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APPRAISING VOLCANIC HAZARDS OF THE CASCADE RANGE*

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The hazard to life and property in the western United States from volcanoes is small by comparison with that from earthquakes, storms, and floods. Nevertheless, the hazard is real and warrants concern. If volcanic events similar to the most violent ones during the last 5,000 years at each of two volcanoes occurred today without warning, thousands of people could be affected. An eruption at Mount St. Helens in Washington could endanger 40,000 persons, and one at Mount Rainier, Washington could affect as many as 50,000. The number of people at risk near these and other volcanoes will surely increase during the next century. Such long-range expectations should concern us now because patterns of land use adopted today will become increasingly difficult to change in the future.

Hazards Appraisals and Predictions of Eruptions

Anticipation of the effects of eruptions at specific volcanoes should be distinguished from prediction of the eruptions themselves. Prediction techniques now being used on volcanoes throughout the world include a wide variety of geophysical and geochemical methods. In the United States, the seismicity of a few volcanoes is being monitored by seismometers and seismic-event counters. Their thermal state is being observed by aerial and ground-based infrared studies and by continuous recording of fumarole temperatures. Possible changes in the surface of the ground on and adjacent to some volcanoes are being monitored by geodetic measurements and tiltmeters. Some of the monitoring techniques now being utilized at the Cascade volcanoes, however, are on an experimental basis rather than being fully operational.

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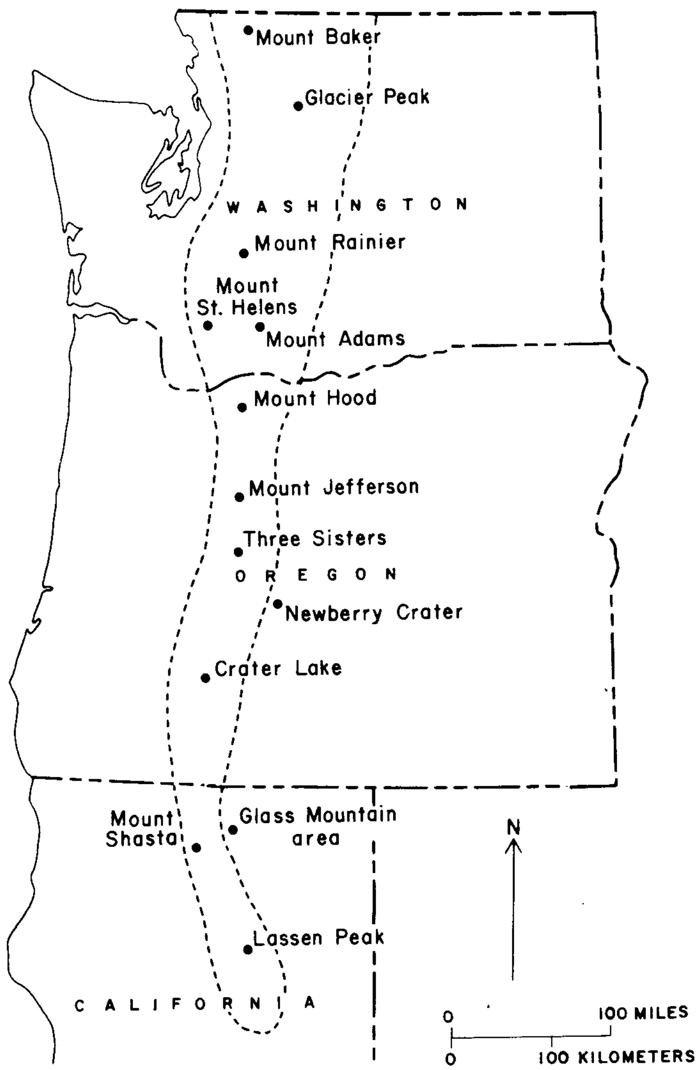
* Adapted from: Appraising Volcanic Hazards of the Cascade Range of the Northwestern U.S., Earthquake Inform. Bull., v. 6, no. 5, p. 3-10, Sept.-Oct. 1974; and Technique and Rationale of Volcanic-Hazards Appraisals in the Cascade Range, Northwestern U.S., Environ. Geol., v. 1, p. 23-32, New York, Springer-Verlag.



Major volcanoes in and near the Cascade Range.

A principal objective of monitoring is to save lives by warning of an impending eruption. Monitoring techniques are all based on the detection of events that occur before eruptions, and their success depends on detection in time to evacuate an endangered populace. Although premonitory events have been detected at some volcanoes, the lack of recent activity precludes our knowing what events and which monitoring techniques will provide the most reliable warning at a specific volcano; furthermore, geophysical monitoring does not indicate the kinds or scale of eruptions to expect, or the areas that might be affected by future eruptions. And, in general, by the time premonitory events have been detected, it is too late to prevent property losses in areas that are subsequently affected by eruptions. Consequently monitoring alone is of little value in deciding which long-range uses of land around a volcano are compatible with the potential risk. This problem can be solved only by obtaining detailed knowledge of how the volcanoes have been behaving and the extent of areas affected by them in the past. This knowledge can also be used in determining what actions should be taken to prevent or reduce loss of lives or property after premonitory events have been recognized, as well as during the initial stages of an eruption. Both monitoring and volcanic hazards appraisals are important and complement one another, but they apply to different aspects of the volcanic risk problem.

Technique of Volcanic Hazards Appraisals

A volcanic hazards appraisal includes a forecast of the kinds of eruptions that can be expected, an anticipation of volcanic events that will endanger human lives and property, and the location of areas that can be affected by the events. The information necessary to achieve these objectives is obtained from four closely interrelated studies: genetic, stratigraphic, chronologic, and cartographic.

