

GEOLOGY OF LAKE OWYHEE STATE PARK AND VICINITY,  
MALHEUR COUNTY, OREGON

By R. E. Corcoran\*

Introduction

One of the most scenic areas in Oregon surrounds the Owyhee Dam and Reservoir in Malheur County of southeast Oregon (figure 1). This region has been well known to sportsmen for many years, because of the abundance of game in the hills and the excellent fishing in the lake. "Rockhounds" from all over the United States have been attracted to the Owyhee country by the many varieties of agate for which the region is famous. In April 1958, the State Highway Department established this area as one of its parks, in order to develop the recreational facilities of the Owyhee Reservoir and make it more accessible to the general public. Since that time a paved road has been constructed from the mouth of Owyhee Canyon into the newly developed park areas on Lake Owyhee. In addition to the state picnic and overnight camp grounds and the boat-launching ramps, there is a private motel and restaurant on the lake shore just beyond the park (figure 2).

Owyhee Dam was built in 1932 to develop a water-storage reservoir for irrigating the low alluvial lands along the Oregon side of the Snake River Plains (figure 3). The dam is 405 feet from foundation to crest, 835 feet long, and forms a reservoir 52 miles in length - the longest lake in Oregon. At the time it was built, Owyhee Dam was considered to be the highest in the world. In addition to the construction of the dam, approximately 15 miles of tunnel were driven eastward through the Owyhee Ridge to carry the water from the reservoir to the main irrigation system along the Snake River and Malheur River valleys.

According to McArthur (1952), the name "Owyhee" is derived from the old way of spelling "Hawaii." During the early part of the 19th

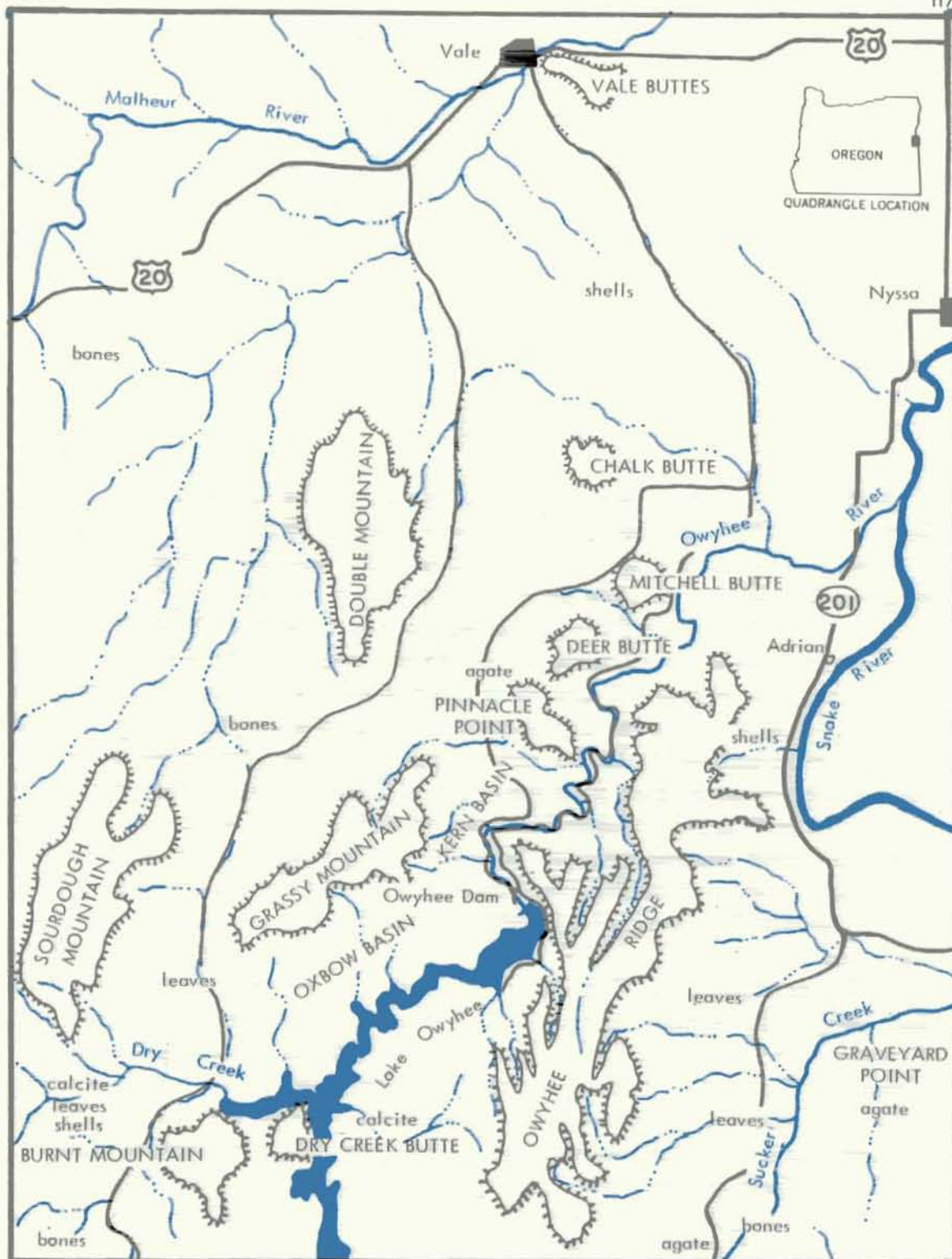
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\* Stratigrapher, Oregon State Dept. of Geology and Mineral Industries.

117° 30'

117° 00'

44° 00'



43° 3'

Figure 1. Index map of the Owyhee country, Malheur County, Oregon, showing the main geographic features and the location of some of the fossils and minerals.

century, natives from the Hawaiian (Sandwich) Islands were brought to the Pacific Northwest to work as laborers for the Hudson's Bay Company and the North West Company. Hawaiians were also used as boatmen to transport the fur traders into the interior parts of what are now the States of Oregon, Washington, and Idaho. Peter Skene Ogden, chief fur trader for the merged Hudson's Bay and North West Companies, was the first to make note of this fact in the report on his second expedition into the Snake River region. On Saturday, February 18, 1826, he "reached Sandwich Island River, so called, owing to 2 of them murdered by Snake Indians in 1819." McArthur states, "There seems to be no doubt that the Owyhee River was named for these Hawaiians, for on June 15 of the same year Ogden uses the word 'Owyhee'."

