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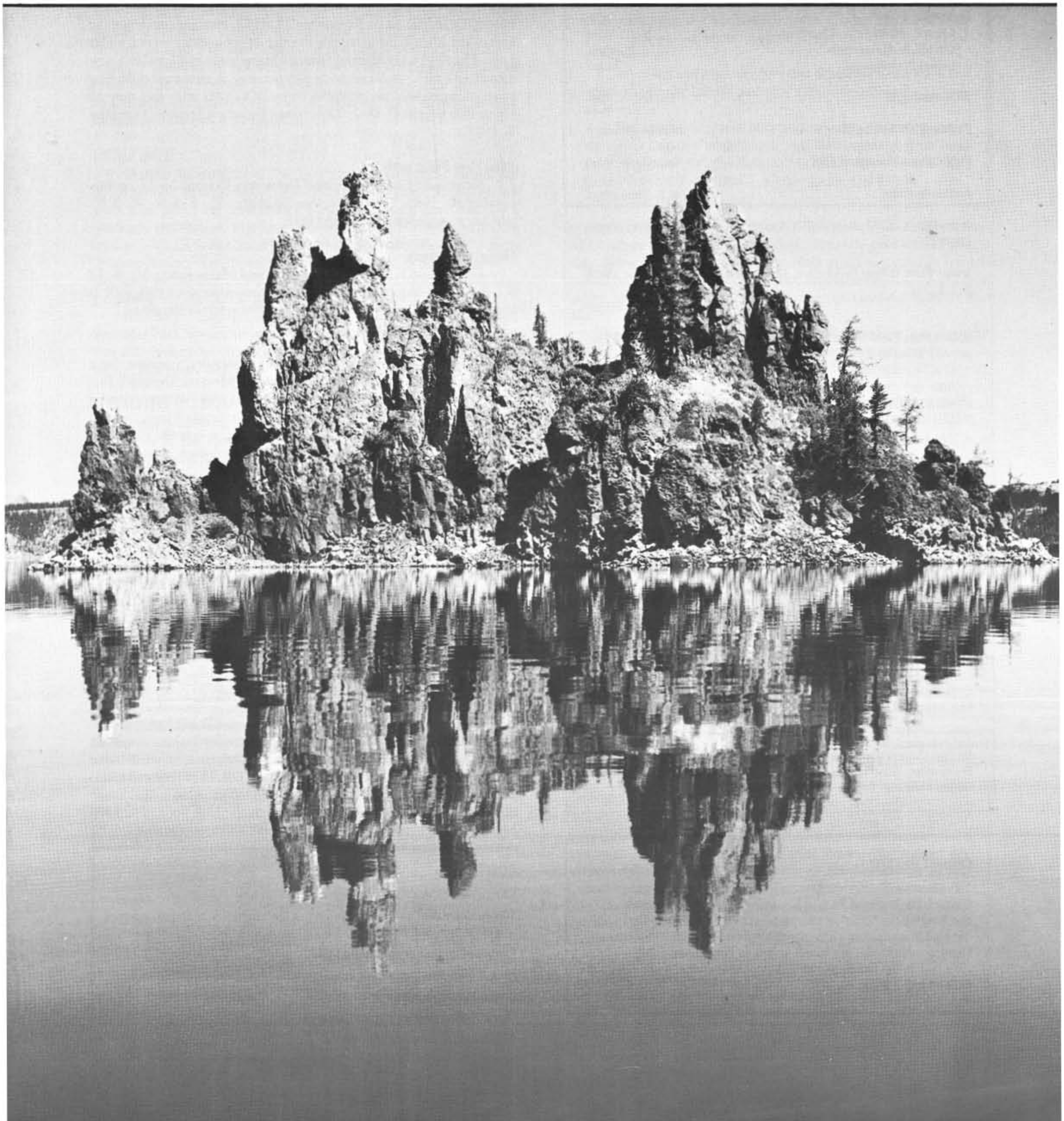

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COVER PHOTO

Phantom Ship, a small island in Crater Lake, the attraction of Crater Lake National Park in Klamath County. The andesitic dikes that hold up the "sails" of the "ship" are related to the oldest rocks exposed in the caldera wall—about 400,000 years old. Under certain viewing conditions, the island seems to become invisible—which gave rise to the name. See stories related to Crater Lake National Park on pages 3 and 10.

OIL AND GAS NEWS

Mist Gas Field boundaries

Oregon Administrative Rules governing the Mist Gas Field allow drilling as close as 250 ft from a spacing-unit boundary without the need for a public hearing. This compares with 500 ft for statewide setback requirements. Due to the complex geology and the small size of pools discovered so far at Mist, the Governing Board of the Oregon Department of Geology and Mineral Industries (DOGAMI), at its November 28, 1983, meeting, enlarged the size of the Mist Field to reduce the size of the setback over a wider area. The field was enlarged from its former size of 42 mi^2 to a new size of 141 mi^2—an increase of 335 percent. A new map reflecting these changes will be available from DOGAMI later this year as Open-File Report O-84-2. The change became effective December 8, 1983.

Mist Gas Field activity

Reichhold Energy spudded Columbia County 23-22 on December 10, 1983. The well is located in sec. 22, T. 6 N., R. 5 W. and has a proposed depth of 5,000 ft.

Douglas County

Glory Hole 1, drilled by Hutchins and Marrs in sec. 10, T. 27 S., R. 7 W., has been suspended. Abandonment of this well is planned, as well as further drilling of other wells in the area.

Morrow County

Oregon Natural Gas Development Company, operator for a group of several companies, has proposed Morrow County's first deep exploration well (see table below). The well, with a proposed depth of 10,000 ft, will be located 10 mi northeast of Heppner and will be drilled this winter. The nearest deep test was the 1957 well drilled by Standard Oil some 35 mi to the southwest, to a depth of 8,726 ft.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
254	Oregon Nat. Gas Development Dougherty 1-21 049-00001	NE¼ sec. 21 T. 1 S., R. 27 E. Morrow County	Location; 10,000

□

Mining-claim information available from BLM

The U.S. Bureau of Land Management (BLM) has information available on regulations and procedures for staking a mining claim on federal lands. For a free packet of information write to Pat Pickens, BLM, P.O. Box 2965, Portland, OR 97208, or call (503) 231-6281. This packet of regulations and information is also available over the counter at the BLM office on the 14th floor of 825 NE Multnomah, Portland. □

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The caves of Crater Lake National Park

by John Eliot Allen, Geo artment, Portland State University, P.O. Box 751, Portland, OR 97207

ABSTRACT

At least five notable caves occur within Crater Lake National Park outside the rim, and over 30 within the rim of the caldera, most of them near the lake level which has varied as much as 30 feet within the last 100 years. The caves originated, in order of abundance, from wave erosion on strongly jointed platy lavas (25), erosion of layers of mudflow (in a few cases possibly morainal) material interbedded between the flows (11), beneath jumbles of great blocks of lava on the surfaces of the rhyodacite flows (2), sublimated gas cavity (1), and meandering of a stream, deeply incised in thick ash-flow material (1).

