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THE AGES OF SOME HOLOCENE VOLCANIC ERUPTIONS IN THE NEWBERRY VOLCANO AREA, OREGON

By N. V. Peterson* and E. A. Groh**

Several episodes of volcanism of Holocene age (since the last 11,000 years) are well recorded within Newberry Crater and on the flanks of Newberry Volcano in central Oregon. Newberry Volcano is a huge shield volcano which rises from the basalt plateau south of Bend and east of the Cascade Range. At the summit of the shield is a large caldera with two lakes and a variety of fresh volcanic features. On its flanks are lava flows that post-date the volcano. Of particular interest are the flows that erupted from a rift zone which extends northwest for 20 miles from the crater to Lava Butte and beyond (plate 1).

How old are these rocks? How long ago did all this happen? These are the questions most frequently asked by visitors who view the shiny black obsidian domes in Newberry Crater, the spiny black lava flows by the Lava Cast Forest campground, or those by Lava Butte.

There has been much speculation by geologists and others on the age of these events, and their guesses range from a few hundred years to a few thousand years. We are never completely satisfied with guesses, so are continually looking for ways to establish the exact sequence and timing of the volcanic eruptions. For the past several years, as a secondary project while studying the extensive and varied volcanic features of central Oregon (Oregon Dept. of Geology and Mineral Industries, 1965), we have been gathering radiocarbon age data on the basaltic flows between Newberry Volcano and Lava Butte. Recently a new technique, developed by geologists of the U.S. Geological Survey for dating obsidian, has given us additional information about the latest volcanic eruptions within the Newberry Caldera.

Lava Butte - Northwest Rift Zone

High-altitude aerial photographs show a more-or-less continuous zone of recent faults and fissures trending N. 30° W. from The Fissure at East

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Lake within Newberry Caldera (figure 1) to Lava Butte (figure 2) and beyond. The sketch map (plate 1) shows that at least eight separate basaltic lava flows have been erupted from this zone, which we referred to previously as the Northwest Rift Zone (Peterson and Groh, 1965). All are aa flows that vary in area and thickness from the smallest North Summit Flow high on Newberry's north flank (less than half a square mile in extent) to the largest and thickest, Lava Butte Flow, at the north end of the rift. The Lava Butte Flow covers nearly 10 square miles and ranges from 30 to 100 feet in thickness. Its vent (figure 2) is at the base of Lava Butte, a symmetrical cinder cone. The U.S. Forest Service has recently designated the cinder cone and the lava field surrounding it as a National Geological Area.

In the central part of the rift zone, sporadic eruptions along fissure vents have produced lava fountains or "fire fountains" which threw out bombs and scoria on the flowing lava (figure 3). The hot, pasty aa lava flowed sluggishly northward and westward down the moderate slope, engulfing pine forests much like those growing in the area today (figure 4). Some of the growing trees remained upright and were surrounded by quickly cooling lava; others were tilted or knocked down by the slowly moving molten mass. The smaller trees and shrubs were burned as the lava approached.

It is believed that within a few minutes after the lava surrounds a tree it cools and forms a thin shell of dense rock; gases and steam are driven from the green wood and the tree is ignited. In most instances the vertical tree burns slowly but completely, leaving a mold the shape and size of the original trunk and extending through the lava flow to the surface. Many of the vertical molds have a prominence or collar on the upstream side which may project a few feet above the surface of the lava (figure 5).

Countless fallen logs must have been covered completely by the flows from the Northwest Rift Zone and, in some places near the margins, subsequent collapse of the thin lava shell has exposed a long horizontal mold (figure 6). Burning of the wood in these molds was not always complete, and charcoal has been found in a few places encased in the lava. This charcoal is ideal for radiocarbon dating.

Our first chance to obtain charcoal for radiocarbon dating was in 1964, when Bill Winney of Bend guided us to a horizontal tree mold in the Lava Cast Forest Flow, where we collected charcoal encased in the lava. This sample was sent to Isotopes, Inc., which determined its age to be 6150 ± 120 years B.P. (before present). We were rather surprised to find that such fresh-looking rocks were this old, but several other radiocarbon dates obtained later confirmed this age. We knew that all the lavas of the Northwest Rift Zone were younger than the climactic eruptions of Mount Mazama (now the site of Crater Lake), which occurred about 6600 years ago, because there was no mantle of Mazama pumice on their surfaces. However, the actual age of the flows was not known until we had obtained radiocarbon data.

