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Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of the bibligraphic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Model of *Tyrannosaurus*, one of a group of animated dinosaur models created by Dinamation International Corp. that are on display through February in the exhibit "Dinosaurs II" at the Oregon Museum of Science and Industry (OMSI). Photo courtesy Burt Peterson and OMSI.

Tyrannosaurus lived during the Late Cretaceous, the period that concluded the Mesozoic era. The cause of mass extinctions that mark the boundaries between geologic eras is the topic of an upcoming lecture program at OMSI. Abstracts of the papers to be presented are printed in article beginning on next page.

OIL AND GAS NEWS

Mist Gas Field

ARCO has finished its 1987 drilling program at Mist with two more successful wells. The Columbia County 21-35-65 and the Foster 42-30-65 were drilled to depths of 1,924 and 2,658 ft, respectively, and both are currently suspended, awaiting connection to gas pipeline. This means ARCO's 1987 drilling program at Mist Gas Field resulted in seven new-pool gas discoveries, one dry hole, and one dry redrill. This is the highest number of new pool discoveries made in a single year since the discovery well at Mist was drilled in 1979.

Production rates for these wells have not yet been released, but may be released in the near future.

Gas production summaries for 1987

During 1987, cumulative gas production at Mist Gas Field was approximately 3.8 billion ft^3 of gas for a value of about $5.9 million. This is down somewhat from the approximately 4.6 billion ft^3 of gas for a value of about $9.2 million produced during 1986. Cumulative gas production at Mist since the 1979 discovery is approximately 31.6 billion ft^3 of gas.

There are currently 12 producing gas wells at Mist, all operated by ARCO, with seven new pool discoveries awaiting gas pipeline connection during 1988. The Tenneco Columbia County 41-28 well was suspended in September pending abandonment.

Mist Gas Field map updated

The Mist Gas Field map has been updated through December 1987 and is now available as DOGAMI Open-File Report O-88-02. It supersedes Open-File Report O-84-04. The purchase price is $5.00. □

Board of Geologist Examiners issues policy for professionals in hydrogeology and geothermal geology

At its regular meeting in Salem on November 10, 1987, the Board of Geologist Examiners adopted the following policy statement, which affects the public practice of geology in Oregon:

In response to questions presented to it, the Board of Geologist Examiners has reviewed the issue of registration requirements for individuals practicing in the fields of hydrogeology and geothermal geology. The review process included the establishment of a subcommittee, solicitation of comments from the community of registered geologists and certified engineering geologists, and discussion of the issue by Board members.

In considering this issue, the goals of the Board have been to ensure minimum risk to the general public, to adhere to the provisions of the statutes and administrative rules governing Board activities, to promote the availability of efficient and economical geologic services, and to ensure the freedom of professionals to pursue gainful practice.

The Board feels that the public practice of hydrogeology and geothermal geology in Oregon clearly is under the category of activities requiring registration and that any person practicing in these fields must be registered as a geologist by the Board. The Board also feels that, as is the case in most fields of geology, the practice of hydrogeology and geothermal geology can and does encompass a broad range of geologic expertise and is clearly not limited to the domain of engineering geology. Because of this, persons practicing in these fields are not required to be certified by the Board as engineering geologists.

However, any registered geologist practicing in the field of hydrogeology or geothermal geology must adhere to the Code of Professional Conduct (Chapter 809 of Oregon Administrative Rules) and must be competent by both training and experience to engage in that practice. —*Board of Geologist Examiners news release*

Mass extinctions: Meteorites or evolution?

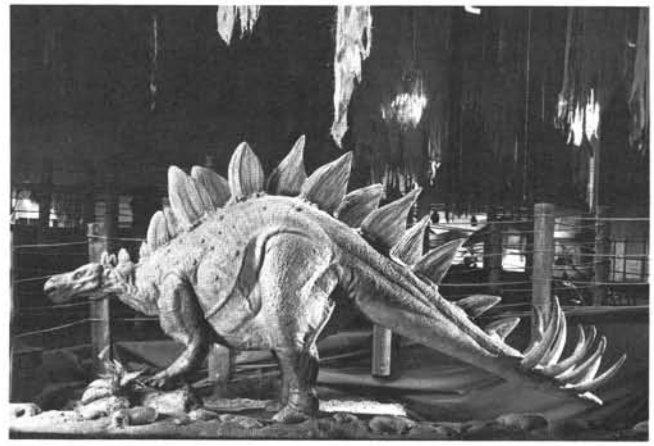
by R.E. Corcoran, private consultant and former State Geologist, Portland, Oregon; D.J. McLaren, Professor of Geology, Department of Geology, University of Ottawa, Ottawa, Canada; William N. Orr, Professor of Geology and Paleontology, Department of Geology, University of Oregon, Eugene, Oregon; and Peter D. Ward, Professor of Geology, Department of Geological Sciences, University of Washington, Seattle, Washington

INTRODUCTION

by R.E. ("Andy") Corcoran

Catastrophic events in the earth's past history are usually of great interest to the general public as well as to scientists. The controversy surrounding the demise of the dinosaurs is certainly no exception. No one is completely certain of the real reason at this time, but it should be largely determined within a few years when ongoing field studies have been completed. In the meantime, the public is being given a rare opportunity to follow the development of an important scientific theory.

The Geological Society of the Oregon Country (GSCO), the Oregon Museum of Science and Industry (OMSI), and the Department of Geology at Portland State University are sponsoring a series of lectures concerning the earth and its development. On February 12, 1988, the second of this series will deal with theories of mass extinction through geologic time. The emphasis will be on the nature of the Cretaceous-Tertiary (K-T) boundary. Three distinguished scientists will be addressing this topic: Dr. William N. Orr, Professor of Geology and Paleontology at the University of Oregon; Dr. Digby J. McLaren, Professor of Geology at the University of Ottawa, Canada; and Dr. Peter D. Ward, Professor of Geology at the University of Washington. Abstracts of the papers they will be presenting at the February lecture and a list of selected reading are printed below.



Model of Late Jurassic Stegosaurus *from "Dinosaur II" exhibit at OMSI mentioned in cover photo caption on previous page. Photo courtesy Burt Peterson and OMSI.*

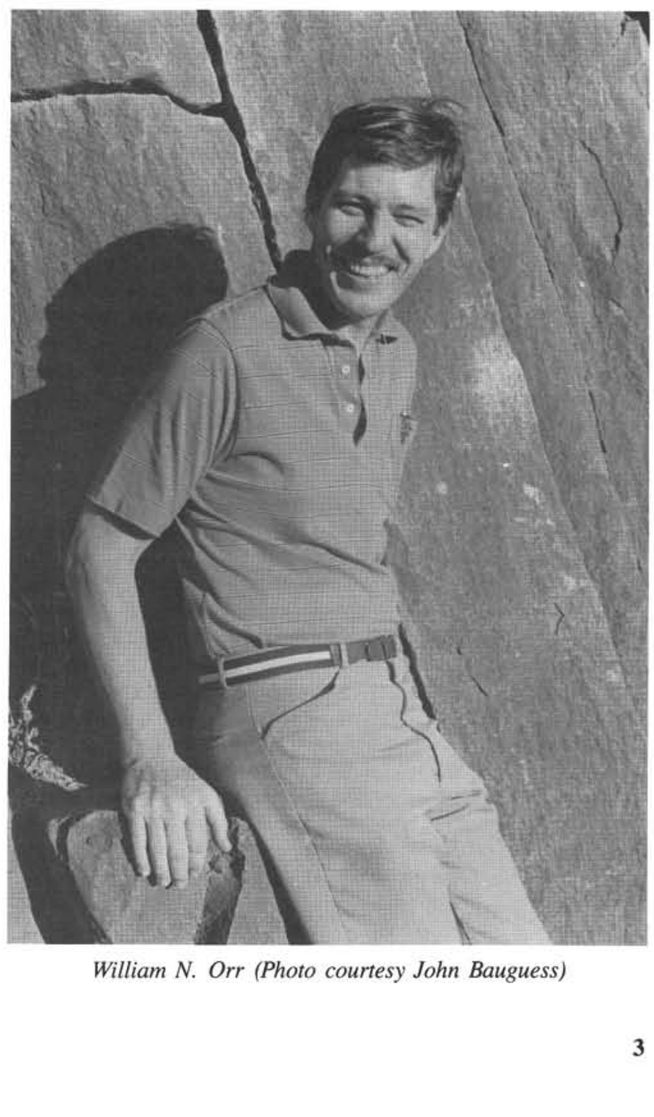
THE TERMINAL CRETACEOUS EVENT: CATASTROPHE OR HYPE?

by William N. Orr

Geologic events that capture the public's imagination are ordinarily real-time happenings such as earthquakes and their stepchildren—tidal waves, volcanoes, landslides, and avalanches. The geologic event that rivets our attention here is none of the above in that it caused no loss of human life or property, and it occurred some 65 million years ago (Ma). Very early on in their study of the earth, geologists came to divide the time scale on the basis of easily recognized changes they noticed in the fossil record at 570 Ma, 240 Ma, and 66 Ma (the Precambrian-Cambrian boundary, the Permo-Triassic boundary, and the Mesozoic-Cenozoic boundary). The most profound of these was without question the Permo-Triassic boundary, when as many as 95 percent of the then-living species experienced extinction. This boundary represents the earth's closest call ever with total annihilation. While the Mesozoic-Cenozoic (or Cretaceous-Tertiary [K-T] boundary) cannot boast nearly the extinction ratio of the Permo-Triassic, it is the current darling of science writers everywhere because (1) its cast of characters included dinosaurs and enormous meteorites as well as a possible "death-star"; and (2) its possible byproducts include a nuclear-winter-style "darkness at noon," acid rain, global wildfires, and tidal waves.

In 1980, Berkeley physicists discovered abnormally high amounts of the element iridium in the K-T boundary interval in Italy. They hypothesized that the concentration of iridium might represent extraterrestrial fallout from a huge meteorite crashing into the earth at 66 Ma to wreak havoc with the earth's biota of that period. Later published reports of abnormal amounts of carbon (soot) at the same level combined with a sprinkling of "shocked" quartz grains and spherules of what looked like microtektites greatly heightened the excitement surrounding the theory.

Meanwhile, back at the fossil beds, paleontologists have in the



William N. Orr (Photo courtesy John Bauguess) cold light of day slowly begun to reexamine the biological events surrounding the K-T boundary and have been able to demonstrate that (1) the "catastrophe" involved several but not all groups of plants and animals; (2) the "event" as recorded by the fossil record is more often than not gradual and not sudden, in some cases beginning several hundred thousand years *prior* to the K-T boundary; and (3) dinosaurs lived well beyond the K-T boundary, and the youngest occur hundreds of thousands of years above the boundary. Worse yet, volcanologists have only recently written papers to suggest that both iridium and shocked quartz might easily be volcanologically derived. Meanwhile, "microtektite" spherules at the K-T boundary have been shown to be unequivocally authigenic and not extraterrestrial in origin. Standing in the wreckage of their rapidly crumbling theory, physicists have retrenched and now suggest "multiple impacts" of meteorites in the general K-T boundary interval. Stay tuned...

Aside from the actual heat of the battle now being fought, this is a major idea of earth and astronomical science that the interested public is monitoring step by step as it matures. Certainly not all bets are in, but most scientists would expect to see the major features of this idea resolved in the next two or three years. Resolution entails careful petrographic, geochemical, and paleontological examination of available K-T boundary sections worldwide. The focus will be a search for a series of events (or lack thereof) common to all the sections. In the meanwhile, the public is being given a rare opportunity to track the progress of an important scientific idea or theory as it evolves.

DETECTION AND SIGNIFICANCE OF MASS KILLINGS
by Digby J. McLaren

Mass killings that involve a large number of animals or plants are found as abrupt disappearances of organisms in the rock succession in many parts of the world. Some are known that appear to have occurred synchronously over wide areas in several continents and, where the record is preserved, in several oceans. Such synchroneity may be difficult to prove but suggests a common cause. Alternative hypotheses are necessarily complex. Such mass killings identify a horizon that may be examined for evidence of cause. Certain misconceptions have developed concerning detection of sudden events. Plotting changes in diversity and the names of genera or families that disappeared against time are of dubious value in detecting periodicity of extinctions and cannot identify an event horizon with any precision. Less common taxa (i.e., named groups) often show a gradual decline before any arbitrary horizon, and survivors after a major disturbance are (fortunately) not uncommon. Geochemical markers may be ephemeral, and their absence may not be significant. Ultimate causes are discussed—impacts of meteoroids or comets and episodes of a paroxysmal volcanicity—although it may be that no single cause was responsible for all events. It appears unlikely that ongoing phenomena such as climate and sea-level changes are primary causes of anomalous episodic extinctions.

Digby J. McLaren

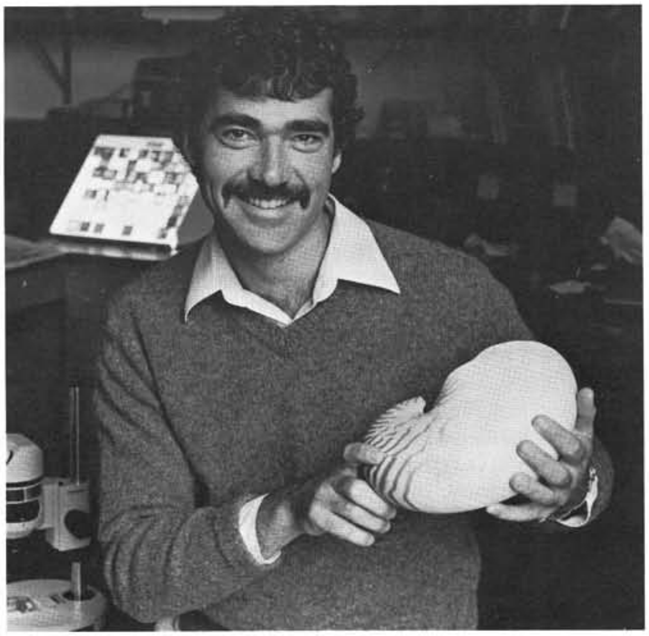
THE CRETACEOUS-TERTIARY BOUNDARY EXTINCTION AND ITS EFFECT ON MARINE INVERTEBRATES
by Peter D. Ward

It has long been known that geologic time is punctuated by a number of major changes in the earth's fossil content, times when a large percentage of animals that previously had left skeletal remains as fossils suddenly disappear from the earth's fossil record. These periods of rather rapid change in the fossil faunas were used by 19th-century geologists to divide the fossil record into major groupings. Today, the three largest divisions of geological time (since the advent of common skeletonized life beginning about 560 Ma) are called (1) the Paleozoic Era, or time of ancient life; (2) the Mesozoic Era, or time of middle life; and (3) the Cenozoic Era, or time of modern life. These three great divisions are separated by mass extinctions, when as many as 95 percent of the species leaving fossils underwent extinction in time periods as short as several million years or less.

One of these mass extinctions ends the Mesozoic Era, which was characterized by dinosaurs on land and curious shelled cephalopods and large reclining bivalves in the sea. These latter two groups, respectively called ammonites and inoceramid bivalves, disappeared at the end of the Mesozoic Era in one of the most interesting of all the mass extinctions. Much research has centered on this particular mass extinction, in large part because of the hypothesis suggesting that this extinction was caused by the impact of one or more extraterrestrial bodies, such as meteors or comets, striking the earth with catastrophic consequences for life on land and in the sea.

In order to resolve whether or not this particular extinction was indeed caused by a catastrophic event of extraterrestrial source rather than longer term changes normal and inherent in earth processes, we need to closely examine the record of fossils in actual piles of sedimentary rock from many localities of the same age. This type of painstaking work is actively being pursued to answer the following fundamental questions: Did the extinctions on land and the sea occur at the same time? How long did the extinctions take? Were the extinctions selective, or did all groups and environmental types of organisms suffer equally? Do the stratigraphic sections giving information about the extinctions record the time when the extinctions took place, or are they only time averages, masking much information?

My research has centered on a depositional basin of Cretaceous age now found in the Bay of Biscay in Europe. In this talk, I will present data about these European stratigraphic sections that will give information pertaining to questions about mass extinctions.



Peter D. Ward

LECTURE PROGRAM INFORMATION

These papers will be presented to the public at a lecture at 7:30 p.m. on February 12, 1988, at OMSI. Tickets will go on sale on February 1. The price of the lecture for OMSI and GSOC members is $3.50, for student or senior-citizen members $2; the cost for nonmembers is $4 and for student or senior-citizen nonmembers $2.50.

SUGGESTED READING

Alvarez, L.W., 1987, Mass extinctions caused by large bolide impacts: Physics Today, July 1987, p. 24-33.