PREFACE

During the summer of 1935, as my very first professional job out of school, I was Ranger Naturalist at Crater Lake. Although my work took up all my time during the week, we did have one day a week off, and we used this for scientific research. I wrote one article on the "Waterfalls of Crater Lake" which was published in the park "Nature Notes," but my main project was caves. It turned out to be too long to publish in the "Notes," and the manuscript has languished in the files at the park for nearly 50 years!

Recently I had occasion to correspond with Ann Cordero, Seasonal Park Naturalist at the lake, and asked her if the manuscript was still in the files. She sent me a copy, which is reproduced here for the first time, with slight additions.

INTRODUCTION

From prehistoric times, caves have occupied a vital place in the affairs of the human race. One of the early fossil men, Synanthropus, lived deep in a limestone cavern in the hills near what is now Beijin (Peking). Cro-Magnon man used the caves of Altamira, Spain, and southern France for ceremonial purposes, and left evidence of his superlative artistry on their walls. The oracles of ancient Greece and Rome frequently chose caves as the dwelling places for their mysteries, and several of the Old Testament prophets spoke from the mouths of caves.

Caves have had a strong effect upon more recent history and literature, from Beowulf to Ali Baba, from King Alfred and Robert Bruce to Captain Jack of the Modoc wars, from the Count of Monte Cristo to Tom Sawyer.

From a place of shelter and protection to which prehistoric man owed his safety, caves in historic times have sometimes taken on an ominous or dreaded aspect, and this spell may well be the result of generations of supernatural and superstitious beliefs.

Before any discussion of caves, the scientist should try to define the term "cave." It must be large enough to enter, or else a rabbit burrow would qualify. It must be enclosed above, or else any deep quarry, crater, or gorge would be a cave. Man-made excavations such as tunnels, adits, and shafts must be excluded. Perhaps "Any natural opening beneath the surface of the earth, large enough to enter and enclosed above" will do, although the definition in the American Geological Institute *Glossary of Geology* runs to five lines!

The area of Crater Lake National Park is underlain entirely by igneous materials (Williams, 1942), predominantly volcanic in origin, consisting, in approximate order of abundance, of andesitic lava flows, glowing avalanche and ash flow and fall deposits, rhyodacite domes and short thick flows, basaltic cinder cones, and glacial moraines. Most of the latter rocks are covered with air-fall deposits formed *circa* 7,000 years ago when Crater Lake was formed but are found within the rim of the caldera beneath the air-fall deposits and interbedded between the lava flows.

All but a few of the caves have been formed during the last 7,000 years, which enables one to calculate the rate of formation of such caves under the conditions prevailing during that very short geologic time.

The most prevalent origin of world caves, of course, is by solution in limestone, which is not found within the park. The andesitic and rhyodacitic lavas are too viscous to form lava tube caves, common elsewhere in the basaltic flows of other parts of Oregon.

The 40 or more caves in Crater Lake National Park (Figure 1) fall into five genetic categories:

1. Twenty-five caves, produced mostly by wave erosion in strongly jointed platy andesitic lava flows. All but six occur within the rim.

2. Eleven caves, produced by erosion of less resistant mudflow or glacial debris lying between lava flows. Six of this type

SPECIAL NOTICE

We are publishing this paper because of its unique contribution to the knowledge about Crater Lake National Park—not as an encouragement to "cavers" for casual exploration.

We must warn our readers that the caves in the Park are considered to be unsafe and are, therefore, off limits to Park visitors.

For special research purposes, a written permit to enter the caves must be obtained. It may be requested from (and **may** be granted by) the Park authorities by writing to Crater Lake National Park, Box 7, Crater Lake, OR 97604. (ed.)

John Eliot Allen

The author of this paper, John Eliot Allen, Professor Emeritus of Portland State University, is one of the "grand old men" of Oregon geology, well known as a geologist, teacher, and author.

Allen began his professional connection with Crater Lake National Park—and indeed his professional career—as a park ranger-naturalist in 1935. He was part of the beginnings of the Oregon Department of Geology and Mineral Industries and served on its staff for nearly a decade. He also guided the early steps of the Portland State University Geology Department, serving as its head for 18 years.

The most recent book in Allen's long list of publications, The Magnificent Gateway *(1979), brought him back to the object of his earliest research, the Columbia River Gorge, about which he wrote his master's thesis in 1932. At present, he is most widely known through his regular contributions to the science section in the Thursday edition of* The Oregonian. *(ed.)*

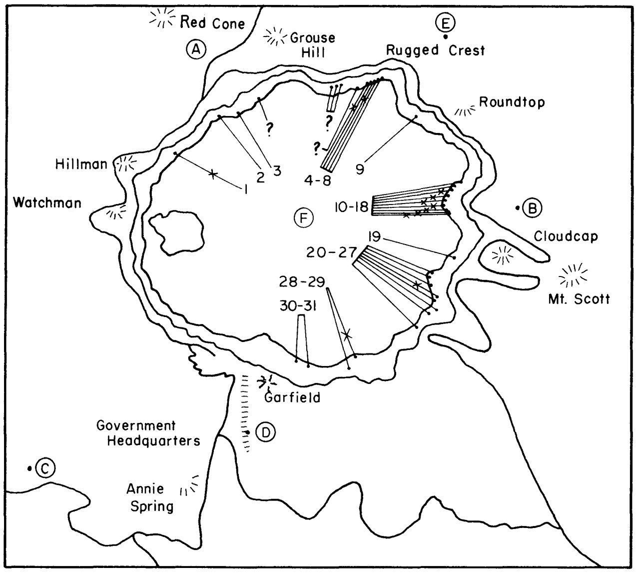

Figure 1. Caves in Crater Lake National Park. A=North Entrance, B=Bear Creek, C=Music Shell, D=Castle Crest, E=Rugged Crest, F (1-31)=caves within the rim, X=caves of special interest within the rim.

occur within the rim (9, 21, 22, 25, 26 and 29) and 5 outside the rim (B and D, nos. 1 to 4).

3. Two caves, one beneath the jumble of large blocks, one on the surface of the Rugged Crest dacite flow (E), and one on Castle Crest (D, no. 5).

4. One cave, the Music Shell (C), was formed by the deep incision of Castle Creek in ash fall and flow deposits, and the meandering of the stream as it cut down to produce a 75-ft overhang.

5. One cave, the North Entrance Cave (A), lies near the surface of the Llao Rock rhyodacite flow, and consists of an elongated complex network of channelways with sublimated minerals on the walls.

NORTH ENTRANCE CAVE (A)

This cave is located on the backslope of the Llao Rock rhyodacite flow on the Diamond Lake Road. The entrance is completely hidden, and it can only be explored with special permission of the Superintendent of the Park. It well merits further study!

In 1935, I slid down a narrow opening in the roof, and the cave quickly opened out into a cavern 40 ft long and over 10 ft wide and high, with numerous small channels, all but a few of them too small to enter, extending downward in all directions (Figure 2).

The general trend of the passages is N. 15° E., and most of the lower passages correspond to this direction. Those that could be explored are shown in the cross section, although they do not all lie exactly in this plane.