Geologists first visited this part of Oregon almost 100 years ago, when Clarence King led a geological exploration of the fortieth parallel for the U.S. Government (King, 1878). Since that time, additional studies have uncovered considerable information regarding the age and stratigraphy of the Tertiary volcanics and continental sediments that underlie this region (Bryan, 1929; Corcoran and others, 1962; Kittleman, 1962). The excellent surface exposures of the rocks in the vicinity of Lake Owyhee State Park make it an ideal "outdoor laboratory" for all those interested in the study of the earth's crust. This report briefly describes the rocks of the area around the state park and summarizes the geological history.

### Physiography and Climate

The Lake Owyhee State Park is situated within the physiographic province called the "Owyhee Upland," which lies in southeastern Oregon, almost entirely within Malheur County (Dicken, 1959). It is characterized by a moderately to highly dissected upland surface with few perennial streams. In the vicinity of the state park, the Owyhee River has cut a deep canyon which, together with its tributaries, has produced an area of high relief. Hole-in-the-Ground is the name given to the part of the canyon immediately above the dam. The crest of Owyhee Ridge which borders the eastern edge of the reservoir has a maximum elevation of almost 5,000 feet. The surface of the lake is approximately 2,600 feet above sea level.

The Owyhee River rises in Nevada and flows northerly and northwesterly through Idaho and Oregon, and then east to its junction with the Snake River four miles north of Adrian, Oregon. Because the Owyhee River passes through an area of deficient rainfall, it possesses only three perennial tributaries.

The entire area lies within the high desert climatic belt of eastern Oregon. The leading characteristics of the high-desert climate in these

northerly latitudes are: wide daily temperature range; small precipitation; generally cloudless skies; hot, dry summers; and moderately cold winters during which there is some rain and snow. The average annual temperature is about 52° F and the total annual rainfall is usually less than 10 inches.

### Stratigraphic Geology

The Lake Owyhee region is underlain by a thick series of continental lake and stream beds, the deposition of which was interrupted from time to time by volcanic activity, as outlined in the stratigraphic column given below. The oldest sediments now exposed at the surface were laid down about 16 million years ago during the late Tertiary period (upper Miocene). The Miocene strata have been tilted by movements of the earth's crust, whereas beds of Pliocene age are in most places only slightly disturbed (Corcoran, 1954).

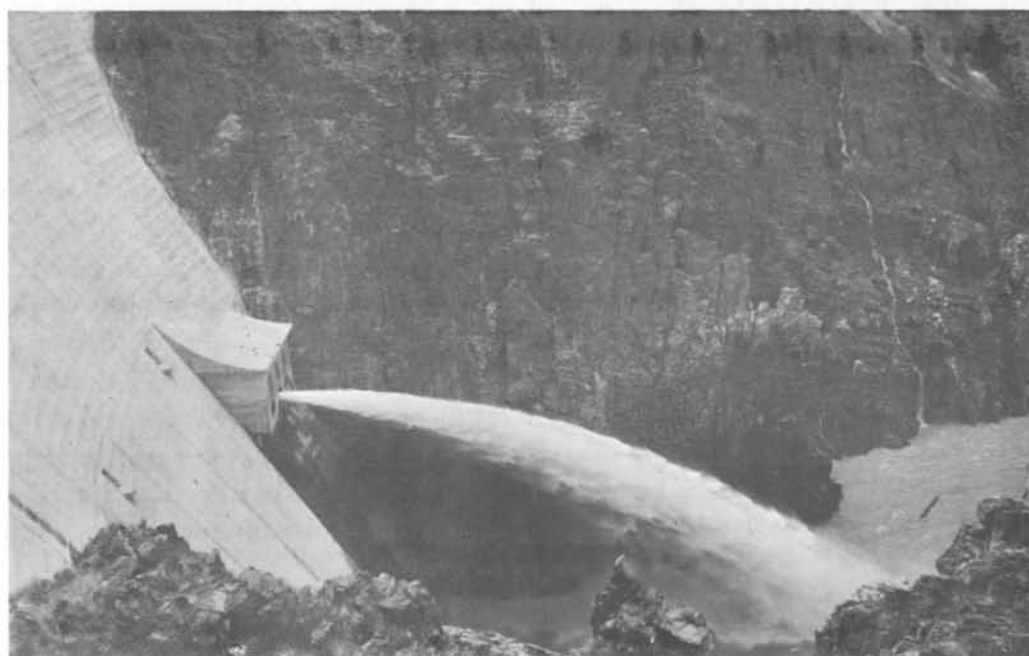
The sequence of sediments and volcanics that crop out in this part of the state have been subdivided into several "formations," based on distinguishing rock characteristics, in order to facilitate their identification in other areas and to aid in correlating the Tertiary stratigraphy of southeastern Oregon. The formational name is usually derived from the geographic

Stratigraphic Column for the Lake Owyhee Region.		
<u>Age</u>	<u>Formation</u>	<u>Description</u>
Middle Pliocene	{ Idaho Group {	Chalk Butte Formation: Mostly fluviatile deposits with a few intercalated basalt flows.
Lower Pliocene		Grassy Mountain Basalt: Olivine basalt flows with interbedded tuffaceous sediments.
		Kern Basin Formation: Tuffs, tuff breccias, and tuffaceous sediments.
Upper Miocene	{	Deer Butte Formation: Tuffaceous sediments in lower part with intercalated lavas grading upward into coarser arkosic sandstones and rhyolite-granite conglomerates.
		Owyhee Basalt: Massive to thin-layered plateau basalts with interbeds of tuffs and ash deposits.
		Sucker Creek Formation: Fine-grained tuffaceous sediments with basaltic lavas in the lower part and rhyolitic lavas in the upper.



Figure 2. Aerial view of Lake Owyhee State Park in September 1960. Privately owned Cherry Creek-Owyhee Resort can be seen at right of photograph. State park area in center of photograph is situated on the Sucker Creek Formation. Water level of lake is approximately 50 feet below normal. Usual level is indicated by vegetation line.