Genesis

The analysis of a volcano's behavior is based on a knowledge of the ways in which various products of volcanism originated. Determination of

Table 1. A summary of recent activity of some major volcanoes in the Cascade Range and adjacent areas. Population at risk is that which could be directly affected by an eruption like the most catastrophic known of the last 12,000 years at that volcano

	Mt. Baker	Glacier Peak	Mt. Rainier	Mt. St. Helens	Mt. Adams	Mt. Hood	Mt. Jefferson	Three Sisters	Mt. Mazama (Crater Lake)	Newberry Volcano (Newberry Crater)	Mt. Shasta	Glass Mtn. area	Lassen Peak-Chaos Crags area
Active in historic time	X		X	X		X					?	?	X
Known products of eruptions, last 12,000 years:													
Lava flow	X		X	X	X	X	X	X	X	X	X	X	X
Tephra (airborne rock debris)	X	X	X	X		?		X	X	X	X	X	X
Pyroclastic flow		X	X	X					X		X		X
Mudflow	X	X	X	X	X	X					X		X
Estimated population at risk:													
More than 1,000	X		X	X		?			X		X		
Less than 1,000		?			X		X	X		X		X	?

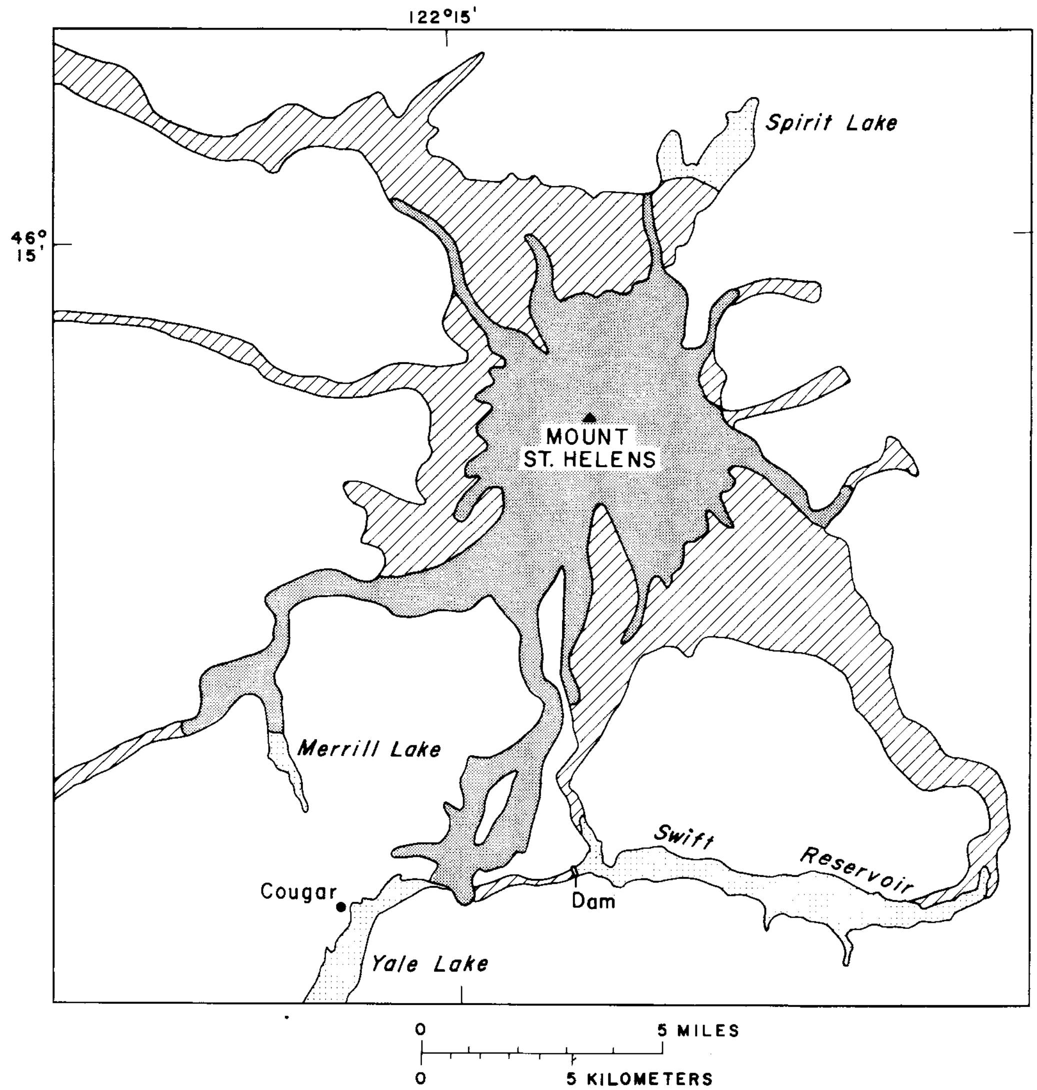
the genesis of some kinds of volcanic deposits is probably the hardest part of the whole study. For example, coarse, poorly sorted and unstratified deposits of volcanic rock debris formed by glaciers and avalanches can be similar in appearance to deposits formed by hot pyroclastic flows and mud-flows. Also, the fine-grained deposits formed by clouds of ash accompanying hot pyroclastic flows resemble tephra, volcanic material which has been erupted into the air and then carried away from a volcano by winds. It is important to distinguish between different modes of origin because each mode implies a different kind of potential hazard from future eruptions.