Gerstel, J., Thunell, R., and Ehrlich, R., 1987, Danian faunal succession: Planktonic foraminiferal response to a changing marine environment: Geology, v. 15, no. 7, p. 665-668.

Izett, G.A., 1987, Authigenic "spherules" in K-T boundary sediments at Caravaca, Spain, and Raton Basin, Colorado and New Mexico, may not be impact derived: Geological Society of America Bulletin, v. 99, no. 1, p. 78-86.

McLaren, D.J., 1970, President's address: Time, life, and boundaries: Journal of Paleontology, v. 44, no. 5, p. 801-814.

Olsen, P.E., Shubin, N.H., and Anders, M.H., 1987, New Early Jurassic tetrapod assemblages constrain Triassic-Jurassic tetrapod extinction event: Science, v. 237, p. 1025-1029.

Petrusky, B., 1986, Mass extinctions: The biological side: Mosaic, v. 17, no. 4, p. 3-13. □

NWMA elects new president, honors students

At its 93rd annual convention held in December 1987 in Spokane, Washington, the Northwest Mining Association (NWMA) announced the election of William B. Booth as its president for 1988. The NWMA has 1,400 individual and 130 corporate members and attracted over 2,000 attendants to the convention.

Booth is assistant to the vice president of investor and public affairs for Hecla Mining Company in Coeur d'Alene, Idaho. He grew up in Post Falls, Idaho, did his undergraduate work at the University of Idaho, and earned his master's degree in business administration at the University of North Dakota while serving in the Air Force as a captain in missile maintenance.

Booth, who succeeds Bernard Guarnera as president, has been a director of the NWMA since 1981 and has worked in the mining industry for 15 years, the past two years with Hecla.

Five prizes were awarded in the convention's student poster contest. The awards were judged on the basis of how well the papers and posters explained the students' technical papers on mining. Chairman of the poster contest was Professor Ernest H. Gilmour of Eastern Washington University. Prizes were donated by the Wray D. Farmin family and the William C. Jordan Fund. The prizes, winners, and their topics were as follows:

Most outstanding poster (a calculator and $100): Jacob Margolis, University of Washington, on "Epithermal gold mineralization, Wenatchee, Washington: Hydrothermal aquifers and structure."

First place ($250): Terri Plake, Western Washington University, on "Structural analysis of the Colebrooke Schist, southwestern Oregon."

Second place ($100): Robert Hammond, University of Idaho, on "Radar mapping of sulfide zones beneath glaciers."

Third place ($75): David Szumigala, UCLA, on "The Tin Creek zinc-lead silver skarn prospects, Farewell Mineral Belt, Alaska."

Fourth place ($50): Jeff Cary and Joe Dragovich, Western Washington University, on "The geology and economic potential of late Triassic metavolcanic area rocks and Cretaceous plutons in the Marble Creek area, Skagit County, Washington."

—Compiled from NWMA news releases

Field mappers working on Oregon-Idaho projects

Field mapping crews from the U.S. Geological Survey (USGS) are working in five counties in Oregon and Idaho, gathering and checking field data that will be used in producing 48 new topographic maps covering about 2,520 mi² of land and water.

Twelve crews of cartographers and field assistants from the USGS Mid-Continent Mapping Center in Rolla, Mo., have been working their way along trails and roads, across pastures and up steep slopes in Baker, Wallowa, and Union Counties in eastern Oregon and Adams and Idaho Counties in western Idaho to locate benchmarks, determine elevations, measure distances, verify occupied and abandoned structures, and locate public boundaries.

The USGS mapping crews have established field offices in Enterprise, Oregon, for the work in both states. Enterprise residents J.R. Bissett, J.W. Ryan, P.O. Schallert, and D.R. Yaccarino have been hired as local field assistants. Transportation for the crews to field areas that are often remote and difficult to reach is by pack horses, in four-wheel-drive vehicles, or on foot.

Much of the Oregon and Idaho mapping is being conducted on federal, state, and state-leased land, but private property is also being mapped and must be traversed when necessary, according to District Cartographer David Bennett of Rolla. Bennett emphasized that the mappers need the cooperation of landowners in allowing USGS crews to go on their properties. "We respect property rights, try to cause as little disruption as possible, and never go on anyone's land without permission," Bennett said. "All we need is access for the short time it takes us to do our work."

The surveyors are using sophisticated electronic distance-measuring instruments and theodolites, as well as the traditional surveyor's alidade and stadia (rods) to measure horizontal and vertical distances and determine elevations. They measure each distance twice to reduce the possibility of errors.

Each of the 48 new maps to be produced from the projects will be at a scale of 1:24,000 (one inch on the map representing about 2,000 ft on the ground) and will cover an area of 7.5 minutes of latitude by 7.5 minutes of longitude or approximately 55 mi². It is the first time these areas in Oregon and Idaho are being mapped at this scale, although various parts were mapped in the 1950's at a less detailed scale.

The new maps, which will be available in about three years, will show individual buildings in rural areas, as well as outbuildings, water and fire towers, civic buildings, campgrounds, and camp shelters. The various types of roads and trails will be designated by solid or dashed lines. Political boundaries, such as city limits, county lines, wilderness boundaries, and the boundaries of state-owned and state-controlled land, will also be outlined.

During their stay in Oregon and Idaho, the USGS mappers are available to talk to civic groups and interested individuals about their work and the USGS mapping program. Inquiries may be directed to David Bennett at the USGS Mid-Continent Mapping Center, Mail Stop 311, 1400 Independence Road, Rolla, MO 65401, phone (314) 341-0885; or to James T. Felkerson, Projects Chief, P.O. Box 218, Enterprise, OR 97828, phone (503) 426-4621.

Information about the mapping projects is also available, in Oregon, from Glenn W. Ireland, State Resident Cartographer, USGS, 847 NE 19th Ave., Portland, OR 97232, phone (503) 231-2019; and in Idaho from Michael Sety, State Resident Cartographer, Idaho Department of Lands, 801 S. Capitol Blvd., Boise, ID 83702, phone (208) 334-2419.

As the nation's largest civilian mapping agency, the USGS expects to sell and distribute, in 1987, more than 7 million copies of its more than 74,000 published topographic and thematic maps. Indexes listing the availability, prices, and outlets for Oregon and Idaho are available free from Map Distribution, USGS, Box 25286, Federal Center, Denver, CO 80225, phone (303) 236-7477. The Oregon Department of Geology and Mineral Industries sells these maps at its Portland office (see first inside page for information).

—USGS news release

USGS develops guidelines for naming aquifers

Guidelines for naming aquifers more systematically have been developed for authors of U.S. Geological Survey (USGS) reports and are described in a recent USGS report.

In the past, aquifer names have been based on a variety of physical, geologic, geographic, and age designations, which has caused confusion among readers of reports that involve descriptions of aquifers. When names are proposed for aquifers, it is recommended now that they be named only after lithologic terms, rock-stratigraphic units, or geographic names, according to the report's authors Robert L. Laney and Claire B. Davidson at the USGS National Center in Reston, Va.

The USGS Water Resources Division is the Nation's largest water-resource information and research agency and publishes more than 1,000 reports each year. The new guidelines are expected to help reduce confusion caused by conflicting or imprecise aquifer terminology in the rapidly expanding field of water-resource studies, which has produced a proliferation of aquifer names.

The report contains examples of comparison charts and tables that are used to define the hydrogeologic framework. Aquifers are defined in 11 hypothetical examples that characterize hydrogeologic settings throughout the country.

Copies of Open-File Report 86-534, *Aquifer-nomenclature Guidelines,* by Robert L. Laney and Claire B. Davidson, may be purchased from the U.S. Geological Survey, Books and Open-File Reports Section, P.O. Box 25425, Federal Center, Bldg. 1, Denver, Colo. 80225, for $8 for each paper copy and $4 for microfiche. Orders must include the report number (OFR 86-534) and checks or money orders payable to the U.S. Department of the Interior—USGS. □

Central Cascades and Gorda Ridge are subjects of new publications

GEOLOGIC MAP OF CRESCENT MOUNTAIN AREA RELEASED

A new geologic map published by the Oregon Department of Geology and Mineral Industries (DOGAMI) and partially funded by the U.S. Department of Energy provides a detailed geologic description of the Crescent Mountain area west of Santiam Pass in the central Oregon Cascade Range. The area includes the transition between rocks of the older Western Cascade Range and the younger High Cascade Range.

Geologic Map of the Crescent Mountain Area, Linn County, Oregon ($6.00), by DOGAMI staff members G.L. Black, N.M. Woller, and M.L. Ferns, has been released in DOGAMI's Geological Map Series as map GMS-47. At a scale of 1:62,500, it covers over 200 square miles of the region both east and west of State Highway 22 between Marion Forks and Santiam Junction. This map complements DOGAMI's recently published map GMS-46 that covered the Breitenbush River area immediately to the north.

The report consists of two parts, a map sheet and a data table sheet. The map sheet (approximately 27 by 40 inches) contains a multicolored geologic map and two geologic cross sections. It describes six surficial and 35 volcanic rock units of Tertiary and younger age and identifies six volcanic vent complexes and eight intrusive rock units in the area. The data-table sheet presents chemical analyses of 77 rock samples and potassium-argon dates for nine samples.

GORDA RIDGE RESEARCH YIELDS TWO MORE REPORTS

DOGAMI has also released two new reports presenting the results of research on the Gorda Ridge. Both reports deal with ecological aspects of this sea-floor spreading region off the coast of southern Oregon and northern California.

Distribution and Abundance of Seabirds in the Vicinity of the Gorda Ridge, off Eureka, California, during July 1986 ($5.00), by D.R. Matthews, has been published as DOGAMI Open-File Report O-87-04. The 49-page report presents research conducted in connection with geologic sea-floor studies at a dive site about 150 nautical miles due west of Eureka, as well as en route to the site. It includes graphs and tables showing seabird distribution and abundance in relation to distance off shore and time of day at the dive site.

Analysis of Benthic Epifaunal Community Structure of the Gorda Ridge ($5.00), by A.G. Carey, Jr., D.L. Stein, and G.L. Taghon of the Oregon State University College of Oceanography, has been published as DOGAMI Open-File Report O-87-05. The 48-page report presents analyses of photographic and video recordings taken by submersibles and camera sleds and of animal collections, all conducted between 1984 and 1986. It is a continuation of earlier research published by DOGAMI in 1986 as Open-File Report O-86-11.

Both reports represent an integral part of the mineral studies in the Gorda Ridge area and will serve as baseline ecological information for assessing the impact of possible submarine mineral exploration on this habitat. DOGAMI published five related ecological reports in 1986 (O-86-06 through O-86-09 and O-86-11).

The Gorda Ridge research program began in 1985 and is directed by the joint federal-state Gorda Ridge Technical Task Force. It is funded by the U.S. Minerals Management Service and managed by DOGAMI.

The new reports are now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. Orders under $50 require prepayment. □

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that we feel are of general interest to our readers.

PETROLOGY OF THE BEND PUMICE AND TUMALO TUFF, A PLEISTOCENE CASCADE ERUPTION INVOLVING MAGMA MIXING, by Brittain Eames Hill (M.S., Oregon State University, 1985 (compl. 1984)

The Bend pumice and Tumalo tuff are products of a Plinian eruption that occurred sometime between 0.89 and 2.6 Ma. The Bend pumice is a poorly consolidated, air-fall vitric lapilli tuff that overlies a zone of reworked tephra. Perlitic obsidian in the reworked zone probably represents the remains of a dome that filled the eruptive vent and is chemically related to the Bend pumice magma. Detailed grain-size analysis of the air-fall part of the Bend pumice shows that the eruptive vent was located approximately 10-20 km west of Bend, Oregon. Grain-size variations in the vertical section are probably related to fluctuations in the diameter of the vent rather than interruptions in deposition of the Bend pumice.

The Tumalo tuff is a nonwelded to moderately welded ash-flow tuff that directly overlies the Bend pumice. Lack of discernible normal grading in the upper 50 cm of the Bend pumice indicates that the Tumalo tuff was emplaced before the Bend pumice was completely deposited and leads to the conclusion that the Tumalo tuff is the product of collapse of the Bend pumice eruption column. The Tumalo tuff was formed by one episode of flow and has a well-developed basal 2a layer. Variations in the distal character of layer 2a are thought to represent complex flow conditions in the head of the Tumalo tuff ash flow. Mixed pumices also are found in proximal Tumalo tuff deposits.

The Bend pumice and Tumalo tuff are peraluminous and rhyodacitic. Within analytical uncertainties, they have identical major, minor, and trace element abundances. Both contain fresh hornblende in the mineral assemblage Plg + Opx + Mgt + Zr + Ap. The hornblende appears to have been a liquidus phase and indicates that the rhyodacite evolved under high-pressure, hydrous conditions. A higher La to Ce ratio and a strong negative Eu anomaly in the Bend-Tumalo rhyodacite further indicate that the Bend pumice and Tumalo tuff evolved under physical conditions quite distinct from other rhyodacites in the central Oregon High Cascades analysed by Hughes (1982).

Mixed pumices in the Tumalo tuff represent the incomplete mixing between Bend-Tumalo rhyodacite and a dacitic magma. Trace element modeling fails to provide an unequivocally common path of crystal fractionation between these two magmas. The magmas cannot be directly related through thermogravitational diffusion or assimilation. While mixed pumice formation is usually attributed to mixing of genetically related magmas, Tumalo tuff mixed pumices were produced through the mixing of genetically unrelated magmas.

GEOLOGY OF THE FISHHAWK FALLS - JEWELL AREA, CLATSOP COUNTY, NORTHWEST OREGON, by David Ezra Nelson (M.S., Oregon State University, 1985)

The study area is located on the northwest flank of the northern Oregon Coast Range. Seven Tertiary formations compose the bedrock units: the Tillamook Volcanics; the Cowlitz, Keasey, and Pittsburg Bluff Formations; Oswald West mudstone (informal); Astoria Formation (Silver Point member); and Grande Ronde (Depoe Bay) Basalt of the Columbia River Basalt Group.

Major-element geochemistry, petrology, and radiometric ages of volcanic rocks near Green Mountain suggest that this is an upthrown tectonic block of middle to upper Eocene Tillamook Volcanics. This outlier is composed of subaerial basaltic andesite flows and epiclastic debris flows which are intruded by complexes of basaltic andesite dikes. The volcanics typically contain 58-62 percent SiO_2 and reflect a rugged stratovolcano or mid-ocean island that rose above sea level. Radiometric dates from the uppermost part of the upper Tillamook Volcanics in and near this study area are from 37.1 $\pm$ 0.4 m.y. (late middle Eocene) to 42.4 $\pm$ 0.5 m.y. (early late Eocene). Preliminary paleomagnetic investigation of three sites in the Tillamook Volcanics and overlying Cougar Mountain intrusions indicates that 48.4° $\pm$ 26° of clockwise rotation has occurred since the late middle Eocene.

The middle to upper Eocene (Narizian) Cowlitz Formation overlies the Tillamook Volcanics with angular unconformity in the study area. The Cowlitz is an onlapping marine sequence of basaltic and arkosic sandstone and deep-marine turbidite sandstone overlain by a regressive sequence of arkosic sandstone. Four lithofacies are considered informal members of the 465-m-thick Cowlitz Formation. These are: a basal fluvial-littoral basaltic andesite conglomerate (Tc_1), a lower shallow-marine sandstone composed of intrabasinal basaltic sandstone and extrabasinal micaceous arkosic sandstone and mudstone (Tc_2), a thin turbidite sandstone and siltstone unit (Tc_3), and an upper shallow-marine arkosic sandstone (Tc_4). The lower sandstones are volcanic arenites derived locally from the Tillamook Volcanics. They are interbedded with micaceous plagioclase-bearing arkosic sandstone redistributed from the Cowlitz delta of southwestern Washington via longshore drift. The friable arkosic upper sandstone member may be correlative to the "Clark and Wilson" reservoir sandstone in the Mist Gas Field.

The Cowlitz Formation is overlain by the 1,640-2,050-m-thick upper Narizian to Refugian Keasey Formation. Three mappable lithofacies of the Keasey are defined as informal members based on lithology and biostratigraphy. The tuffaceous Jewell mudstone forms the lower member of the Keasey Formation. It contains foram and coccolith assemblages that correlate to the *Valvulineria tumeyensis* Zone of California of Donnelly (1976). The middle member is the Vesper Church member, which is late Refugian in age. This well-bedded to laminated graded sandstone and mudstone unit was deposited in nested slope channels by turbidites as micaceous arkosic Cowlitz sands and muds were redistributed offshore. The thick-bedded, structureless tuffaceous upper mudstone member is upper Refugian and contains Foraminifera equivalent to the *Uvigerina vicksburgensis* Zone of California. Foraminifera paleoecology suggests that the three members were deposited in upper bathyal depths.