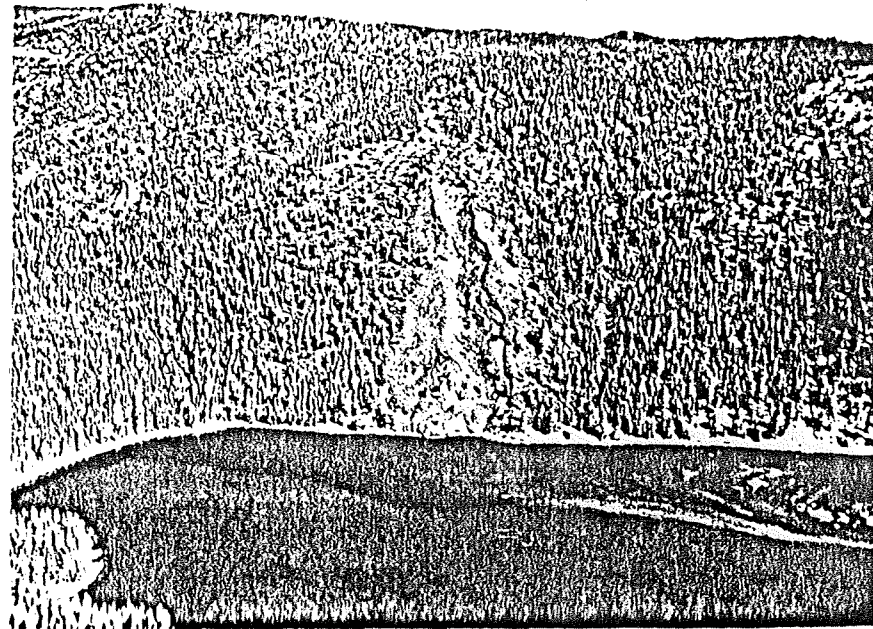


Figure 1. Rising from the shore of East Lake is The Fissure. It is located on the north wall of Newberry Crater, and represents the southern terminus of the Northwest Rift Zone.

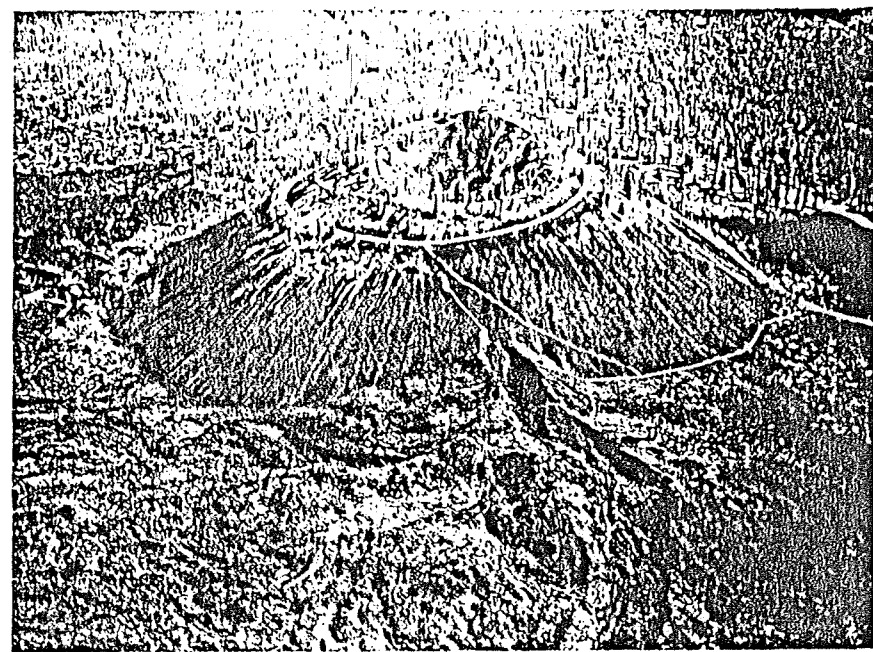


Figure 2. Lava Butte viewed from the south. It is adjacent to U. S. Highway 97, about 10 miles south of Bend, and is one of the prime geologic attractions in Oregon.

Table 1. Radiocarbon ages of some Holocene eruptions on Newberry Volcano.

Name of flow	Age - years before present (B.P.)*	Laboratory
Pumice bed in Newberry Crater	1270 ± 60	University of Texas
Lava Cascade Flow	5800 ± 100	Gakushuin Univ.
Gas-Line Flows	5800 ± 150	Columbia University
Forest Road Flow	5960 ± 100	Gakushuin Univ.
Surveyor Flow	6080 ± 100	Gakushuin Univ.
Lava Cast Forest Flow	6150 ± 210	Isotopes, Inc.
	6380 ± 130	Gakushuin Univ.

* Based on Libby half-life.