A cold draft sufficiently strong to extinguish a match comes out through the entrance, and as far as could be tested, is derived from the northern rather than the southern channels.

The walls when fresh are of highly scoriaceous lava, often spiny or fibrous, rough and cindery, and extremely hard on the hands! This forms a crust from 1 to 2 in. thick over the wall rock of well-banded glassy rhyodacite, whose flow structure is in places alternated with pumiceous or included fragments.

A considerable amount of thin crystalline flakes of specular hematite was found on the rough surfaces in several places, especially in the northern channels, indicating that sublimation had been at work at temperatures above 500° C.

The cave is in no way a lava tube; the evidence seems to point toward an origin as a steam vent, opened by fracturing of the extremely viscous rhyodacite while still hot.

BEAR CREEK CAVE (B)

Bear Creek heads in a dry ravine just east of Skell Head on the Rim Road. The south side of the ravine forms a line of cliffs 200-300 ft high which extend out to a point about ¾ mi east of the rim. If one follows eastward along the base of the cliffs to just around the point, one comes, at an elevation of about 6,950 ft, upon the largest cave now known in the park.

This cave, whose mouth is 40 ft wide and about 10 ft high, extends back and up to the west into a dacite cliff for over 150 ft, rising about 80 ft within this distance (Figure 3). It averages 20 ft in diameter and is nearly circular, but its origin is not that of a lava tube. The material of the floor, beyond a few feet of sandy accumulation near the mouth, is a mudflow or moraine.

Many of the cave surfaces are covered with minute (½ to 1 in.) siliceous stalactites, resulting from the weathering and redeposition of the silica from the feldspars abundant in the dacite above. A few of them may be calcareous, since they could be scratched with a knife blade, but no acid for testing was available.

The cave is a result of the erosion by stoping of the less resistant material of a ridge buried beneath the dacite flow.

This cave was discovered by white men on June 11, 1932, by a party composed of Ed Johns, Al Swan, P.H. Rushmore, and others, engaged in pine beetle control work in the park. Indians are said to have mentioned it, saying that on rare occasions their hunters had used it for shelter.

THE MUSIC SHELL-LLAO'S HALLWAY (C)

At the lower end of that weird, vertical-walled gorge in the ash flows called Llao's Hallway, just above the junction of Castle Creek and Little Castle Creek, the west-flowing stream, which is dry most of the time during late summer months, makes a sudden meander to the south.

This meander grew in radius as the stream cut down through the 200 ft of tough pumice and ash flow until at the present time the gorge wall has been undercut to form an overhang of over 75 ft, resulting in a remarkably perfect natural acoustic arch at least 50 ft high, which is most effective in concentrating the sounds of Castle Creek at its focus.

CASTLE CREEK CAVES (D)

Several caves are visible from Government Headquarters in the face of the steep cliffs that rise on the east side of Munson Valley and are known as Castle Crest. Some of these are only accessible with rock-climbing gear, others may be reached by a steep climb up the talus and through chimneys, or by climbing down from above.

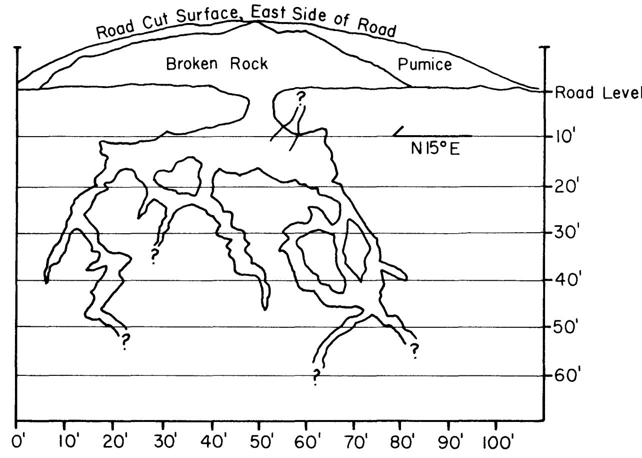

Figure 2. North Entrance cave, longitudinal section.

Those that were visited in 1935 are numbered on Figure 4 and described below. Others, several of them larger and more imposing, at least from the vantage point of the opposite wall of the valley, could not be reached.

1. The mouth of this cave measures 10 by 30 ft and is nearly 25 ft deep. Another cave just north of it could not be reached. The caves are cut in a layer of mudflow or moraine over which the lava poured. The cliffs were later formed by the erosion of the glacier that cut Munson Valley.

2. With a mouth from 5 to 10 ft wide and 4 to 6 ft high, this cave has an overhang of at least 30 ft. Its origin is the same as for cave 1. A 10-ft pinnacle in the mud flow rises opposite the mouth of the cave.

3. This cave is one of the most spectacular of the group, lying just above the steep wall at the top of the cliff. The cave is really a natural tunnel, since it goes through and opens out to the rear as well as below the main cliff face. The front entrance, about 10 ft in diameter, lies below the back entrance, which is an open pit on the level of the ridge top. The roof is only 5 to 10 ft thick and about 15 ft wide from front to back. The cave was caused when a pile of mudflow or morainal rubble, overwhelmed and buried by a lava flow, was later eroded out to form the cave.

4. Two other small caves have the same character as the last, except that they both lie entirely within the mudflow. The southern cave has an 8- by 10-ft opening, is 15 ft long, with a 3- by 8-ft back door. The second, only 40 ft farther north, is still shorter, with an entrance only 5 ft in diameter and a roof of about that thickness.

5. This cave resulted when a giant block of lava leaned against the base of the cliff to produce a cavity 10 ft deep and wide, with a height of about 5 ft.

As far as can be told from a distance, the other unexplored caves in Castle Crest originated by erosion of the more easily eroded mudflow or morainal material, most often opening just below the base of a massive flow of overlying andesite.

RUGGED CREST CAVES (E)

In a reconnaissance of the peculiar castellated rocks on the surface of the Cleetwood Cove rhyodacite flow (including Mazama Rock and many others), two caves of sufficient size to merit attention were discovered.

They lie about ¾ mi northeast of Cleetwood Cove at an elevation of about 6,675 ft, on the edge of a steep break in the slope to the north, several hundred yards west of the valley wall which drops off to the east.

Here two giant blocks of dacite, the western one 300 ft long by 75 ft wide and 30 ft high, and the eastern 200 by 50 by 40 ft, each have within them a cave. The western cave is a tortuous passage extending downwards for over 30 ft at an angle of more than 45° along a cleft which has split the rock apart about 4 ft.

The other cave, 300 ft to the east, is a horizontal north-south-trending passage completely through the rock about 10 ft above its base. It averages 4 ft in height and 7 ft in width. This cave, rather than being caused by displacement, is the result of the erosion of a mudflow layer enclosed within the rock.

CAVES WITHIN THE RIM (F)

A total of over forty caves with dimensions varying from 3 or 4 to 50 ft may be seen from the surface of the lake, and several of these are of sufficient interest or beauty to merit pointing out on the special boat trip. These caves are marked with x's on Figure 1 and asterisks in the text.