The upper Eocene to Oligocene (upper Refugian to Zemorrian) 200-500-m-thick Pittsburg Bluff Formation disconformably overlies the Keasey Formation. The thick-bedded tuffaceous to arkosic Pittsburg Bluff sandstones were deposited in a shallow-marine inner to middle shelf environment. Local uplift and/or eustatic sea level fall (corresponding to the end of cycle TE3 of Vail and Hardenbol, 1979) combined to cause a late Eocene marine regression and disconformity at the base of the Pittsburg Bluff Formation.

The mollusc-rich bioturbated Pittsburg Bluff sandstone and the overlying tuffaceous Oswald West deep-marine mudstone are, in part, coeval facies that represent inner to middle shelf sands and an adjacent deep-water outer shelf-upper slope depositional environment, respectively. An Oligocene marine transgression corresponding to Vail and Hardenbol's cycle TO1 eventually caused onlap of Oswald West slope muds over inner shelf Pittsburg Bluff sands. The Oswald West is Oligocene (Zemorrian) in age in the thesis area but is as young as lower Miocene (Saucesian) in western Clatsop County. The deep-marine lower Miocene to middle Miocene Silver Point mudstone and the turbidite sandstones of the Astoria Formation overlie the Oswald West mudstones with minor unconformity.

The sedimentary strata of the thesis area were intruded by several dikes and sills of middle Miocene tholeiitic basalt. Principal among the intrusions are three extensive dikes (Beneke, Fishhawk Falls, and Northrup Creek) composed of low-MgO-high-TiO_2 and low-

MgO-low-TiO_2 basalt. These subparallel northeast-trending dikes are 10 to 20 km long and are geochemically and magnetically correlative to low-MgO-high-TiO_2 and low-MgO-low-TiO_2 subaerial flows of the Grande Ronde Basalt that are exposed 6.5 km northeast of the thesis area near Nicolai Mountain and Porter Ridge. This correlation supports the hypothesis of Beeson and others (1979) that these intrusions were formed by "invasive" flows of Columbia River basalt. The dikes and flows represent the R_2 and N_2 magnetozones. Paleomagnetic results and detailed mapping along the three major dikes indicate that the dikes are cut into many small blocks by northeast-trending dextral and northwest-trending sinistral faults. Oblique slip along these faults may have rotated these small blocks clockwise from the expected middle Miocene declination. One such fault-bounded block in Beneke quarry has been rotated 11° clockwise relative to other blocks in the quarry.

The area has apparently undergone four periods of structural deformation. Late Eocene deformation produced normal faults and a highly faulted anticline in the Cowlitz, Keasey, and Pittsburg Bluff Formations. Uplift of the Oregon Coast Range commenced during the Oligocene. Northwest-southeast extension in the middle Miocene permitted intrusion of the northeast-trending dikes, perhaps along pre-existing faults or joints. Post-middle Miocene north-south compression produced a conjugate shear couplet of dextral northwest-trending and sinistral northeast-trending oblique-slip faults and associated east-west thrust faults. These may compose a 20-km-wide zone of distributed shear between the Oregon Coast Range tectonic block and the smaller tectonic blocks of southwestern Washington (Wells, 1981). These post-middle Miocene faults may be related to wrench tectonics and northwest-trending dextral slip faults observed on the Columbia Plateau. They may have formed sympathetically to regional right-lateral wrenching of the North American plate by oblique subduction of the Juan de Fuca plate and/or extensional opening of the Basin and Range province (Magill and others, 1982).

The north-central and eastern parts of the study area hold the greatest potential for natural gas accumulation in the permeable upper Cowlitz sandstones (Tc_4) that may be correlative to the Clark and Wilson sand. Mapping of the limited outcrops of this potential reservoir suggests that the unit may pinch out to the west. It is overlain by Keasey mudstones that could form cap rock. A highly faulted northwest-trending antiform in the subsurface, postulated from surface mapping, represents the best structural trap in the area if the reservoir sands are not breached by faulting.

GEOLOGY, PETROLOGY, AND VOLCANIC HISTORY OF A PORTION OF THE CASCADE RANGE BETWEEN LATITUDES 43° - 44° N, CENTRAL OREGON, U.S.A., by David R. Sherrod (Ph.D., University of California, Santa Barbara, 1986)

This report describes the stratigraphy, structure, and petrology of the Cenozoic volcanic and volcaniclastic rocks mapped along a 30-minute by 60-minute strip of the Cascade Range between latitudes 43° -44°N (map scale 1:125,000). That part of the Cascade Range is customarily divided into physiographic subprovinces: the deeply eroded Western Cascades and the relatively uneroded High Cascades. In the map area, the Western Cascades are built chiefly of rocks about 24 to 3.5 m.y. old that were tilted slightly eastward ($<5°$) between 8? and 3.5 m.y. ago; whereas rocks in the High Cascades were erupted during the last 3.5 m.y. and are essentially undeformed.

The High Cascades-Western Cascades boundary began developing about 4 to 5 m.y. ago. Late Miocene or early Pliocene normal faults with up to 300 m of dip separation mark 45 percent of the boundary length. The remaining 55 percent of boundary is a somewhat diffuse zone of volcanic onlap. There is no subprovince-wide graben coincident with High Cascades volcanism between latitudes 43° -44° N.

Though volcanism in the map area has been more or less continuous during the last 24 m.y., two temporally distinct, well-defined arcs allow comparison of composition and rate. Middle Miocene rocks (about 17 to 12? m.y. old) are in volumetric proportions of 30:35:35 for basalt:basaltic andesite:andesite-to-rhyolite, respectively. They were erupted at a minimum rate of 3 to 4 km^3 per kilometer per m.y. (km^3/km/m.y.). The modern arc—the volcanic rocks of the High Cascades (3.5 to 0 m.y. old)—has volumetric proportions of 40:50:10, erupted at a rate of 3 to 6 km^3/km/m.y. Although temporally distinct, the rocks from these two suites are chemically and mineralogically similar: for example, low K_2O (1.0-1.5 percent at 57.7 percent SiO_2); and moderate TiO_2 (1 percent at 57.5 percent SiO_2). The chemical similarity of rocks younger than 17 m.y. old suggests relative source homogeneity and the repeated operation of similar petrogenetic mechanisms through time.

A STRATIGRAPHIC AND STRUCTURAL STUDY OF COAL MINE BASIN, IDAHO-OREGON, by Kyle Douglas Walden (M.S., Michigan State University, 1986)

Coal Mine Basin, Idaho-Oregon, lies within a broad, block-faulted, gently plunging anticline or dome northwest of the Owyhee Mountains of southwestern Idaho. The major emphasis of this study was the preparation of a measured stratigraphic section and a structural map of the basin. The composite stratigraphic section measured is comprised of 265 m of predominately volcaniclastic fluvial, lacustrine, and deltaic sediments of the Miocene Sucker Creek Formation. Reconnaissance field observation led to the suggestion of three tentative stratigraphic marker zones. Maar volcanism was widespread during Sucker Creek time, leaving local stratigraphic marker tuffs. Twenty-one plant and two animal fossil zones were precisely placed stratigraphically. The rocks of Coal Mine Basin have been subdivided into five episodes during Sucker Creek time based on sediment source and depositional environment.

MID-TERTIARY ECHINOIDS AND OLIGOCENE SHALLOW MARINE ENVIRONMENTS IN THE OREGON CENTRAL WESTERN CASCADES, by Robert Andrew Linder (M.S., University of Oregon, 1986)

Fossil echinoids from the late Oligocene Scotts Mills Formation were studied to determine their stratigraphic occurrences, systematic paleontology, paleoautoecology, and paleobiogeographic distribution. The echinoid remains collected are referable to the genera *Salenia, Glyptocidaris, Arbacia, Lytechinus, Gagaria, and Kewia.* These echinoids supplement the sparse fossil record of Echinodermata in Oregon, which includes fossil material from 27 formations ranging from the Permian to middle upper Miocene. Of particular interest are the preservation of *Kewia* tests infilled with abundant heavy minerals, and several whole *Arbacia* tests that are spineless with intricate epistromal ornamentation. The echinoid fossils occur in sediments associated with basaltic sea stacks that were deposited in a rocky-coast, storm-dominated environment. The sediments were dated by obtaining K-40/Ar-40 ages of the nonconformabley underlying "Little Butte Voclanics" and intrusive dikes, along with compatible age assignments suggested by echinoids as well as the associated fossils *Chlamys* sp. and *Balanus* sp.

CURIE-POINT ISOTHERM MAPPING AND INTERPRETATION FROM AEROMAGNETIC MEASUREMENTS IN THE NORTHERN OREGON CASCADES, by Robert W. Foote (M.S., Oregon State University, 1986 [thesis compl. 1985])

During the summer and fall of 1982, personnel from the Geophysics Group in the School of Oceanography at Oregon State University conducted an aeromagnetic survey in the northern Oregon Cascades to assess geothermal potential and study the thermal evolution of the Cascade volcanic arc.

Total field and low-pass filtered magnetic anomaly maps obtained from the survey data show high amplitude positive and negative anomalies associated with volcanic cones and shallow source bodies along the axis of the High Cascades. Spectral analysis of the aeromagnetic data yielded source depths and depths-to-the-bottom of the magnetic sources. The magnetic source bottom, in the northern Oregon Cascades, is interpreted as the depth to the Curie-point isotherm.

The northern Oregon study area shows shallow Curie-point isotherm depths of 5 to 9 km below sea level (BSL) beneath the axis of the High Cascades from the southern boundary (44° N. latitude) to near Mount Wilson (45° N. latitude). A smaller region of shallow Curie-point depths of 6 to 9 km BSL lies west of Mount Wilson (45° N. latitude, 122° W. longitude). The shallow Curie-point isotherm suggests the emplacement of relatively recent intrusive bodies in the upper crust beneath the axis of the High Cascades and west of Mount Wilson.

A major northeast-trending structure observed in magnetic and residual gravity anomalies near Mount Wilson is the northernmost extent of shallow Curie-point depths and high geothermal gradients mapped in the northern Oregon Cascades. This northeast-trending structure appears to mark a division between high intrusive activity in localized areas south of Mount Wilson and intrusive activity confined beneath the major cones north of Mount Wilson.

TEMPORAL VARIATIONS IN VOLUME AND GEOCHEMISTRY OF VOLCANISM IN THE WESTERN CASCADES, OREGON, by Emily Pierce Verplanck (M.S., Oregon State University, 1985)

Fifty-one K-Ar age determinations of basalts, basaltic andesites, and ash-flow tuffs from the central Western Cascades in Oregon range in age from 32 to 3.0 m.y. The oldest material is exposed on the western margin, and ages decrease progressively with increasing elevation and distance eastward. The age data indicate decreasing eruption rates with time in the Western Cascades volcanic arc. There was approximately twice as much volcanic material deposited between 30 and 20 m.y. as between 20 and 10 m.y.

Major- and trace-element geochemical analyses on the dated samples reveal temporal variations during the Western Cascades eruptive history. There is an increase in calc-alkaline volcanism relative to tholeiitic volcanism and an increase in K_2O/SiO_2 and Zr/Nb ratios with time.

It is proposed that the volume and geochemical character of volcanism in the Western Cascades volcanic arc are influenced by changes in the direction and rate of convergence between the Farallon and North American Plates. A model of the convergence rate and direction, based on the mantle-fixed hotspot reference frame, during the Tertiary indicates a factor of five decrease in rate (16.0 to 3.2 cm/yr). When the clockwise rotation of the Coast Range and Western Cascades is compared with the convergence vectors, the convergence angle is found to decrease with time from about 35 m.y. to the present. Apparently, slower, more oblique subduction results in a decrease in eruption rate, an increase in calc-alkaline composition relative to tholeiitic compositions, and an increase in K_2O/SiO_2 and Zr/Nb ratios.

GEOLOGY OF THE IDOL CITY AREA: A VOLCANIC-HOSTED, PRECIOUS-METAL OCCURRENCE IN EAST-CENTRAL OREGON, by Daniel J. McGrane (M.S., University of Montana, 1985)

The Idol City area is 32 km northeast of Burns, Harney County, Oregon. The property is underlain by a thick sequence of lower Miocene lavas of intermediate composition. These lavas were intruded by several porphyritic rhyolite dikes and plugs and coarser grained quartz-porphyry granitic bodies. Intrusive and extrusive rocks are exposed along the crest of a regional south-plunging anticline and are flanked by younger ash-flow tuffs. Base- and precious-metal mineralization is confined to andesitic rocks, which are sheared, brecciated, and hydrothermally altered.

Previous studies viewed mineralization at Idol City as typical of the upper part of a vein-type hydrothermal system. This study shows that base and precious metals occur primarily as disseminations and filling stockworks within two broad tourmalinized breccia zones that formed during explosive hydrothermal activity. Mineralization within these zones is remarkably consistent over broad vertical and lateral distances.

Deposition of metals occurred in response to boiling triggered by episodic explosive brecciation events. Boiling temperatures of approximately 300° C, which were determined from fluid inclusion studies on mineralized stockworks, indicate that metal deposition could have occurred at depths as shallow as 315 m. Felsic intrusive bodies are spatially, temporally, and probably genetically related to the mineralizing event.

VOLCANIC STRATIGRAPHY AND GEOCHEMISTRY OF THE HOLE IN THE GROUND AREA, OWYHEE PLATEAU, SOUTHEASTERN OREGON, by Patrick S. Plumley (M.S., University of Idaho, 1986)

Volcanic and volcaniclastic units of middle to late Pliocene age are exposed along a 28-km-long section of the Owyhee River Canyon, located immediately south of Lake Owyhee in Malheur County, southeastern Oregon. Geologic mapping has defined the stratigraphy and structure of this previously unmapped portion of the Owyhee Plateau. The oldest volcanic rocks exposed are rhyolitic ash-flow tuffs. The tuffs are overlain by silicic volcaniclastic sediments intercalated with basalt, andesite, and occasional rhyolite lava flow units. Two fault sets have been recurrently active since the Miocene: (1) a north-trending fault set that is the manifestation of Basin and Range faulting in the Owyhee Plateau, and (2) a subordinate west-northwest-trending fault set.

The oldest volcanic unit is the Leslie Gulch tuff: a nonwelded, phenocryst-poor, ash-flow and air-fall tuff sequence that was erupted from the Mahogany Mountains caldera. Overlying the Leslie Gulch tuff is the Birch Creek tuff, a small volume (<1 km), densely welded, rhyolitic ash-flow tuff that was erupted from a water-rich, homogeneous magma. The tuffs are overlain by a thick sequence of sediments that have been divided into several units. The sediments are predominantly fine-grained, evenly bedded tuffaceous sediments that accumulated in lacustrine and fluvial-lacustrine settings. The composition and texture of the sediments indicates that they were derived primarily from silicic and pyroclastic-rich source areas. The volcaniclastic sequence is 1,200 m thick and includes a total of 300 m of intercalated mafic to intermediate (49-61 percent SiO_2) lava flows. These lavas do not display systematic compositional changes with time, although there is a tendency toward eruption of less evolved magma with time. The youngest volcanic rocks are depleted olivine tholeiites that veneer the Owyhee Plateau and are the most primitive lavas in the sequence. In addition, basaltic and rhyolitic lava flows interfinger together in the sequence and record a period of pene-contemporaneous bimodal volcanism.

Chemically, the entire suite of volcanic rocks is calc-alkaline. The area evolved petrologically from rhyolite volcanism in middle Miocene to bimodal basalt-rhyolite volcanism in late Miocene to late Pliocene time. Furthermore, chemical data suggest that the mafic and silicic suites were not derived from a single parent magma composition.

STRATIGRAPHY, SEDIMENTOLOGY, AND PETROLOGY OF NEOGENE ROCKS IN THE DESCHUTES BASIN, CENTRAL OREGON: A RECORD OF CONTINENTAL-MARGIN VOLCANISM AND ITS INFLUENCE ON FLUVIAL SEDIMENTATION IN AN ARC-ADJACENT BASIN, by Gary Allen Smith (Ph.D., Oregon State University, 1986 [compl. 1985])

Neogene rocks of the Deschutes basin include the middle Miocene Columbia River Basalt Group and Simtustus Formation and the upper Miocene to lower Pliocene Deschutes Formation. Assignment of Prineville chemical-type flows to the Grande Ronde Basalt of the Columbia River Basalt Group is based upon correlation of these lavas from their type area, through the Deschutes basin, and onto the Columbia Plateau, where they have been previously mapped as Grande Ronde Basalt. The Simtustus Formation is a newly defined unit intercalated with and conformable upon these basalts and is unconformably overlain by Deschutes Formation.