Stratigraphy

The stratigraphic aspect of the study of a specific volcano requires a decision as to what interval of its history will be most appropriate to examine in detail. The study should be extended back far enough in time to include a wide range of kinds of volcanic events. The history of Mount Rainier probably goes back at least a million years, but because events before the last major glaciation, which began about 25,000 years ago, are poorly recorded and difficult to date, the eruptive record of only the last 10,000 years has been studied. At Mount St. Helens the entire life of the volcano, which may have come into existence shortly before 38,000 years ago, is under study. The volcanic hazards appraisal now underway at Mount St. Helens will be based on the eruptive events of only the last 4,000 years, however, since

Table 2. Generalized stratigraphic sequences of the last 4,000 years which have been recognized on three sides of Mount St. Helens volcano

Tephra deposit and age (years)	Southeast side	Southwest side	North side
	Lahars Lava flows	Pyroclastic flows	Lahars Lava flows
W (450)	Tephra W	Tephra W ...	Tephra W
		Lahars	Lava flows Pyroclastic flows,
B(1500-2500)...	Lahars and tephra B...	Tephra B.....	lahars and tephra B
		Lava flow(s)	Lava flow(s)
P(2500-3000)...	Pyroclastic flows, lahars and tephra P	Tephra P	Pyroclastic flows, lahars and tephra P
Y(3000-4000)...	Pyroclastic flows, lahars and tephra Y	Tephra Y....	Tephra Y



Areas covered by lahars and pyroclastic flows (line pattern) and lava flows (gray) from Mount St. Helens during the last 4,000 years.

virtually the entire visible volcano was formed within this time and this period seems to have been preceded by a long interval of little or no activity. Furthermore, the behavior of the volcano is well documented by at least four major eruptive periods within the last 4,000 years, which included many tens of eruptive events.

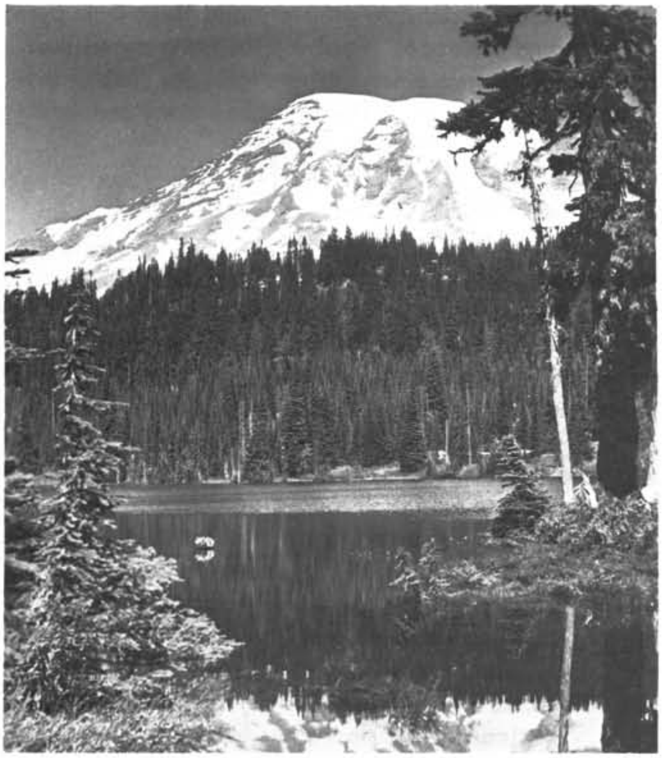
An especially important aspect of a volcanic hazards appraisal is a detailed study of surficial deposits around a volcano. Surficial deposits provide information about a volcano's past behavior. The behavior pattern for volcanoes that have been inactive or rarely active during historic time can be reconstructed only by inferring various kinds of events from the volcanic deposits they created. A more complete record of eruptive activity can often be found beyond the flanks of a volcano rather than on the volcano itself where rocks as well as surficial deposits are readily removed by erosion or covered by the products of new eruptions. Thus, eruptive products which are easily transported from the volcano by wind, pyroclastic flows, mudflows, and river and deposited in more stable environments may provide the best record, and perhaps the only record, of a significant part of a volcano's history.

Rocks and surficial deposits of volcanic origin should not be studied to the exclusion of everything else. If a volcano is within a region of alpine glaciation, a knowledge of the extent of glaciers in late Pleistocene and Holocene time can be useful in establishing the ages of certain episodes of volcanism. Weathering profiles can approximately date volcanic deposits when they are compared with those on texturally and lithologically similar glacial deposits of known age in the same area. Intervals when there was no pyroclastic activity at a volcano can be recognized from weathering profiles and also from tephra-free sequences of deposits, such as peat, which are on the near downwind side of a volcano.

Chronology

Rocks and surficial deposits of volcanic origin can be relatively dated by their stratigraphic relation to one another and to glacial drift, by weathering profiles, and by geomorphic relations where deposits form successive terraces within a valley. These stratigraphic units can also be put into a framework of absolute time by means of radiocarbon age determinations. Charcoal, which can be used for radiocarbon dating, is abundant in many pyroclastic-flow deposits; wood is common in mudflows; organic material is often found interbedded with airfall tephra. Tree growth-rings have been used to date or limit the age of deposits as much as several hundred years old at Mount St. Helens and more than 700 years old at Mount Rainier. Lichen diameters are also being used for dating lava flows, mudflows, and avalanche deposits in unvegetated areas.

The importance of airfall tephra in establishing a chronologic framework for stratigraphic successions on all sides of a volcano cannot be over-



South side of Mount Rainier and Reflection Lake, Washington. The lake was formed about 5,000 years ago when a mudflow formed a natural dam.

emphasized. Once a recognizable tephra layer has been dated, it provides a time horizon wherever it can be found. The airfall tephra most useful for correlation purpose may be a product of a different volcano than the one being studied. For example, although there have been at least 11 pyroclastic eruptions at Mount Rainier during the last 10,000 years, the most useful layers for correlating stratigraphic sequences there were erupted by two other volcanoes. These layers are much more widely distributed and are of more consistent thickness and grain size than those from Mount Rainier.