Many caves above the water's edge were not visited due to inaccessibility or lack of time. Some of these are described, others are only noted on the map with a question mark. All but six of these caves (1, 9, 21, 22, 25, and 26) have resulted from the erosion of the lava flows along joints; the six are due to erosion in mudflow or morainal material between the lava flows.

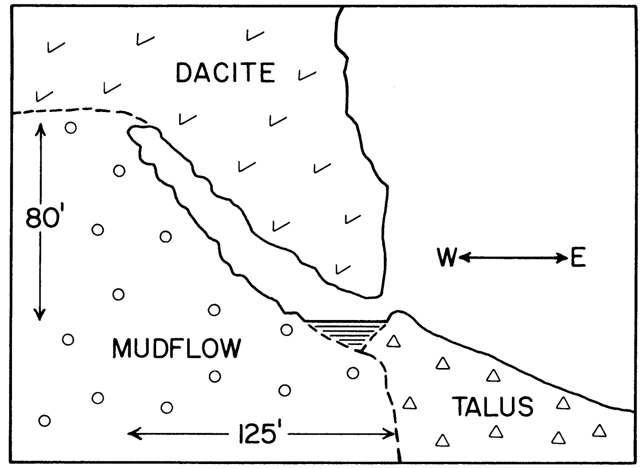

Figure 3. Bear Creek cave, cross section.

Since the time this article was written, conditions have changed a bit. The elevation of the water in the lake changes with time. When J.S. Diller was there in 1896, he placed a brass plug in a cliff face at the water's edge below the present Sinnott Memorial. When I was there in 1935, after considerable search, we found this plug, then 25 ft above the water level. Since that time, the water level has fluctuated about 3 ft (M. Briggs, personal communication, 1983). The current status of the lake level should be determined and the necessary mental adjustments should be made before one tries to repeat the following clockwise boat trip around the lake.

1. On the south side of the base of the Devil's Backbone, over 200 ft above the water level, is a cave of considerable dimensions, which was not visited but which seems to be due to the erosion of a mudflow partially surrounded by the lava dike.

2. A small cave with a bottom 4 ft below water level lies ¼ mi west of Llao Rock. Its dimensions are 10 ft wide, 5 ft deep, with a 7-ft roof. It resulted from the breaking-out of jointed rock.

3. This cave is a low crevice at the water's edge, perhaps 5 ft deep.

The caves on the west side of Cleetwood Cove (numbered 4 to 8) are carved in a thick (40-50 ft) flow of gray andesite, which is characterized by a fine (½ to 1 in.) horizontal platy cleavage. When these plates break out, governed by the major vertical joints (which trend east-west), they leave rounded columns with more or less perfect gothic arches between them over the caves. For this reason, the name "Cathedral Columns" is suggested for these cliffs on the west side of the Cove.

*4. "House Cave," the largest and westernmost cave of the area, differs from the others in being nearly square, with dimensions averaging 20 ft in all directions; more accurately, 25 ft deep, 15-20 ft wide, with a roof 10-15 ft high.

5. "Fireplace Cave" has a mouth only 4 ft wide and 2½ ft high, but inside, 10 ft back from the mouth, the roof rises to over 10 ft, and it is possible to stand erect.

6. "Arch Cave" is the most perfect and the deepest of the gothic recesses between the columns. It is 12 ft high, 6 ft wide at the base, and extends inward for 20 ft. Since, like the other caves, it extends east-west, it can be seen only from well within Cleetwood Cove.

7. This is a broader cave, without special characteristics. It is 25 ft high, 15 ft deep, and 10 ft wide.

8. This is a small cave with an entrance only 5 ft high, but it extends back for 15 ft, narrowing and forking toward the end.

9. This group of caves is located at the base of a 75-ft cliff, just west of the West Palisade, about 300 ft above the water. One cave is as much as 15 ft deep; others are 20-30 ft wide and 10 ft deep, but with very low entrances. They are the result of the erosion of a layer of mudflow which lies beneath the massive lava flow. At one place,

where the cliff overhangs at least 35 ft, the jointed lava has broken out in a chimney 15 ft square, the top of which extends upwards for 20 ft, entirely enclosed except at the base.

10. This is a small cave between Skell Head and the point to the north, that faces to the north and lies about 15 ft above the water. It is only 5 ft wide and quickly narrows to a crevice.

11. Several shallow caves in platy andesite lie above a rock beach about ¼ mi north of Pinnacle Rock ("Captain Applegate").

Around the base of Skell Head there is a large number of caves and crevices at the water's edge which have for many years been called "The Grottos." Most of them are the result of the breaking-out of blocks in the vertically cleaved andesite, whose wavy patterns give a unique loveliness to the cliffs there. Seven of these caves are sufficiently noteworthy for description and naming.

12. "Square Grotto," the first to be seen on the boat trip, lies just south of Pinnacle Rock, at the water's edge, and is about 5 ft square.

*13. "Lens Grotto" is a peculiar lens-shaped cavern 20 ft high, 6 ft wide, and 10 ft deep, which lies about 3 ft above the water. It is caused by the erosion of a lens-shaped body of mudflow within the lava.

*14. "Grotto Crevice" lies 300 ft south of Lens Grotto. This is a cave that is not easy to find, since it is only 5 ft wide at its entrance and about 6 ft high, with a floor at least 20 ft below the water's surface. If one places the nose of the boat in the opening, there is a narrow ledge along which one can climb into the crevice, which extends for 20 ft into the andesite.

15. "Llao's Jaws" is not a water-level grotto, since it is at the head of a rock slope 30 ft above the water. It has an entrance 10 ft square, the top of which is jagged and toothed. The floor rises another 15 ft, and the greatest length of the cave, about 40 ft, is nearly at right angles to the entrance. The entrance faces almost north.

*16. "The Grotto" is located 100 ft south of Llao's Jaws and is the largest and loveliest of the grottos. The opening, which faces northwest, is about 6 ft wide, and the roof is only 6 ft above the lake level (1935) and is studded with the same jagged toothlike spires as Llao's Jaws. The cave is 20 ft deep, and when the boat is run into it, the water below the boat has a deep brilliant blue color that is indescribable. Although the entrance is only 6 ft wide, the cave below the water surface is twice that deep. An overhang that almost reaches the water cuts off half the opening.

17. A small south-facing grotto lies 300 ft south of The Grotto; it is 10 ft wide and 7 ft high and narrows to a crack within 25 ft.

18. "Hidden Grotto" faces almost due south, so that it can be seen only from a boat skirting the shore very closely. It is 5 ft wide, 15-20 ft high and 20 ft deep, of just such proportions that, the floor being below water level, a rowboat will fit in and be completely hidden. This is the last of the Grotto group.

19. Below one of the cliffs that lie under and to the south of Castle Rock is a cave at least 25 ft wide, with an opening 5-8 ft high. Since it lies 150 ft above the water at the base of a 150-ft thick andesite flow, it was not explored.

20. This cave lies above a rock slope 10 ft above water level. It is 8 ft wide, 5-6 ft high, and 10 ft deep with several short side openings.

21. At the tip of Sentinel Point there is a cave with a water floor in a mudflow. The cave is 15 ft wide, 20 ft high, and 10-15 ft deep.