Burial of mature topography by middle Miocene basalts raised local base levels and initiated aggradation by low-gradient streams within the basin represented by the tuffaceous sandstones and mudstones of the Simtustus Formation. These sediments are enriched in pyroclastic constituents relative to contemporary Western Cascades volcanics reflecting preferential incorporation of easily eroded and more widespread pyroclastic debris in distal sedimentary sequences compared to epiclastic contributions from lavas.

Following a 5- to 7-m.y. hiatus, aggradation was renewed at about 7.5 Ma, when coarse-grained volcanogenic sediments, lava flows, and ignimbrites from the early High Cascades entered the basin for 2 m.y. The proximal Deschutes Formation is primarily basalt and basaltic andesite lava flows, but andesite to rhyolite ignimbrites are the primary volcanic constitutents in the sedimentary-dominated section farther east. Deposition on a broad, eastward-tapering alluvial plain was by debris flows, sheetfloods, and hyperconcentrated flood flows. Episodic aggradation correlates to periods of sediment influx following eruptions of widespread pyroclastic debris and was separated by periods of incision.

The abundance of basalts, combined with the paucity of hydrous minerals and FeO and TiO_2 enrichment in intermediate lavas, characterizes early High Cascade volcanics as atypical for convergent-margin arcs. These petrologic characteristics are consistent with high-level fractionation in an extensional regime. Extension culminated in the development of an intra-arc graben that ended Deschutes Formation deposition by structurally isolating the basin from the High Cascade source area. Intra-arc extension may represent invasion of Basin and Range tectonism into the Cascades or may relate to plate-margin processes, particularly decreasing convergence rate and highly oblique convergence vector. □

BOOK REVIEW

Earth Treasures (volume 3): Northwest Quadrant, 1987, by Allen W. Eckert. Published by Harper and Rowe, 10 East 53rd Street, New York, New York.

Earth Treasures is a four-volume publication designed to show where to collect minerals, rocks, and fossils in the United States. The publishers have divided the U.S. into four quadrants, and the *Northwest Quadrant* (volume 3) claims to be "a precise guide to more than 1,000 specific localities in Idaho, Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, North Dakota, Oregon, South Dakota, Washington, and Wyoming." Although the concept is admirable and the need for such a book quite apparent, Oregon Department of Geology and Mineral Industries (DOGAMI) reviewers soon discovered that the book did not live up to its promise—-as least as far as Oregon is concerned.

Northwest Quadrant contains numerous inaccuracies, ranging from errors in a diagram showing compass directions to misinformation, such as stating that, in Multnomah County, superb-quality agate, bloodstones, jasper, and petrified wood are found "countywide in gravel bars of the Willamette River"—a tough job, as anyone who has walked beside or boated on the Willamette knows.

The information is often old or incomplete. For Jefferson County, Eckert mentions the Kennedy Ranch, which is now instead part of the Richardson Ranch; the highway locations of the Richardson and former Kennedy Ranches are inaccurately given; and the Priday Ranch that he mentions is now controlled by the Richardsons. The location for the hyalite and opal deposit on Opal (Peters) Butte is shown at the town of Heppner but is actually 30 road miles to the south—and Eckert provides no information on how to find the site.

The instructions on how to find the "Dolly Drummond Agate Beds" in Linn County are wrong, which is just as well because they and other nearby locations that are mentioned are all closed down and are not available for digging. Furthermore, none of the Quartzville mining district sites where pyrite, quartz, tourmaline, galena, and sphalerite occur are even mentioned in the Linn County section.

In his introduction, Eckert warns the reader to learn and obey local regulations while collecting—a prudent reminder because in his Deschutes County section, he tells his reader to "collect [obsidian] on both sides of the road between Paulina Lake and East Lake [in Newberry volcano]." Anyone who has been to the Big Obsidian Flow will remember the signs warning against just such collecting. In fact, collecting from many of the sites mentioned in the Oregon section is impossible because of local, State, or federal regulations or because of restrictions placed on private property by owners.

Sources of data used in the book are not cited, the author's credentials for doing such a volume are not given, and local sources of information and names of local collecting clubs are not provided. In general, Oregon's rocks, minerals, and fossils are not given the treatment they deserve—and a purchaser of the book will spend many long hours trying to follow woefully inadequate or inaccurate instructions. So while *Northwest Quadrant* is attractive, handy to pack (4½ by 8½ inches), and impressive at first glance, it is not the "precise guide" it claims to be—at least for Oregon. What it does do, however, is point out the need for a comprehensive, accurate, and easy-to-follow collecting guide to the rocks, minerals, and fossils of Oregon. □

"Maturation profiles" explained

Several readers told us that they did not understand the term "maturation profiles" in the article published in the November 1987 issue of Oregon Geology. This may provide some explanation.

Organic-rich sediments, which provide the material from which hydrocarbons (oil and gas) form, are called source rocks. When the organic-rich sediments accumulate, they are subjected to increased pressure and temperature as they are buried. The organic material changes as it becomes stratified and is converted into oil and gas during what is called the maturation process. The maturation state of the sediments may be gauged by the degree to which they have been thermally altered during burial and stratification. Generally, source rocks may be indexed as immature (not yet generating significant hydrocarbons), mature (rich in hydrocarbons), or metamorphosed (lean in hydrocarbons due to the destruction of the hydrocarbon-generating capacity of the source rock.

In the November article by Summer and Verosub, maturation profiles show the degree of maturity of sediments as a relationship between measured vitrinite reflectance and depth. Normal profiles show a gradual increase of maturity with depth (see comparison of "normal" and measured profiles in the article's Figure 2 on page 137). In contrast to normal profiles, however, studies in the Pacific Northwest showed near-vertical profiles, which was attributed to heating of sediments at shallow depths by volcanic rocks. □

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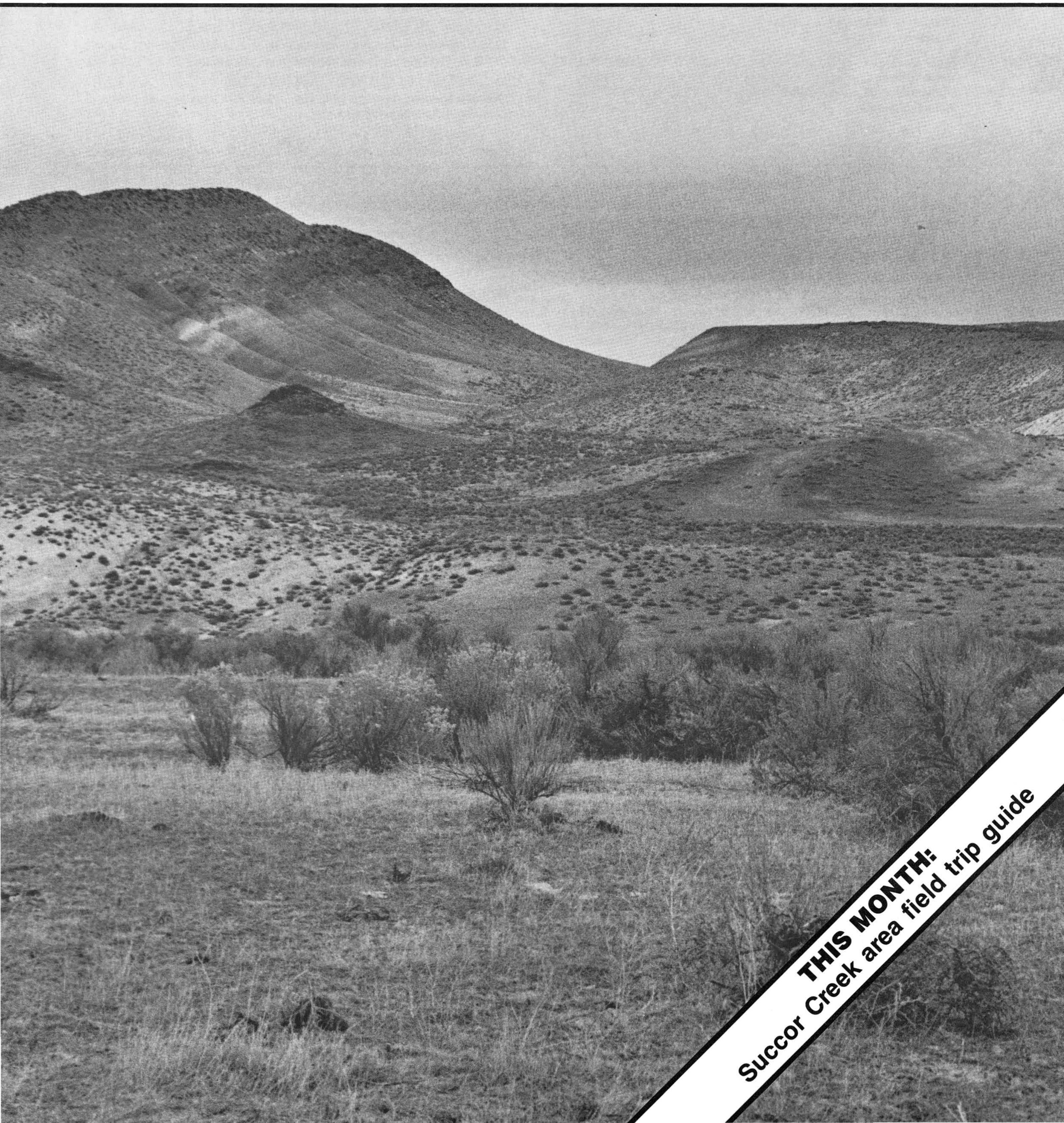
VOLUME 50, NUMBER 2 **FEBRUARY 1988**



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The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of the bibligraphic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Looking north at boundary of Succor Creek State Park, the south side of Stop 3 of field trip guide beginning on next page. Slope on left exposes top of stratigraphic column of the Sucker Creek Formation with gravels at the top. Knoll left of center is a basalt dike. Area in photo is cut by north-south-trending and northwest-southeast-trending faults.

Map summarizes data on geothermal-resource area at Newberry Crater

A new map published by the Oregon Department of Geology and Mineral Industries (DOGAMI) provides information on geothermal exploration in the Newberry Crater area.

Newberry Crater Geothermal Resource Area, Deschutes County, Oregon, by DOGAMI staff members Dennis L. Olmstead and Dan E. Wermiel, has been released as DOGAMI Open-File Report O-88-3. The blackline ozalid print is approximately 36 by 52 inches large and uses a topographic base at the scale of 1:24,000. It covers the area in and around Newberry Crater, the locations of past and future geothermal drilling activity.

The map contains detailed information, such as location, total depth, date, name of operator, and status, for all geothermal wells drilled or proposed as of January 1988. It also outlines the areas that are considered suitable or unsuitable for drilling and those that are closed or restricted with regard to geothermal exploration.

Over the years, Deschutes County and, particularly, Newberry Crater have been the focus of strong interest in geothermal energy. Temperature-gradient wells have been drilled since the 1970's in attempts to determine whether an economical geothermal resource occurs in the area. The new DOGAMI map is intended as a summary of past drilling activity as well as a guide for future planning. It will be updated periodically to reflect new drilling activity or changes in area restrictions.

The new release, DOGAMI Open-File Report O-88-3, is available now at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. The purchase price is $5. Orders under $50 require prepayment. □

MMS to sponsor workshop in Portland

The U.S. Department of the Interior, Minerals Management Service (MMS) is sponsoring a conference/workshop on recommendations for studies in Washington and Oregon relative to offshore oil and gas development. The conference will be held in Portland, Oregon, on May 23-25, 1988. Conference participants will identify and develop recommendations for future studies concerning offshore oil and gas development activities.

Discussion topics will include air quality, physical oceanography/meteorology, fates and effects/chemistry, biology/ecology, sea birds, marine mammals, and socioeconomics.

The meeting will (1) summarize available information on environmental processes of the outer continental shelf (OCS) off Washington and Oregon; (2) identify subject areas in which additional information is required for reasonable understanding and prediction of the environmental effects of oil and gas development activities in this area; (3) develop recommendations for the MMS Environmental Studies Program to deal most effectively with information gaps related to the environmental impacts in this planning area; and (4) improve awareness of the scientific work being conducted in the Washington and Oregon OCS Planning Area.

Inquiries regarding the conference should be directed to Bio/Tech Communications, MMS-OCS Conference Planners, 600 SW 10th Avenue, Suite 418, Portland, OR 97205.

--Bio/Tech news release

Geologic field trip guide to the northern Succor Creek area, Malheur County, Oregon

by David C. Lawrence, Department of Geology and Geophysics, Boise State University, 1910 University Drive, Boise, Idaho 83725

INTRODUCTION

This field trip guide describes interesting and unusual geologic features in Miocene volcanic and sedimentary rocks of the Sucker Creek Formation (Kittleman and others, 1965, p. 6) that are exposed between the town of Adrian, Oregon, and the Succor Creek State Park. The guide, which supplements an earlier guide to the geology of the Owyhee region (Kittleman, 1973), was designed to introduce this interesting area both to geologists and to lay readers and may also be used by earth science teachers and students. Major points of interest include basalt and rhyolite flows, pillow lavas, hyaloclastites, leaf and mammal fossils, and fault breccias.

The area is accessed from Oregon State Highway 201. Nearby towns are Homedale, Idaho, and Adrian, Oregon (Figure 1). Take Highway 201 south from Adrian and turn off at the "Succor Creek State Park" sign onto an all-weather country gravel road leading south. This turnoff is 8.1 mi from Adrian and 7.1 mi west of Homedale. During wet weather, do not leave the gravel road. Much of the area off the gravel is made hazardous by soft clay soil that

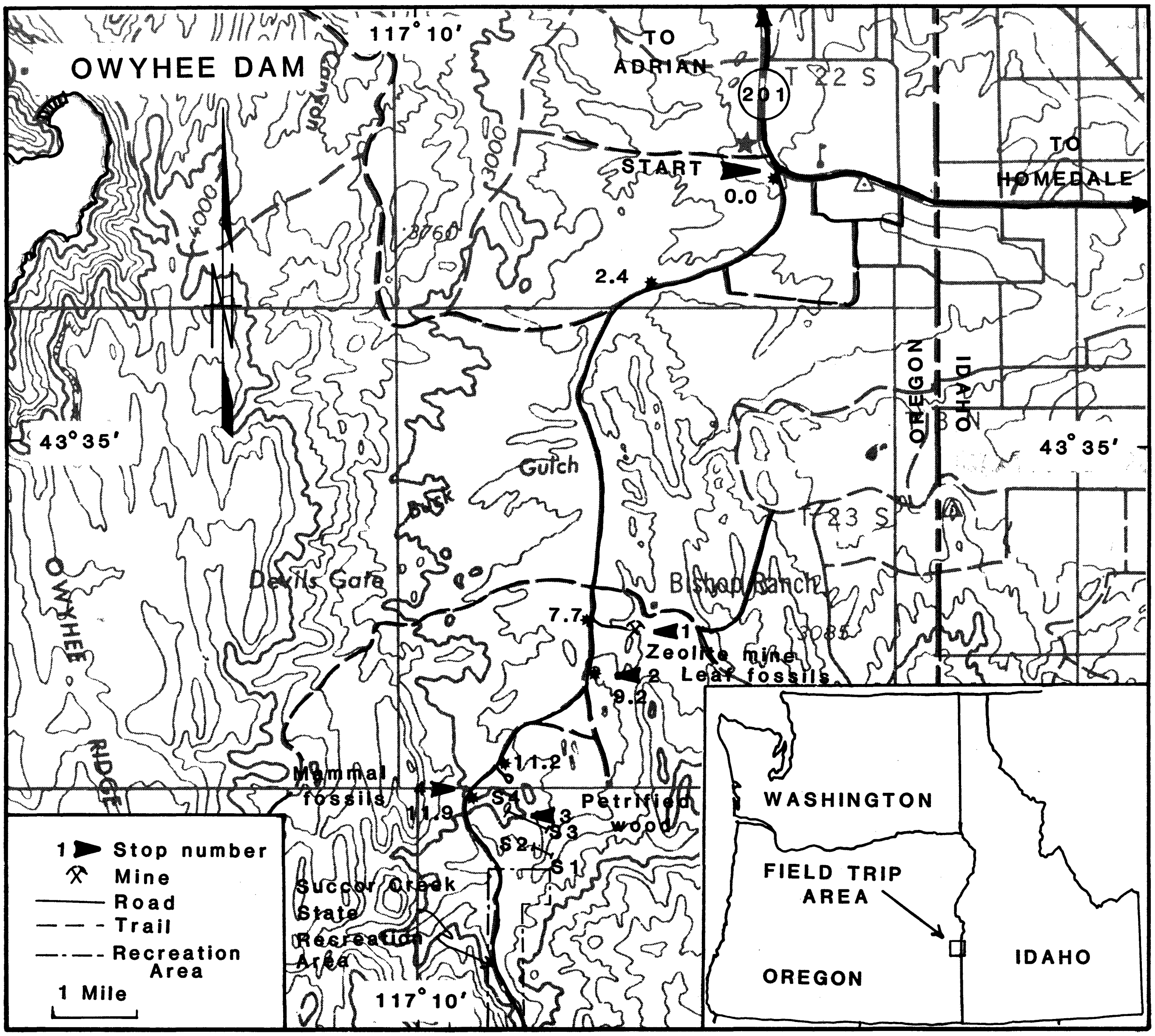

Figure 1. Map along the Oregon-Idaho border, showing field trip route and location of stops described in the text. Asterisks indicate cumulative mileage check points along the trip route. Lines S1-S2 and S3-S4 locate the traverse along which the stratigraphic section of Figure 4 can be observed.

becomes soft and sticky when wet and will immobilize even the hardiest of motor vehicles.

