rests directly upon SUCKER CREEK FORMATION, so that there are two formations of like appearance one on top of the other. This makes difficult the job of deciding, while making a geologic map, exactly where one formation ends and the other begins.

25.7 2.0 **THE RIDGE ON THE LEFT** (east) is made of basaltic flows within the SUCKER CREEK FORMATION, called the basalt at *Bishop's Ranch.*

OWYHEE RIDGE

29.1 3.4 **STOP 2. TO THE RIGHT, in the distance,** is the eastern rampart of *Owyhee Ridge.* The nearest parts are made of JUMP CREEK RHYOLITE (early Pliocene). Low down on the escarpment an outlying reddish ridge of rhyolite is breached by *Camp Kill Creek*, forming a gap called *Devils Gate.* Ahead (south), in the distance is the rugged western wall of *Succor Creek*, made of JUMP CREEK RHYOLITE, which is cut by many north-trending faults. The JUMP CREEK is poorly understood. Apparently it formed as flows erupted from closely spaced fissures sometime after OWYHEE BASALT had been laid down, and perhaps after a kind of trough already had begun to form near the present course of *Succor Creek.* The rhyolite flowed over a large area east and south of here but stopped against *Owyhee Ridge.*

29.8 0.7 **IN THE GULCH ON THE RIGHT** is a body of basalt in the SUCKER CREEK FORMATION. It probably is an irregularly shaped mass of lava that penetrated surrounding rocks at shallow depth but did not reach the surface.

32.2 2.4 **STOP 3. SUCKER CREEK FORMATION** (elevation, 3000 feet). The jagged ridge on the skyline is made of JUMP CREEK RHYOLITE and the somber hills on the right (west) belong to the SUCKER CREEK FORMATION (Fig. 30). These outcrops fairly represent the SUCKER CREEK FORMATION as a whole, and it is worthwhile to walk over to them to look. The slopes of these hills are washed bare of soil, and little grows on them. Examination shows that they are mostly covered by a mantle of loose dirt several inches thick that is as slippery as grease when it is wet and is cracked, powdery, and puffed up rather like popcorn when it is dry. This mantle is the characteristic result of the weathering of some kinds of volcanic rocks in a dry climate, and it is called popcorn weathering by some geologists. Much of the SUCKER CREEK FORMATION is made of layers that were originally deposits of air-borne volcanic ash erupted from distant volcanoes. Volcanic ash of this sort is made up of tiny fragments of pumice and other kinds of natural glass, usually with some small amount of mineral grains. These fragments of glass readily decompose after the layers containing them have been buried by later deposits. The main product of the decomposition is a mineral called montmorillonite, a kind of clay which has the ability to absorb water. It swells up and feels greasy when it does so. When these rocks are exposed to weathering at the earth's surface, they swell, crack, and slough off, and repeated wetting and drying forms the loose clayey mantle that is steadily washed from the hillsides, beginning a new cycle of erosion, transportation, and deposition. Digging through the mantle reveals the underlying solid, montmorillonite-rich layered rocks of vari-

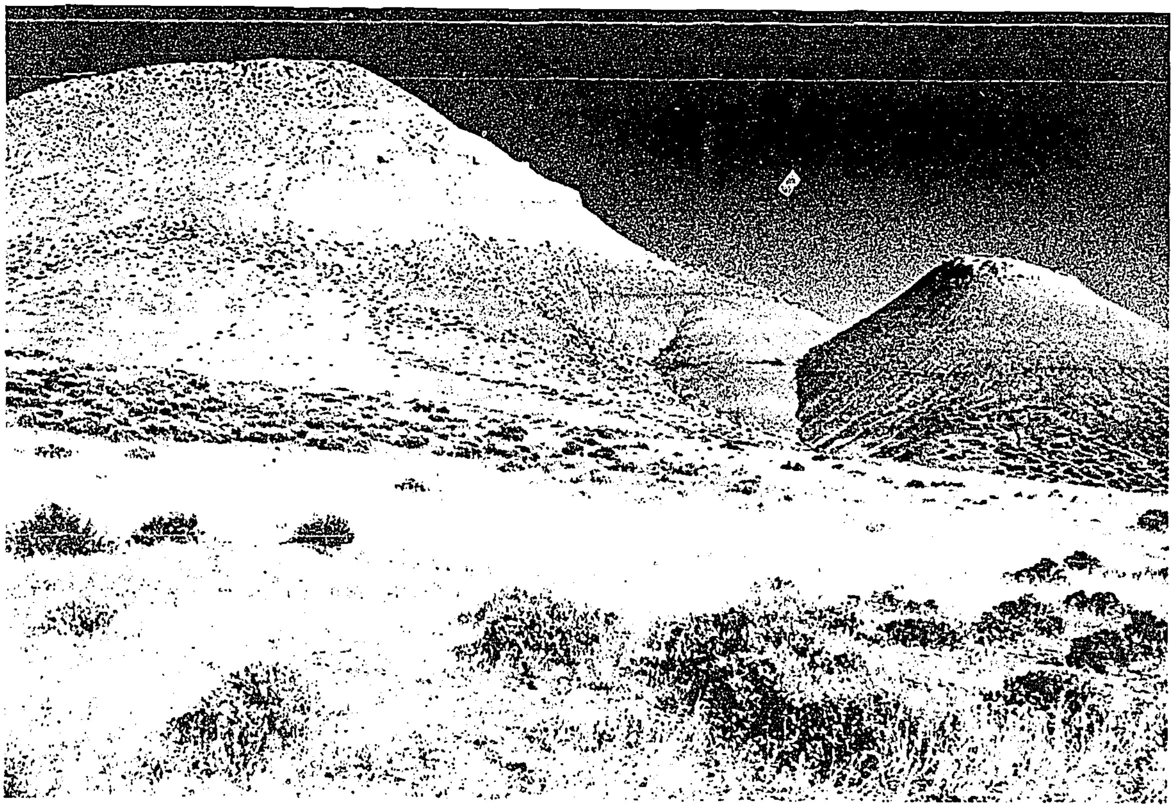


Figure 30. Hills of Sucker Creek Formation *in Succor Creek Valley. The bare slopes reveal layers of tuffaceous volcanic rocks.*

ous olive or brown colors and with various amounts of gritty mineral grains. There are a few sandy layers rich in quartz and feldspar, brought by ancient streams from granitic outcrops in southwestern Idaho, and there are some layers of silvery-gray vitric tuff, composed of tiny slivers of volcanic glass that, for some reason, have escaped decomposition.