22. A small cave 300 ft southeast of Sentinel Point lies 10 ft above the water in a mudflow. It is 8 ft deep, 5 ft high, and 4 ft wide.

*23. "Blue Crevice" is a deep, mossy crevice in the vertically cleaved rock that, although only 2½ ft wide at the entrance, averages twice that width in the 25 ft of its depth. The crevice is 20 ft high, and the floor slopes so steeply below the water level that at the mouth the water is at least 75 ft deep, and a resulting deep blue light comes from below. If the nose of the boat is placed in the opening, there is a narrow ledge along which one can climb into the crevice and get the full effect of the color. A third of the way from the end, there is a side opening 2½ ft wide and 4 ft deep. The crevice bears N. 75° W.

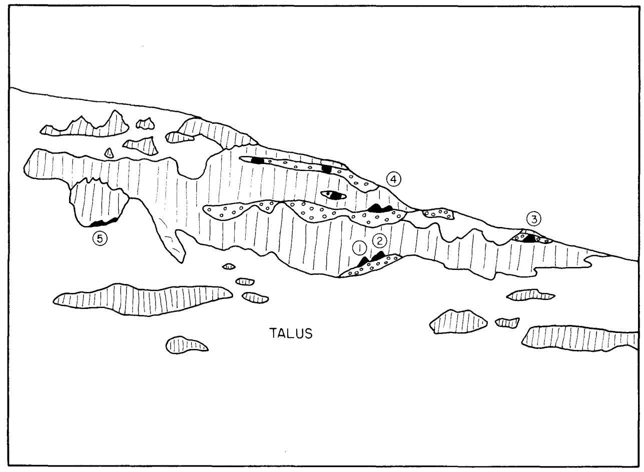

Figure 4. Caves in Castle Crest, east of Government Headquarters.

24. There are several vertical openings in the jointed andesite at the water's edge here, none of them very deep. They average 5-10 ft wide and 15-30 ft high.

25 and 26. These are two inaccessible openings 200 and 400 ft above the water in the face of the cliffs. They are of interest in that they are eroded into layers of mudflow and stand out quite clearly in the morning light. Neither can be very deep.

27. A small cave 5 ft above water level, on the first point northeast of Kerr Notch, is 4 to 5 ft wide and 10 ft deep.

*28. "Phantom Cave" lies just east of the Phantom Ship and derives its name from the fact that from within the cave the Ship is framed in its triangular opening. The top of the opening is 13 ft above the water, and its base is 10 ft wide. The cave slopes back and upwards for 30 ft from the mouth, the roof being 12-18 ft high. The cave has resulted from the breaking-out of the rock along rhomboidal cleavages.

29. Another unvisited cave lies almost 900 ft above the water at the base of Dutton Cliff, at the head of the great talus slope. It appears to be about 30 ft wide and 15 ft high at the entrance. It is due to the erosion in a fragmental layer of mudflow or moraine underlying the massive cliff.

30. This tiny cave lies 8 ft above the water, with an entrance 5 ft square. It is only 4 ft deep.

31. Another similar cave 10 ft above the water is 10 ft deep, with an entrance 3 ft high and 4-6 ft wide. Both these last two caves are the result of the breaking-out of cleaved rock fragments.

ACKNOWLEDGMENTS

Ann Cordero, Seasonal Park Naturalist in 1983, kindly copied and sent me a copy of the 1935 manuscript. William Robert McCulloch redrafted the figures.

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Temperature data and drilling history of the Sandia National Laboratories well at Newberry caldera

by Gerald L. Black, George R. Priest, and Neil M. Woller, Oregon Department of Geology and Mineral Industries

ABSTRACT

A new geothermal well drilled by Sandia National Laboratories in Newberry caldera reached temperatures in excess of 158° C at depths of 350 to 424 m. Artesian fluids entered the well between about 379 and 397 m at a rate of about 340 liters per minute (lpm). The temperature of the main fluid entry is probably in excess of 170° C. The temperature-depth profile of the Sandia well is similar in shape to the nearby Newberry 2 drill hole but reaches higher temperatures at equivalent depths. It is possible that the Sandia well, which is closer to the caldera ring-fault system than Newberry 2, intercepted some of the same hot-water aquifers that Newberry 2 encountered, but the Sandia well is closer to the source of the fluids.

INTRODUCTION

Sandia National Laboratories, Albuquerque, New Mexico, drilled well RDO-1 in Newberry caldera in September and October of 1983. The drilling began on September 16, 1983, and the hole was abandoned on October 20, 1983, as a result of casing problems. The well, which reached a depth of 424 m, was drilled about 457 m southeast of the U.S. Geological Survey (USGS) Newberry 2 drill hole (Figure 1).

The Oregon Department of Geology and Mineral Industries (DOGAMI) and Columbia Geoscience of Hillsboro, Oregon, assisted Sandia scientists with planning and logging the well. Edward A. Sammel of the USGS was also involved in the planning stages.

This report focuses on the temperature data obtained from the well. Lithologic data will be presented in later papers by Marshall Gannett of Columbia Geoscience, John Eichelberger of Sandia National Laboratories, and Terry E.C. Keith of the USGS, and the drilling history will be discussed by Sandia.

TEMPERATURE LOG ANALYSIS

General observations

The final temperature log of RDO-1 was taken on October 6, 1983, two days after mud circulation ceased (Figure 2, Table 1). The log is characterized by very low gradients in the upper part of the well and a very high gradient in the lower part. In the interval from 38 m to approximately 274 m, the hole is essentially isothermal, with a temperature of about 40° ±5° C. From 274 m to the last measurement at 350.5 m, the hole has a linear (conductive) gradient of 1,665° C/km. The temperature probe failed at a depth of 350.5 m, so the final log did not reach total depth.