REGIONAL SETTING

Rocks of the Sucker Creek Formation comprise a thick sequence of fluvial and lacustrine sediments predominantly from volcanic source areas. Interbedded are silicic and basaltic intrusive and flow rocks. Outcrops of the formation are distributed in Malheur County, Oregon, and Owyhee County, Idaho (Kittleman and others, 1967; Ekren and others, 1981). The geologic history recorded by these rocks is intriguing because the area lies at the juncture of several major geologic provinces of the northwestern United States. These provinces are the northern Basin and Range, the Columbia Plateau, the Snake River Plain, and the Owyhee Uplands-High Lava Plains.

The geologic characteristics of these provinces were determined primarily by volcanism and tectonic movements during the Miocene epoch. The stratigraphic position of the Sucker Creek Formation with respect to better known geologic units of these provinces is shown in Figure 2. The age of the entire Sucker Creek section is known only approximately, and interpretations of the age may change as the formation is more thoroughly studied. The formation clearly underlies the Owyhee Basalt dated between 13.1 and 15.3 million years (m.y.) (Brown and Petros, 1985). A 3,200-ft-thick section of fluvial and lacustrine sediments similar to the Sucker Creek Formation lies beneath Miocene basalt that may be Columbia River basalt under the Snake River Plain (Wood, 1984, p. 54). The relation of the Sucker Creek Formation to older units of the Columbia River Basalt Group is not well understood, but these sediments appear to occupy a north-south-trending structural trough that was also in existence during the time of earliest eruptions of Columbia River basalt lava flows. Recent studies (Rytuba and others, 1985; Vander Meulen and others, 1987a) have identified a large peralkaline rhyolite caldera complex 17 mi south of the map area. Peralkaline classification refers to igneous rocks with a proportion of alumina that is less than the sodium and potassium oxides combined. Major ash-flow tuff units (tuffs of Leslie Gulch and others) within the Sucker Creek Formation were erupted from this complex 15 to 16 m.y. ago.

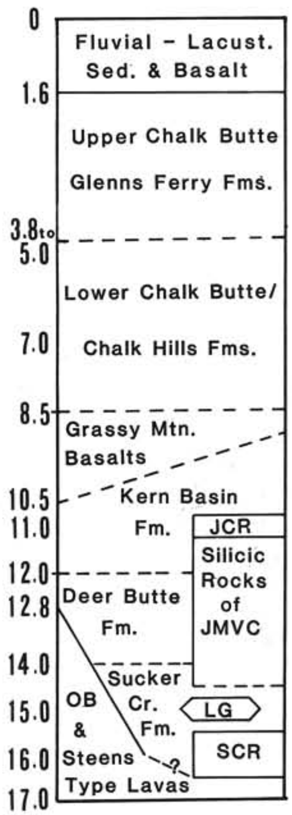

Figure 2. Comparison of generalized Jordan Valley-Owyhee River region showing the Sucker Creek Formation with a tentative age of between 14.0 and 16.5 m.y. Regional stratigraphy is modified after Hart and others (1985) and Armstrong and others (1980). JCR = Jump Creek rhyolite; JMVC = Juniper Mountain volcanic complex; LG = Leslie Gulch ash-flow tuff; OB = Owyhee Basalt; SCR = Silver City rhyolite.

In a regional study of volcanic rocks, Hart and others (1985, p. 6) tentatively placed the Sucker Creek Formation age between 14.0 and 16.5 m.y. The formation is overlain by the Jump Creek Rhyolite dated by Armstrong and others (1980, p. 5) at 11.1±0.1 m.y. Ekren and others (1982, p. 217) show that part of the Sucker Creek Formation in Owyhee County in Idaho overlies an upper rhyolite, rhyolite porphyry flow, dated by Armstrong (1975, p. 9) at about 15.6 m.y., which appears to be the rhyolite of Silver City Range dated by Ekren and others (1981) at 16.0±0.3 m.y. The tuffs of Leslie Gulch, which are thought to be in about the middle of the Sucker Creek Formation, are dated at 15.8±0.6 m.y. (Ekren and others, 1984, p. 10) and 15.5±0.5 m.y. (Vander Meulen and others, 1987a,b). Outcrops of the tuffs of Leslie Gulch, as mapped by Kittleman and others (1967), terminate approximately 2 mi south of the area of this report and have not been specifically related to the geologic section described here. Within the area of this report is the basalt at Bishop's Ranch, which Kittleman and others (1967) placed near the base of the Sucker Creek Formation. This basalt, as mapped by Kittleman and others (1967), is the same basalt as shown in Figure 3. Kittleman and others (1965, p. 6) described this basalt body as a possible equivalent to the one described about 19 mi south of Bishop's Ranch and radiometrically dated at 16.7 m.y. by potassium-argon dating (Evernden and James, 1964, p. 971, sample KA 1285).

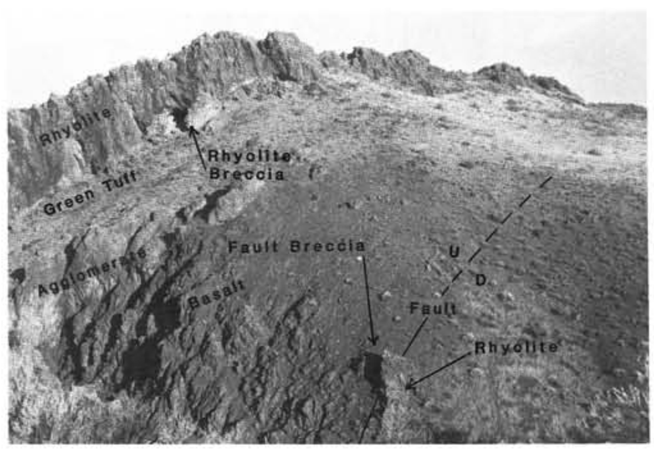

Figure 3. View looking north of zeolite pit. Fault breccia can be seen along the north-south-trending normal fault. West footwall is basalt. The upper zone of the basalt is an agglomerate. Claystone lacustrine sediments overlie basalts. Flow-banded rhyolite overlies the claystones. Volcanic rhyolite breccia and shallow caves are located near the bottom of the rhyolite.

LOCAL STRATIGRAPHY

The oldest strata of the Sucker Creek Formation in the area are bentonitic claystones of a fluvial and lacustrine environment. Conglomerates and gravels interbedded with claystone comprise the upper Sucker Creek Formation within the area of the road log. These coarse sediments indicate that active stream systems coexisted with the lacustrine environment during the later part of time represented by this local section. A system of olivine basalt dikes later invaded this part of the Sucker Creek Formation. Contrary to initial impressions, the low-lying green tuffs of Spring Creek are not the oldest strata in this area. According to current interpretation by James Rytuba, Dean B. Vander Meulen, Thomas L. Vercoutere, and Scott A. Minor of the U.S. Geological Survey (USGS) and unpublished mapping by Mark Ferns of the Baker Field Office of the Oregon Department of Geology and Mineral Industries (DOGAMI), the green tuffs and glassy welded tuffs are caldera-fill material that washed over the older **bentonitic claystones** and have subsequently been downfaulted. Because the green tuff section is faulted against the bentonitic claystone section in this area, stratigraphic relationships have not yet been determined. The tabular basalt unit within the green tuff (Figure 4) has been interpreted as a flow by some geologists and as an intrusive sill by others. In this area of the field trip guide, the Sucker Creek Formation also contains rhyolite and basalt flows and intrusives.

In 1965, Kittleman and others indicated that the type section for the Sucker Creek Formation was 590 ft thick in secs. 28 and 33, T. 24 S., R. 46 E., about 6 mi south of the road log area, and that a section exposed at Owyhee Reservoir may be 1,600 ft thick. Wood (1984, p. 54) indicates the Sucker Creek Formation is about 3,200

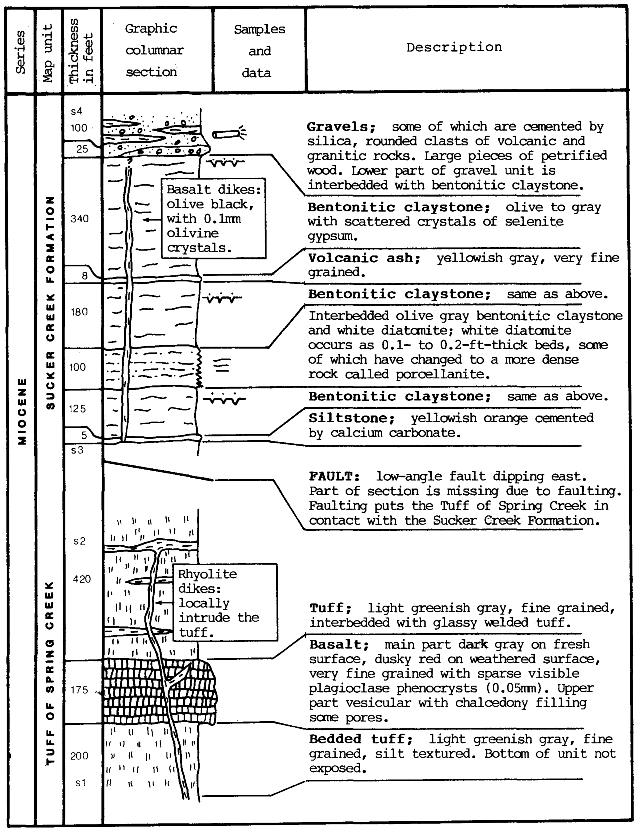

Figure 4. Columnar section for part of the Sucker Creek Formation based on unpublished 1:12,000-scale geologic mapping by Lawrence (1986). This section is located in NW¼ sec. 5 and NE¼, sec. 6, T. 24 S., R. 46 E., Malheur County, Oregon, in the road log area (Figure 1). Although the green bedded tuffs appear topographically low at the bottom of the section, regional mapping by the USGS and DOGAMI suggests that the tuffs are younger than the topographically overlying sedimentary rocks. Interpretation of the relationship of the younger bedded green tuff of Spring Creek to the older sedimentary rocks in the Sucker Creek Formation and the intervening caldera-forming event is from the current geologic mapping and interpretation by Dean B. Vander Meulen, James J. Rytuba, Thomas L. Vercoutere, and Scott A. Minor of the USGS and Mark Ferns of DOGAMI. Gravels and conglomerates locally cap the section of the Sucker Creek Formation in the area of the road log.

ft thick at a well drilled by Chevron-Halbouty in the western Snake River Plain. The mapped section in the area includes at least 780 ft of tuffaceous sedimentary units (Lawrence, 1986, p. 25). As this guide shows, the Sucker Creek Formation contains a variety of volcanic and sedimentary facies. No one type section can be considered typical. No good marker beds have been established. There is clearly a need for detailed mapping to establish lithostratigraphic units of the Sucker Creek Formation and to provide a basis for understanding the basin evolution. It is hoped that this guide will encourage continued detailed studies of the formation.

ROAD LOG

0.0 *Begin at State Highway 201 and the sign "Succor Creek State Park" showing the turnoff to a gravel road leading to the field trip area (Figure 1). Mileage of the road log starts at the Succor Creek State Park sign and is cumulative throughout the field trip. Travel south on the public gravel road, which is normally well maintained for hauling bentonitic clays from the Teague Mineral Company pits.*

2.4 Owyhee Ridge is on the skyline directly southwest. Owyhee Ridge was described by Kittleman (1973) as being composed of Owyhee Basalt. Kittleman recorded the Owyhee Basalt as a thick, multiple-flow unit of olivine-poor basalt that overlies the Sucker Creek Formation near Owyhee Dam. The basalt seen on the skyline clearly overlies the Sucker Creek Formation and is probably Owyhee Basalt as described by Kittleman and others (1965). Current mapping by Mark Ferns (personal communication, 1987) suggests it may also be an unnamed sequence in the uppermost Sucker Creek Formation.

7.7 STOP ONE. Zeolite mine 0.3 mi to the east. A short side road leads to an open-pit zeolite mine. Glen Teague, of Teague Mineral Products located 2 mi south of Adrian, operates the mine and should be contacted for permission to visit the mine prior to entering the area. Parking is available on the northwest side of the mine.

Just south of the parking area, basalt lava flows overlie the zeolite deposit (Figure 5a). At this locality, the basal part of the basalt sequence is composed of pillow lavas. Glassy skins enclose the pillows (Figures 5b and 5c), indicating sudden chilling of molten basalt as it flowed underwater. Around the pillows is fine-grained yellow-brown material formed by decrepitation of the lava surfaces into water, producing a material called hyaloclastite. The yellowish-brown color in the hyaloclastite is from glassy basalt shards that have been altered to palagonite. Palagonite is an isotropic mineraloid formed by hydration and devitrification of basaltic glass.

North of the parking area and across Camp Kettle Creek Canyon are prominent cliff-forming rhyolites (Figure 3). To observe features of the rhyolite flow, make a 20-minute descent and ascent across the canyon. Walk from the parking area east to a fence and follow the fence to the bottom of the canyon. Caution should be taken on the steep rocky hillside. You cross a north-south-trending fault shown in Figure 3 as you head west up the bottom of the creek toward the rhyolite. The fault plane dips 67° to the east. Geologic mapping by Squires (1985) indicates this is a normal fault with the downthrown block toward the east. Fault breccia contains fragments of wall rock crushed by repeated movements in late Cenozoic time. The footwall block, which is west of the fault, is basalt. The fault zone contains an enigmatic layer of rhyolite approximately 8 ft thick that is inclined at the angle of the fault plane. Basaltic footwall fragments occurring within the rhyolite were probably incorporated into it during its emplacement into the fault zone. This coherent mass of rhyolite could be either a sliver of sheared rhyolite in the fault zone or a viscous rhyolite dike intruded into the fault zone.

Basalt of the footwall block is very fine grained and massive. This massive basalt exposed in the canyon is at least 50 ft thick and probably much thicker. The upper 15 ft is a basalt agglomerate. The massive basalt grades almost imperceptibly upward into the agglomerate. The agglomerate becomes more fragmental upwards, and

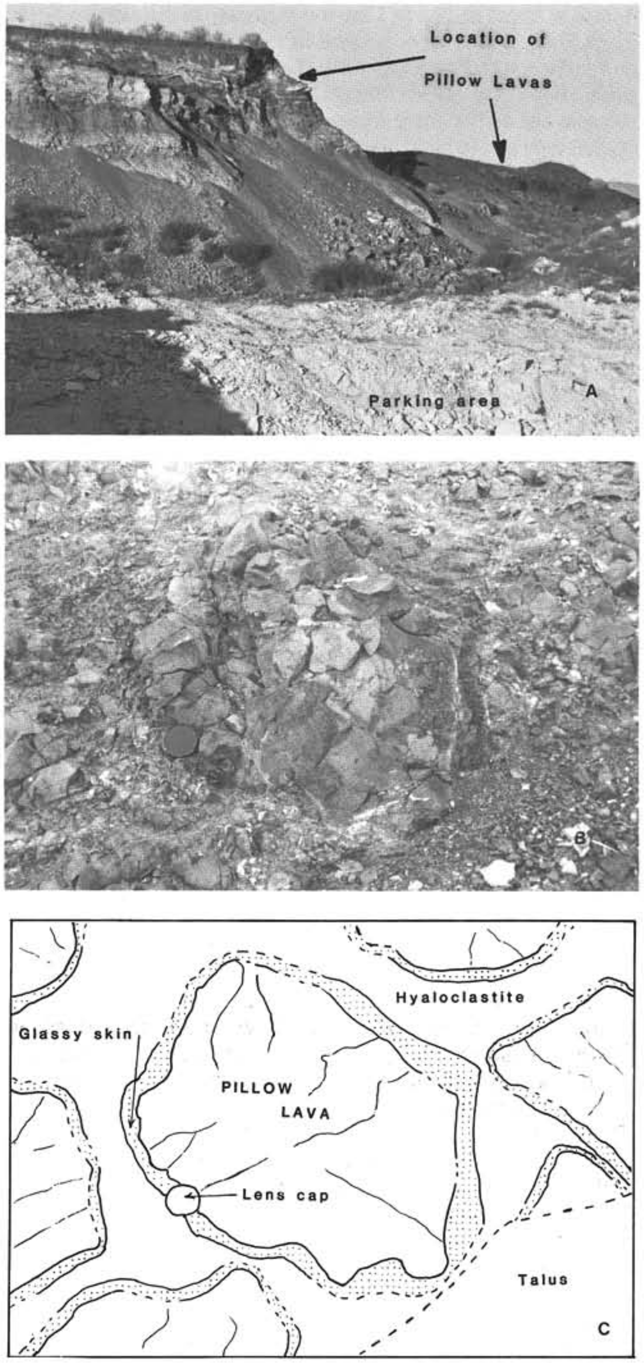

Figure 5. Pillow lavas at the zeolite mine. A. Looking south from the parking area, where pillow lavas are overlying the zeolite bed in the foreground. Zeolite shows bedding of the original volcanic-ash beds (white laminae) that underlie the basalt. B. Photo of a basalt pillow taken on the west face of the outcrop shown in Figure 5A. C. Interpretive sketch of Figure 5B showing cross section of pillows embedded in the hyaloclastite. Sudden chilling formed glassy skins, and spalled debris formed the hyaloclastite. Radial joints are crudely columnar.

the upper 8 ft is clearly a breccia with a fine matrix. This uppermost zone of the breccia has a dusky yellow matrix with inclusions of basalt and water-altered lake sediments.

