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HOLE-IN-THE-GROUND, CENTRAL OREGON
Meteorite Crater or Volcanic Explosion?

by

Norman V. Peterson* and Edward A. Groh**

Lewis McArthur, in Oregon Geographic Names, has described Hole-in-the-Ground as follows: "Hole-in-the-Ground, Lake County. This very remarkable place is well described by its name. It covers an area of about a quarter of a square mile, and its floor is over 300 feet below the surrounding land level. It is about eight miles northwest of Fort Rock."

Hole-in-the-Ground is a large, almost circular, bowl-shaped crater in the northwest corner of Lake County. It has a slightly elevated rim and looks very much like the famous Meteorite Crater in north-central Arizona. This remarkable resemblance and the lack of an explanation of the origin in the published literature was brought to the attention of the department by Groh and is the basis for the present study.

The original plans for the study included only Hole-in-the-Ground and the nearby larger, shallower crater, Big Hole, but very soon after arriving in the area the writers noticed other interesting volcanic features of explosion origin. These features, shown on the index map (figure 1), include Fort Rock, Moffit Butte,

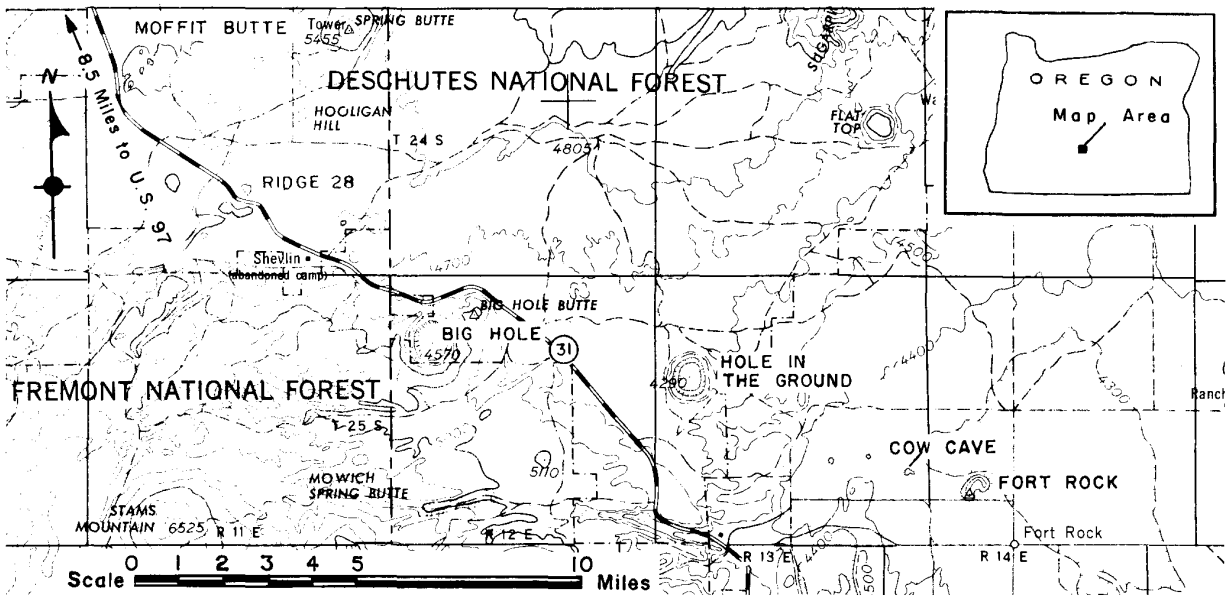

Figure 1. Index map of the Hole-in-the-Ground area, central Oregon.

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Flat Top, and several unnamed landforms north and west of Hole-in-the-Ground. All were examined and are described briefly in later paragraphs.

After a reconnaissance of the geology of the whole area was made, two days were spent studying the rocks in the walls and rim of the Hole-in-the-Ground crater and searching for evidences of meteoritic material.