Distribution of volcanic deposits

After a detailed knowledge about a volcano's recent behavior has been acquired, it is necessary to determine what areas have been affected by past eruptions in order to forecast the possible extent of similar phenomena in the future. This may be done by mapping the distribution of lava flows, tracing mudflows and pyroclastic-flow deposits down valleys, and determining the extent of airfall tephra. Future eruptions may not affect exactly the same areas in the same way and to the same degree, but a map of areas affected in the past can be used as a rough guide. From such a map of some deposits at Mount St. Helens we might infer that a significant potential hazard to property exists from lava flows within a distance of about 15 km from the volcano, and a hazard to property and lives from pyroclastic flows within about the same distance. Further, mapping shows that a potential hazard from mudflows extends down valley floors for tens of kilometers, and a potential hazard from tephra fallout reaches many tens of kilometers downwind.

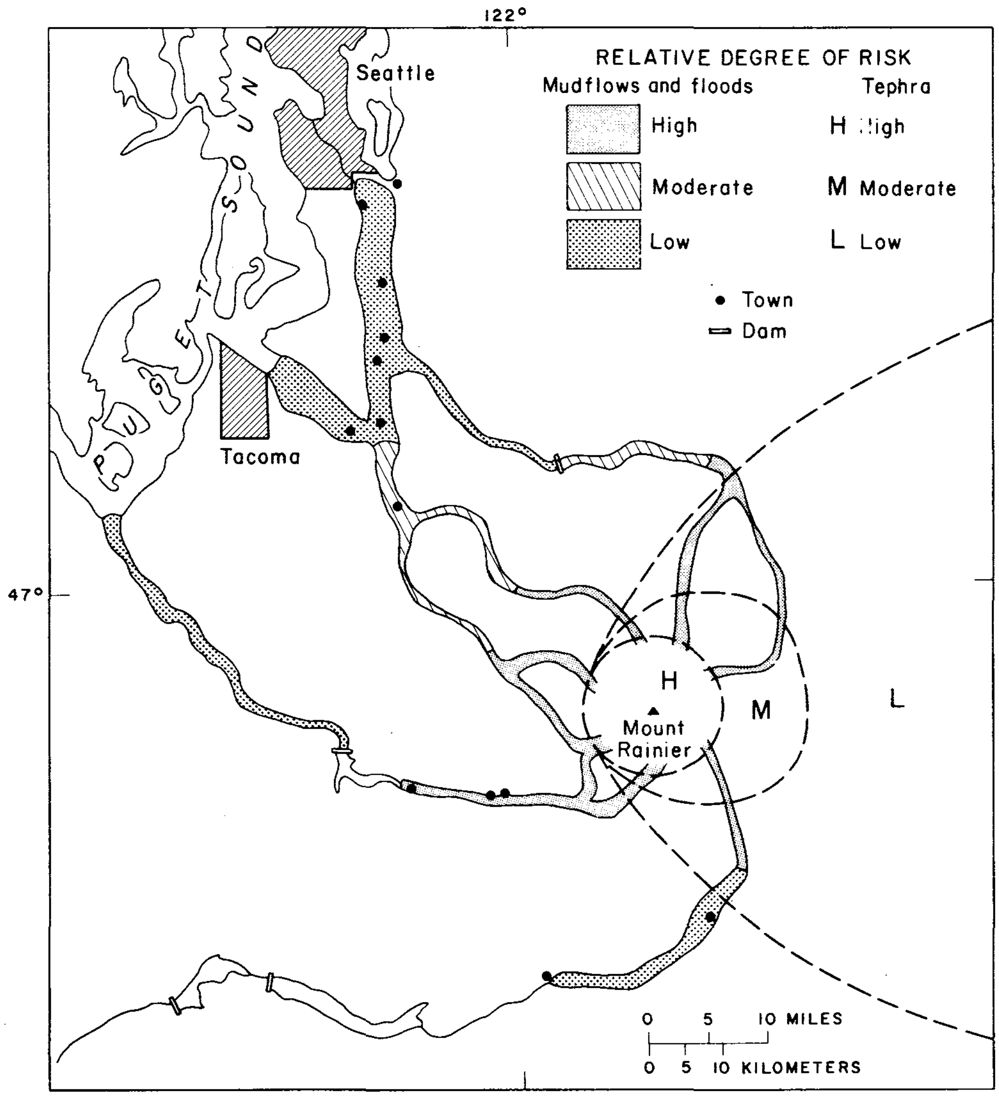
Risk Zones

Inferences like these lead to the preparation of a map on which zones of relative risk are defined. An assignment of the degree of risk is based not only on the past history of events affecting a specific area, but also on changes which have occurred at the volcano which might influence future events such as meteorological conditions, especially prevailing winds, and man-made changes such as dams and reservoirs. These factors must all be considered when analyzing what will most probably occur in the future and the risks that will result. A risk-zone map of the area near Mount Rainier shows that the greatest hazard on valley floors is from mudflows and floods. In each valley the risk generally decreases with increasing distance from the volcano and with increasing height above the valley floor in any part of the valley. At Mount Rainier, the record of postglacial eruptions suggests that tephra fallout is a significant hazard only very close to the volcano and that the degree of risk decreases abruptly in all directions except to the east, downwind from the volcano, and decreases fairly rapidly even in that direction.