Because of the difficulty in finding charcoal in horizontal tree molds, our attention turned to the idea that perhaps the roots of the now vanished trees might have become carbonized and would still be present in the soil zone beneath the lava flow. The generalized sketch (figure 7) shows what we found in almost every vertical tree mold we explored. After removing debris from the bottom, we encountered a pumiceous soil layer, reddish near the top where oxidized by the heat of the lava. Then, 6 inches to a foot into the soil zone, lay the charred root material. The only tools needed to extract it were a small shovel, a bucket on a rope, and persistence. A hard hat and a holpor to hoist the bucket aided the operation.

We were successful in obtaining charcoal from tree molds in four out of eight flows along the Northwest Rift Zone and also one sample from the Surveyor Flow, which is a similar basaltic aa lava on the south flank of the broad Newberry shield. Table 1 shows that the radiocarbon ages of these five flows range from 5800 ± 100 years B.P. to 6380 ± 130 years B.P., indicating that most, if not all, of these volcanic events were confined to a short eruptive period about 6000 years ago.

Radiocarbon dating is in agreement with the stratigraphic relationship shown by Lava Cascade Flow which spread over part of the Lava Cast Forest Flow. This is the only visible example of superposition of one flow over the other along the Northwest Rift Zone. A radiocarbon date was obtained for only one of the Gas-Line Flows, but we believe that both were erupted simultaneously from the same short fissure.

We searched for tree molds along some of the margins of both the Lava Butte and Mokst Butte Flows without success. It is probable that these thick outpourings of lava completely overwhelmed and buried every tree

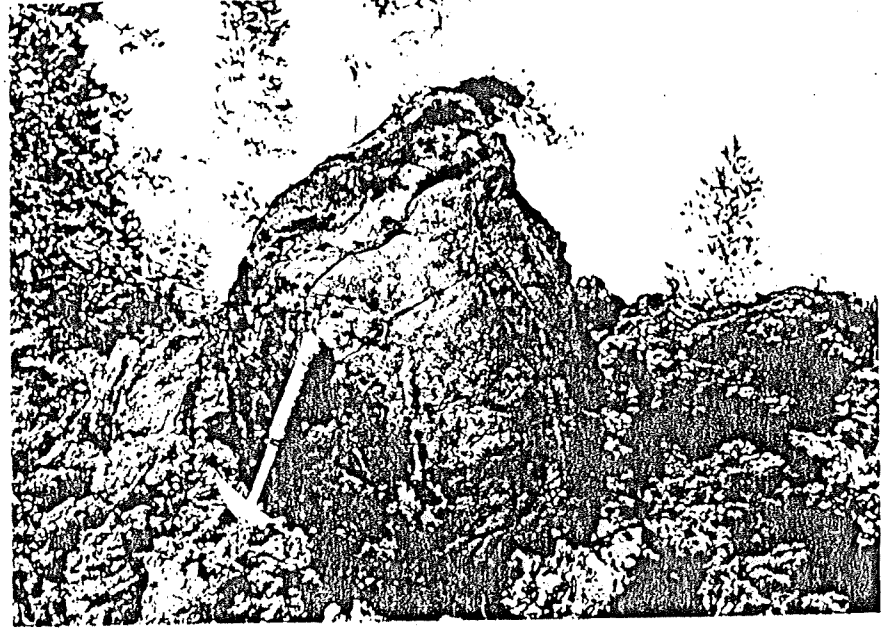


Figure 3. A large, almond-shaped bomb thrown out from a fissure vent of the Lava Cascade Flow during an explosive eruption.