From these hills there is a view northward (Fig. 31) into the lower valley of *Succor Creek*. This landscape, composed mostly of rocks of the SUCKER CREEK FORMATION, slopes through a series of foothills, spurs, and ridges from *Owyhee Ridge* on the left (west) to *Succor Creek* on the right. Steeper slopes, where vegetation is scant, reveal variously slanting layers of the SUCKER CREEK FORMATION, indicating that the rocks have been cut by faults that have broken them into tilted blocks.

RETURN TO THE ROAD.

32.4 0.2 **STOP 4. VIEW OF SUCCOR CREEK GORGE.** The scene ahead (south) is the mouth of *Succor Creek Gorge* (Plate III), where the stream leaves a chasm within cliff-forming hard rocks and enters more easily eroded terrane of the lower *Succor Creek Valley*. The lower cliffs of the gorge are made of ash-flow tuff, the LESLIE GULCH MEMBER of the SUCKER CREEK FORMATION. The higher cliffs that rim plateaus on both sides of the canyon are of JUMP CREEK RHYOLITE (early Pliocene). The rocks are broken by many roughly parallel faults that trend

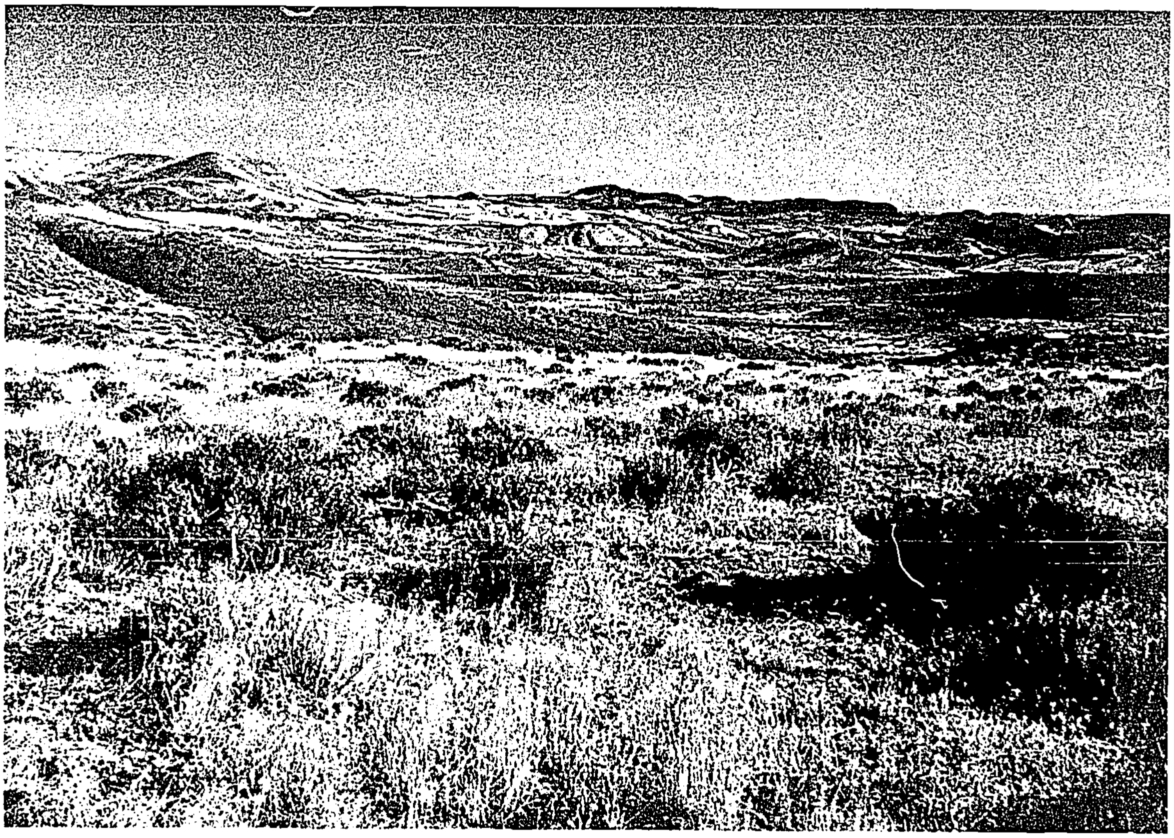


Figure 31. Lower Succor Creek Valley *is floored by volcanic sedimentary rocks of the Sucker Creek Formation. In this scene, an erosionally sculptured surface slopes eastward (right) toward Succor Creek. The layers of rock are disarranged by faulting, and tilted layers are visible on the bare sides of hills.*

north and south. It is these faults that give the landscape its rugged appearance by forming long, closely spaced ridges made of tilted fault-blocks (Figs. 32, 33, and 34). The course of *Succor Creek* in this part of the canyon also was determined by faults, because movement along a fault shatters nearby rocks forming an easily eroded path for the stream to follow.

33.2 0.8 **ON THE LEFT** (north) is a mass of basalt that probably was squeezed up into the SUCKER CREEK FORMATION from below but did not erupt onto the surface.

35.2 2.0 **MOUTH OF SUCCOR CREEK GORGE.** The exposures on the right (west) are SUCKER CREEK FORMATION. The green color may be caused here by chemical changes in the rock produced by hot water rising along a nearby fault before the canyon was formed. The saw-toothed ridge above is LESLIE GULCH ASH-FLOW TUFF.