Hole-in-the-Ground

Hole-in-the-Ground (figure 2) is in sec. 13, T. 25 S., R. 13 E., in the extreme northwestern corner of Lake County. It can be reached by turning east from Oregon Highway 31 on a well-marked Forest Service road 25 miles southeast of the junction with U.S. Highway 97 near Lapine, Oregon.

The depression or crater has many of the characteristics of a meteorite crater. It is almost circular with steep walls sloping to a flat floor that is about 425 feet below a raised rim. The highest point on the rim is at an elevation of 4800 feet, about 500 feet above the floor of the crater.

The resemblance between Hole-in-the-Ground and the Arizona meteorite crater is shown by the following comparison:

	"Hole-in-the-Ground"	"Meteorite Crater"
Diameter	5000'	4000'
Depth (crest of rim to crater floor)	425'	613'
Height of rim above surrounding plain	100' to 200'	148' to 223'
Rim slope to plain	about 5°	3° - 5° ($\frac{1}{2}$ mile)
Rock in walls	Basalt, ash flow, tuff, and explosion debris	Limestone and sandstone
Age	At least 2000 to 9000 years, based on dating of pumice falls from Newberry Crater and Mount Mazama (Crater Lake).	20,000 to 75,000 years.

The rocks that crop out in the walls of Hole-in-the-Ground are shown on the accompanying cross-section (figure 3) and are, from bottom to top, an ash flow tuff, a series of fine-grained light-gray olivine basalt flows, explosion tuffs that contain many types and colors of rock fragments, and large blocks as much as 10 feet in diameter of explosion debris including a conspicuous porphyritic olivine basalt that is believed to occur deeper than the rocks exposed in the crater walls. The floor, steep slopes, and rim are blanketed by pumice from Mount Mazama (Crater Lake) and Newberry Crater. A thin soil zone has developed on the pumice. The rim is slightly higher and broader to the east, indicating a westerly wind at the time of the explosion. A small fault offsets the basalt flow in the east wall of the crater.

The crater rim was carefully examined to determine if metallic meteoritic material, shattered rocks, deposits of rock flour, or minute metallic droplets of vaporized meteoritic nickel-iron were present. As the crater and explosion debris were already present when the latest pumice showers occurred, holes were dug to a level beneath the pumice and the soil screened and tested with strong magnets for the presence of metallic magnetic material. Magnetite from the pumice and underlying lavas and tuffs is abundant in the soil, but no identifiable meteoritic fragments or metallic droplets could be found. An examination of the outcrops of the basalt flows also did not show the great shattering and upward tilting that should accompany the explosion of a large meteorite.

It is almost certain that, if this crater were the result of a meteoritic impact explosion, fragments of nickel-iron and metallic droplets or their oxidized products would be present in abundance on and around the rim, as is the case at the Arizona Meteorite Crater. This should be true even for a stony meteorite, because they generally contain several percent of nickel-iron in metallic form. It is very doubtful if a large stony meteorite could survive passage through the atmosphere to produce a crater of this size; rather, the sudden

Figure 2. Aerial view of the Hole-in-the-Ground looking to the northwest. Road in foreground leads from Oregon Highway 31 to east rim viewpoint. Basalt flow visible in far wall of crater. White spot is small playa at bottom of crater. East rim viewpoint is about 500 feet vertically above this playa.