Figure 3. Owyhee Dam, constructed in 1932 for irrigation purposes. The dam is situated on a rhyolite vent which served as a feeder for the massive Sucker Creek flows that crop out beneath the Owyhee Basalt. Note the well-developed vertical jointing in the wall of the canyon. (Photographs courtesy Oregon State Highway Department.)



locality where the unit best shows its distinguishing lithologic character. In discussing the geology of the Lake Owyhee area in this report, the oldest rocks are described first, followed by progressively younger units. These are, in order: Sucker Creek Formation, Owyhee Basalt, Deer Butte Formation, Kern Basin Formation, Grassy Mountain Basalt, and Chalk Butte Formation. Within each formation there may be one or more major rock types which have some form of similarity compared to the stratigraphic units above and below. Formations may be separated on the basis of "unconformities" which represent old erosion surfaces, but this is not a necessary requirement for subdivision.

The generalized geologic map accompanying this report (p. 90-91) shows the areal distribution of the rock formations which underlie Lake Owyhee State Park and vicinity. It should be pointed out that there is considerable variation in the nature of the continental sediments in any one formation. The climate in southeastern Oregon in the late Tertiary period was more humid than now, and during any particular interval of time, streams or rivers were depositing medium to coarse sands in some areas while lakes were slowly filling with fine mud and silts in adjacent basins. Basalt or rhyolite lavas may have poured down a broad valley in one direction and left an adjacent valley completely undisturbed. The lateral variation in rock types caused by differences in sedimentary environments has complicated the problem of formational identity, and in some places the correlation of one series of rocks with another is based partly on time equivalency of the fossils found within them.

### Sucker Creek Formation (Tsc)

The Sucker Creek Formation of upper Miocene age is named from exposures along Sucker Creek, approximately eight miles southeast of Lake Owyhee State Park (figure 4). The formation is also exposed in the Owyhee Canyon near the dam, but the lake has now covered most of it. Before the dam was built, Renick (1930) measured a 500-foot section between the floor of the canyon and the base of the overlying Owyhee Basalt. The camp and picnic grounds at the state park are situated on the sediments of the Sucker Creek Formation. The rocks are varicolored volcanic tuffs and tuffaceous lake bed deposits that are characterized by their high ash content and lack of induration. In other areas platy shales, massive volcanic agglomerates, and siltstones predominate. Thin beds of air-laid ash are fairly widespread, but make up only a small proportion of the entire section.

Because of its relatively unstable volcanic content, most of the original material in these beds has been altered to bentonite clay (montmorillonite). This has resulted in a characteristic type of weathered surface that





Figure 4. Sucker Creek canyon southeast of Lake Owyhee State Park. The stream has cut a deep canyon through resistant volcanic tuffs of the Sucker Creek Formation. Agates, thundereggs, and fossil leaves are found in this area. (Photograph courtesy of Oregon State Highway Department.)

can be seen at many outcrops in this area. When saturated with moisture during the rainy season, the bentonite absorbs excess water and swells considerably. Subsequent dry periods cause the clay to shrink, giving the weathered outcrop a cracked or "expanded" aspect. Plates of selenite (gypsum) are also quite common as a product of surface weathering of the bentonites.

Rhyolite flows occur in the upper part of the Sucker Creek Formation. The rhyolite (Tsr) is best exposed along the eastern scarp of the Owyhee Ridge east of the dam and along the sides of the Owyhee River canyon in the reservoir area. The dam itself was constructed on an old rhyolite vent which appears to have been the source of the flows that spread westward from this point (see figure 3). The vent shows well-developed flow banding which is nearly vertical and has a general northeasterly trend. The rock, however, is locally contorted, and small-scale folds and crenulations are prominent below the dam. The flow structure in the vent is noticeable even at a distance because of the well-developed jointing and fracturing which tend to parallel the banding. The agate deposits in the Graveyard Point area near the Idaho border are found within the Sucker Creek Formation and probably originated from high-silica solutions emanating from some of the acid magmas associated with the rhyolitic volcanic activity.

The fossilized leaves and bones that have been found in the Sucker Creek Formation portray well the environment that prevailed during deposition of this series. The over-all climate was warm to cool temperate, with an average annual rainfall of more than 20 inches. An upland forested region is indicated, with oaks as the dominant form on the slopes and lakes or swamps occupying the intervening lowlands. Ancestors of the modern horse, deer, camel, and pronghorn were abundant during this period and suggest that there were probably extensive grasslands as well as forested areas. Along the swampy lowlands beaver were common. Elephant and rhinoceros remains in beds of the Sucker Creek Formation show that this part of Oregon may have resembled the present African plateau.

After the period of rhyolitic activity interspersed with lake and stream sedimentation, a lowering of base level or general uplift of the area ushered in a time of erosion that stripped the sedimentary cover from some of the acid flows of the Sucker Creek Formation and produced a surface of fairly rugged relief.

### Owyhee Basalt (Tob)

Following the erosional interval described above, there was a resumption of volcanic activity and great thicknesses of basalt were laid down on the existing land surface. Valleys quickly became filled, and the



region soon took on the aspect of a featureless volcanic plateau. Large sections of what are now eastern Oregon and Washington and southwestern Idaho became covered to depths of several thousand feet by this series of lavas. Later erosion of the plateau removed much of the volcanic surface, but remnants of this thick sheet of upper Miocene lavas are well displayed in such areas as the Columbia River Gorge, Picture Gorge, Abert Rim, Steens Mountain, and the Owyhee Plateau.

The main mass of the Owyhee Basalt crops out in the canyon walls of the Owyhee River from the general vicinity of the state park to a point just south of Mitchell Butte, where the river leaves the canyon. The flows form the upland surface that constitutes the main portion of the Owyhee Ridge east of the park area. In the Hole-in-the-Ground where the dam is located, the basalts are at least 1,300 feet thick. The original thickness was probably much greater before erosion removed some of the overlying sediments and the upper layers of basalt.