SUCCOR CREEK GORGE

35.6 0.4 **STOP 5. NORTHERN SUCCOR CREEK GORGE.** Stop in the shade of the poplar tree. Here, *Succor Creek*, on the left (east), runs between cliffs of LESLIE GULCH TUFF capped by rimrock of JUMP CREEK RHYOLITE. Nearby on the right (west) is a huge block of the rhyolite that has slid down from the rim above. It is red, purple, or grayish red, platy, and contains tiny rectangular or square crystals of plagioclase. The lower exposures on the left are SUCKER CREEK FORMATION.

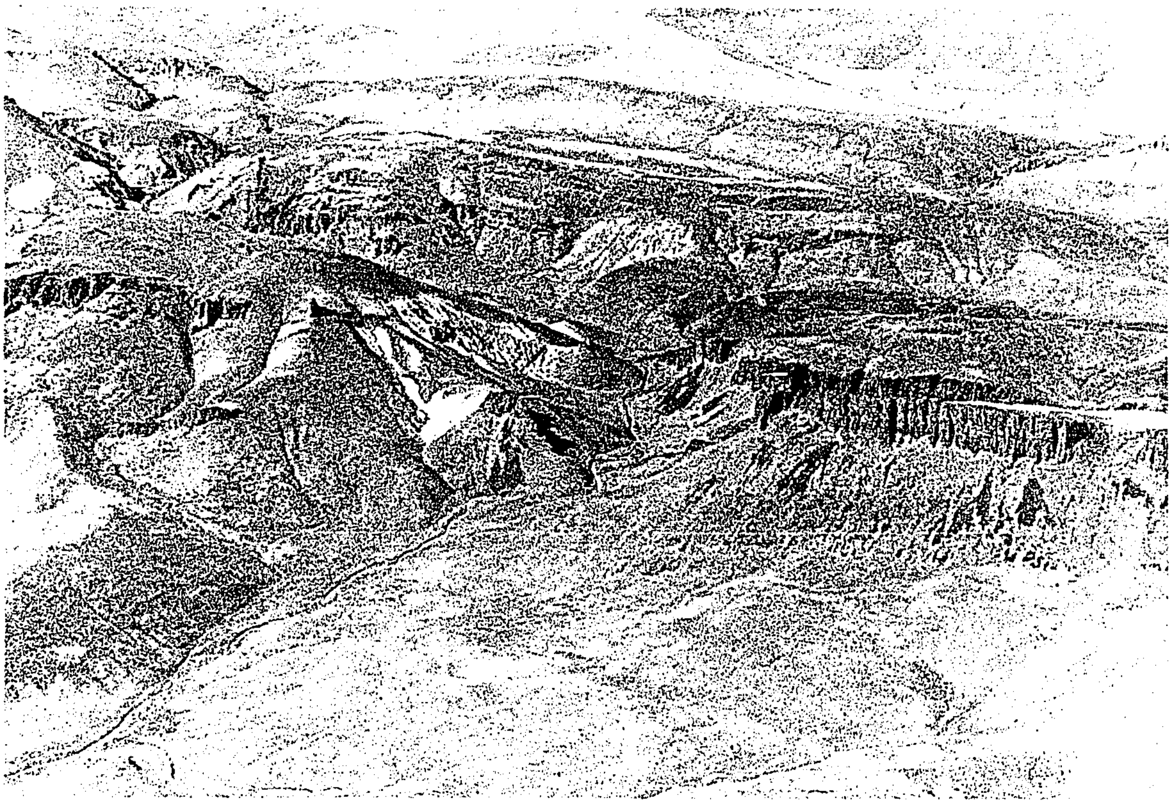


Figure 32. Owyhee Ridge *from the air. This westward view, from a point nearly above Stop 3, shows Jump Creek Rhyolite broken and tilted by faults to form long ridges.*

36.5 0.9 **STOP 6. SPRING IN SUCCOR CREEK GORGE.** Here *Succor Creek* flows between overhanging cliffs of LESLIE GULCH ASH-FLOW TUFF (Fig. 35). The LESLIE GULCH TUFF is an unusual rock that extends, in its several varieties, from here southward to the *Mahogany Mountains* (Map 3). It is a thick body of ash-flow tuff that erupted from a yet-unknown vent as a glowing mixture of frothy molten rock and hot volcanic gases. After the flow came to rest, trapped gas escaped and the mass cooled only slowly, while chemical processes that require high temperatures continued. Crystals grew and gas bubbles formed in the still-molten rock. It is these later processes, which happened after deposition, that produced many of the interesting features of the rock. On a freshly broken surface, can be seen clear, glassy crystals of sanidine, surrounded by a very fine-grained pink material that is a mixture of silica minerals and feldspar. There are round structures that are cross-sections of spherical arrangements of tiny crystals, and there are irregular or spherical cavities lined by little sugary crystals. Around here nodules are found that people call "Succor Creek eggs." They are the fillings of roughly spherical cavities formed in the molten rock by bubbles of escaping gas. The cavities, once formed, became lined by growths of small crystals, and later after the rock had cooled they were filled by deposits of chalcedony from circulating groundwater.