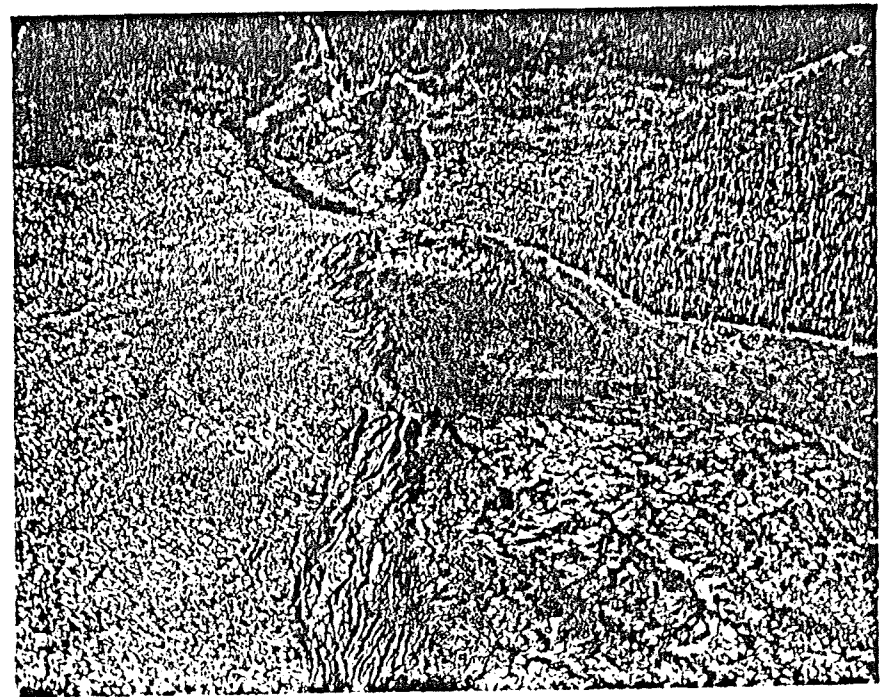


Figure 4. Looking south across upper part of the Lava Cascade Flow. Basaltic lavas were erupted as fire fountains near the eastern (left) edge of the flow and moved westward (right).

Table 2. Hydration ages of obsidian flows within Newberry Crater.*

Name of flow	Age - years**
Big Obsidian Flow	1350
Interlake Obsidian Flow	1700
East Lake Obsidian Flow - Western	1900
East Lake Obsidian Flow - Eastern	2600
Pumice Cone Crater Obsidian Dome	5000

* Laboratory: U.S. Geological Survey, Branch of Isotope Geology.
 ** Calculations based on a hydration rate of 5 microns²/1000 years.

in their paths. At this time we can state only that the Lava Butte Flow is younger than the nearby Gas-Line Flows (dated at 5800 ± 150 years) because the Gas-Line Flows are mantled by volcanic ash from Lava Butte.

Newberry Caldera

Excellent descriptions of the geology and landforms of the Newberry Volcano have been written by Williams (1935) and by Higgins and Waters (1967, 1968), who recognized that the obsidian flows and domes were some of the latest volcanic eruptions in the caldera. Williams described the Big Obsidian Flow as by far the largest and youngest of the group (figure 8 and plate 1). In 1966, charcoal from a log in pumice just beneath the Big Obsidian Flow was submitted to the University of Texas by U.S. Clanton of NASA and was determined to be 1270 ± 60 years B. P. (table 1).

Not long ago, Friedman and Smith (1960) of the U.S. Geological Survey devised a technique for dating obsidian artifacts by measuring the hydration rind that develops on a surface exposed to the atmosphere (explained more fully in a later section of this report). Their method is also useful in dating volcanic glasses such as obsidian flows (Friedman, 1968). Samples of five obsidian domes and flows (listed in table 2) were sent to Dr. Friedman at the Branch of Isotope Geology, U.S. Geological Survey, in Denver. His measurements revealed that the specimens vary in age but that all are Holocene. The two nearly contiguous East Lake Obsidian Flows (figure 9) appear to have been erupted contemporaneously from the same fissure, but since the hydration-rind dates show a 700-year difference in their ages, the two flows may have erupted several hundred years apart. The age difference may be due also to the range in hydration-rate error, or to a misinterpretation in sampling what was considered to be the original



Figure 5. Lava tree mold showing an exposed chilled collar above the lava surface at Lava Cascade Flow.