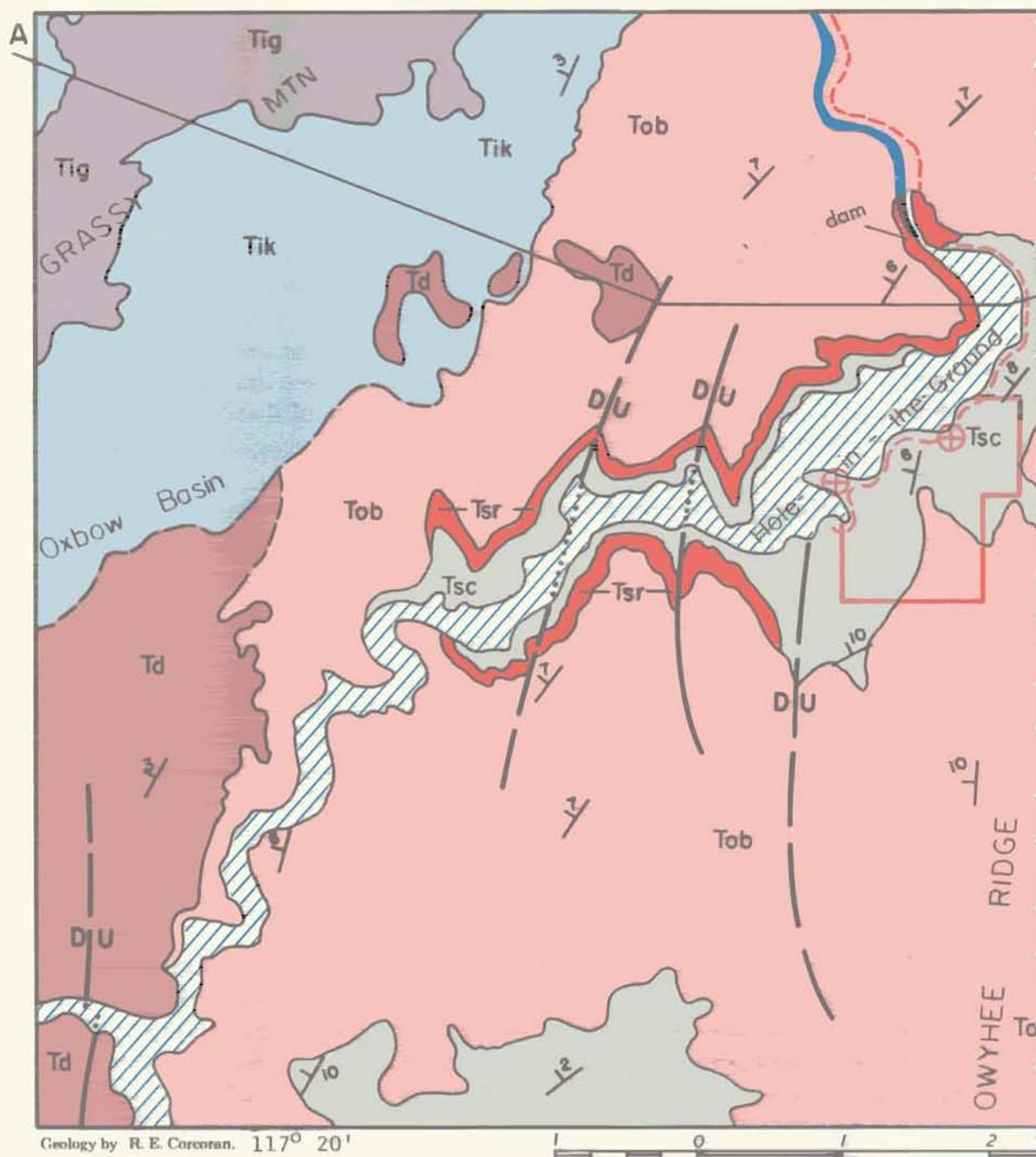
Interbedded tuff and ash deposits, representing explosive phases of volcanic activity, are common throughout the Owyhee Basalt section. In some outcrops these layers, as much as 10 or 15 feet thick, appear to make up at least half of the total section, but a lack of consolidation causes them to weather down readily and they usually are hidden beneath the basalt rubble of the overlying flows.

In hand specimen the basalt is generally fine grained, dark gray to black, and ranges from very dense to highly vesicular. Most of the vesicular zones occur in the upper part of the flows, where rising bubbles of gas in the hot liquid portion were trapped in the colder surface crust. The minerals commonly present in the basalts are plagioclase feldspars (in the ground-mass and as phenocrysts), augite, hypersthene, olivine, magnetite, and minor amounts of glass, chlorite, iddingsite, and calcite. Zeolites fill the vesicles of many of the less dense flows.

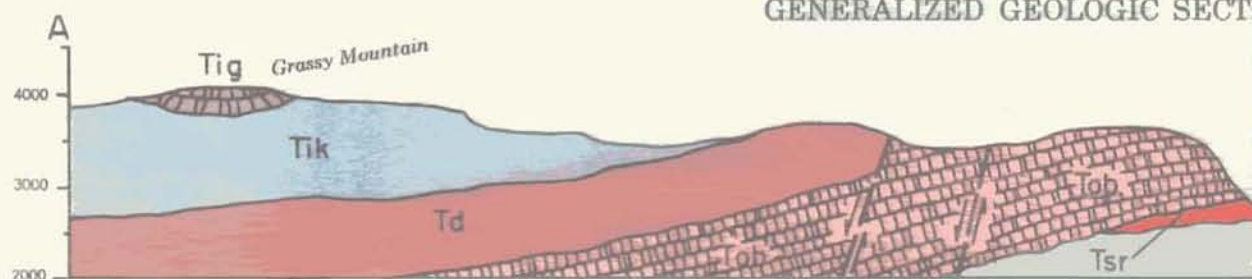
Numerous feeder dikes are visible on the canyon wall that makes up the east face of the Hole-in-the-Ground (figure 5). Most of these are no more than a few feet wide where they cut through the underlying Sucker Creek beds, and probably represent fissure fillings along fractures that once provided channelways for the basaltic magmas. They are of the same mineralogic composition as the flows but are generally denser, more finely crystalline, and non-porphyrific.

After the period of volcanism in which numerous flows of Owyhee Basalt were poured out, the area was gently upwarped and once more subjected to erosion. To the south, where the lavas appear to have been thinner, the entire volcanic layer was stripped and a surface of fairly rugged topography was developed on the underlying Sucker Creek Formation.