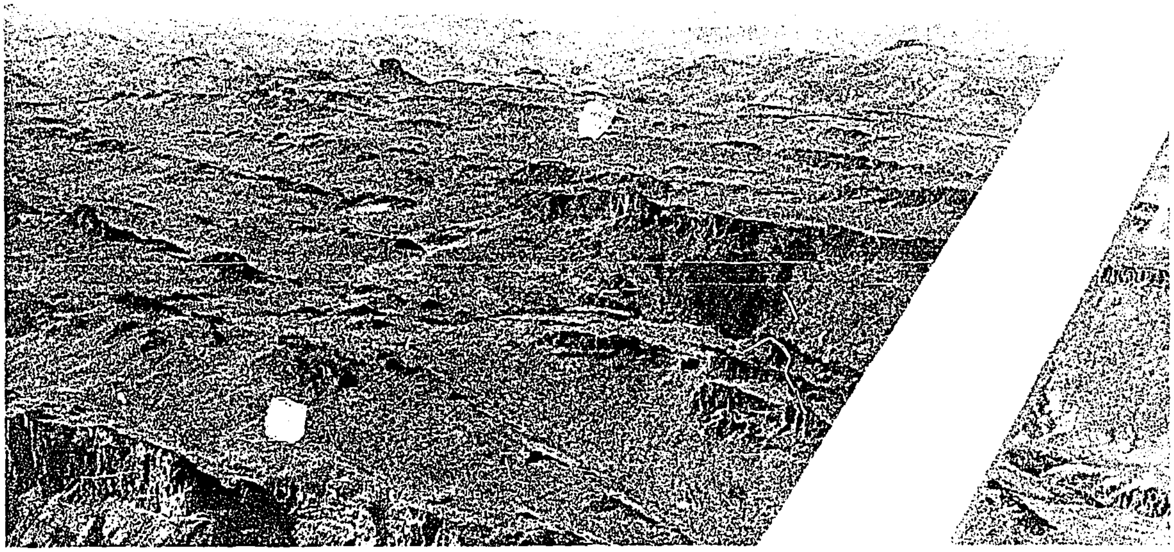


Figure 33. Three Fingers Butte, *at the left of center in the middle distance, is a rhyolitic volcanic neck perched upon Owyhee Ridge. The ridge itself is Jump Creek Rhyolite, broken by faulting into many sharp ribs that run horizontally across the picture. This aerial view is southwestward from a point nearly above Stop 5.*

39.9 3.4 **SUCCOR CREEK STATE PARK.**

41.5 1.6 **TURN LEFT (east) onto the side-road** and drive or walk to the viewpoint one-quarter mile distant.

41.7 0.2 **STOP 7. VIEW OF SUCCOR CREEK CANYON.** *Succor Creek Gorge* is to the north. Figure 36, made from the air, shows the straight cliffs whose positions are determined by faults. At the lower right, exposures of LESLIE GULCH TUFF are cut off by a fault at the left side of the meadow. To the west (left), rocks on the skyline belong to the JUMP CREEK RHYOLITE. To the right (east) is a mesa of the same rhyolite. Below it near the creek are varicolored rocks of the SUCKER CREEK FORMATION. The exposures there have been designated the type locality of the formation, that is, it is a formally recognized place where the formation is particularly well exposed and characteristic of the formation as a whole. Geologic formations are not named capriciously, but rather the names are given according to a set of rules generally recognized by geologists and made by a national commission. Names are taken from local geographic features. The SUCKER CREEK FORMATION illustrates an interesting application of these rules. When the formation was named, the nearby stream was shown on maps as *Sucker Creek*, and the rocks were named SUCKER CREEK FORMATION. The

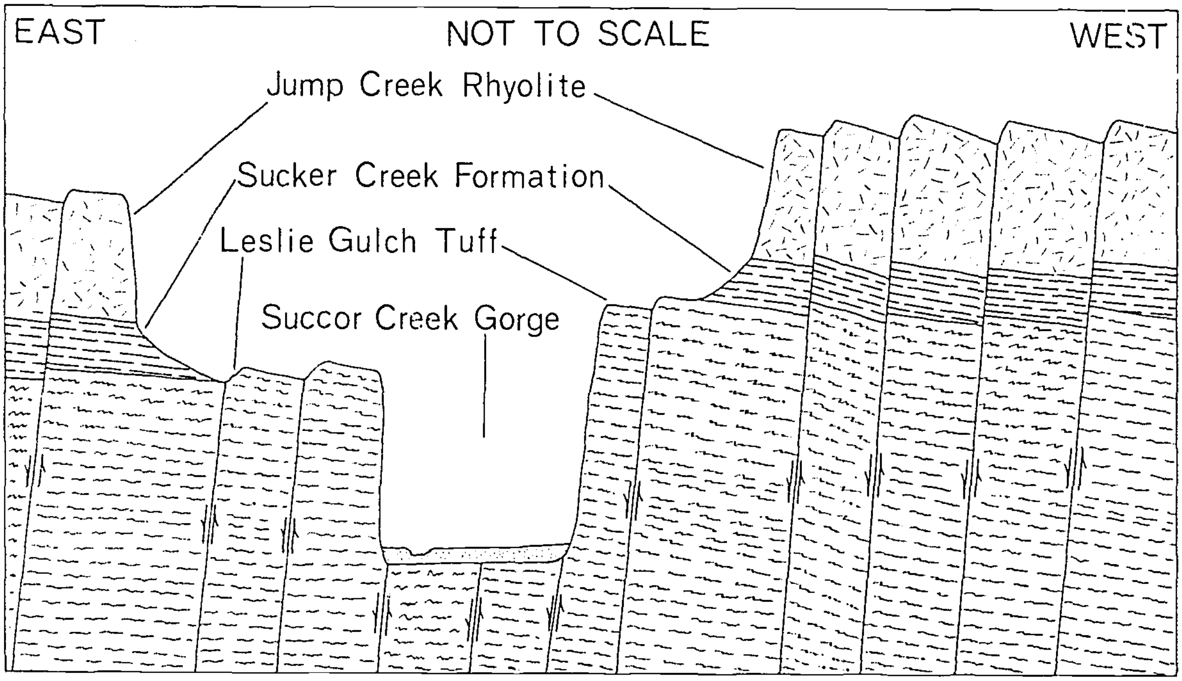


Figure 34. *Simplified diagram of Succor Creek Canyon in cross-section.*

stream, however, was known to some people as *Succor Creek*, which seems to have been the earliest name given to it. The U.S. Board of Geographic Names formally changed the name to *Succor Creek*, in recognition of the earlier usage. The rocks named for the stream continue to be called SUCKER CREEK FORMATION, because, to avoid confusion that might be caused by changes in geographic names, the rules say that a formation, once named, shall keep that name, even if the name of the geographic feature changes.