The sequence of basalt grading upward to a breccia with included siltstones suggests that lavas were erupted over lacustrine sediments, flowing out and then burrowing down into the sediments. Also, the absence of red oxidation colors indicates an oxygen-poor environment, suggesting that some of the lava eruption may have occurred beneath an existing lake.

Overlying the basalt unit is a yellowish-gray to pale yellowish-brown volcaniclastic siltstone grading upward into a green tuff, which is then overlain by the cliff-forming rhyolite. Celadonite, a soft earthy-green to gray-green mineral, gives the tuffaceous unit its green color (Odom, 1984, p. 545). Celadonite is a very fine-grained mineral of the mica group and appears to replace fine glass fragments and pumice.

Walk about 230 to 260 ft up the hill to the north along the bottom contact of the rhyolite. Flow-banding is common in the lower zones of the rhyolite where the lava swirled and flowed over an uneven surface. Volcanic breccias and shallow caves occur near the bottom of the rhyolite. These features can be seen by following the cliff-forming unit north. Figure 6 shows a volcanic breccia with clasts of preexisting country rock (tuff) and clasts of the rhyolite flow rock. Siliceous deposits formed by precipitates of presumably warm ground water can be observed in the joints of the rhyolite along the cliff.

Figure 6. Rhyolite volcanic breccia shown in Figure 3. Preexisting country rock (tuff) and tuff clasts are included in the rhyolitic breccia.

Return to the zeolite mine parking area. The zeolite bed in the pit contains interbedded hard siliceous jasperoid zones near the upper part. The presence of jasperoids with zeolites suggests a low-temperature (50° to 100° C) hydrothermal alteration. The jasperoid breaks with a subconchoidal fracture, and some gem-quality "picture jasper" has been collected from here by rockhounds.

The zeolite in the quarry is apparently an authigenic (formed in place) silicate mineral. Sheppard and Gude (1983, 1987) indicate shards of silicic glass deposited as a volcanic ash layer in a freshwater lake environment that is highly saline and alkaline typically alter to the zeolite mineral clinoptilolite $(Na_4K_4)(Al_8Si_{40}O_{96})\cdot 24H_2O$ (Mumpton, 1977, p. 5). The glass was probably altered by flowing or percolating ground water to form the zeolite mineral.

Leppert (1986, p. 496) indicates that clinoptilolite mined here can be used commercially to absorb many organic and inorganic compounds. In this way, zeolites are used to control pollutants in air and water. They appear to provide cost-effective solutions to some environmental problems associated with hazardous waste.

Return to the main gravel road and turn left heading south to Stop Two.

9.2 STOP TWO. Leaf fossils in the Sucker Creek Formation. Leaf fossils are common in white siltstone of the Sucker Creek Formation. Park along the side of the road and walk down the draw to the southeast (S. 70° E.) to a leaf fossil area. To the east of the road, where the vehicle is parked, are two dry stream beds with a low ridge between them. Near the confluence of the streambeds, about 600 yd southeast of the main gravel road, is the fossil area. Fossils are not plentiful, but a diligent search should produce two or three good specimens of leaf fossils similar to the one in Figure 7 in hard siltstone slabs. These sediments must have accumulated rapidly, so that delicate leaves were protected from circulating water and organisms that would have consumed or decayed them.

Figure 7. Fossils such as this deciduous-tree leaf fossil can be found at Stop Two and at many other locations of slabby white siltstone in the Sucker Creek Formation, as indicated in the Succor Creek road log.

Most common leaf fossils in the Sucker Creek Formation are forms of *Cedrela* (South American cedar), *Quercus* (oak), and *Populus* (cottonwood), illustrated in Orr and Orr (1981, p. 33), who also mention (p. 32) that Graham (1965) pointed to the presence of *Cedrela* as indication that the minimum temperatures of the environment where *Cedrela* grew did not dip below freezing, an interesting contrast to the present climate.

Return to the vehicles and head south to Stop Three (Figure 1).

11.2 STOP THREE. Petrified wood in conglomerates. Two short dirt tracks head to the east (Figure 8). If the area is dry and no rainstorms appear threatening, drive east on the second dirt track and follow it 0.2 mi to an area where there is room to turn around (Figure 9); otherwise walk there. This is Stop Three. Walk approximately 1,300 ft to the top of the hill. About 120 ft vertically below the top of the hill is a conglomerate layer bearing the petrified wood shown in Figure 10. This petrified wood is a result of silica replacement of woody material. Silica is deposited from solution and preserves the cell structure of the wood. We ask that visitors not pick at this particular stump. Abundant petrified wood occurs elsewhere in the conglomerate and float in the area.

Gravel and conglomerate cap the hills along this area of Succor Creek. Conglomerate beds are interfingered with uncemented gravels and bentonitic claystones and are a part of the Miocene Sucker Creek Formation. Gravel beds strike to the northwest and southwest and dip 24° to the west. The total thickness of the original deposits cannot be determined because the upper part is eroded away. The mapped thickness of the conglomerates is over 100 ft, with the basal conglomerate resting on bentonitic claystone forming the lower contact in many areas of the road log.

The conglomerates are poorly sorted, but clasts are rounded, with a mixture of sizes ranging from boulders to sand. The coarse fluvial conglomerates and gravels intertongue with lacustrine claystones above the petrified-wood locality shown in Figure 10 at Stop Three. Coarse gravels and conglomerates containing petrified wood are interpreted to be evidence of high-energy stream systems. Claystones interfingering with the gravels and conglomerates indicate that a nearshore lake environment existed here at one time. Fragments of petrified wood contained in younger gravels capping many hills are probably reworked materials from these conglomerates.

Return to the parking area and head toward Stop Four.

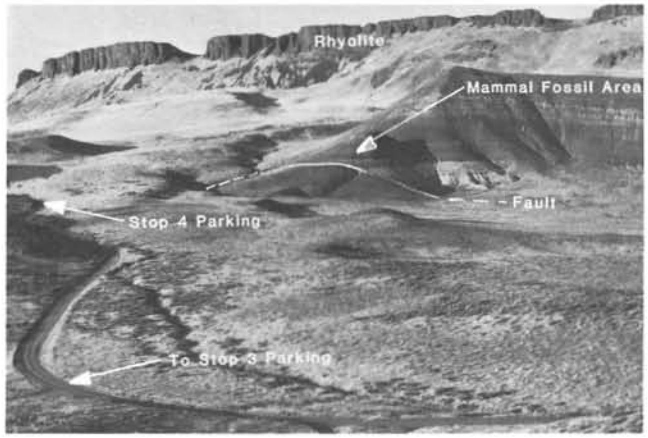

Figure 8. Geologic relationships at Stop Four. View is to the west. Turnoff to Stop Three is at lower left corner of photo. Sucker Creek Formation shows zones of sediments and bentonitic claystones that appear to be capped by an overlying rhyolite. Recent unpublished mapping by Mark Ferns of DOGAMI has shown that these rhyolites are a dome complex locally overlying the section of Sucker Creek deposits discussed in this paper. Sedimentary beds are diatomaceous bentonitic claystones and volcanic ash. Fragments of mammalian vertebrate fossils occur where the arrow points.

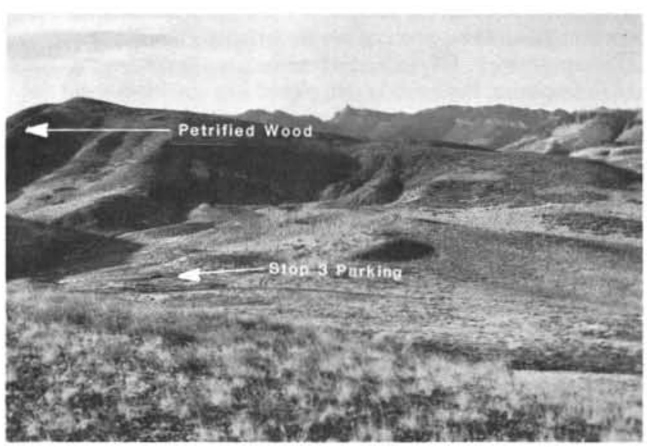

Figure 9. Geologic relationships at petrified-wood area and parking for Stop Three. View is to the south. Gravels and conglomerates that contain petrified wood cap the hill south of the parking area.

Figure 10. Petrified wood in conglomerates. This petrified wood is at the location where the arrow points in Figure 9. Poorly sorted conglomerate beds dip 24° to the west. This petrified wood appears to be a remnant of a horizontally lying tree stump with a root visible below the pen.

11.9 STOP FOUR. Mammal fossil area. The area in which a few fragments of mammal fossils have been found can be reached by parking alongside the road and walking to the mammal fossil area shown in Figure 8.

Pieces of fossilized mammal bones are in bentonitic claystones. Beds of bentonitic claystone weather to popcornlike material. Gypsum crystals ($CaSO_4 \cdot 2H_2O$) associated with the claystone are found scattered over the surface. These claystone beds are interlayered with diatomaceous claystones and volcanic ash. Bentonitic claystones are derived mostly from volcanic glass shards that formed the vast majority of the original sediments in the lakes.

Both bentonitic clay and clinoptilolite zeolite are formed by alteration of rhyolitic volcanic ash. Whether the fine ash particles alter to bentonitic clay or zeolite depends upon both salinity and alkalinity of the water altering the volcanic ash. In extremely alkaline and saline water, the volcanic glass alters to clinoptilolite zeolite (Surdam, 1977, p. 65). In fresher waters, volcanic glass alters to bentonitic clay. The exact chemical conditions and the length of time over which these alterations of glass occur are not completely understood. After deposition of rhyolitic volcanic ash in fresh water, the ash hydrates and releases silica and alkalies during the alteration of glass to clay minerals. Bentonitic clay is primarily montmorillonite clay (Leppert, 1986, p. 496). The montmorillonite clay puffs and swells when it absorbs water. When the clay dries, it forms the popcornlike texture that characterizes the surface. If you dig 1 or 2 ft beneath these popcornlike surfaces, you can see the original compact claystone.

Leppert (1986, p. 497) indicates bentonite is used in drilling fluids and in foundries. Bentonite is also placed as a sealant to water flow beneath hazardous-waste sites. Open-pit mines in the area produce good-quality bentonite that is currently marketed mostly for sealant.

Mammalian vertebrate fossil remains (Figure 11) are not abundant in the Sucker Creek Formation, but some good specimens have been collected. *Oreodonts*, "even-toed" hooved mammals that were about the size of a pig, were recovered about 6 mi south of Stop Four (Walden, 1986, p. 41; identification by Greg MacDonald, Idaho Museum of Natural History). Walden also indicates that a *Merichippus*, a Miocene horse, was found near Succor Creek south of Stop Four, the mammal fossil area. Both of the mammals were grazers, which implies an environment of grasslands near a lake.

The colorful canyon at Succor Creek State Park is about 1 mi south of Stop Four. Tables are located about 5 mi south of the recreation area boundary, and this is a nice place to have lunch. Those wishing a geologic guide farther up Succor Creek Canyon should consult Kittleman (1973).

ATTENTION

Glen Teague should be contacted at Teague Mineral Products, 1925 Highway 201 South, Adrian, OR 97901, phone (503) 339-4385, before the field trip for permission to enter the zeolite mine. Also, the road can become very slick during the wet seasons, so caution should be used.

ACKNOWLEDGMENTS

The author thanks Spencer Wood, Department of Geology and Geophysics, Boise State University, and Edward Squires, student in geology, Boise State University, who contributed valuable information to the preparation of this road log.

Figure 11. Mammalian vertebrate fossils. These bone fragments may be from common grazers, such as Dromomeryx *(cervoid),* Merycodus *(pronghorn), or* Merychippus *(Miocene horse), which roamed the area during the Miocene (Smiley and others, 1975, p. 10).*

REFERENCES CITED

Armstrong, R.L., 1975, The geochronometry of Idaho: Isochron/West, no. 14, 50 p.

Armstrong, R.L., Harakal, J.E., and Neill, W.M., 1980, K-Ar dating of Snake River Plain (Idaho) volcanic rocks--new results: Isochron/West, no. 27, p. 5-10.

Brown, D.E., and Petros, J.R., 1985, Geochemistry, geochronology, and magnetostratigraphy of a measured section of the Owyhee Basalt, Malheur County, Oregon: Oregon Geology, v. 47, no. 2, p. 15-20.

Ekren, E.B., McIntyre, D.H., and Bennett, E.H., 1984, High-temperature, large-volume, lavalike ash-flow tuffs without calderas in southwestern Idaho: U.S. Geological Survey Professional Paper 1272, 76 p.

Ekren, E.B., McIntyre, D.H., Bennett, E.H., and Malde, H.E., 1981, Geologic map of Owyhee County, Idaho, west of longitude 116° W.: U.S. Geological Survey Miscellaneous Investigations Series map I-1256, scale 1:125,000.

Ekren, E.B., McIntyre, D.H., Bennett, E.H., and Marvin, R.F., 1982, Cenozoic stratigraphy of western Owyhee County, Idaho, *in* Bonnichsen, B., and Breckenridge, R.M., eds., Cenozoic geology of Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 215-235.

Evernden, J.F., and James, G.T., 1964, Potassium-argon dates and the Tertiary floras of North America: American Journal of Science, v. 262, no. 8, p. 945-974.

Graham, A.K., 1965, The Sucker Creek and Trout Creek Miocene floras of southeastern Oregon: Kent State University Research Series 9 (Bulletin, v. 53, no. 12), 147 p.

Hart, W.K., Mertzman, S.A., and Carlson, R.W., 1985, Late Cenozoic volcanic geology of the Jordan Valley-Owyhee River region, southeastern Oregon: Boise, Idaho, Geological Society of America, Rocky Mountain Section, 38th annual meeting, unpublished composite field trip guide.

Kittleman, L.R., 1973, Guide to the geology of the Owyhee region of Oregon: Eugene, Oreg., University of Oregon Museum of Natural History Bulletin 21, 61 p.