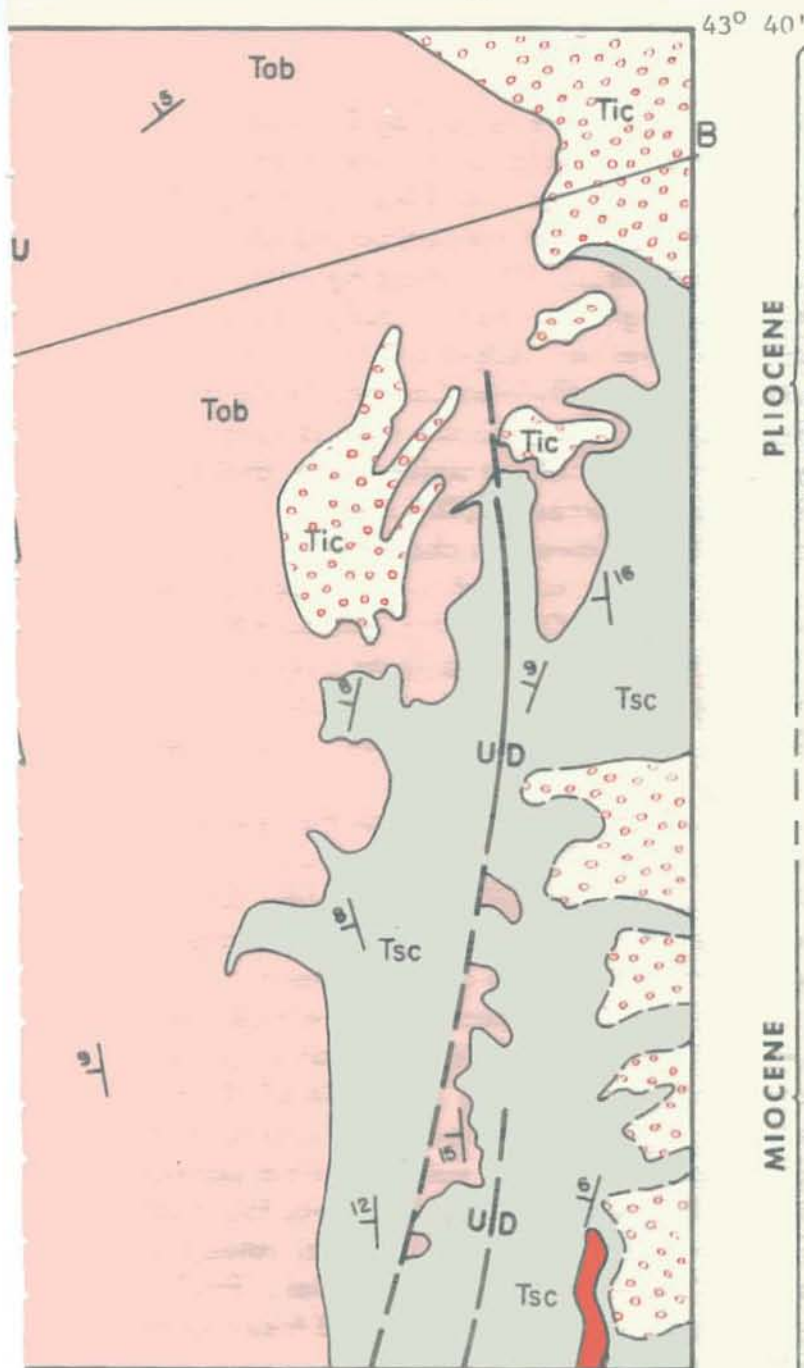
# Geologic Map of the Lake Owyhee State Park



## GENERALIZED GEOLOGIC SECTION



# Malheur Co., Oregon



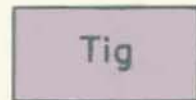
## EXPLANATION



### Chalk Butte Formation

Loosely consolidated tuffaceous conglomerate, sandstone and siltstone of lacustrine or fluvial origin with lesser amounts of ash and fresh-water limestone, Tic.

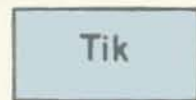
### UNCONFORMITY



### Grassy Mountain Basalt

Thin flows of normal olivine basalt, Tig; includes interflow sediments.

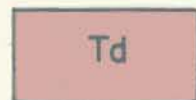
### DISCONFORMITY



### Kern Basin Formation

Tuffaceous sandstone and siltstone with bedded tuffs, ash deposits and massive tuff breccias. Conglomerate beds common in basal part of section.

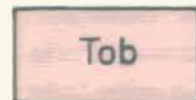
### UNCONFORMITY



### Deer Butte Formation

Soft tuffaceous siltstones and shales grading upward into interbedded tuffaceous siltstones, massive silicified arkosic sandstones and rhyolite-granite conglomerates, Td.

### UNCONFORMITY



### Owyhee Basalt

Massive and scoriaceous basalt flows with tuffs and ash deposits.

### UNCONFORMITY



### Sucker Creek Formation

Predominantly bedded and massive varicolored tuffs and tuffaceous shales with minor siltstone and sandstone, Tsc; includes massive flows and intrusions of rhyolite, in upper part, Tsr.



Lake Owyhee



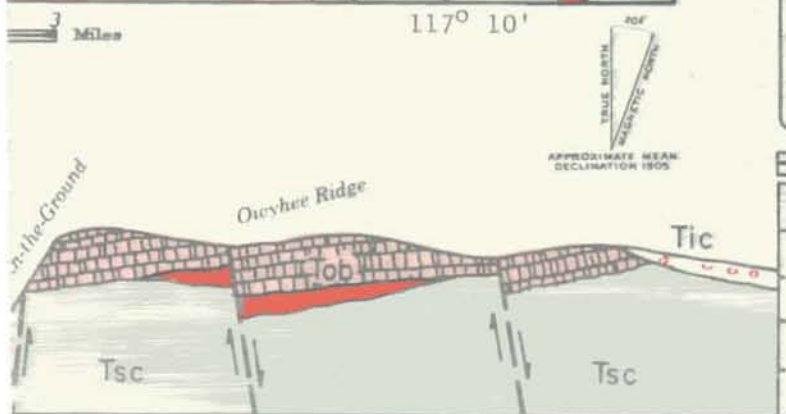
Lake Owyhee State Park



Developed areas of park



Access road



## Deer Butte Formation (Td)

Near the end of the Miocene epoch, the region again became a basin of deposition. The first sediments to be laid down were chiefly fine-grained tuffaceous rocks with a few intercalated lava flows. Later on, the source area became more varied and the nature of the sediments changed to coarser grained sandstones and conglomerates. Silica-bearing waters permeated the coarser beds, firmly cementing them into very resistant arkoses that today stand out conspicuously as prominent ledges and high buttes.