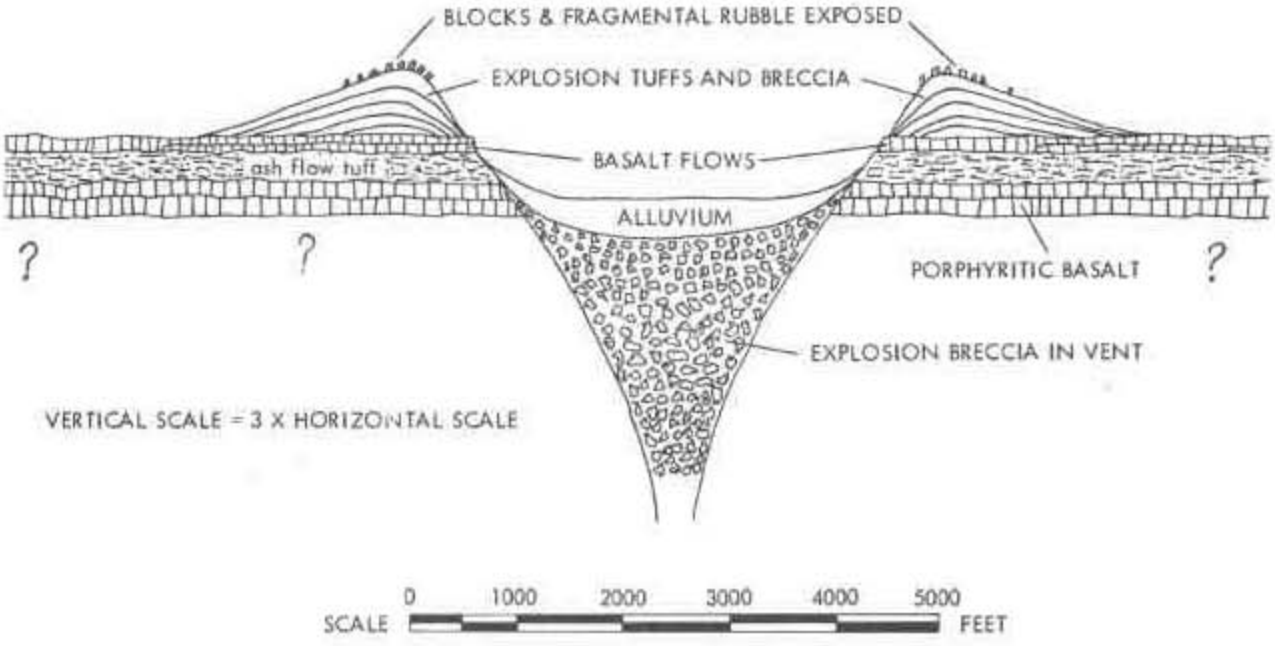

Figure 3. Generalized geologic cross section of the Hole-in-the-Ground.

Figure 4. Aerial view of Fort Rock looking to the northeast. Differential weathering has accentuated bedding in nearest wall. This wall is a sheer cliff about 200 feet high and more than 300 feet above the plain. Pleistocene lake terraces have been cut into both ends of "horseshoe".

heat and pressure evolved upon encountering the denser air mass would cause the meteorite to break into many fragments. Only small craters or pits would result when these struck the earth.

In the absence of any positive evidence for its formation by meteorite impact, the location of the crater in an area of known recent volcanic activity and the many associated volcanic features point to an abrupt volcanic explosive origin for the Hole-in-the-Ground.

It is believed that Hole-in-the-Ground resulted from a single or a very brief series of violent explosions caused when rising magma suddenly came in contact with water-saturated rock. The source of the water could have been the extensive lake that once existed in Fort Rock Valley. The explosion blew out large quantities of older rocks, together with pyroclastic material, and formed an embryonic tuff ring. Apparently the magma withdrew after this brief activity and did not continue or return to eject additional pyroclastic material in the quantity for the formation of a large tuff ring. A detailed description of this process is given in the discussion of Big Hole, a similar but more fully developed feature.

Big Hole

This large depression, as shown on the index map, is in secs. 5, 6, 7, and 8, T. 25 S., R. 12 E. It is a broad shallow crater with walls and rim made up of dark-gray and brown lapilli explosion tuffs and breccias. These rocks dip outward from the center of the crater. The rims are not quite as well defined as at Hole-in-the-Ground and a heavy stand of timber within and around the crater makes detail difficult to see. Big Hole, however, is a much better developed tuff ring than Hole-in-the-Ground in that a greater volume of pyroclastic debris has accumulated around the rim. Although both craters are young geologic features, Big Hole appears to be the older. In other respects the two craters are alike.