TURN AROUND and return to the main road.

41.9 0.2 **SUCCOR CREEK ROAD. TURN LEFT (south).**

43.5 1.6 **EXPOSURES OF THE SUCKER CREEK FORMATION on the right (west).** Cliffs of JUMP CREEK RHYOLITE are on the left (east) in the distance.

43.8 0.3 **THE LARGE RED CONE on the right** is made of JUMP CREEK RHYOLITE and may be the remains of one of the vents from which the rhyolite erupted.

HORSE RIDGE

45.6 1.8 **STOP 8. VIEW OF HORSE RIDGE** and the upper basin of *Succor Creek*. This is the highest spot on the *Succor Creek Road* (elevation, 3800 feet). The landscape ahead (south) is mostly underlain by rocks of the SUCKER CREEK FORMATION. In the distance, to the southwest, is *Horse Ridge* (elevation, 4600 feet), and made of the LESLIE GULCH ASH-FLOW TUFF. Southward, in the far distance, is brush-covered *Mahogany Mountain* (elevation, 6500 feet), which has JUMP CREEK RHYOLITE on its crest, with LESLIE GULCH TUFF below. The prominent spire in the middle distance is made of LESLIE GULCH TUFF, and to the left of it a little, lower down, is *Smith Butte*, of the same material. A mesa of JUMP CREEK RHYOLITE is on the left (east). Nearby on the

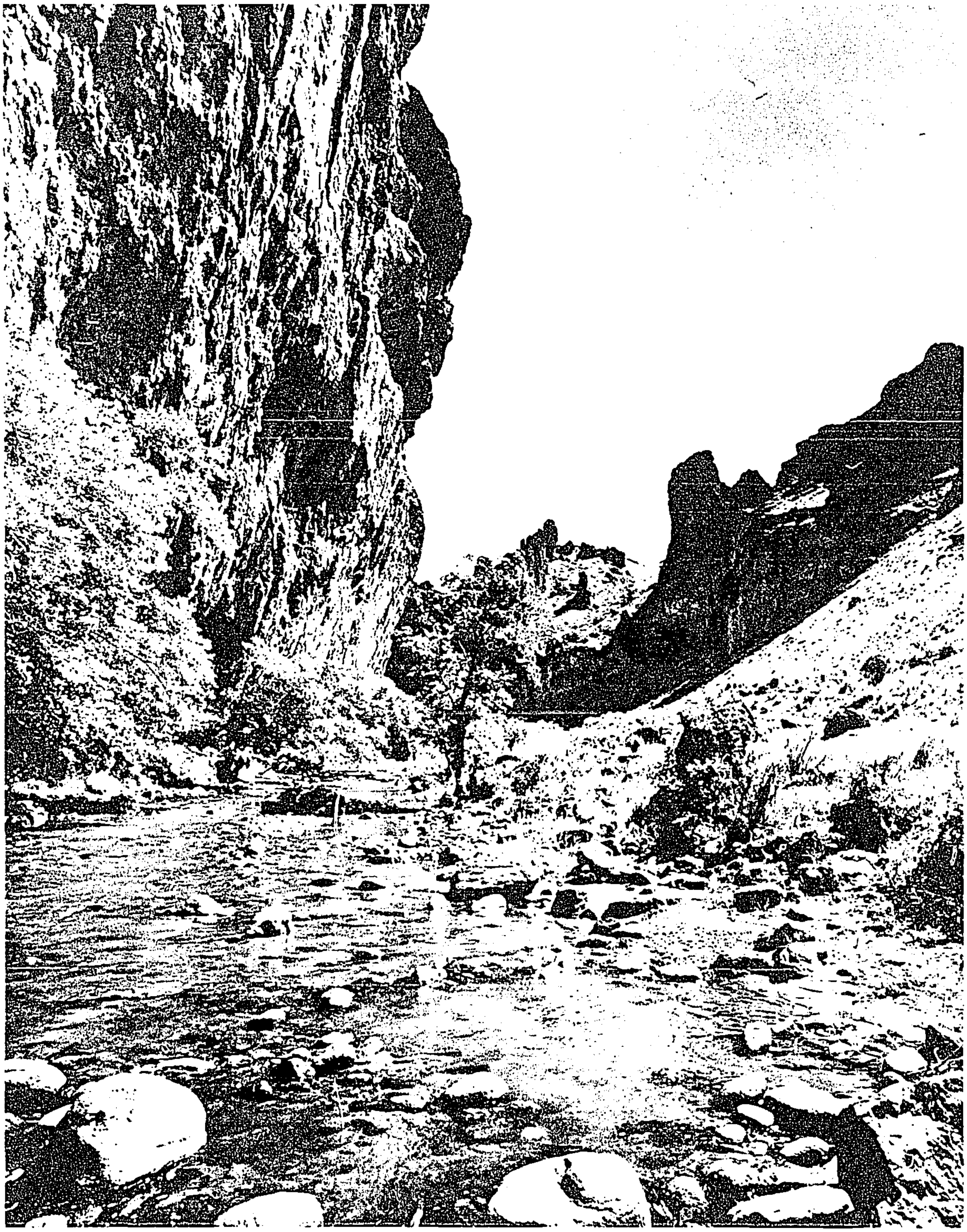


Figure 35. Overhanging cliff *deep within Succor Creek Gorge. The rock is Leslie Gulch Ash-Flow Tuff.* [Photograph by Oregon Highway Division]