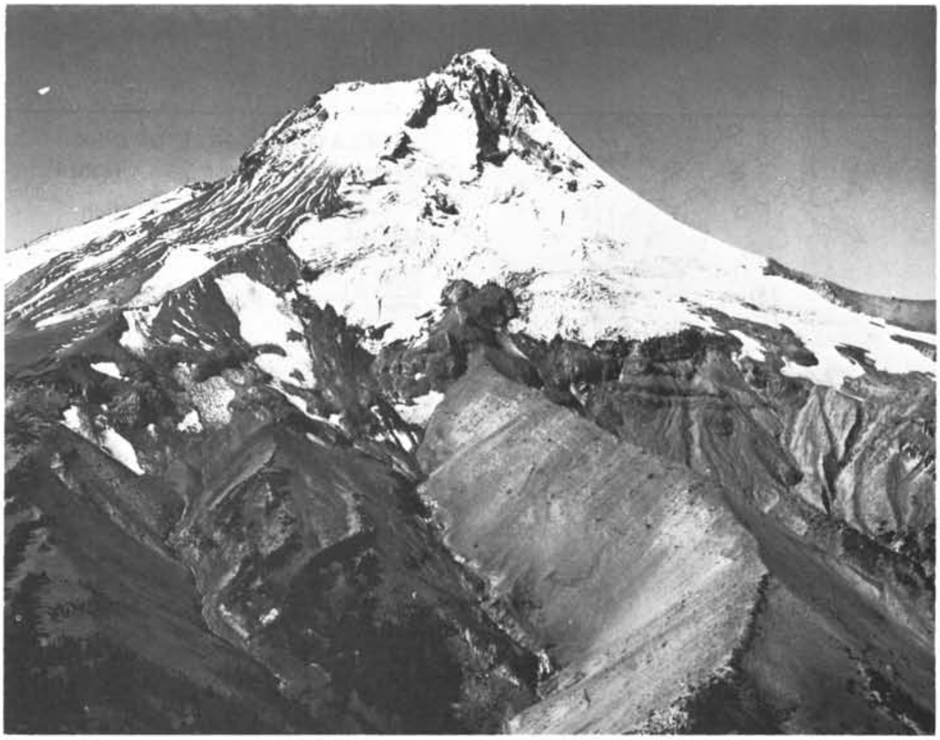
Goals and Rationale

The eruptive behavior of volcanoes can be characterized, and the potential hazards defined from the four aspects of volcanic-hazards appraisals just described. Both kinds of information are important for planning optimum use of land around volcanoes. Defining zones of differing degrees of risk is a particularly troublesome problem. Time may show that the boundaries of the risk zones and the levels of risk within them are much overrated or underrated. Perhaps the greatest ultimate benefit of showing risk zones graphically will be to call attention to areas where some degree of risk exists, rather than to the specific degree of risk.

Forecasting future eruptive behavior of a volcano from the events of the past raises a fundamental question: How can we be sure that the volcano will not change its "life style"? It has been said that andesitic volcanoes typically become more explosive late in life. What assurance have we that the next eruption of Mount Rainier, for example, will be the same kind as has occurred repeatedly during the last 10,000 years, rather than a catastrophic Mount Mazama-type eruption which will destroy the volcano and devastate the entire adjacent region? Although it cannot be said that Mount Rainier will never be another Crater Lake, the possibility of such a



Relative degrees of potential hazard from tephra, mudflow, and floods which could result from an eruption of Mount Rainier.



Mount Hood from the east showing the canyons deeply eroded into the vast lava flows below Newton-Clark glacier. A late September picture.

violent eruption occurring within the next few centuries is so remote that it cannot be planned for either economically or pragmatically. Measures that would protect the public fully from such an eruption would require costly major changes in land use over a very large area of western Washington. It would be unrealistic to propose to the people and legislature of a State that they should prepare today for such an eruption. For one thing, we do not know which, if any, of the volcanoes will erupt in this manner. We believe that a more credible case can be made for preparing for the kinds of events which have occurred fairly often at a specific volcano, and which, therefore, are likely to occur there again. In the event that a catastrophic eruption does begin, the only solution probably will be a mass evacuation of the region.

The Cascade Range volcanoes have been so peaceful during the present century that there has been virtually no concern for potential volcanic hazards. As a result, dams and reservoirs have been built in valleys which have been repeatedly affected by large mudflows, pyroclastic flows, or lava flows in the very recent geologic past. No special provisions have been made for the quick emptying of some of these reservoirs in the event of a volcanic eruption upstream. In other areas near volcanoes, new homes are being built on top of mudflow deposits no more than a few centuries old.

It is hoped that appraisals of volcanic hazards will provide information which will help responsible officials and planning agencies, as well as individuals, make informed decisions concerning the future use of land near volcanoes. This information should help people at various levels of government anticipate what problems will arise when the next eruption occurs. Plans can be made in advance for the necessary communications and warning systems, and for safely evacuating people from threatened areas. The ultimate objective is to minimize the risk to people and property from future eruptions.

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REICHHOLD-NORTHWEST NATURAL GAS FINISH 1975 PROGRAM

Reichhold Energy Corp., Tacoma, Washington and Northwest Natural Gas Co. finished drilling four deep exploratory holes in October. The companies undertook a joint venture to search for oil and gas in western Oregon this past summer and if the geologic structures do not contain commercial hydrocarbon deposits, they will study the potential for underground storage of natural gas. Data on the exploratory drillings are contained below:

Permit No. 65 API 36-052-00004 NNG-Crown Zellerbach 1	NE$\frac{1}{4}$ sec. 22, 2S 10W Tillamook County	Abandoned at 5,557 feet
Permit No. 66 API 36-053-00021 NNG-Finn 1	SW$\frac{1}{4}$ sec. 17, 6S, 4W Polk County	Abandoned at 7,258 feet
Permit No. 67 API 36-047-00007 NNG-Merrill 1	SW$\frac{1}{4}$ sec. 24, 8S, 4 W Marion County	Abandoned at 5,282 feet
Permit No. 68 API 36-009-00006 NNG-Crown Zellerbach 2	NW$\frac{1}{4}$ sec. 8, 4N, 3W Columbia County	Abandoned at 5,805 feet

Well records on drilling in Oregon are required to be kept confidential for 2 years after completion or abandonment but then are opened to the public.

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IN MEMORIAM
Roscoe E. Stewart

Roscoe E. Stewart, former micropaleontologist with the Department, died in Portland, Oregon on Sunday, November 1, 1975, at the age of 84. He was employed by the Department in 1944 and retired in 1959 after 15 years of service. Roscoe Stewart and his wife, Katherine C., contributed much to the knowledge of West Coast micropaleontology.