The Big Hole tuff ring is very similar to the well-known Diamond Head tuff ring on Oahu, one of the Hawaiian Islands. A tuff ring or tuff cone is a broad-floored ring-enclosed volcanic crater. Such features typically have steep inner walls that show the edges of both inward and outward dipping layers of explosion tuffs and breccias. The ejected fragments have been dropped directly into place after being hurled high into the air. The tuffs and breccias are composed of consolidated heterogeneous mixtures of vitric material from the parent magma and fragments of previously formed rocks.

There is a very definite association of tuff rings with water, and they are believed to occur where intrusive magmas have come into contact with water-saturated rocks at shallow depths. Tuff rings are thought to be formed in a very short period of time (a few days to a few months) by a rapid series of explosions that eject fine ash and rock fragments high into the air. Each explosion is followed by slumping of the crater walls and rock falling directly back into the crater to form a plug; then water rushing into the crater furnishes the steam for another explosion. Crude gravity sorting of the particles that are dropped directly into place accounts for the distinct layered structure of the tuff rings.

Big Hole, Hole-in-the-Ground, and the other tuff ring features in the area may have been formed as far back as Pliocene time, but more likely during the Pleistocene or even Recent epochs when large pluvial lakes occupied valleys formed by block faulting. At the time these lakes existed there was sufficient ground water in the area to affect the intruding magma in the manner that has been described.

Eroded Remnants of Other Tuff Rings

Fort Rock

In Oregon Geographic Names, Lewis McArthur described Fort Rock as follows: "The rock is an isolated mass, imperfectly crescent shaped, nearly one-third of a mile across and its highest point is about 325 feet above the floor of the plain on which it stands. It has perpendicular cliffs 200 feet high in places."

A brief inspection of this striking, well-known landmark (figure 4) in the broad Fort Rock Valley shows that it is an isolated erosional remnant of what was once a much larger tuff ring. The yellowish and brown tuffs with a variety of dark to light colored volcanic fragments are similar to the explosion tuffs at Big Hole.

A detailed study of the attitudes of the tuff layers would probably show whether or not the eroded central part of Fort Rock is actually the crater from which the tuff has been ejected. In general, the thin layers of airborne tuffs dip to the southeast and this would seem to put the center of volcanism to the northwest outside the present confines of Fort Rock. Similar layered explosion tuffs are known to occur beneath the soil zone a mile to the north.

The unusual shape of Fort Rock does not seem to be the direct result of its original volcanic form; rather it is more likely the result of later erosion by wave action in a large pluvial lake, as shown by terraces cut into the southern end of the horseshoe-shaped walls. Hole-in-the-Ground and Big Hole, on the other hand, were unaffected by wave erosion as they lay at an elevation above the level of the lake.

Moffit Butte

Moffit Butte is a bold erosional feature just to the north of State Highway 31 in sec. 7, T. 24 S., R. 11 E., about 10 miles southeast of Lapine. The steep cliffs and badlands type of erosional landforms can be seen from the highway.

The cluster of ridges and hills that makes up the butte appears to be composed of the remnants of one or more tuff rings. Thin to thick layers of yellowish to brown lithic explosion tuffs and tuff breccias occur in a roughly circular to elliptical pattern with the dips of the beds or layers toward the center. There is enough variation in the attitudes at different places so that this may be a cluster of tuff rings superimposed on one another.

Near the highway at the southern edge of the butte there is a small area capped by a thin, cindery, reddish-black basalt flow. A narrow dike or pipe-like mass that is probably the source of the flow cuts the tuffs nearby.

Ridge 28

This unnamed northeast-trending, low ridge in sec. 28, T. 24 S., R. 11 E., is also made up of yellow-brown lithic explosion tuffs that dip to the northwest, south, and southeast. This landform is also believed to be only an erosional remnant of a once larger tuff ring.