Deer Butte, near the north end of the Owyhee Canyon, is the type locality for which the formation is named. This resistant knob is composed of the coarser and more highly cemented part of the series. The total thickness of the Deer Butte Formation probably exceeds 2,000 feet.

The well-cemented arkoses and conglomerates characteristic of the upper part of the section are responsible for many of the more prominent hills surrounding the state park, including Dry Creek Butte, Pinnacle Point, and Mitchell Butte (figure 6). In several places these knobs crop out as isolated steptoes separated from the main body of the formation by younger sediments and lavas. The Vale Buttes, just south of the town of Vale, are a good example of this type of erosional feature.

In the area around Dry Creek, near the south edge of the geologic map, the tuffaceous shales, siltstones, and claystones are particularly widespread. These deposits are quite similar in appearance to the older Sucker Creek Formation, and the two sedimentary units are difficult to distinguish in the field in areas where the intervening Owyhee Basalt is missing.

An interesting feature of the fine-grained sediments in the lower part of the Deer Butte Formation near Dry Creek is the occurrence of numerous veins of calcite. Some of these veins are as much as 25 feet in width and half a mile long. The deposits were investigated by the Department several years ago to determine whether crystals of sufficient size for optical purposes could be extracted from the veins. Unfortunately, no method was found for removing clear crystals in big enough pieces to be of commercial value, but rockhounds can still obtain large rhombs of good quality material. Fossil collectors can also find well-preserved specimens of leaves and fresh-water snails in the sediments that surround the calcite veins.

The cobbles which make up the conglomerates in the Deer Butte Formation are as much as 6 or 8 inches across and are composed predominantly of granites, rhyolites, quartzites, and quartz. The amount of basaltic material in these beds is quite low, which is rather surprising in view of the fact that this formation rests on the erosion surface of the underlying Owyhee Basalt. The source area for these rocks is not definitely known, but it appears to be in the vicinity of Silver City, Idaho, approximately 50 miles

southeast of the state park. A mineralized Mesozoic granite stock about 10 miles wide by 25 miles long has been unroofed in this mountainous region by erosion of the overlying Tertiary rhyolites, tuffs, and basalts.

The environmental conditions that prevailed during Deer Butte time seem to have been similar to those which existed a few million years earlier when the Sucker Creek Formation was being deposited. Vertebrate remains collected from Deer Butte beds or formational equivalents farther to the west suggest a semihumid or perhaps a forest environment. Among the larger animals living in the area were grazing horses, camels, and antelopes. Rodents were abundant and included the tree and ground squirrels, rabbits, and so-called mountain beaver.

The depositional period marked by the Deer Butte Formation was interrupted for a short time, during which the basins were uplifted and faulted and a surface of relatively high relief developed on the older rocks.

### Idaho Group

At the beginning of the Pliocene epoch about 12 million years ago, a major structural basin, which was developed in part by block faulting, began to form in the area along the present Idaho-Oregon border. Lake and stream sediments derived from the surrounding uplands were widely distributed over the basin, known as the Snake River plains, from the general vicinity of Hagerman, Idaho to Huntington, Oregon. Because the formations dip generally toward the center of the plains, this region is sometimes called the Snake River downwarp. Along the margins of this downwarp in the Lake Owyhee region, fine- to coarse-grained sediments were deposited on the eroded surface of the Deer Butte Formation or on the Owyhee Basalt and Sucker Creek Formation in areas where the Deer Butte had been stripped. Sedimentation, although locally interrupted by periods of volcanism and erosion, was on the whole fairly continuous throughout most of the Pliocene.

In 1883, E.D. Cope described an extensive fauna of fresh-water fishes from fossil collections made by the Clarence King expedition of 1869. These fossils came from the banks of Castle and Sinker Creeks, tributaries to the Snake River in southwestern Idaho. On the basis of his studies, Cope proposed the name "Idaho Formation" for the sediments and assigned them a Pliocene age. More recent geological studies have shown that sedimentary and volcanic rocks in southwestern Idaho and southeastern Oregon included in the Idaho Formation are quite diverse in lithologies and source areas and are difficult to trace from one basin to another. For this reason it has been proposed to elevate the formation to a group so that distinctive lithologic units which are characteristic of various areas in and bordering the Snake River plains, but which cannot be closely correlated, can be adequately





Figure 5. Basaltic feeder dike in right foreground cuts through tuffaceous rocks of Sucker Creek Formation near Lake Owyhee State Park. Flows of Owyhee Basalt can be seen on both sides of the dam in background. (Photograph courtesy Oregon State Highway Department.)

Figure 6. Deer Butte Formation exposed in Mitchell Butte near Adrian. Resistant benches are well-cemented sandstones and conglomerates typical of the upper part of the section.





described. In the Lake Owyhee region the Idaho Group has been subdivided into three units: the Kern Basin Formation (lower Pliocene), Grassy Mountain Basalt (lower Pliocene?), and Chalk Butte Formation (middle Pliocene).

#### Kern Basin Formation (Tik)

Good exposures of the Kern Basin Formation can be seen in Oxbow, Sourdough, and Kern Basins (figure 7) where the sediments form steep bluffs from 100 to more than 600 feet in height capped by Grassy Mountain Basalt. The beds vary in color from white to green with occasional dark bands. Most of the beds are loosely consolidated and tend to weather into pinnacled or "hoodoo" forms. They include tuff, tuffaceous siltstone and sandstone, low-rank graywacke, and conglomerates, deposited under conditions that fluctuated from stream environments to broad, shallow lakes.