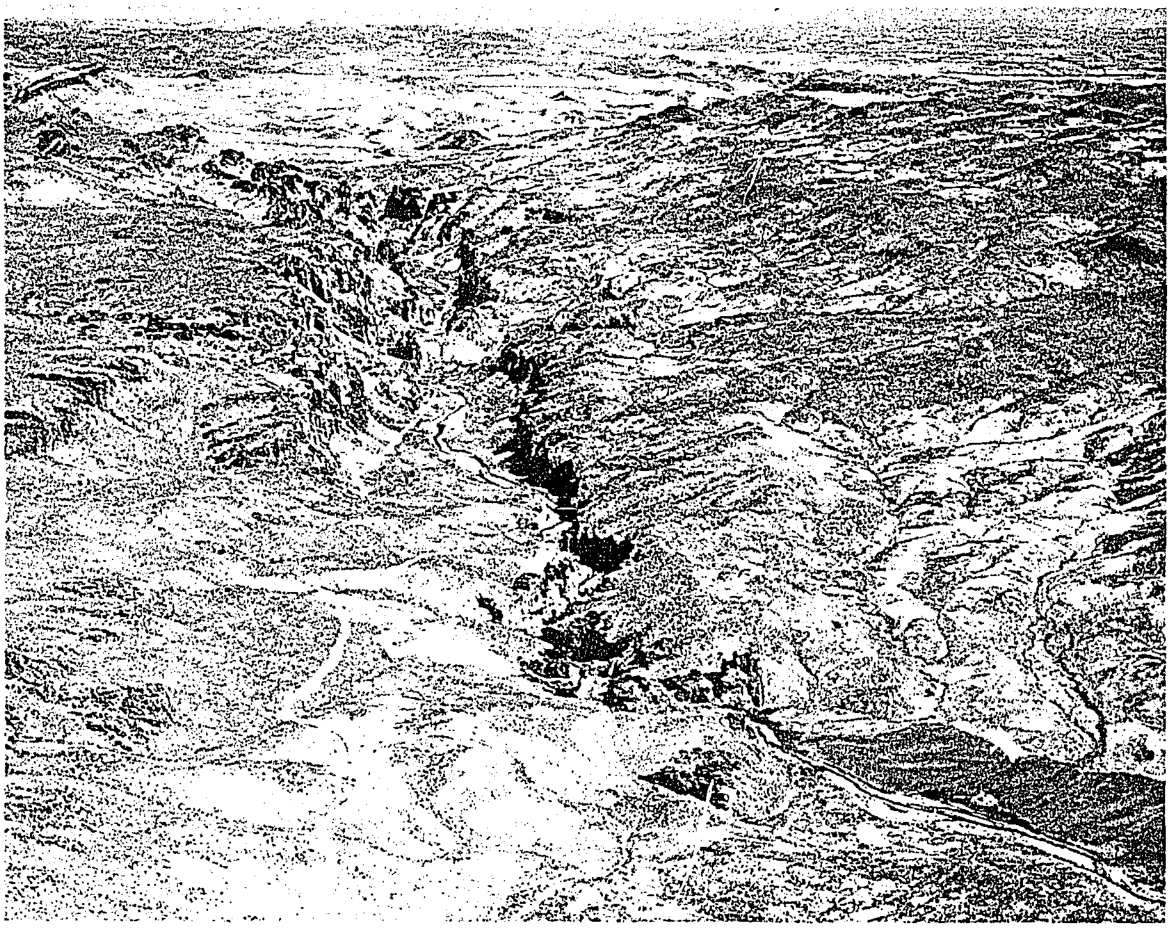


Figure 36. Succor Creek Gorge *in a northward aerial view. The creek flows in a straight, narrow cleft that was created by erosion along the line of a fault.* [Photograph by Oregon Highway Division]

left, lower down, are white exposures of SUCKER CREEK FORMATION, here made of papery, tuffaceous shales that probably were deposited in a pond or small lake.

48.1 2.5 **STOP 9. SMITH BUTTE on the right** (west) is made of LESLIE GULCH TUFF. It is a hard, pale-brown to gray rock that resembles that of the same formation seen at Stop 6 (mile 36.5), with small spherical nodules and cavities and sparkly, clear grains of feldspar and quartz.

This part of Succor Creek Valley, which contains bottomland suitable for crops or graze, was settled about 1888. Some of the ranches here are still occupied by families descended from the first settlers.

50.9 2.8 **JUNCTION WITH LESLIE GULCH ROAD. TURN RIGHT** (west) to begin Side-Trip C_1 to *Leslie Gulch.*

Side-Trip C_1 to Leslie Gulch
30 miles, round-trip

0.0 0.0 **LESLIE GULCH JUNCTION. TURN RIGHT** (west).
ENROUTE, the road crosses rocks of the SUCKER CREEK FORMATION as

it climbs the eastern side of *Horse Ridge*. To the south (left) is a mesa capped by JUMP CREEK RHYOLITE. As elevation is gained, there are increasing views northward of *Horse Ridge* and upper *Succor Creek Valley*. The ridge is the drainage divide between *Succor Creek* and the *Owyhee River*.

3.1 3.1 **CREST OF HORSE RIDGE** (elevation, 4800 feet). At about the crest. the roadway enters, leaves, and re-enters terrain of LESLIE GULCH ASH-FLOW TUFF, which is part of and layered amongst the SUCKER CREEK FORMATION,

6.3 3.2 **ENTER LESLIE GULCH.** The road descends the gulch from here, at an elevation of about 4600 feet, to *Owyhee Reservoir*, nine miles away and more than 2000 feet lower. There are steep grades. Travelers should be careful not to over heat their brakes going down or engine coming back. The whole way is among cliffs and pinnacles of LESLIE GULCH ASH-FLOW TUFF. The tuff is perhaps as much as 2000 feet thick in places and is exposed throughout an area of about 100 square miles. Here it is softer than at *Succor Creek Gorge* (Stop 6, mile 36.5) or at *Smith Butte* (Stop 9, mile 48.1), and is recognized by its jagged exposures, brown, cream, and almost white colors, and small, sparkly crystals of quartz and sanidine, which are surrounded by a fine, abrasive substance. The spectacular cliffs and spires in *Leslie Gulch* (Plate IV) owe their existence to the great thickness of uniform tuff without important layering and to the ability of the tuff to stand as steep slopes that will not hold soil.