Flat Top

The eroded edges of the layered explosion tuffs are present as far north as Flat Top in secs. 13 and 14, T. 24 S., R. 14 E. Here again the lithic explosion tuffs have variable attitudes. Unlike most of the other features described, this one is capped by a thin flow of basalt. This basalt probably filled a shallow broad

crater soon after the explosive phase that was responsible for the layered tuffs and overflowed to the northwest. This basalt and the eroded tuffs are surrounded by Recent younger vesicular basalt flows in which original flow features like pressure ridges, lava tubes, and ropy crusts can still be seen.

Niggers Heel and Toe Butte (Cow Cave, Fort Rock Cave)

This small butte about 1½ miles west of Fort Rock is famous as the cave where some of the oldest Indian artifacts from Oregon were found. Sandals woven from shredded sagebrush bark were discovered beneath a layer of pumice that had exploded from Newberry Crater. Dating by the carbon-14 method shows that the sandals were made at least 9000 years ago.

The butte is made up of a variety of pyroclastic and flow rocks. The western part in which the cave (known locally as the Cow Cave) occurs is made up of reddish scoria fragments that are rather loosely cemented. The eastern part of the butte is capped by a thick reddish to black basalt flow that forms a steep cliff with large blocks at its base.

The waves from the large lake that once occupied Fort Rock Valley eroded the cave in the loosely cemented scoriaceous material of this butte, at the same time cutting the terraces at Fort Rock.

Summary

Hole-in-the-Ground remains a unique topographic feature of Oregon for its marked similarity to a meteorite crater, though its origin is volcanic. The meteorite crater of Arizona was produced by the explosion of an iron meteorite, estimated to have weighed between 20,000 and 60,000 tons, upon impact with the earth. The release of the colossal kinetic energy of a body this size, travelling at an estimated speed of around 10 miles per second at impact, blasted out the crater. For Hole-in-the-Ground the energy came from hot magma making contact with water or water-bearing rock, forming suddenly enormous steam and gas pressure which punched its way through the overlying rock to the surface in one or two bursts. The explosive energy needed to produce a crater this size with a buried nuclear charge would be over 5,000,000 tons, TNT equivalent, on the basis of a similar estimate for the Arizona meteorite crater. Thus can be realized the tremendous energy contained in volcanic forces that produced the Hole-in-the-Ground and the other volcanic explosion features described previously.

The volcanism producing the landforms described in this article was but a small part of the activity going on in the region to the north at Newberry Crater and to the west in the High Cascades during the Pleistocene and Recent epochs. Much of this volcanism was the relatively quiet outpouring of fluid lavas, yet at the same time explosive activity ejected gigantic amounts of pyroclastics. The pumice falls of Mt. Mazama (Crater Lake) and Newberry Crater bear witness of this as two examples in Recent time alone.

Further study of this area will probably reveal more of these tuff cones or their eroded remnants. Doubtless others remain hidden, having been covered by later volcanic flows and lake sediments.

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SOVIET OIL FLOODS CENTRAL EUROPE*

During 1964 at the latest a pipeline will be ready to connect the Caucasus with the West

Duesseldorf. Oil from Soviet Russia started some time ago to play an increasingly important part in the economy of the world.** During all negotiations with partners from the West the Russians insist on finding buyers for their oil. The production is enforced with quickening speed. The transportation will be taken care of by a large pipeline, having three branches from the Caucasus to Europe, and which will be ready for use by 1964. At the same time a price-squeezing maneuver toward the big international enterprises is in the making.

The Eastern interests produced a total of 166 million tons of oil during 1960. The largest part was by the Soviet Union with 147 million tons as compared with only 38 million in 1950. Compared with the world production of more than 1 billion tons, the production of Soviet Russia need not cause much concern. Compared with the Eastern interests, which during 1960 produced only 16% of the world output, North America with 37%, the Near East with 25%, and South America with 17% are still larger producers. Of the proved global reserves of oil, the Near East has 60%, North America more than 13%, and the Eastern interests have only 11%.