He began his education at Northwestern University in Illinois in 1915. His schooling was interrupted by World War I when he served overseas as an officer in France and Germany. He resumed his education at the University of Chicago after returning home from the war and graduated with a B.S. degree in geology in 1923. Roscoe attended Columbia University, New York, where he studied micropaleontology. The following year he and his wife, Kay, studied under the renowned Dr. Joseph Cushman at the Cushman Laboratory in Sharon, Mass. Roscoe and Kay continued their paleontological studies at the University of Southern California and both received M.S. degrees from that school in 1935. This common interest, which began at the University of Chicago where they first met, was continued over the next three decades. They coauthored the Department's Bulletin 36, Papers on Tertiary Foraminifera, with Dr. Cushman, and Roscoe published several articles with the Department on micropaleontology.

Survivors include a daughter, Mary Jane (Mrs. Campbell) Wade, Charlottesville, Virginia.

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COOS AND DOUGLAS COUNTIES ENVIRONMENTAL GEOLOGY

"Environmental Geology of Western Coos and Douglas Counties, Oregon," the latest of the Department's bulletins on environmental geology of Oregon counties, has been published as Bulletin 87. Authors are Dr. John D. Beaulieu, Department stratigrapher and environmental geologist, and Dr. Paul W. Hughes, a consulting geologist.

The study area is the western half of Coos County and the northwestern-most corner of Douglas County extending east to Scottsburg. The report is written for the use of planners, engineers, and construction personnel, as well as the professional geologists and resource specialists. It discusses engineering geology, mineral resources, geologic hazards (wave and wind erosion, floods, tsunamis, storm surges, landslides, stream erosion, and earthquake potential), and geology of estuaries and relates these to land uses.

The 148-page report, including 16 maps in color and at a scale of 1:62,500, is available for $9.00 at the Department offices in Portland, Baker, and Grants Pass.

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PLAN FOR ISSUANCE OF EARTHQUAKE PREDICTIONS PROPOSED

For the first time, a Federal plan for issuance of earthquake predictions and warnings has been proposed for consideration by Federal, State, and local agencies. The plan was outlined in early November by Dr. V. E. McKelvey, Director of U.S.G.S., at a conference on earthquake warning and response.

McKelvey emphasized that although not now operational, a capability for reliable earthquake prediction can be expected to be developed in the near future.

"We are now entering an age," the U.S.G.S. Director said, "when scientific instruments are detecting geophysical signals that can be interpreted to forecast earthquake occurrence. Because of increasing optimism about reaching the long-sought goal of earthquake prediction, it is not premature to consider a plan to issue predictions."

"A prediction, as we are using it here," McKelvey explained, "is a statement that an earthquake will occur at a certain time and place, have a certain magnitude, and produce certain effects. A warning is a recommendation or order to take some defensive action, such as to reduce the water level in a reservoir or to evacuate a building."

In the proposed plan, the U.S. Geological Survey has the responsibility to issue a prediction, but local officials have the responsibility to issue a warning. The following are some key elements in the proposed plan:

Scientists of the USGS Office of Earthquake Studies receive and interpret data from field instruments and are the starting point for contact with the public.

A peer review will be provided by the USGS Earthquake Prediction Council composed of five to ten Survey scientists with experience covering all aspects of earthquake prediction technology, plus scientists from outside the USGS with expertise to contribute.

The Earthquake Prediction Council's report would go to USGS headquarters, Reston, Va., where the decision would be made on issuing a prediction.

USGS headquarters would issue a statement to the Governor of the State potentially affected, to Federal agencies with responsibilities for disaster preparedness and response, and to the public.

The Governor's office would alert the State office(s) concerned with disaster response and might also call together his own group of experts to evaluate the evidence.

Scientists not funded by the USGS who find evidence of an earthquake precursor are not specifically considered in this plan. "We believe, however," McKelvey said, "that these other scientists would discuss their data with either the USGS Council or the State review group."

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THESES ON OREGON GEOLOGY ADDED TO LIBRARY

The following unpublished master's theses and doctoral dissertations have been added to the Department's library (not available on loan, however):

Armentrout, John M., 1973, Molluscan paleontology and biostratigraphy of the Lincoln Creek Formation, late Eocene-Oligocene, s.w. Washington. Univ. Wash. doctoral.

Avolio, Gennaro W., 1973, Granulometric analysis of recent sediments of Tillamook Bay, Oregon. PSU master's.

Cordell, Donald A., 1973, Geology of the Pedro Mountain tonalite and associated rocks, n.e. Oregon. Univ. Oregon master's.

Dingus, Delmar D., 1974, The nature and properties of amorphous colloids formed from Mazama tephra. OSU doctoral.

Doak, Wm. H., 1972, Cation retention and solute transport related to porosity of pumiceous solids. OSU doctoral.

Donato, Mary M., 1975, The geology and petrology of a portion of the Ashland Pluton, Jackson County, Oregon. Univ. Oregon master's.

Dudas, Marvin J., 1973, Mineralogy and trace element chemistry of Mazama ash soils. OSU doctoral.

Gaston, Larry R., 1975, Biostratigraphy of the type Yamhill Formation, Polk County, Oregon. PSU master's.

Hales, Peter O., 1975, Geology of Green Ridge area, Whitewater River quadrangle, Oregon. OSU master's.

Harris, Billy L., 1973, Genesis, mineralogy, and properties of Parkdale soils, Oregon. OSU doctoral.

Jackson, Ronald L., 1975, A mineralogical and geochemical study of the ferruginous bauxite deposits in Columbia County, Oregon and Wahkiakum County, Washington. PSU master's.

Jarman, Clara B., 1973, Clay mineralogy and sedimentary petrology of the Cretaceous Hudspeth Formation, Mitchell, Oregon. OSU doctoral.