LESLIE GULCH

15.1 8.8 **STOP 10. OWYHEE RESERVOIR** (elevation, 2660 feet). Here *Leslie Gulch* meets the reservoir about 35 miles upstream from *Owyhee Dam* (Excursion B, mile 37.9). The reservoir lies between sheer walls of LESLIE GULCH TUFF that rise more than 1000 feet within a mile of the lake.

OWYHEE RESERVOIR

TURN AROUND and head back up *Leslie Gulch*.

20.3 5.2 **DIKE ON THE LEFT (northwest).**

30.2 9.9 **JUNCTION WITH SUCCOR CREEK ROAD. END of Side-Trip C_1. TURN RIGHT** (south) to continue Excursion C.

Resume Excursion C

50.9 . . . **LESLIE GULCH JUNCTION. CONTINUE SOUTHWARD** on *Succor Creek Road*.

52.4 1.5 **CARTER CREEK JUNCTION. STAY TO THE LEFT on the main road** and cross *Carter Creek*.

52.7 0.3 **JUNCTION. ROCKVILLE SCHOOL. TURN LEFT (north) up the hill** and stay on the main road for the next 9 miles.

62.0 9.3 **JUNCTION. HIGHWAY 95. TURN LEFT (north) onto the paved highway.** This junction is in *Idaho*. The *Oregon* border, unmarked. is about 5 miles back.

ENROUTE, the highway is built on SUCKER CREEK FORMATION. The overlying JUMP CREEK RHYOLITE makes the caprock of the large mesa on the left (northwest). The highway gradually gains elevation until it enters exposures of the rhyolite.

FRENCH JOHN HILL

70.5 8.5 **FRENCH JOHN HILL.** The highway is among exposures of JUMP CREEK RHYOLITE. On the right (southeast) is the canyon of *Squaw Creek* that in many places is a jumble of great blocks of rhyolite dislodged by landsliding. As the highway loses elevation, the bottom of the rhyolite can be seen in places, where underlying rocks of the SUCKER CREEK FORMATION have been baked red, churned up, and gouged by moving rhyolitic lava.

73.8 3.3 **STOP 11. VIEW OF SNAKE RIVER PLAIN.** This spot on the edge of the *Owyhee Upland* overlooks the western *Snake River Plain*. The view is toward the northeast. The plain is a flat-bottomed, northwest-trending trough about 35 miles across. The *Snake River* flows along the southwestern side, and the city of *Boise, Idaho,* lies close to the escarpment on the opposite side. This trough is bounded on both sides by series of parallel faults, along which Miocene and early Pliocene rocks have sunk down as much as 9000 feet. The sinking happened slowly during the last 10 million years, and, as it progressed, the trough filled with basaltic flows and the sediments of streams and lakes. It is these deposits that are seen on the floor of the trough now. Older rocks, such as JUMP CREEK RHYOLITE, form the ramparts on both sides, where they rise as much as 4000 feet above the plain. Beneath the floor of the plain, these same older rocks are deeply buried by the younger deposits.

84.7 10.9 **JUNCTION. TURN LEFT (west) onto Idaho Highway 55.**

92.4 7.7 **ENTER HOMEDALE, IDAHO**

93.1 0.7 **JUNCTION. TURN LEFT (west) onto Idaho Highway 19.**

98.0 4.9 **ENTER OREGON.** The route number changes to Oregon Highway 201.

109.3 11.3 **ADRIAN. CONTINUE northward on Highway 201.**

121.7 12.4 **NYSSA.**

END OF EXCURSION C.

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MEANINGS OF GEOLOGIC WORDS

andesite—volcanic rock similar in appearance and mineral content to basalt, but with lighter color, more silica, and more sodium in its feldspar.

ash-flow tuff—volcanic rock erupted as a froth of ash and molten rock, usually rhyolitic.

basalt, basaltic—heavy, dark-colored, fine-grained volcanic rock erupted usually as extensive flows. It contains labradorite, clinopyroxene, magnetite, and sometimes olivine. **Basaltic**—having the composition of basalt.

breccia—sedimentary or fragmental volcanic rock in which the individual fragments are sharp, angular, and more than 1/12th of an inch in size.

butte—an isolated hill with steep sides.

chalcedony—one of the silica minerals; a form of microscopically crystalline quartz of which agate and other silica minerals are made.

clay—any of a large group of silicate minerals, the clay minerals, which are extremely fine-grained and are soft and plastic when wet. Some varieties are used to make pottery.

clinopyroxene—a silicate mineral rich in magnesium and iron. It is found in volcanic rocks as tiny, clear, pale-green or brown grains.

columnar structure—a condition, common in basaltic flows, caused by the fracturing the rock during cooling from a molten state in such a way that tall, five- or six-sided columns are formed.

conglomerate—sedimentary rock in which most of the fragments are rounded pebbles or cobbles of other rocks more than 1/12th inch in size.

cross-stratification—a kind of layering of sedimentary rocks in which layers within a single bed are inclined at an angle to the top and bottom of the bed.It forms in dunes of windblown sand and in dunes on streambeds.

crystal, crystalline—a body of a chemical element or compound having a regular internal arrangement of atoms, often expressed as symmetrically arranged facets. **Crystalline**—having the form or composition of crystal.

diatomite, diatomaceous—white, soft, light-weight sedimentary rock made mostly or wholly of the microscopic opaline shells of plants called diatoms which live in bodies of water. **Diatomaceous**—composed of diatoms or diatomite.

dip—the inclination of a layer of rock in relation to the horizontal.

epoch—a sub-division of geologic time next in rank below period, for example, Pliocene Epoch of the Tertiary Period.

era—a main sub-division of geologic time, for example, the Cenozoic Era.

erosion—the process of removal of soil and surficial rock by action of running water and wind.