Low Home Consumption

By 1965 the Soviet Union wants to increase her production to 240 million tons (7 barrels per ton. ed.), which means that the participation of Soviet oil in the world market will go up, even taking into consideration the increases in all other production centers. Far more to worry about is the fact that the consumption of oil in the Soviet Union is far below the standard in western countries. The Soviet Union may have consumed during 1960 barely 100 million tons, compared with approximately 500 million tons consumed by the U.S.A. As the home consumption in Soviet Russia very unlikely will rise during the next few years, as it will in the West, there will be increasingly larger quantities available for export. No doubt the Satellites of the Soviet Union will demand more oil, but despite that there will be an increasing export offensive of Soviet oil to be noticed during the coming years. An increase of the share of supply, especially to Western Europe, has to be reckoned with. During 1955 only 4 million tons of Soviet oil reached Western Europe, but by 1958 there were 11 million tons. At the present the Russians are supplying between 8 and 9% of the West European consumption. The whole of Iceland and Finland are already consuming only Russian oil, Greece a good fifth, Italy 15%, Sweden and Austria each 14% and the German Federation (Western Germany) a little under 10%.

West Not Competitive

Behind that thrust into Europe stands a policy against which the western oil companies have no equivalent counter weapon. It counts in that connection that the Russian production is not burdened with duties and taxes which the western enterprises have to pay to their countries for concessions and which amount to nearly one-half of the income. On top of that, the Soviet oil is offered to the West far cheaper than behind the Iron Curtain. This is done with the special purpose and goal of using oil as payment for important industrial goods, by which we mean steel pipes for the pipelines and precision installations for the planned refineries.

Italy has overstepped with her oil imports the negotiated obligations considerably. That procedure has caused considerable criticism, as the Eastern oil can reach Western Europe much easier through the Italian refineries and as the Italians are eager through new pipelines to divert that heavy stream into southern Germany. Finally, it has to be taken into consideration that the 4,000 km pipeline with its terminal at Pressburg, which is under construction, will end just in front of the entrance to all big West European consuming centers. The second branch will end in Schwedt on the Oder, where a great petrochemical project will be constructed, and the third branch will end in Memel with Scandinavia the export goal.

(Sueddeutsche Zeitung, September 19, 1961)

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* Translated by R. P. Zobl, Accountant, State of Oregon Department of Geology and Mineral Industries.

**According to a news release from the U.S. Bureau of Mines, the Soviet tanker fleet has been nearly doubled in the past 10 years by the addition of 108 ships, and even though the carrying capacity of the present fleet represents only 2 percent of the world capacity, this accomplishment indicates the intensity with which Russia is entering the oil market. Included in the 7-year plan (1959-65) is the construction of another 140 tankers. The Russians expect to obtain 49 of these from the Free World yards of Finland, Yugoslavia, Japan, and Sweden.

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WESTERN GOVERNORS MINING ADVISORY COUNCIL ELECTS OFFICERS

The Western Governors Mining Advisory Council, at its meeting held September 12 at the time of the American Mining Congress in Seattle, elected the following as officers for the coming year: James A. Williams, State Geologist, Alaska (Chairman); J. B. Pullen, Assistant General Manager, Phelps Dodge Corp., Douglas, Arizona (Vice Chairman); and Hollis M. Dole, Director, State of Oregon Department of Geology and Mineral Industries (Secretary). Retiring Chairman Al Teske, Executive Secretary of the Idaho Mining Association, reviewed the activities of the council during the year, noting that one of the council's recommendations on the Wilderness Bill had been incorporated in the Senate-passed bill. This recommendation requires consultation with the Governor of the State when an area is to be included in a Wilderness withdrawal. Other recommendations of the Council pressed for by the Western Governors included a statement on gold and policy stands on the nonferrous metals.