#### Grassy Mountain Basalt (Tig)

Overlying the Kern Basin Formation is the series of flows referred to by Kirk Bryan (1929) as the "Grassy Mountain Basalt." The basalts cap the hills northwest of the state park, and flows of similar stratigraphic position and composition can be traced for several miles westward. The formation contains several sedimentary interbeds, the number and thickness of which vary considerably. The basalts are massive, but usually no more than three or four separate flows can be observed at any one locality. Individual flows range in thickness from a few feet to about 100 feet.

In the hand specimen, the basalt is brownish-gray to olive-black in color, fine-grained with phenocrysts of plagioclase and olivine. Vesicles in the lava may be lined or filled with secondary zeolites and calcite. One of the distinguishing mineralogic characteristics of the flows in this unit is the presence of olivine, readily visible in hand specimens, as straw-yellow crystals as much as 2mm in diameter scattered through a fine-grained matrix. In some flows the olivine has altered to the secondary mineral iddingsite, which gives it a red, speckled appearance.

#### Chalk Butte Formation (Tic)

The Chalk Butte Formation is the most widely distributed sedimentary unit north and east of Lake Owyhee State Park in the region of the Snake River downwarp. The formation consists of unconsolidated to semi-consolidated clay, silt, sand, volcanic ash, diatomite, fresh-water limestone, and conglomerate. The road south from Vale towards the mouth of



Figure 7. Light-colored tuffaceous sedimentary rocks of the Kern Basin Formation at the type locality. Note fluted weathering of the beds.



Figure 8. Massive varicolored tuffs of the Sucker Creek Formation form the canyon walls near the upper end of Lake Owyhee. This scenic region is easily accessible by boat from the state park. (Photograph courtesy Oregon State Highway Department.)

Owyhee Canyon crosses a low, hilly region composed of continental lake and stream deposits of this formation. Thin remnants of Chalk Butte sediments visible on some of the higher parts of Owyhee Ridge indicate that these deposits covered much of the area through which the Owyhee River and its tributaries now flow. Stream erosion, begun after the region was uplifted, has stripped most of the sedimentary cover from the older rocks.

The formation appears to have been deposited chiefly by streams and rivers, with the diatomite, limestone, silt, and clay representing local lake basins. The younger beds of the Chalk Butte Formation are coarser grained, particularly on the Idaho side of the Snake River plain, and are apparently derived from weathering and erosion of the Idaho batholith to the east. A study of the oil and gas exploratory well logs drilled in the central portion of the plains shows that the Chalk Butte beds or their correlatives may be as much as 4,000 to 5,000 feet thick (Newton and Corcoran, 1963).

### Conclusions

Some of Oregon's most scenic and geologically interesting areas are to be found in the dry eastern parts of the state. A region that is becoming better known is that in the vicinity of Lake Owyhee in central Malheur County. There is something here for everyone who enjoys the outdoor life, whether it be hunting, fishing, "rockhounding," fossil collecting, or just plain camping. The colorful and varied rock formations, unobscured by vegetation, are a delight to the amateur photographer. A good paved road gives easy access to the camp areas above the dam. Those who wish to explore the upper reaches of the lake can do so easily by boat (figure 8) and in this way see some of the otherwise inaccessible scenic areas of the Owyhee country.

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## TUALATIN VALLEY GEOLOGY PUBLISHED

"Geology and Ground Water of the Tualatin Valley, Oregon," by D. H. Hart and R. C. Newcomb, has been published by the U.S. Geological Survey as Water Supply Paper 1697. The 172-page report includes well records, geologic maps, and cross sections. It may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 for \$3.00.

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## AN OLD MINE? -- GOOD LUCK!

What is cold and dark, has hidden pitfalls, treacherous floors, walls, and ceilings, bad air, poisonous water, wild animals and reptiles, loose sticks of dynamite, no house number or street address, and attracts hundreds of people every year? Answer: OLD MINES.

The rapidly growing interest in rockhounding, prospecting, and geology unfortunately also creates a lot of interest in old mines. This is easy to understand, since there is bound to be a lot of curiosity about where all the gold, in some cases millions of dollars worth, came from in an old mine. Crystal hunters also are interested in old workings and there are those who "just want to look around underground." In addition to mine tunnels, there are also glory holes, vertical shafts and open pits, to watch out for in "mining country." All of them pose some real hazards not well appreciated by the general public.

Here are a few rules to keep in mind when you are out in the hills and come across an old mine: (1) If you can't resist the urge to enter, go in with extreme caution; (2) watch for rotten timbers and flooring over shafts, loose rock, rusty nails in timbers, abandoned dynamite and caps, foul air, poisonous water, short-tempered wild animals and reptiles, and confusing cross tunnels; (3) leave somebody outside to go for help; (4) wear a hard hat, heavy shoes, and warm clothing; (5) take a carbide lamp, canteen, matches, and a rabbit's foot. Better yet, stay on the outside and just peer inside.

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## THE TACOMA EARTHQUAKE OF APRIL 29, 1965

By

E. F. Chiburis, Peter Dehlinger, and W. S. French\*

About the time Seattle and Tacoma people were going to work on the morning of April 29, 1965, the Pacific Northwest states were shaken by their largest earthquake in decades. The shock was as large, or larger, than the famous Tacoma shock of April 13, 1949. The recent quake was felt over Washington, Oregon, Idaho, and British Columbia, and as far away as Coos Bay, Oregon. Considerable damage occurred in the Tacoma-Seattle area, where at least three persons were killed. The shock was so strong that recordings at most seismograph stations in the Northwest went off scale, and subsequently recorded vibrations were so large that the different waves could not be identified. Consequently, the magnitude of the shock could be determined only at distant stations, where recorded amplitudes were smaller.

The magnitude of the shock was reported to be  $6\frac{1}{2}$  (Richter scale)\*\* by the Seismological Laboratory in Pasadena, California, and 7 by the Seismographic Stations in Berkeley, California. The maximum intensity was estimated to be VIII (Modified-Mercalli scale)\*\* in the Tacoma-Seattle region, decreasing to intensities of VII at Longview, Washington; IV at Corvallis, Oregon; and III at Coos Bay, Oregon. By comparison, the Portland earthquake of November 5, 1962, had an estimated magnitude of  $4\frac{3}{4}$ , with intensities of VI in Portland and III in Corvallis.