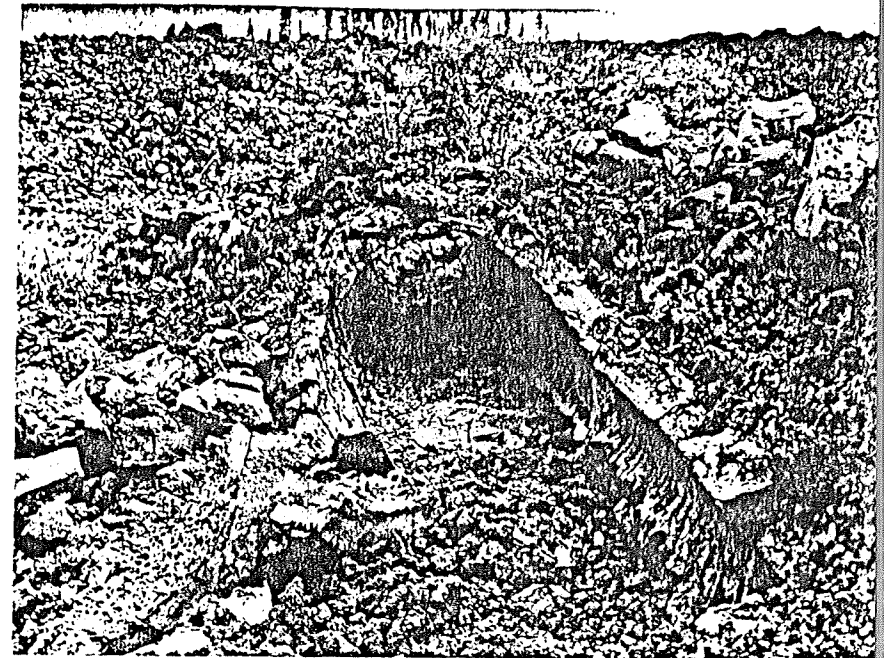


Figure 6. Mold of horizontal tree entombed by the Lava Cascade Flow. The shell formed when violent emission of steam and gases from the burning wood rapidly chilled the lava. (Oregon State Highway Department photograph.)

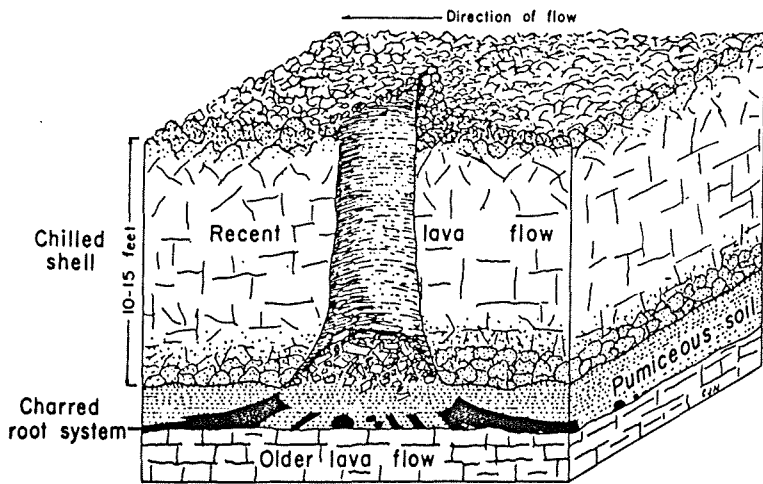


Figure 7. Cross section of a typical vertical tree mold formed in recent lava flows on the flanks of Newberry Volcano.



Figure 8. Big Obsidian Flow. A light coating of snow accentuates the flow ridge pattern. Paulina Lake in the foreground.

surface.

In general, the hydration-rind dates confirm the relative ages inferred by the earlier investigators. The Pumice Cone Crater Obsidian Dome is by far the oldest, at 5000 years. Next in age are the East Lake Obsidian Flows at 2600 and 1900 years. The Interlake Obsidian Flow (figure 10) is next at 1700 years; and, as expected, the Big Obsidian Flow is the youngest at 1350 years. The discrepancy between this date and the radiocarbon date for charcoal in the underlying pumice (1270 ± 60) is within the range of errors inherent in the dating techniques.

Perhaps the oldest of the recent obsidian flows in Newberry Caldera is the Game Hut Obsidian Flow, which is heavily mantled by pumice. Samples of this volcanic glass did not prove satisfactory for hydration dating.

Dating Methods

Radiocarbon dating

This procedure for dating carbonaceous materials derived from previously living plant or animal matter has been in use for some 20 years. The method is used also on nonorganic carbonaceous substances such as caliche and carbonate precipitates. Many thousands of dates or ages that otherwise could not have been determined have been established for archaeological sites and late Quaternary stratigraphic units.

The radioactive carbon isotope, called carbon-14 (C^{14}), is produced in the atmosphere by the neutron-proton reaction of cosmic rays on the abundant isotope nitrogen-14. The radiocarbon thus formed emits a low-energy beta particle and gradually changes back into the stable isotope nitrogen-14. Its half-life is about 5700 years, which allows dating to a maximum of about 50,000 years. Thus, the radiocarbon method is extremely useful for dating man's early history and recent geologic events.

The radiocarbon formed in the atmosphere is soon oxidized to radioactive carbon dioxide and follows ordinary carbon dioxide in its distribution about the earth and in the oceans. Through photosynthesis it becomes converted to plant tissue and by means of the plant-animal food cycle it reaches equilibrium throughout all living matter. Therefore, every living organism in the world at present has essentially the same amount of radiocarbon per unit of contained carbon, and this constant ratio is maintained by the turnover of food consumption and respiration.


An exception to the above is found in long-lived organisms such as trees. As new wood tissue is formed, it no longer takes part in the carbon-exchange cycle and thus passes from equilibrium. The radiocarbon now begins to diminish. The innermost annual ring of the living tree has a radiocarbon age equivalent to the age of the tree, and the wood becomes progressively younger in radiocarbon age, reaching zero with the newest sap-wood.