Johnson, Floyd R., 1975, Geology of the Quartzburg mining district, Grant County, Oregon. OSU master's.

Kienle, Clive F., Jr., 1971, The Yakima Basalt in western Oregon and Washington. Univ. Calif., Santa Barbara doctoral.

Klosterman, Keith E., 1974, An evaluation of the ERTS I imagery in a structural study and a map application of ERTS I imagery in s.w. Washington, n.e. Oregon, and part of w. Idaho. Univ. Wash. master's.

Mathiot, Richard K., 1973, A preliminary investigation of the land use limitations of the major landforms along a portion of the Lincoln County coast, Oregon. PSU master's.

Maynard, Leroy C., 1974, Geology of Mount McLoughlin. Univ. Oregon master's.

Neal, Kenneth G., 1973, A tectonic study of part of n. Eagle Cap Wilderness area, n.e. Oregon. PSU master's.

Parker, Donald J., 1974, Petrology of selected volcanic rocks of the Harney Basin, Oregon. OSU doctoral.

Reckendorf, Frank F., 1973, Techniques for identifying flood plains in Oregon. OSU doctoral.

Rooth, Guy H., 1974, Biostratigraphy and paleoecology of the Coaledo and Bastendorff Formations, s.w. Oregon. OSU doctoral.

Seeley, Wm. O., 1974, Geology of the s.e. quarter of the Dixonville quadrangle, Oregon. Univ. Oregon master's.

Stembridge, James E., Jr., 1975, Shoreline changes and physiographic hazards of the Oregon Coast. Univ. Oregon doctoral.

Storm, Allen B., 1975, Stratigraphy and petrology of the Grassy Mountain Formation, Malheur County. Univ. Oregon master's.

Stovall, James C., 1929, Pleistocene geology and physiography of the Wallowa Mountains with special reference to the Wallowa and Hurricane Canyons. Univ. Oregon master's.

Tang, Rex Wai-Yuen, 1974, Geothermal exploration by telluric currents in the Klamath Falls area, Oregon. OSU master's.

Tucker, Elizabeth R., 1975, Geology and structure of the Brothers Fault Zone in the central part of the Millican s.e. quadrangle, Deschutes County, Oregon. OSU master's.

Wells, Ray E., 1975, The geology of the Drake Peak rhyolite complex and the surrounding area, Lake County, Oregon. Univ. Oregon master's.

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PS Form 3526 (Page 1) Jan. 1975 — *(See instructions on reverse)*

COASTAL EROSION REPORTS ISSUED BY OSU

Two reports recently issued by the School of Oceanography, Oregon State University, discuss the effects of erosion of two large spits on the Oregon Coast where housing developments have been either threatened or destroyed. The reports, which may be consulted at the Department library, are:

1. "Development and Erosion History of Bayocean Spit, Tillamook, Oregon," by T. A. Terich and P. D. Komar; Oregon State Univ. Sch. of Ocean. Reference 73-16, 145 pages, photos, maps.
2. "The Erosion of Siletz Spit, Oregon," by C. C. Rea and P. D. Komar; Oregon State Univ. Sch. of Ocean. Reference 75-4, 105 pages, photos, and maps.

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BLM ISSUES OIL AND GAS LEASES IN COLUMBIA COUNTY

Eight oil and gas leases on 14,079 acres of Federal land in Columbia County have been issued by the Bureau of Land Management. The land is between Vernonia and Scappoose; leases are for 10 years at 50¢ per acre per year.

Four BLM leases were issued to Gas Producing Enterprises, Inc., of Houston, Texas. They totaled 8,459.12 acres. Other leases were to: Janet K. Dorman, Golden, Colorado, 1,620.20 acres; David A. Forson, Lakewood, Colorado, 1,892.96 acres; Dorothy L. Wahle, Littleton, Colorado, 280.0 acres; and Faye A. Reuth, Lakewood, Colorado, 1,826.90 acres.

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WEYERHAEUSER-PPL TO DRILL GEOTHERMAL TEST

The Department issued a geothermal drilling permit to Weyerhaeuser and Pacific Power & Light Co. on October 28, 1975 to drill a 2,000-foot exploratory hole approximately 8 miles northwest of the city of Klamath Falls in the NW¼, sec. 15, T. 37 S., R. 7 E., Klamath County. The hole is being drilled on lands owned by Weyerhaeuser under a joint operating agreement.

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SAN JUAN OIL CO. TO DRILL FOR STEAM

The Department issued a permit to the San Juan Oil Co. of Tulsa, Oklahoma to drill a 7,500-foot geothermal well in Lake County. The well is located in NW¼ sec. 22, T. 38 S., R. 24E., approximately 1 mile southeast from the town of Adel in Warner Valley. San Juan is drilling the well on a Gulf Oil Co. lease under a "farm out" arrangement.

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AVAILABLE PUBLICATIONS

(Please include remittance with order; postage free. All sales are final - no returns. Upon request, a complete list of Department publications, including out-of-print, will be mailed.)