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WILDERNESS BILL HEARINGS SCHEDULED IN WEST

The House Interior Committee's Subcommittee on Public Lands will hold hearings on proposed Wilderness legislation at McCall, Idaho, on October 30 and 31; at Montrose, Colorado, on November 1; and at Sacramento, California, on November 6. All aspects of the several wilderness bills pending before the House are expected to be studied. The field hearings will enable people in the states that would be materially affected by wilderness legislation to make their views known to the Committee, and those who are interested are urged to respond and appear or submit their views to the Subcommittee. Representative Al Ullman, Oregon, states that witnesses from Oregon are welcome at the McCall meeting or any of the other sessions. Chairman of the Subcommittee is Representative Pfost, Nampa, Idaho. (See August, 1961, Ore.-Bin for location of 750,000 acres of National Forest land in Oregon included in Wilderness Bill.)

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VINYL ACETATE EXHIBIT IN DEPARTMENT MUSEUM

Pacific Carbide & Alloys Co., Portland, has placed an exhibit in the departmental museum showing by small-scale model the basic steps for producing vinyl acetate. Also in the exhibit are some of the many manufactured products utilizing the adhesive and binding qualities of this material, such as safety glass, Durwood, floor tiles, tubing, phonograph records, glues, and paints. The company has been producing calcium carbide and acetylene at its Portland plant for a number of years, but the production of vinyl acetate (the results of chemical research on acetylene) is a new West Coast industry. The exhibit will be on display to the public through November.

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OIL TEST RECORDS RELEASED

The Department released Ross Mitchell "Bliven No. 1" well records from the confidential files on September 25, 1961. The drilling was begun in August 1959 and reached a depth of 1347 feet before it was abandoned. The well was located in sec. 15, T. 8 S., R. 5 W., Polk County.

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MORE PUBLIC LANDS SLATED FOR WITHDRAWAL

The Bureau of Land Management has announced (September 28, 1961) the proposed withdrawal of a total of 1,702.5 acres of National Forest lands from all forms of appropriation under the general mining laws only. Largest segment is 1,565 acres in the Bachelor Butte Recreation Area (within T. 18 S., R. 9 E.) in the Deschutes National Forest. Other areas, totalling 137.5 acres(within Tps. 39-41 S., Rs. 1-5 W.), lie in the Rogue River National Forest. They include the Wrangle, Thompson Creek, and Sturgis Campgrounds,and the lands embracing the Star Ranger Station and the Squaw Peak and Whiskey Peak Lookout Stations. The lands involved in the withdrawals are described in the notice as needing "strengthened security of tenure."

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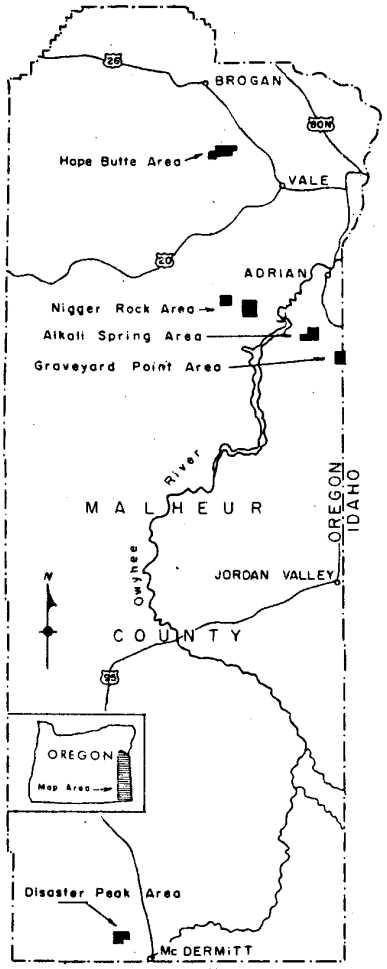
ATTENTION ROCKHOUNDS - THIS WITHDRAWAL AFFECTS YOU

Something new in withdrawals is being initiated by the U.S. Bureau of Land Management. The Bureau, in filing application for withdrawal No. 62-7, Serial Number Oregon 011886, is taking nearly 20,000 acres in Malheur County from location under the mining laws for the nonmetallic minerals (see accompanying index map). The reason given for the withdrawal is ". . . to preserve these lands for the use and enjoyment of the public for recreational pursuits pertaining to petrified materials." However, the notice states that the withdrawal covers all "nonmetalliferous minerals." The leasing laws whereby material can be extracted under lease arrangements with the Bureau still apply and the lands will still be ". . . open to exploration, discovery, occupation, and purchase under the mining laws so far as the same apply to metalliferous minerals."