Legend

1. Lava Butte Flow
2. Gas-Line Flows
3. Mokst Butte Flow
4. Twin Vent Flow
5. Forest Road Flow
6. Lava Cast Forest Flow
7. Lava Cascade Flow
8. North Summit Flow
9. The Fissure
10. Surveyor Flow
11. Big Obsidian Flow
12. Interlake Obsidian Flow
13. East Lake Obsidian Flow - Western
14. East Lake Obsidian Flow - Eastern
15. Pumice Cone Crater Obsidian Dome
16. Game Hut Obsidian Flow
17. Pumice Bed

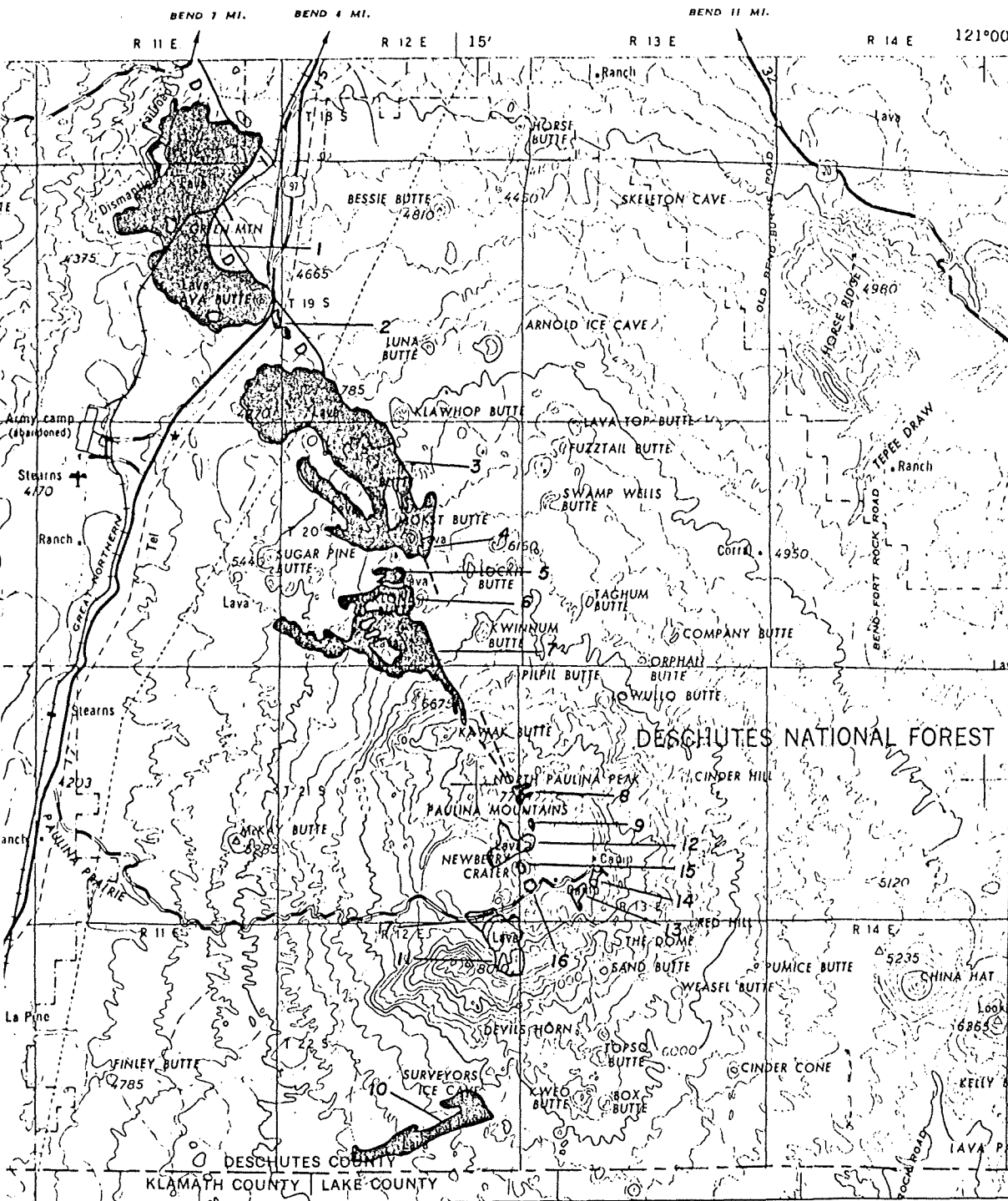
 Basaltic Lava Flows

 Rhyolitic Obsidian and Pumice

 Faults and Fractures



Contour interval 200 feet.



late 1. Sketch map of some Holocene lava flows of Newberry Volcano, Deschutes County, Oregon.