Earlier temperature logs utilizing Sandia's thermocouple

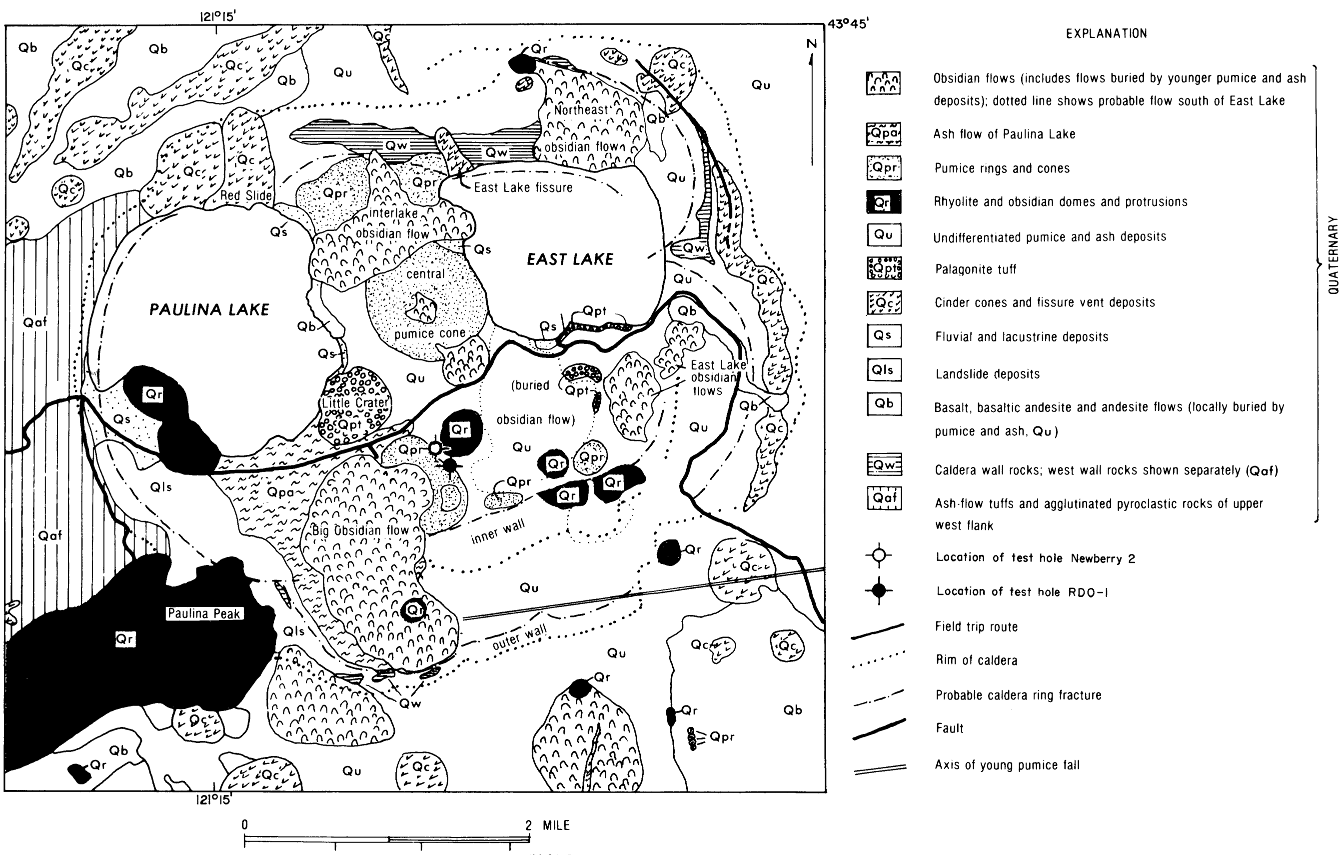

Figure 1. Locations of USGS well Newberry 2 and Sandia National Laboratories well RDO-1. Geologic map is from MacLeod and Sammel (1982).

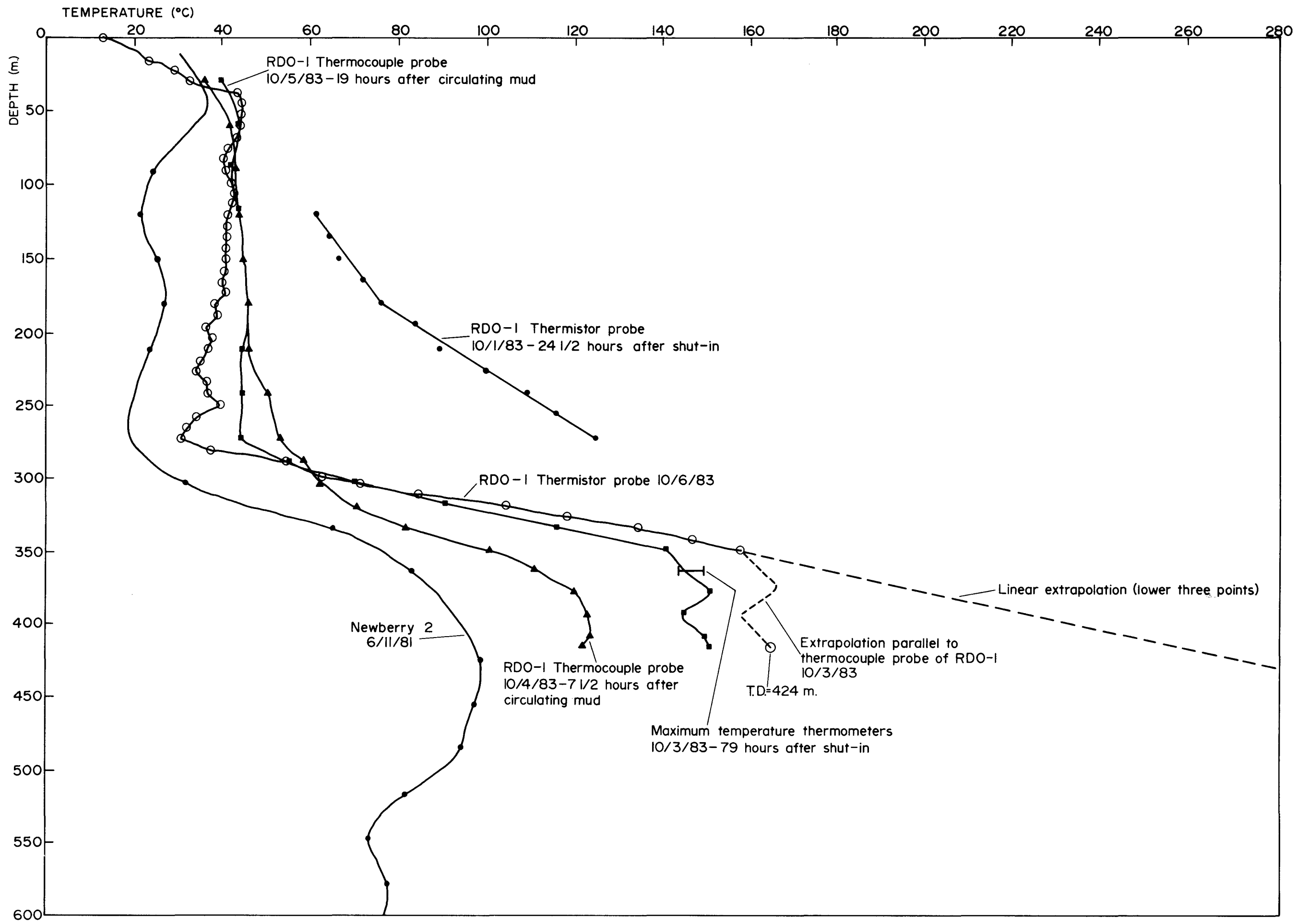

Figure 2. Temperature-depth profiles run at various times during and after drilling the RDO-1 drill hole compared to the profile of the Newberry 2 drill hole at equivalent depths. Thermocouple logs were run by Sandia National Laboratories. The thermistor probe was provided by David D. Blackwell, Southern Methodist University. The first thermistor log was run by Marshall Gannett of Columbia Geoscience; the final log was run by Gerald L. Black of the Oregon Department of Geology and Mineral Industries.

probe indicate that the temperature profile below about 351 m has a very low, irregular gradient, which probably reverses near the bottom of the hole. The earlier logs also show considerable cooling in the lower part of the well as a result of mud circulation. It is probable that the hole was not in complete thermal equilibrium when the final log was completed.