BULLETINS

26.	Soil: Its origin, destruction, preservation, 1944: Twenhofel.	$0.45
33.	Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen .	1.00
35.	Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin . . .	3.00
36.	Papers on Tertiary foraminifera: Cushman, Stewart & Stewart.	vol. 2-1.25
39.	Geology and mineralization of Morning mine region, 1948: Allen and Thayer . .	1.00
44.	Bibliography (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere.	1.00
46.	Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25
49.	Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch . . .	1.00
52.	Chromite in southwestern Oregon, 1961: Ramp	5.00
53.	Bibliography (3rd suppl.) geology and mineral resources of Oregon, 1962: Steere, Owen	3.00
57.	Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors . .	3.50
60.	Engineering geology of Tualatin Valley region, 1967: Schlicker and Deacon . .	7.50
61.	Gold and silver in Oregon, 1968: Brooks and Ramp	7.50
62.	Andesite Conference Guidebook, 1968: Dole	3.50
64.	Geology, mineral, and water resources of Oregon, 1969	3.00
65.	Proceedings of the Andesite Conference, 1969: McBirney, editor (photocopy) . .	10.00
66.	Geology and mineral resources of Klamath and Lake Counties, 1970.	6.50
67.	Bibliography (4th suppl.) geology and mineral industries, 1970: Roberts . . .	3.00
68.	Seventeenth biennial report of the Department, 1968-1970	1.00
69.	Geology of the southwestern Oregon Coast, 1971: Dott	4.00
70.	Geologic formations of western Oregon, 1971: Beaulieu	2.00
71.	Geology of selected lava tubes in the Bend area, 1971: Greeley	2.50
72.	Geology of Mitchell quadrangle, Wheeler County, 1972: Oles and Enlows . .	3.00
73.	Geologic formations of eastern Oregon, 1972: Beaulieu	2.00
75.	Geology, mineral resources of Douglas County, 1972: Ramp	3.00
76.	Eighteenth biennial report of the Department, 1970-1972.	1.00
77.	Geologic field trips in northern Oregon and southern Washington, 1973. . . .	5.00
78.	Bibliography (5th suppl.) geology and mineral industries, 1973: Roberts and others	3.00
79.	Environmental geology inland Tillamook Clatsop Counties, 1973: Beaulieu. . .	7.00
80.	Geology and mineral resources of Coos County, 1973: Baldwin and others . . .	6.00
81.	Environmental geology of Lincoln County, 1973: Schlicker and others	9.00
82.	Geol. Hazards of Bull Run Watershed, Mult. Clackamas Counties, 1974: Beaulieu	6.50
83.	Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00
84.	Environmental geology of western Linn Co., 1974: Beaulieu and others. . . .	12.00
85.	Environmental geology of coastal Lane Co., 1974: Schlicker and others . . .	12.00
86.	Nineteenth biennial report of the Department, 1972-1974	1.00
87.	Environmental geology of western Coos and Douglas Counties, Oregon, 1975 . .	in press
88.	Geology and mineral resources of upper Chetco River drainage, 1975: Ramp . .	in press

GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck $2.00; mailed -	2.50
Geologic map of Oregon (12" x 9"), 1969: Walker and King	0.25
Geologic map of Albany quadrangle, Oregon, 1953: Allison (from Bulletin 37) . . .	1.00
Geologic map of Galice quadrangle, Oregon, 1953: Wells and Walker	1.50
Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts	1.50
Geologic map of Bend quadrangle, and portion of High Cascade Mtns., 1957: Williams	1.50
GMS-1: Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka	2.00
GMS-2: Geologic map, Mitchell Butte quadrangle, Oregon: 1962	2.00
GMS-3: Preliminary geologic map, Durkee quadrangle, Oregon, 1967: Prostka . .	2.00
GMS-4: Gravity maps, Oregon onshore & offshore; [set only]: at counter $3.00, mailed	3.50
GMS-5: Geology of the Powers quadrangle, 1971: Baldwin and Hess	2.00
GMS-6: Preliminary report, geology of part of Snake River Canyon, 1974: Vallier. .	6.50

[Continued on back cover]

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Available Publications, Continued:

SHORT PAPERS

18. Radioactive minerals prospectors should know, 1955: White and Schafer $0.30
19. Brick and tile industry in Oregon, 1949: Allen and Mason 0.20
21. Lightweight aggregate industry in Oregon, 1951: Mason 0.25
24. The Almeda mine, Josephine County, Oregon, 1967: Libbey 3.00

MISCELLANEOUS PAPERS

1. Description of some Oregon rocks and minerals, 1950: Dole 1.00
2. Oregon mineral deposits map (22 x 34 inches) and key (reprinted 1973): 1.00
4. Rules and regulations for conservation of oil and natural gas (rev. 1962) 1.00
5. Oregon's gold placers (reprints), 1954 . . . . 0.50
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton 3.00
7. Bibliography of theses on Oregon geology, 1959: Schlicker 0.50
   (Supplement) Bibliography of theses, 1959 to Dec. 31, 1965: Roberts 0.50
8. Available well records of oil and gas exploration in Oregon, rev. 1963: Newton . 1.00
11. A collection of articles on meteorites, 1968 (reprints from The ORE BIN) 1.50
12. Index to published geologic mapping in Oregon, 1968: Corcoran 0.50
13. Index to The ORE BIN, 1950-1974. . . . . 1.50
14. Thermal springs and wells, 1970: Bowen and Peterson 1.50
15. Quicksilver deposits in Oregon, 1971: Brooks 1.50
16. Mosaic of Oregon from ERTS-1 imagery, 1973: 2.50
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975 . . . 2.00

OIL AND GAS INVESTIGATIONS

1. Petroleum geology, western Snake River basin, 1963: Newton and Corcoran . . . 3.50
2. Subsurface geology, lower Columbia and Willamette basins, 1969: Newton . . . 3.50
3. Prelim. identifications of foraminifera, General Petroleum Long Bell No. 1 well . . 2.00
4. Prelim. identifications of foraminifera, E. M. Warren Coos Co. 1-7 well: Rau . . 2.00

MISCELLANEOUS PUBLICATIONS

Landforms of Oregon: a physiographic sketch (17" x 22"), 1941 . . . . 0.25
Mining claims (State laws governing quartz and placer claims) 0.50
Oregon base map (22" x 30"). 0.50
Geologic time chart for Oregon, 1961 . . . . free
Postcard - geology of Oregon, in color . . . . 10¢ each; 3 - 25¢; 7 - 50¢; 15 - 1.00
The ORE BIN - Annual subscription . . . . ($8.00 for 3 yrs.) 3.00
   Available back issues, each . . . . 25¢; mailed 0.35
   Accumulated index - see Misc. Paper 13