exposure—a part of a body of rock made visible for examination either naturally, as in a cliff, or artificially, as in a roadcut.

fault—a through-going crack in the rocks of the earth's crust along which the rocks on one side of the crack have moved in relation to those on the other. Faulting is the process of the formation of faults or the motion along them.

fault-block—a block of rocks bounded on the sides by faults and commonly tilted in relation to adjacent rocks.

feldspar—a group of silicate minerals composed of potassium, sodium, and calcium, in addition to silicon and oxygen. It occurs in volcanic rocks as clear, crystalline grains of rectangular outline.

flow-layering—a structure in volcanic rocks that consists of layers or sheets formed by flowage of the rock while molten.

formation—a layer or layers of rock that is recognizable as a unit and is given a formal name, for example, Hunter Creek Basalt.

fossil—the remains of a once-living thing preserved in rock or sediment by a natural process.

glass-shard—a microscopic fragment of volcanic natural glass, commonly of complex shape and containing tiny bubbles or consisting of the fragments of the walls of what were once bubbles in molten rock.

granite, granitic—coarse-grained igneous rock, formed at great depth, composed mainly of quartz and potassium-bearing feldspar. **Granitic**—having the composition of granite.

iddingsite—a deep-red mineral formed in basaltic volcanic rocks by the chemical decomposition of olivine.

igneous rocks—rocks which were once molten or which formed at depth by great heat.

labradorite—one of the plagioclase feldspars that is rich in calcium.

lava—molten rock. Sometimes the word is also applied to rocks, once molten, that have solidified, as in lava-rock.

magnetite—a heavy, black, metallic mineral composed of oxides of iron.

mesa—a flat-topped hill with a rocky cap and steep sides. The word is the Spanish for table.

matrix—the fine-grained material in rocks that surrounds coarse grains or crystals.

mineral—a naturally occurring chemical compound.

montmorillonite—one of the clay minerals that has the property of absorbing water, then swelling greatly and becoming sticky.

neck—a volcanic landform made of volcanic rock that has solidified in the throat of a small volcano, but is now exposed and left standing by erosional removal of the surrounding parts of the former volcanic cone.

obsidian—volcanic rock composed wholly of solid natural glass.

olivine—a silicate mineral rich in magnesium and iron. It occurs in basalts as small, rounded grains of greenish, glassy appearance.

opal, opaline—a natural substance made of non-crystalline silica in which a small amount of water is incorporated. **Opaline**—composed of opal.

outcrop—an occurrence, at the surface, of solid rock free of soil or other covering.

patterned ground—regular geometric arrangement of stones on the surface of the ground believed to have been formed by churning of soil caused by repeated freezing and thawing.

peperite—a mass of volcanic rock finely broken and shattered by its injection from below into water-logged sediment while still molten.

period—a subdivision of geologic time intermediate in rank between era and epoch, for example, Tertiary Period.

plagioclase—a silicate mineral within the feldspar group composed of variable amounts of sodium and calcium, along with silicon and oxygen. Plagioclases in volcanic rocks form small, clear crystalline grains of rectanguler shape.

plateau—a flat, elevated tract of land.

pumice—volcanic rock made of frothy natural glass. It is very light in weight, so that it will float on water, and it contains countless tiny air-spaces that were once bubbles.

quartz—a mineral made of silicon dioxide. It is clear, crystalline, and very hard.

rhyodacite—fine-grained volcanic rock, similar to rhyolite, whose essential ingredients are quartz and feldspars of both calcium-bearing and potassium-bearing varieties, or which has the chemical constituents of those minerals.

rhyolite, rhyolitic—fine-grained volcanic rock whose essential ingredients are quartz and potassium-bearing feldspar, or which has the chemical constituents of those minerals. **Rhyolitic**—having the composition of rhyolite.

sandstone—fragmental sedimentary rock, the consolidated equivalent of sand, whose individual grains are fragments of minerals or of previously existing rocks of the size of sand (between 1/12th inch and 2/1000ths inch).

sanidine—potassium-bearing feldspar. It is common in volcanic rocks, where it is found as small, glass-clear grains.

sediment—deposits formed in or by flowing or standing bodies of water, or by the wind, as, for example, sands and gravels, which are the sediment of streams.

sedimentary rock—rock formed by the consolidation of sediment, as sandstone, a rock formed from sand, or limestone, a rock formed from limy mud.

silica, siliceous—a chemical compound composed of silicon and oxygen. Quartz and agate are silica minerals. **Siliceous**—containing or composed of silica.

silicate minerals—a large, important group of minerals which are the main constituents, of most rocks; composed of silicon and oxygen, together with a great variety of other elements.

stone-stripe—long, regularly arranged streams of stones on hillsides believed to have been formed by churning of repeatedly frozen and thawed soil.

strike—the direction taken by a horizontal line imagined to be drawn on the surface of a tilted layer of rock. The strike is at a right-angle to the direction of dip, and the two together give the orientation of a tilted layer.

tuff, tuffaceous—rock composed of fragmental volcanic debris, as, for example, the consolidated equivalent of volcanic ash. **Tuffaceous**—consisting wholly or mainly of fragmental volcanic debris.

vent—the opening, usually considered to be roughly circular, through which volcanic material erupts, for example, the throat of a volcano. Long, narrow openings are called fissures.

vitric ash, vitric tuff—volcanic ash or tuff composed wholly or mainly of glass-shards.

volcanism, volcanic—the activity of volcanoes. **Volcanic**—having to do with volcanism or its products.

volcanic ash—fragmental material of the size of sand-grains erupted with explosive violence from a volcanic vent and hurled through the air.

weathering—mechanical and chemical processes by which rocks at the earth's surface are disintegrated, decomposed, or altered by exposure to the elements of the weather.

welded ash-flow tuff—ash-flow tuff in which individual particles of ash have become welded together and flattened by heat and pressure in the flow after the mass came to rest.

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