Detailed log analysis

0-38 m: In this interval, the gradient is 770° C/km. It represents conductive heat flow between the surface and a warm aquifer at 38 m. Nearby water wells indicate that the volcaniclastic rocks from 12 to 38 m are saturated. The conductive gradient indicates that there is probably neither rapid lateral nor vertical ground-water flow in this interval.

38-67 m: A warm aquifer (44.5° C) causes this isothermal section of the profile.

Negative inflection at 84, 183, 198, 239, and 274 m: All of these negative inflections (Figure 2) occur in the portion of the hole which has been cased off (casing was set to 305.7 m), so it is unlikely that they are the result of disturbances caused by the injection of drilling fluid into permeable zones in the formation. Mud was circulated in the hole shortly before the temperature log of 10/4/83 was run. As can be seen in Figure 2, the upper portion of the hole was roughly isothermal at a temperature just over 40° C, 19 hours after mud circulation ceased, although the wide separation of data points could allow short wave length temperature inflections to go unnoticed. On the final log of 10/6/83 (Figure 2), the upper portion of the hole had apparently cooled (the DOGAMI thermistor probe and the Sandia thermocouple were not calibrated against one another), and several negative temperature inflections are present. The inflection at 84 m correlates with a pumiceous layer and probably represents a relatively cool aquifer. The inflections at 183, 198, 239, and 274 m do not correlate with lithologic changes. All occur in a portion of the hole composed of uniform basaltic lapilli tuff (Marshall Gannett, personal communication, 1983). The inflections at 183 and 198 m are minor and may be of no significance, or they may represent very small, slightly cool aquifers. The inflections at 239 and 274 m are of higher amplitude than those of 183 and 198 m. They flank what is probably a small, warm aquifer at 250 m. The minimum at 274 m correlates precisely with a cool aquifer in the nearby Newberry 2 drill hole (MacLeod and Sammel, 1982). The convex shape of the temperature-depth curve above and below the temperature minimum indicates that the hole is not yet in equilibrium at that point. Projection of the linear segments just above and below the convex segments indicates that the temperature should eventually stabilize at about the same temperature as observed in Newberry 2.

111-274 m: The overall gradient, except for one interval from 121 to 175 m which is essentially isothermal at a temperature of 41.5° C, is −69.8° C/km. This overall negative gradient, which reaches a minimum temperature of 31.4° C at 274 m, indicates the influence of a cold aquifer at 274 m.

274-350.5 m: The smooth linear gradient of 1,665° C/km in this interval is representative of conductive heat flow through relatively impermeable rocks. These rocks consist predominantly of the fine clay-rich volcanic sediments and devitrified tuffs which are incompetent and incapable of sustaining open fractures for fluid movement (Marshall Gannett, personal communication, 1983).

350.5-424 m (total depth): The last temperature probe did not cover this interval because of failure of the cable and loss of the probe at 350.5 m.

The log of 10/4/83 turns isothermal at approximately 375 m. The hot aquifer occurs between 379 and 397 m (Marshall Gannett, personal communication, 1983). The log of 10/5/83 turns isothermal at approximately 350 m. The difference between the two logs results from intraborehole upflow caused by the overpressured hot aquifer. The negative inflection at approximately 380 m may result from the injection of drilling mud into the hot aquifer. Approximately 80 barrels of fluid were pumped back into the thermal aquifer about two days before this log was run (Marshall Gannett, personal communication, 1983).

By projecting the gradient from the thermocouple log of 10/5/79 onto the bottom of the thermistor profile of 10/6/83, a highly speculative bottom-hole temperature of 158°-166° C is predicted. However, in view of the amount of fluid pumped back into the formation, it is likely that the bottom-hole temperature is in excess of 170° C.

POSSIBLE RELATIONSHIP OF RDO-1 TO NEWBERRY 2

The absolute temperatures in the RDO-1 hole are higher than the nearby Newberry 2 well, but the thermal profiles of the two wells are very similar (Figure 2). This similarity implies that components of common aquifers were encountered in both holes. The fluids in Newberry 2 may be cooler than those in RDO-1 as a result of conductive cooling and mixing with cool meteoric water. RDO-1 may therefore be closer to the source of the upwelling thermal waters which have migrated laterally to the Newberry 2 well. RDO-1 is also closer to the caldera ring fault system than Newberry 2. While it is only speculation, a possible interpretation is that thermal water is convecting up the nearby ring faults and spreading out laterally along permeable layers within the caldera. If this is the case, then similar lateral circulation may be occurring from the ring faults into permeable layers outside of the caldera as well.

CONCLUSIONS

Drill hole RDO-1, drilled to 424 m by Sandia National Laboratories, intercepted a moderate-temperature hydrothermal system at shallow depth in Newberry caldera. Between about 379 and about 397 m, fluids in excess of 158° C produced artesian flow at 340 lpm. Although not reliably measured, the temperature at the fluid entry was probably in excess of 170° C.

Table 1. *Temperature-depth log of the Sandia well in Newberry caldera, taken 10-6-83, approximately two days after circulating mud. Total depth of well=1,390 ft; depth logged=1,150 ft*

Depth (ft)	Temp. ° C	Depth (ft)	Temp. ° C
0	14.43	600	39.15
25	20.08	625	39.60
50	23.68	650	36.93
75	29.47	675	38.19
100	33.10	700	37.15
125	43.78	725	35.84
150	44.67	750	34.38
175	44.58	775	36.82
200	44.36	800	37.51
225	43.87	825	40.13
250	41.64	850	35.08
275	40.38	875	32.20
300	41.23	900	31.40
325	42.26	925	38.06
350	42.79	950	55.39
375	42.47	975	63.22
400	41.74	1000	71.78
425	41.64	1025	85.04
450	41.35	1050	104.92
475	41.17	1075	118.78
500	41.38	1100	134.70
525	40.98	1125	147.58
550	40.53	1150	158.27
575	41.28		

Temperatures, although not fully recovered from drilling effects, clearly show that the temperature-depth profile of RDO-1 is very similar to, but much hotter than, that of the nearby Newberry 2 hole drilled by the USGS. The RDO-1 hole may be closer to the source of the shallow thermal water encountered in Newberry 2. Closer proximity of RDO-1 to thermal fluids possibly upwelling in a caldera ring-fracture system may be the cause of the differences in temperature between the two wells.

REFERENCES CITED

MacLeod, N.S., and Sammel, E.A., 1982, Newberry volcano, Oregon: A Cascade Range geothermal prospect: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 44, no. 11, p. 123-131.

——— 1981, Results of test drilling at Newberry volcano, Oregon: Geothermal Resources Council Bulletin, v. 10, no. 11, p. 3-8 □

Unique state map produced by OSU

Oregon State University researchers at the Environmental Remote Sensing Applications Laboratory (ERSAL) have produced this map of Oregon called the Oregon Landsat Mosaic. It combines satellite pictures of Oregon in a conventional map format with standard map information such as roads, towns, and county boundaries, and Oregon is the first state for which a map of these pictures has been prepared.