When an organism dies, the equilibrium is disrupted, because the radiocarbon content is no longer maintained. Radiocarbon in the parts of these organisms that will remain preserved, such as bone, shell, wood, charcoal, or peat, now begins its radioactive decay. Figuratively, the "clock" is set to ticking. In the laboratory a sample of these materials is cleaned of any visible modern contaminants such as hair roots or fungi. The sample is then treated with sodium hydroxide to remove humic acids and with hydrochloric acid to remove extraneous carbonate deposits, except in the case of carbonate samples such as bone or shell. In the presence of radon-free oxygen the sample is ignited and oxidized to carbon dioxide, which is drawn into special gas-handling equipment. Here the carbon dioxide may be given one of several chemical treatments for further purification. In some laboratories the carbon dioxide is converted to another gas containing carbon such as methane or acetylene. Finally, a specific volume of the purified gas is introduced into a specially shielded counter tube and its radioactivity is measured over a period of time, generally several days. The amount of radiocarbon present is thus determined and the age calculated, that is, the time on the "clock" is read.

The radiocarbon ages listed in Table 1 are based on a half-life of 5568 years for the radiocarbon isotope, called the Libby half-life. In recent years, more accurate measurements have raised this value to 5730 years, or about a 3 percent increase. To give a closer approximation to the true age this correction can be added, although it is usually considered negligible in geologic dating. To avoid any misunderstanding in the literature, all dates continue to be based on the Libby half-life.

More important in absolute chronology, as supported by radiocarbon dating, is the discrepancy between the true age in calendar years and the ages dated in radiocarbon years (Stuiver and Suess, 1966). Radiocarbon ages older than about 2200 B.P. are progressively younger than true ages obtained from tree rings and historically dated samples. This divergence as found at this time continues back to about 6000 years B.P. Thus conversion of the radiocarbon ages of the lava flows given in Table 1 to their true ages would date them at 7000 to 8000 calendar years ago. The cause for the variation in past radiocarbon levels is not definitely known, but it may be due to changes in cosmic ray flux and as a consequence an increased production of radiocarbon in the past. Another factor may have been changes in the earth's climate which could have altered the total carbon-dioxide content of the atmosphere.

Hydration dating

The hydration method was developed a few years ago to determine the age of obsidian artifacts found in many archaeological sites (Friedman and Smith, 1960). This method can also be applied to dating obsidian flows (Friedman, 1968).

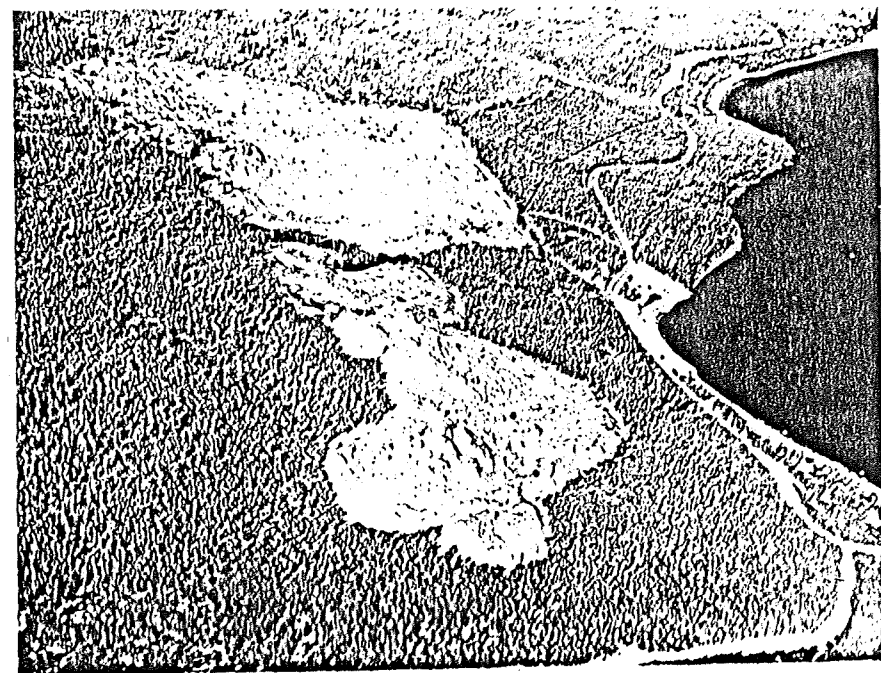


Figure 9. The East Lake Obsidian Flows. Uppermost is the Western Flow and below, the Eastern Flow.