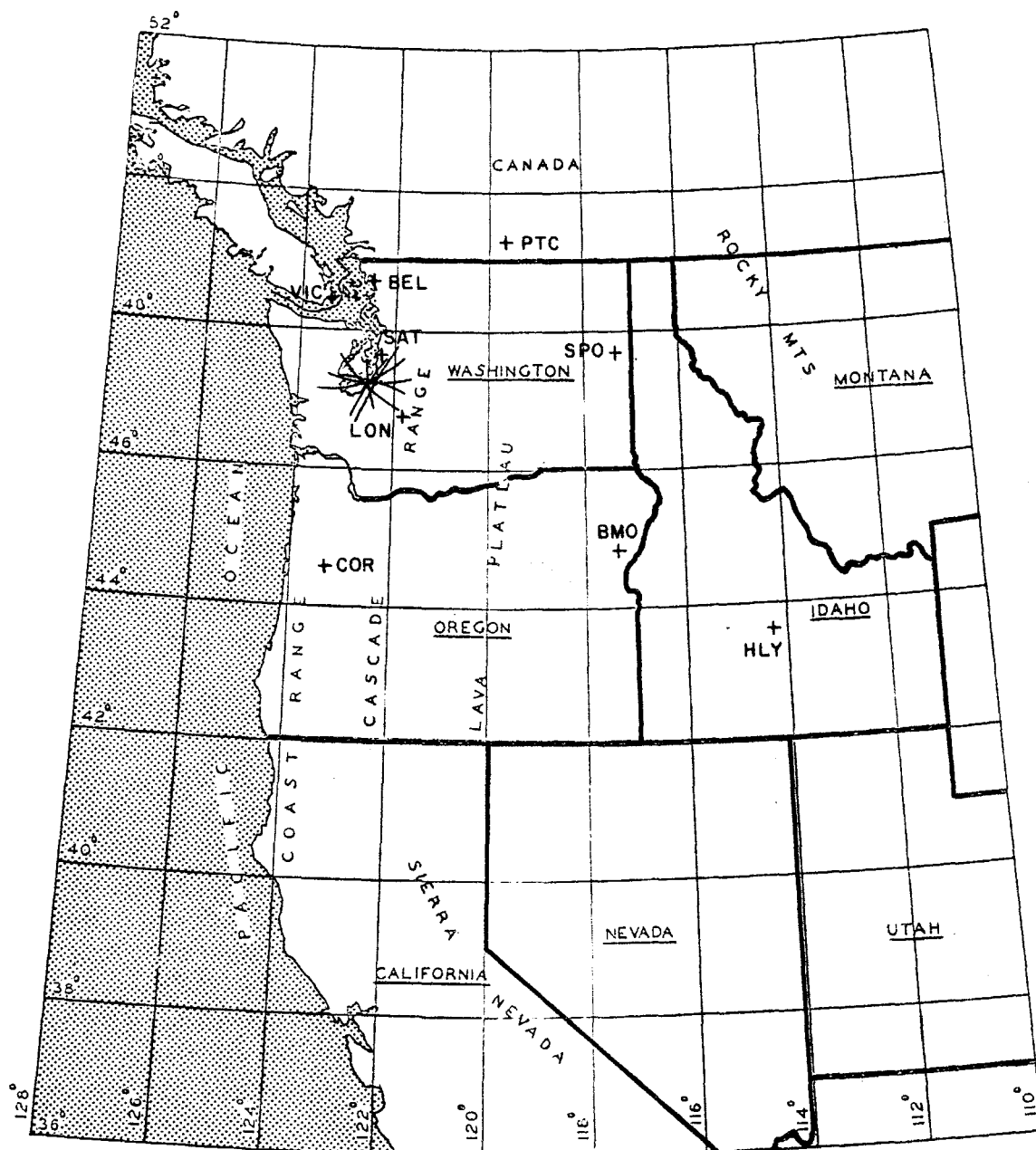
The epicenter was located in the northeast part of Tacoma, at latitude  $47^{\circ}16.8'N$ , longitude  $122^{\circ}29.7'W$ , very near the epicenter of the 1949 quake (see map on next page). The origin time was calculated to be 08:28:41.9 PDT (15:28:41.9 GCT). The depth of focus, for an assumed average velocity of 7.0 km/sec to Seattle and Longmire, was 80 km, and for an assumed average velocity of 6.3 km/sec, it was 66 km.

The quake was relatively deep for the Pacific Northwest region, although it would be classed as shallow to intermediate in depth (shallow shocks are 0-60 km deep; intermediate 60-300 km; deep 300-700 km). By contrast, the depth of the Portland shock of November, 1962, is estimated to have been 10-15 km. Had the Tacoma shock been only 10 km deep, extensive damage indeed would have occurred throughout the city and adjacent regions. The actual damage corresponds to that from the shocks at epicentral distances of 70 km or more.

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\* Geophysical Research Group, Department of Oceanography, Oregon State University, Corvallis.

\*\* Richter scale is the instrumentation measurement as determined by a seismograph; Modified-Mercalli scale is a subjective measurement of the intensity by people who feel the quake.



The above map shows the epicentral location of the earthquake as determined by arc intersections from the following seismic stations:

<u>Seismic Stations</u>	<u>Arrival times</u>	<u>Epicentral distance (km)</u>	<u>Travel time (sec)</u>
Seattle, Wash. (SAT)	08:28:54.5 PDT	45	
Longmire, Wash. (LON)	08:28:58.4	77	
Victoria, B. C. (VIC)	08:29:05.9	152	24.5
Bellingham, Wash. (BEL)	08:29:08.5	162	25.9
Corvallis, Oregon (COR)	08:29:26.4	303	44.2
Penticton, B. C. (PTC)	08:29:27.4	311	45.2
Spokane, Wash. (SPO)	08:29:35.8	388	55.3
Blue Mtn. Obs., Oregon (BMO)	08:29:48.8	476	66.4
Hailey, Idaho (HLY)	08:30:22.0	755	101.4