All this means that land will still be open for location of mining claims for the metalliferous minerals, such as gold, silver, copper, and quicksilver, but the lands will not be open for mining claim location of materials such as limestone, diatomite, pumice, building stone, and semiprecious gem minerals, including petrified wood. However, the nonmetalliferous minerals can be leased from the Bureau of Land Management - the withdrawal just prevents mineral location, that is, mining of the nonmetalliferous minerals can continue but under the direction and control of the Bureau and only upon lease arrangements.

For a period of 30 days from October 13, persons having cause may present their objections in writing to Russell E. Getty, State Director, U. S. Bureau of Land Management, 710 N.E. Holladay Street, Portland 12, Oregon. If circumstances warrant it, a public hearing will be held at a convenient time and place which will be announced. The areas of withdrawal include the following: Hope Butte area, Nigger Rock area, Alkali Spring area, Graveyard Point area, and Disaster Peak area. The total area of withdrawal is 19,496.11 acres.

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McCOLLOCH APPOINTED TO GOVERNING BOARD

Frank C. McColloch, Portland attorney, was appointed September 28, 1961, to the Governing Board of the Department of Geology and Mineral Industries by Governor Mark Hatfield. McColloch succeeds William Kennedy, Portland, whose term expired March 16, 1961.

Following World War I, McColloch practiced law in Baker, Oregon, where he specialized in mining and water law. In succeeding years he was a member of the State Mining Board, served as State Public Utilities Commissioner, and was on the interim committee which authored the present State Water Resources Act and Ground Water Code. Since 1937, he has practiced law continuously in Portland as a member of the firm of Koerner, Young, McColloch, & Dezendorf and its predecessor firms. His appointment to the Department's Governing Board continues until March 16, 1965.

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AMC WESTERN GOVERNORS FOR OREGON ELECTED

Members of the Western Governors of the American Mining Congress for Oregon were elected at the annual meeting in Seattle September 10 to 13. These members are: Frank E. McCaslin, President, Oregon Portland Cement Co., Portland; Fay I.Bristol, President, Bristol Silica Co., Rogue River; and Hollis M. Dole, Director, State of Oregon Department of Geology and Mineral Industries, Portland.

It was announced that the 1962 meeting of the American Mining Congress will be in San Francisco September 24 to 27; the 1963 meeting in Los Angeles September 15 to 18; and the 1964 meeting in Portland September 13 to 16.

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NORTHWEST MINING ASSOCIATION TO MEET

The 67th annual meeting of the Northwest Mining Association will be held in Spokane on December 1 and 2. Approximately 900 mining men from the Northwest and Canada are expected to be in attendance. Chairman for the meeting is Frank N. Marr and the program will be developed under the leadership of David E. Watson. Details are to be announced shortly. Those interested can obtain the full program by writing to: Program Chairman, 67th Annual Convention, Northwest Mining Association, 522 West First Avenue, Spokane 4, Washington.

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GEOLOGIC MAP OF THE LOWER UMPQUA RIVER AREA

The U.S. Geological Survey has recently issued Oil and Gas Investigations Map OM-204, "Geological map of the lower Umpqua River area, Oregon", by Ewart M. Baldwin. The map includes the Reedsport, Scottsburg, and Elkton quadrangles in Coos and Douglas counties, and covers a large gap in the geologic mapping of southwestern Oregon. The map area is underlain by the Eocene Tyee and Coaledo formations and by lesser amounts of Pleistocene and Recent alluvium and dunes. Descriptive text and cross sections are included on the map sheet. Map OM-204 may be purchased for 75 cents from the Geological Survey, Denver Federal Center, Denver, Colorado.

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