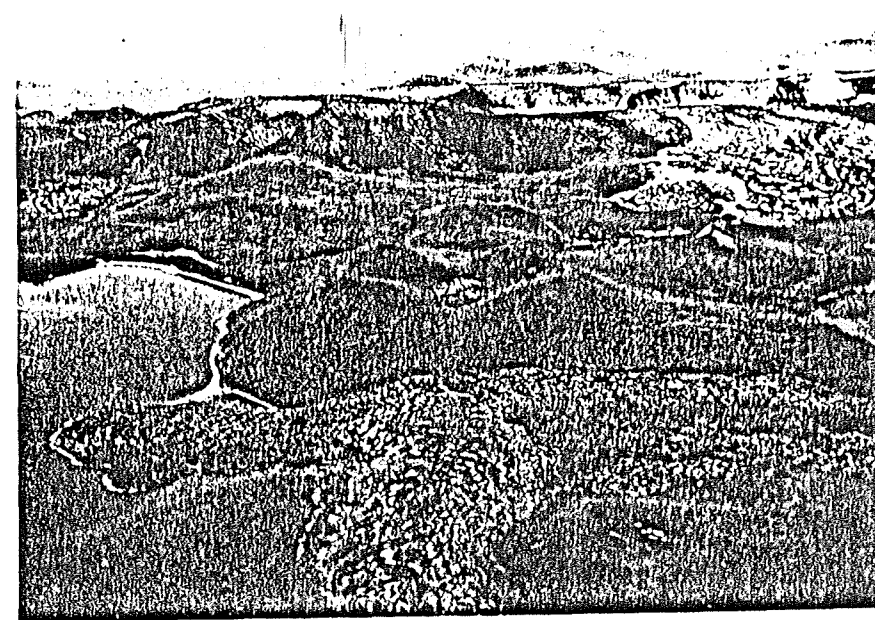


Figure 10. Looking south across Newberry Crater. In the foreground, Interlake Obsidian Flow has divided into two tongues, one flowing left into East Lake and the other in the opposite direction to the shore of Paulina Lake. In the center is the notched crater of Pumice Cone. In the distant right is Big Obsidian

An exposed obsidian surface adsorbs a film of water which diffuses into the rock along a distinct and sharply defined front. The hydrated layer, or rind, has a higher index of refraction. When viewed microscopically in a thin section cut perpendicular to the surface, this layer shows a distinct phase contrast under ordinary light. Because the thickness of this hydration layer is usually only a few microns, high magnification and capability of precise measurement to within 0.2 microns are necessary.

The rate of hydration for obsidian is not dependent on the humidity present in the particular environment; rather, the rate is determined by the temperature the obsidian is subjected to over its history. Data from experimental studies and from obsidian samples throughout the world have established a hydration rate for several climatic zones (Friedman and others, 1966). At present the hydration rate is liable to an error of about 20 percent, but further research will undoubtedly reduce the magnitude of the error.

The hydration ages listed in table 2 appear to present good approximate ages for those particular eruptive events in Newberry Crater. Further sampling and refinement of the hydration rate may provide more accurate dates for these flows, although no radical changes are expected.

Conclusions

Radiocarbon dating of charcoal and hydration-rind dating of obsidian from the Newberry Volcano area give us a sequence of volcanic eruptions ranging from 6380 ± 130 years to 1270 ± 60 years ago.

These events are but a few of the many volcanic eruptions that have occurred in the region since late Pleistocene time (Oregon Dept. Geology and Mineral Industries, 1965). There are numerous other examples of recent volcanism in central Oregon and also in the eastern part of the state and in the High Cascades. The ages for some of the High Cascade eruptions have been obtained by the radiocarbon method (Taylor, 1965).

As part of its continuing studies on volcanism in central and eastern Oregon, the State of Oregon Department of Geology and Mineral Industries will attempt to date more of these volcanic episodes. It is hoped that other investigators of young volcanic rocks in the state will also be interested in obtaining dates for the events in their areas and that eventually we can establish the chronology of late Quaternary volcanism in Oregon.

Acknowledgments

We wish to thank Bill Winney and Phil Brogan of Bend, Oregon, who were very helpful in supplying locality information during the extended time we were gathering data for this report. We are greatly indebted to the various persons who provided age data: Dr. Irving Friedman of the U.S. Geological Survey determined the hydration dates on the samples of obsidian

we collected from Newberry Crater; Harry Gibbon, through Columbia University, provided the radiocarbon dates for root charcoal from the Gas-Line Flows; and U.S. Clanton of NASA Manned Spacecraft Center, Houston, Texas, submitted the charcoal from the Newberry Crater Pumice Bed to the University of Texas for dating.

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