Kittleman, L.R., Green, A.R., Haddock, G.H., Hagood, A.R., Johnson, A.M., McMurray, J.M., Russell, R.G., and Weeden, D.A., 1967, Geologic map of the Owyhee region, Malheur County, Oregon: Eugene,

Oreg., University of Oregon Museum of Natural History Bulletin 8, scale 1:125,000.
Kittleman, L.R., Green, A.R., Hagood, A.R., Johnson, A.M., McMurray, J.M., Russell, R.G., and Weeden, D.A., 1965, Cenozoic stratigraphy of the Owyhee region, southeastern Oregon: Eugene, Oreg., University of Oregon Museum of Natural History Bulletin 1, 45 p.
Lawrence, D.C., 1986, Geologic report on Miocene volcanics and sediments within the Sucker Creek Formation, Malheur County, Oregon: Unpublished field geology report, 27 p., geologic map, scale 1:12,000. Copy available upon request from Department of Geology and Geophysics, Boise State University, Boise, Idaho 83725.
Leppert, D., 1986, Environmental uses of natural zeolites and bentonites: Proceedings of the 22nd Symposium on Engineering Geology and Soils Engineering, Idaho, Department of Transportation, P.O. Box 7129, Boise, Idaho, p. 496-510.
Mumpton, F.A., 1977, Natural zeolites, *in* Mumpton, F.A., ed., Mineralogy and geology of natural zeolites: Mineralogical Society of America, Short Course Notes, v. 4, p. 1-17.
Odom, E., 1984, Reviews in mineralogy (Micas): Washington, D.C., Mineralogical Society of America, p. 545-572.
Orr, W.N., and Orr, E.L., 1981, Handbook of Oregon plant and animal fossils: Eugene, Oreg., available from the authors, P.O. Box 5286, Eugene, OR 97405, 285 p.
Rytuba, J.J., Vander Meulen, D.B., Plouff, D., and Minor, S.A., 1985, Geology of the Mahogany Mountains caldera, Oregon [abs.]: Geological Society of America Abstracts with Programs, v. 17, no. 4, p. 263.
Sheppard, R.A., and Gude, A.J., 3rd, 1983, Field trip stop 3, Sheaville zeolite deposit, Sheaville, Oregon, *in* Mumpton, F.A., ed., Zeo-Trip '83. An excursion to selected zeolite deposits in eastern Oregon, southwestern Idaho, and northwestern Nevada, and to the Tahoe-Truckee water reclamation plant, Truckee, California, July 7-10, 1983: Brockport, N.Y., International Committee on Natural Zeolites, c/o Department of Earth Sciences, State University College, Brockport, N.Y. 14420, p. 25-31.
———1987, Field trip guide to the Sheaville and Rome zeolite deposits, southeastern Oregon: Oregon Geology, v. 49, no. 1, p. 3-10.
Smiley, C.J., Shah, S.M.I., and Jones, R.W., 1975, Guidebook for the later Tertiary stratigraphy and paleobotany of the Weiser area, Idaho: Idaho Bureau of Mines and Geology Information Circular 28, 13 p.
Squires, E., 1985, A field study of Miocene volcanics and sediments within the Sucker Creek Formation, Malheur County, Oregon: Unpublished field geology report, 24 p., available upon request from Department of Geology and Geophysics, Boise State University, Boise, Idaho 83725.
Surdam, R.C., 1977, Zeolites in closed hydrologic systems, *in* Mumpton, F.A., ed., Mineralogy and geology of natural zeolites: Mineralogical Society of America Short Course Notes, v. 4, p. 65-91.
Vander Meulen, D.B., Rytuba, J.J., King, H.D., Plouff, D., and Scott, D.F., 1987a, Mineral resources of the Honeycombs Wilderness Study Area, Malheur County, Oregon: U.S. Geological Survey Bulletin 1741-A, p. A1-A15.
Vander Meulen, D.B., Rytuba, J.J., Vercoutere, T.L., and Minor, S.A., 1987b, Geologic map of the Rooster Comb quadrangle, Malheur County, Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-1902, scale 1:24,000.
Walden, K.D., 1986, A stratigraphic and structural study of Coal Mine Basin, Idaho-Oregon: East Lansing, Mich., Michigan State University master's thesis, 70 p.
Wood, S.H., 1984, Review of late Cenozoic tectonics, volcanism, and subsurface geology of the western Snake River Plain, *in* Geology, tectonics, and mineral resources of western and southern Idaho: Dillon, Mont., Tobacco Root Geological Society, P.O. Box 370, p. 48-60. □

Allen publishes *Time Travel Two*

Time Travel Two in Oregon, a Geology Scrapbook, mostly written by John Eliot Allen. Price $10. Available from J.E. Allen, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207-0751

John Eliot Allen, Emeritus Professor of Geology at Portland State University, has published a second volume of geologic articles from his "Time Travel" column in the weekly science section of Portland's newspaper *The Oregonian.*

Two years after the first publication of such articles in a separate volume, Allen now has collected 106 more articles that appeared between November 1985 and November 1987. On 153 pages, the spiral-bound book reproduces the newspaper articles as they appeared originally, often with accompanying illustrations. In addition to Allen, 14 other authors contributed to the column. □

DOGAMI moves to new warehouse and expands core repository

by Dan E. Wermiel, Oregon Department of Geology and Mineral Industries

On December 1, 1987, the Oregon Department of Geology and Mineral Industries (DOGAMI) occupied its new warehouse which is located near downtown Portland. The following types of materials are stored in the warehouse, enabling DOGAMI to serve the public better:

1. PROPRIETARY OIL, GAS, AND GEOTHERMAL-WELL SAMPLES

Laws regulating oil and gas exploration were first passed in Oregon in 1923, but it was not until 1953 that statutes were passed authorizing DOGAMI to supervise oil and gas development in the state. As a result, all well cuttings and cores for all wells drilled for oil and gas in Oregon since 1953 are now maintained by DOGAMI and are stored in the warehouse. This repository consists of samples from over 200 wells ranging in depth from less than 1,000 ft to over 13,000 ft.

By State law, the cuttings and cores for oil and gas wells remain confidential for a two-year period after a well is drilled and then are made available to the public for inspection. Arrangements to inspect well samples can be made by contacting Dennis Olmstead or Dan Wermiel at DOGAMI to schedule a time to study the material. A work room is provided, but microscopes and other examination equipment are not supplied by DOGAMI. A complete list of wells and the cuttings and cores stored in the warehouse is provided in a recently released publication (Oil and Gas Investigation 16, *Available Well Records and Samples of Onshore and Offshore Oil and Gas Exploration Wells in Oregon).*

In addition, when an analysis in which slides are produced is done on well samples, the slides are permanently stored in the warehouse. If well samples are treated for a particular analysis, such as a paleontological study, the samples are also stored and are

Chuck Radasch, warehouse curator, checks oil and gas samples stored in new warehouse.

available for public inspection.

Similarly, geothermal well cores and cuttings are also stored in the warehouse and are available to the public for inspection after a four-year confidentiality period. Arrangements to study a geothermal well should be handled in the same manner as for oil and gas wells.

2. NONPROPRIETARY DRILL-HOLE SAMPLES

The warehouse will now also serve as a storage facility for samples from selected nonproprietary, geologically significant holes drilled in the state. There is no confidentiality period for any of this material. For example, the cores obtained from the recent supercollider studies in Oregon are now stored in the DOGAMI warehouse.

All well samples should be marked with the name of the operator and the location from which the samples are obtained and any pertinent information or data derived from the samples. A recommended time of duration to store the samples should be determined when the samples are delivered to DOGAMI. The samples may be skeletonized if there is an excessive volume. DOGAMI will consider accepting skeletonized cores from appropriate new or existing wells in the state. Anyone wishing to submit drill-hole samples for consideration should contact DOGAMI.

3. OUTCROP HAND SAMPLES

When a DOGAMI field project in which outcrop samples are taken is in progress, they are stored in the warehouse for use on the specific project. When the project is completed, the outcrop rocks are discarded. However, if a significant analysis has been made, such as age determination, the samples may be retained. Also, slides made from the samples are stored indefinitely.

4. LABORATORY MATERIAL

Lab samples are stored in the warehouse for use until the discard date of the material is reached. This is generally five years from the date of the last use of the material. Lab pulp from assays is stored indefinitely in the warehouse.

5. DOGAMI PUBLICATIONS

The warehouse is also used for storage of the numerous publications, including maps and written documents covering a wide range of geologic subjects, that are available from DOGAMI. A list of publications can be obtained and publications may be purchased from DOGAMI's Portland, Baker, and Grants Pass offices. An abbreviated list of available publications appears on the back cover of each issue of *Oregon Geology.* □

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that we feel are of general interest to our readers.

GEOLOGY AND PETROLEUM POTENTIAL OF THE HAY CREEK ANTICLINE, NORTH-CENTRAL OREGON, by Stephen I. Wareham (M.S., Loma Linda University, 1986)

For many years, it has been reported that the core of the Hay Creek Anticline exposes metamorphic rocks of Paleozoic or Mesozoic age. On closer study, it was found that these rocks consist of only slightly metamorphosed black to dark-gray siltstones and sandstones with less abundant chert pebble conglomerate and recrystallized limestone. The sequence is here informally named "Hay Creek Formation." Calcareous nannofossils recovered and identified from the limestone yielded an age of early to middle Eocene.

The depositional environment of the "Hay Creek Formation" is interpreted to be a submarine turbidite fan. Siltstones were deposited as pelagic rain and turbidite fallout. Sandstones were deposited in turbidite flows as evidenced by flute casts. The Hay Creek Anticline formed as a result of multiple compressional forces, with periods of deposition and erosion between orogenic events.

The petroleum potential of the "Hay Creek Formation" is good. The total organic carbon in the siltstones, the kerogens, and the maturity indicators suggest that oil and/or gas have been produced from these rocks. Shallow exploration drilling in the area has revealed that petroleum is present.

THE GEOLOGY AND ALTERATION OF THE BEAR CREEK BUTTE AREA, CROOK COUNTY, CENTRAL OREGON, by Richard Matthew Wilkening, (M.S., Portland State University, 1986)

The Eocene Clarno Formation, the Oligocene John Day Formation, and basalts of the High Lava Plains are exposed in the Bear Creek Butte area in central Oregon. In this area, the Clarno Formation can be divided into a lower sequence composed of intermediate lava flows with intercalated mudflows and volcaniclastic sediments and an upper sequence of rhyolite and basalt flows and felsic tuffs. Separating the two units is a well-developed saprolite. The change from intermediate to rhyolite-basalt volcanism reflects a change in the tectonic environment of the Cascade volcanic arc from compression to relaxation, as subduction of the Farallon plate by the North American plate slowed, allowing extension of the continental plate margin to occur.

Hydrothermal alteration has affected rocks of the Clarno and John Day Formations in the Bear Creek Butte area. The Oronogo and Platner Mines and the Admunsen prospect, currently being worked, are hosted in the Clarno Formation. Alteration is most intense at the Platner Mine, where hydrothermal alteration forms an ellipse along north-northwest-trending faults. Hydrothermal breccias are associated with silicified and kaolinitized felsic tuffs and a mafic intrusion at this mine. At the Admunsen claim, located south of the Platner Mine, a mafic intrusion is argillized and cut by fine quartz veinlets, and felsic tuffs have been silicified. At the Oronogo Mine, the northernmost property, alteration zones are confined to fractured basaltic andesite along a northwest-trending fault. Alteration consists of silicification with minor argillization of plagioclase phenocrysts in the basaltic andesite.

The Platner Mine contains the highest concentrations of As and Sb. Trace-element geochemistry indicates Sb concentrations (maximum 102 ppm, average 44 ppm) are highest in the area of the Platner Mine and decrease northward along the controlling structure more gradually than to the south of the mine. Arsenic concentrations increase northward along the controlling structure from the Platner Mine (maximum 45 ppm, average 12 ppm). Hg is irregularly distributed along the structure and has its highest concentration south of the Platner Mine. Trace concentrations of U occur along the fault zones in the areas of alteration.

Altered rocks of the John Day Formation, which unconformably overlies the Clarno Formation, host uranium mineralization. The alteration zones are located along northwest- to west-northwest-trending faults. The alteration assemblages are similar to that at the mercury prospects: clays, predominately kaolinite, and fine-grained quartz. Trace-element geochemistry indicates anomalous U (maximum 59 ppm, average 24 ppm) and Mo concentrations.

The presence of cinnabar + hematite $\pm$ pyrite indicates that the hydrothermal system that operated at the mercury prospects was an oxidizing system. Deposition of U and Mo required a reducing environment. The differences in the environment of deposition for mercury and uranium indicate that two different systems were active in the study area.

Although alteration is extensive and hydrothermal breccias are present in the Bear Creek area, significant base- and precious-metal anomalies have not been detected along controlling structures. □

AVAILABLE DEPARTMENT PUBLICATIONS

GEOLOGICAL MAP SERIES

		Price	No. copies	Amount
GMS-4.	Oregon gravity maps, onshore and offshore. 1967	$ 3.00		
GMS-5.	Geologic map, Powers 15-minute quadrangle, Coos and Curry Counties. 1971	3.00		
GMS-6.	Preliminary report on geology of part of Snake River canyon. 1974	6.50		
GMS-8.	Complete Bouguer gravity anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-9.	Total-field aeromagnetic anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-10.	Low- to intermediate-temperature thermal springs and wells in Oregon. 1978	3.00		
GMS-12.	Geologic map of the Oregon part of the Mineral 15-minute quadrangle, Baker County. 1978	3.00		
GMS-13.	Geologic map, Huntington and part of Olds Ferry 15-min. quadrangles, Baker and Malheur Counties. 1979	3.00		
GMS-14.	Index to published geologic mapping in Oregon, 1898-1979. 1981	7.00		
GMS-15.	Free-air gravity anomaly map and complete Bouguer gravity anomaly map, north Cascades, Oregon. 1981	3.00		
GMS-16.	Free-air gravity anomaly map and complete Bouguer gravity anomaly map, south Cascades, Oregon. 1981	3.00		
GMS-17.	Total-field aeromagnetic anomaly map, south Cascades, Oregon. 1981	3.00		
GMS-18.	Geology of Rickreall, Salem West, Monmouth, and Sidney 7½-min. quads., Marion/Polk Counties. 1981	5.00		
GMS-19.	Geology and gold deposits map, Bourne 7½-minute quadrangle, Baker County. 1982	5.00		
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GMS-21.	Geology and geothermal resources map, Vale East 7½-minute quadrangle, Malheur County. 1982	5.00		
GMS-22.	Geology and mineral resources map, Mount Ireland 7½-minute quadrangle, Baker/Grant Counties. 1982	5.00		
GMS-23.	Geologic map, Sheridan 7½-minute quadrangle, Polk/Yamhill Counties. 1982	5.00		
GMS-24.	Geologic map, Grand Ronde 7½-minute quadrangle, Polk/Yamhill Counties. 1982	5.00		
GMS-25.	Geology and gold deposits map, Granite 7½-minute quadrangle, Grant County. 1982	5.00		
GMS-26.	Residual gravity maps, northern, central, and southern Oregon Cascades. 1982	5.00		
GMS-27.	Geologic and neotectonic evaluation of north-central Oregon. The Dalles 1°x2° quadrangle. 1982	6.00		
GMS-28.	Geology and gold deposits map, Greenhorn 7½-minute quadrangle, Baker/Grant Counties. 1983	5.00		
GMS-29.	Geology and gold deposits map, NE¼ Bates 15-minute quadrangle, Baker/Grant Counties. 1983	5.00		
GMS-30.	Geologic map, SE¼ Pearsoll Peak 15-minute quadrangle, Curry/Josephine Counties. 1984	6.00		
GMS-31.	Geology and gold deposits map, NW¼ Bates 15-minute quadrangle, Grant County. 1984	5.00		
GMS-32.	Geologic map, Wilhoit 7½-minute quadrangle, Clackamas/Marion Counties. 1984	4.00		
GMS-33.	Geologic map, Scotts Mills 7½-minute quadrangle, Clackamas/Marion Counties. 1984	4.00		
GMS-34.	Geologic map, Stayton NE 7½-minute quadrangle, Marion County. 1984	4.00		
GMS-35.	Geology and gold deposits map, SW¼ Bates 15-minute quadrangle, Grant County. 1984	5.00		
GMS-36.	Mineral resources map of Oregon. 1984	8.00		
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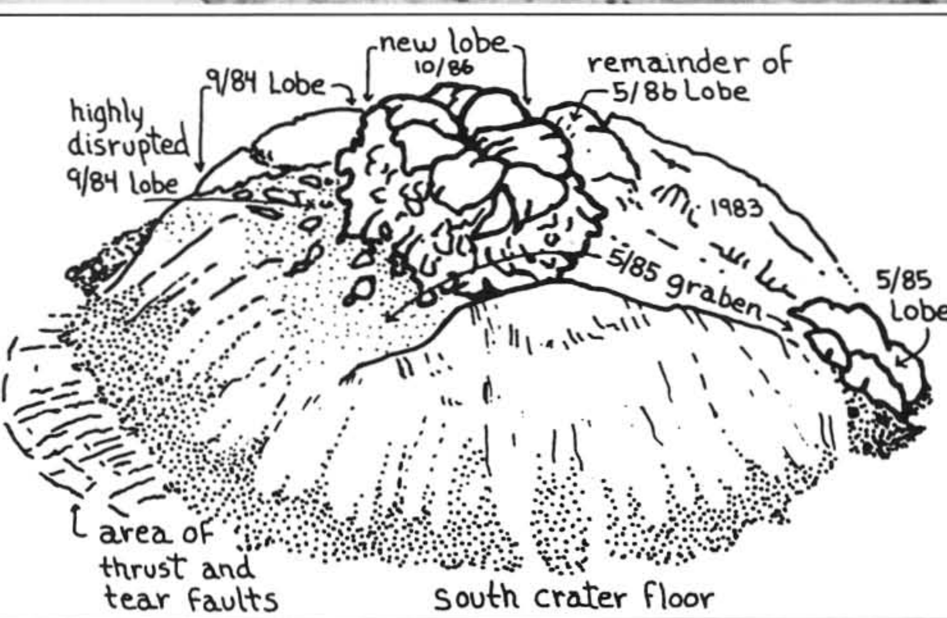

THIS MONTH:

Geologic guide: Monitor Ridge climbing route at Mount St. Helens

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COVER ILLUSTRATION

Photo shows view north from south crater rim of Mount St. Helens toward lava dome. Spirit Lake and area devastated by the lateral blast of May 18, 1980, lie north of dome. Mount Rainier is in background. Sketch of lava dome is from photos taken October 28, 1986, showing dome details in roughly the same view as photo (sketch by Bobbie Meyers, USGS, David A. Johnston Cascades Volcano Observatory). Article on climbing Mount St. Helens begins on next page.