The Oregon Landsat Mosaic is a composite of 74 different satellite photographs, the most detailed satellite imagery of Oregon available through 1982—that of Landsat-3 RBV (Landsat is the name of the satellite, and this one is the third in a series launched by NASA in 1978; RBV designates the camera system as "Return Beam Vidicon").

Landsat-3 has been taking pictures from a circular orbit at an altitude of 920 km (570 mi). The orbit is synchronized with the rotation of the earth and also sun-synchronous, so that the satellite covers areas repeatedly, on a regular schedule, and at approximately the same time of day (in this case, 10:05 a.m. PST). Since clouds often cover the state and block the satellite's view, the pictures chosen for the mosaic are mostly summertime photos taken in 1978, 1979, and 1980.

Portions of the RBV pictures were composed for the mosaic by matching them to the 1:500,000 base map of Oregon produced by the U.S. Geological Survey. The resolution quality of the pictures is better than 40 m (43 yds).

The resulting Oregon Landsat Mosaic measures 42 by 53 in. and is available in a black-and-white and a three-color version. A 1,000-word text of technical information about the satellite system and the mosaic is included in the side margin. The three-color version is sold by the Oregon Department of Geology and Mineral Industries in Portland. See the listing under "Miscellaneous Publications" on the last page of this issue. □

Howel Williams honored in new geographic name

The U.S. Board on Geographic Names approved, at its October 1983 meeting, the name "Williams Crater" for a previously nameless but quite conspicuous and geologically fascinating feature in Crater Lake National Park. Thanks to the efforts of U.S. Geological Survey geologist Charles R. Bacon, who has been studying Crater Lake for several years now, the new name will be published in the Board's Decision List 8304 reading, in part, as follows:

Williams Crater: cinder cone, in Crater Lake National Park, on the slope of Mount Mazama, 0.97 km (0.6 mi) WNW of Hillman Peak; named for Dr. Howel Williams (1898-1980), Professor of Geology at the University of California at Berkeley, and author of "The Geology of Crater Lake National Park". . . .

To quote Bacon, "Williams wrote the definitive account of the geology of the park and many landmark papers in volcanology. At the time of his death in 1980, he was perhaps the world's preeminent volcanologist. . . . Crater Lake was dear to his heart, and his work there has had an impact on countless park visitors."

Informally, the small cinder cone just outside the Crater Lake caldera had been known as "Forgotten Crater"—a name Williams made known in his 1942 study (Williams, 1942), where he referred to a 1932 note by D. LeC. Evans in the *Nature Notes* published by the park's staff. Williams recognized that this cone was not much older than the caldera itself, that it might be related to the eruptive center at Hillman Peak, one of the few still remaining eruptive peaks that once made up the volcanic complex of Mount Mazama, and that it had erupted a puzzling variety of lavas.

Bacon's research now shows that Williams crater is probably 22,000 to 30,000 years old. The three gray lava flows emanating from the rusty-red cinder cone are composed of spectacularly banded, "commingled" andesite and dacite lava, which itself contains inclusions of basalt. What happened here "may have been initiated by an eruption of typical High Cascade basaltic magma. . . . Because of its proximity to the Mazama magmatic system, this disturbance came under the influence of the local stress field and allowed the basaltic magma access to the margins of a compositionally zoned system by opening of radial fractures. Eruption of highly complex, varyingly mixed and commingled magmas followed" (Bacon, 1983).

Bacon says that he chose this feature around the Crater Lake caldera to commemorate Williams because it was first described by Williams "and because virtually every topographic pimple [there] already has a name."

REFERENCES CITED

Bacon, C.R., 1983, Eruptive history of Mount Mazama and Crater Lake caldera, Cascade Range, U.S.A., *in* Aramaki, S., and Kushiro, I., eds., Arc volcanism: Journal of Volcanology and Geothermal Research, v. 18, p. 57-115.

Williams, H., 1942, The geology of Crater Lake National Park, Oregon: Carnegie Institution of Washington Publication 540, 162 p. □

Oregon land use symposium planned

A symposium on Oregon's land use planning process will be held February 17-18, 1984, on the campus of Lewis and Clark Law School in Portland. The program is sponsored by *Environmental Law*, the school's law journal.

The symposium is entitled "Oregon Land Use: Promoting Growth and Preservation in the Next Decade" and will take a retrospective and prospective look at Oregon's statewide land use planning process which has been criticized as an obstacle to economic growth and applauded as a model of environmental prudence.

Speakers will include local, state, and national experts in land use law, planning, and practice, chosen to provide a cross section of viewpoints.

The agenda will focus both on current policy issues and the practical aspects of participating in the Oregon land use planning process. Continuing legal education credit is available for Washington attorneys and may be available for other states.

For more information, contact Renee Fitzgerald, Editor-in-Chief, (503) 244-1181, x701; or Laurie Bennett, Program Chairperson, (503) 244-1181, x702. □

AIME annual meeting announced

The American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) will hold its 113th annual meeting in Los Angeles, California, from February 26 to March 1, 1984. Concurrently, there will be annual meetings of SME-AIME, TMS-AIME, and WAAIME.

There will be all-Institute meetings and social events, as well as extensive technical programs by several of the subgroups of the Institute. Featured speaker at the all-Institute luncheon on February 27 will be Harry M. Conger, Chairman of the Board and Chief Executive Officer of Homestake Mining Company.

For advance registration (deadline February 10, 1984) and further information, write to Society of Mining Engineers of AIME, Meetings Dept., Caller No. D, Littleton, CO 80127. □

Grant money available from Mazamas

Each year the Mazamas provide grants to aid scholarly studies related primarily to living features of the outdoors and the interaction between people and their environment. The Mazamas have recently supported research on such subjects as the vegetation of Baldy Mountain, the geology of the Slesse Peak area, the ecology of Bighorn Sheep, and the perception of climbers of their impact on Grand Teton National Park. Preference is given to subjects of interest to Mazamas.

Applications for such grants must be postmarked or received by the Research Committee before March 1, 1984. Grants will be awarded by the Research Committee on May 1, 1984. Detailed information on conditions of awards, deadlines, and application procedure may be obtained from the Mazamas, 909 NW 19th Ave., Portland, OR 97209. Letters requesting information should be marked "Mazama Research Grant Information" on the envelope. □

New mineral display at State Capitol features Salem meteorite

The Willamette Agate and Mineral Society of Salem is providing the collection for December 1983 through February 1984 in the State Capitol display case of the Oregon Council of Rock and Mineral Clubs.

More than 50 specimens are being shown, all of them from Oregon and representing 12 Oregon counties. The varied display includes thundereggs (the "Oregon state rock"), various kinds of petrified wood, jade, obsidian, rough and faceted sunstones, and fossils.

Featured in the display are the fragments of the Salem meteorite of 1981, the first Oregon meteorite whose fall was witnessed and which was then recovered. The meteorite specimens were loaned by finder and owner Deputy Sheriff Jim Price of Salem.

The Rogue Gem and Geology Club of Grants Pass will provide the subsequent display scheduled to open March 1, 1984. □

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(If Gift, From: ____________________)