OIL AND GAS NEWS

ARCO releases results of 1987 Mist drilling program

ARCO Oil and Gas Company drilled eight exploratory wells and one redrill at Mist Gas Field during 1987. Of these, seven were completed as gas wells, with one plugged and abandoned and one abandoned redrill. This is the greatest number of successful gas completions in a single year since the field was discovered in 1979. Combined flow rates for the seven new gas wells is 10-12 million cubic feet (MMcf) of gas per day, with combined proven reserves of 11-14 billion cubic feet (Bcf) of gas, which will extend the life of the field for many years. Production at Mist should increase from the current 10 MMcf to about 15 MMcf of gas per day once these wells are all connected to gas pipelines.

During 1987, ARCO's rental and royalty payments plus taxes added up to over $1 million in direct payments to Columbia County. The total economic impact, statewide and primarily in Columbia County, of ARCO's involvement in the Mist Gas Field in 1987 was over $6 million.

Permit for Columbia Basin wildcat issued

ARCO has been issued an oil and gas drilling permit for a significant wildcat well in eastern Oregon's Columbia Basin. The Hanna No. 1, located about 6 mi northeast of Heppner in sec. 23, T. 2 S., R. 27 E., Morrow County, has a proposed total depth of 9,000 ft. This well will penetrate the surface volcanic rocks that dominate the area to test the underlying strata containing a sedimentary section that is interpreted to have favorable conditions for hydrocarbon generation and entrapment.

Recent permits

Permit no.	Operator, Well API number	Location	Status, proposed total depth (ft)
397	ARCO Hanna -1 36-049-00002	NE ¼ sec. 23 T. 2 S., R. 27 E. Morrow County	Location; 9,000.
398	ARCO CFI 34-1-55 36-009-00232	SE ¼ sec. 1 T. 5. N., R. 5. W. Columbia County	Application; 1,625.
399	ARCO Johnston 44-19-65 36-009-00233	SE ¼ sec. 19 T. 6. N., R. 5. W. Columbia County	Application; 3,125.
400	ARCO Col. Co. 12-19-65 36-009-00234	NW , sec. 19 T. 6. N., R. 5. W. Columbia County	Application; 3,300.

□

SW Oregon miners, BLM form committee

Representatives from the U.S. Bureau of Land Management's (BLM) Medford district Glendale and Grants Pass resource areas and from the miners in the Grave and Galice Creek areas of southwestern Oregon have organized to provide a forum for issues, opportunities, and new mining-industry information. The committee consists of nine mining representatives and three BLM staff members.

Recently, BLM committee members, accompanied by miners, toured two placer operations and a patented lode claim during their meeting. Mining operations and activities incidental to mining were discussed at each location.

—Matt Craddock, BLM News

Geologic guide to the Monitor Ridge climbing route, Mount St. Helens, Washington*

by William M. Phillips, Washington Division of Geology and Earth Resources, Olympia, Washington 98504

INTRODUCTION

For nearly seven years following the cataclysmic eruption of May 18, 1980, the summit of Mount St. Helens lay in the forbidden "red zone," with access prohibited to all but a handful of scientific researchers. Mountain climbers could only look wistfully at the volcano, once among the most popular ascents in the Pacific Northwest.

Now, due to waning eruptive activity and improved eruption prediction by scientists—as well as active lobbying by various mountaineering groups—Mount St. Helens is once again open to climbers. Beginning May 15, 1987, the U.S. Forest Service (USFS), which is responsible for the Mount St. Helens National Volcanic Monument, instituted a climbing permit system.

Making the trudge to the top has proved spectacularly popular. According to Forest Service estimates, as many as 12,000 people may have reached the 8,363-ft summit by Labor Day, 1987. In good weather, climbers crowd the mountaintop, eating lunch and exchanging "where were you when the mountain blew" stories.

Before 1980, when the mountain boasted a 9,677-ft summit, Mount St. Helens was recognized as an excellent climb for the novice mountaineer. Lacking truly steep slopes and offering splendid scenery, "America's Fujiyama" was ascended by thousands. Today, climbing Mount St. Helens offers unparalleled opportunities for close views of some of the most spectacular volcanic terrain in North America. Remarkable panoramas of crater walls, the lava dome, and Spirit Lake reward the climber at the summit. And while dangers do exist (outlined in "Climbing hazards" below), the ascent is, weather permitting, well within the abilities of most physically fit people. The trip to the top and back takes most people six or seven hours.

This article presents a guide to geologic features along the popular Monitor Ridge climbing route (Figures 1, 2, and 3). On Monitor Ridge are a number of well-displayed volcanic landforms, including lava levees and pressure ridges. Descriptions of points of geologic interest visible from the summit are also presented.

MAKING THE CLIMB

Climbing permits

Climbing permits are required for all travel above 4,800 ft (about timberline) on the mountain. The permits are valid for 36 hours: from noon of the day prior to the date of the permit to midnight on the day of the permit.

From November 1 to May 15, climbers simply register before and after climbing at Yale Park, located 2 mi west of Cougar, on Washington State Route 503 (Figure 1). No other written permit is required.

From May 16 to October 31, a quota system is in effect, limiting permits to 100 per day. Advance reservations for 70 permits per day are available by mail or in person at Monument headquarters at Amboy. "Day of the climb" reservations for 30 permits are available on a first-come, first-served basis at Jack's Restaurant and Store, located on Highway 503, 23 mi east of Woodland, Wash., and 3.5 mi west of Yale Park, open daily from 5:00 a.m. to 9:00 p.m. These permits may be obtained the afternoon before or the morning of the day of the climb. Climbers must still sign in and out at the Yale Park register regardless of the type of permit.

Climbing Mount St. Helens is extremely popular. During the summer of 1987, advance permits for weekend climbs were booked up by early June. The Forest Service reported processing up to 600 calls per day concerning mountain climbing. Day-of-climb permits often required waiting in line all night at Yale Park (where camping is not permitted). To avoid disappointment, plan ahead and get your permit early!

A party size of 12 is the maximum per climbing permit. However, smaller groups are recommended in order to minimize damage to biological or geological features of the Monument and to preserve the backcountry spirit of the mountain.

Hikers interested in exploring the crater must sign in and out at the Yale Park register but do not otherwise need a written permit. The crater is open to hikers only when the crater floor is snow-covered. Camping is not permitted in the crater. The Spirit Lake basin, north of Mount St. Helens and below 4,800 ft, is closed to public access.

The Mount St. Helens National Volcanic Monument can be contacted at **Mount St. Helens National Volcanic Monument, Route 1, Box 369, Amboy, WA 98601.** The special telephone number for information on all climbing concerns, such as permit availability, mountain conditions, or gear requirements, is (206) 247-5800.

Climbing access

Climbing routes within the Mount St. Helens National Volcanic Monument are reached from the south side of the volcano, near Cougar, Washington (Figure 1). Access roads are plowed during winter to the junction of Roads 83 and 830, and to the junction of Roads 83 and 8312. Plowing of roads and parking areas is conducted by the Washington State Snow Park program. All parked vehicles must display a valid "Snow Park" emblem, which costs $10 and is available from some stores in the Monument area but not in the Monument.

Climbing hazards

While Mount St. Helens is not considered a difficult mountain, scaling it exposes climbers to some hazardous conditions. Chief among these are rapidly changing weather conditions. The wise climber should prepare for travel on slick, steep, snow- or ice-covered slopes in fog, heavy rain, or snow. Take a compass, the U.S. Geological Survey 1:24,000-scale topographic map of Mount St. Helens, and an ice axe. Crampons are a good idea for early-season climbs when the route will be snow covered. Beware of hypothermia, and take plenty of extra warm clothes.

Water is scarce and of uncertain quality on the climbing routes. Particularly during the summer, climbers should prepare for the desert (sunglasses, sunblock lotion, hats) and bring extra fluids.

The south slopes of Mount St. Helens lack distinctive landmarks. Climbers hurrying down from the summit may follow ravines or lava levees that end considerable distances from trailheads. Plan the descent of the mountain carefully, preferably following the same route as on the way up.

NOAA weather radios are an excellent and inexpensive investment for all mountaineers; continuous 24-hour broadcasts from stations in Olympia and Portland can be received at Mount St. Helens. In case of volcanic emergency, projected ash trajectories will be broadcast.

**Because we know that it will be of interest to our readers, this article was reprinted from* Washington Geologic Newsletter, *v. 15, no. 4 (October 1987), p. 3-13, with kind permission of the Washington Division of Geology and Earth Resources.*

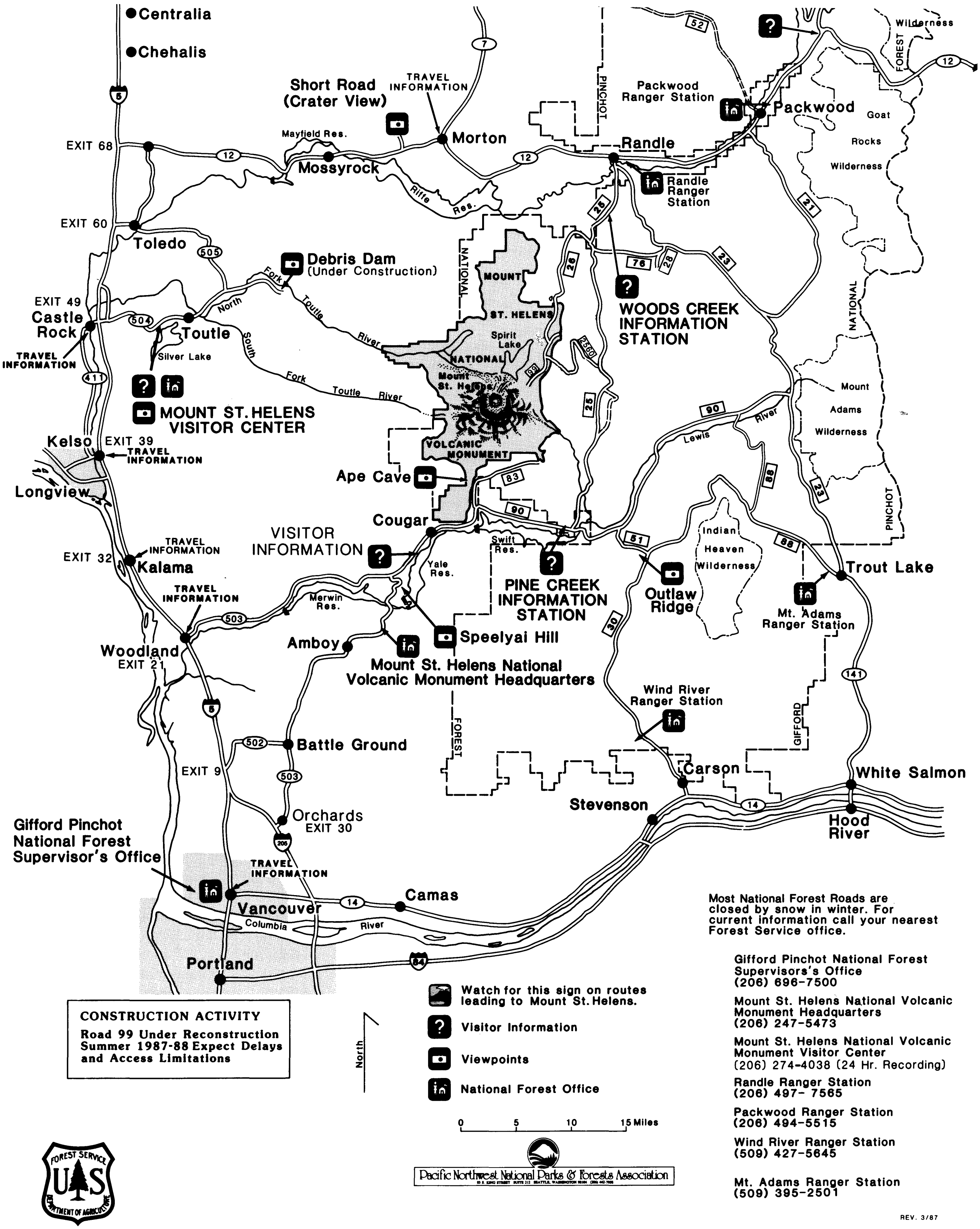

Figure 1. Location map of the Mount St. Helens area. Road conditions are subject to change. Check with Mount St. Helens National Monument Headquarters for current conditions (map by permission of the Pacific Northwest National Parks and Forests Association).

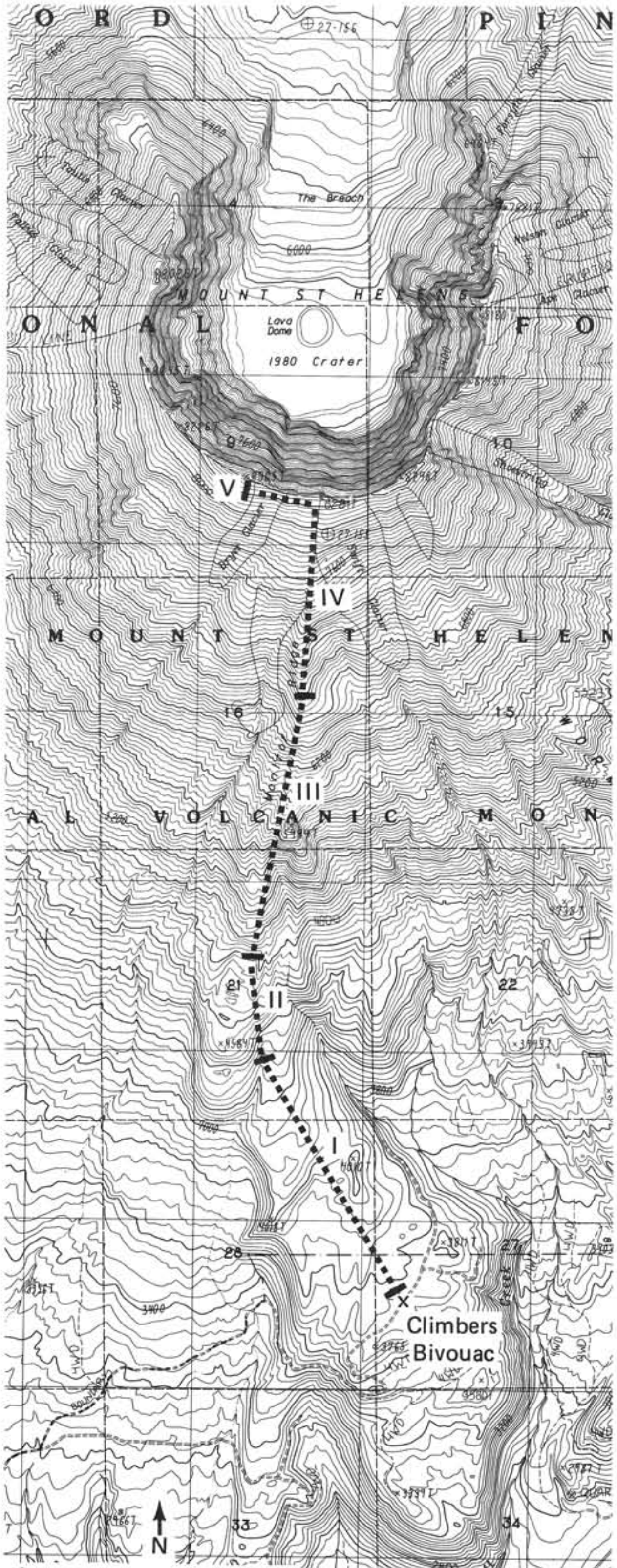

Figure 2. Topographic map showing the Monitor Ridge climbing route (from U.S. Geological Survey Mount St. Helens 1:24,000-scale quadrangle map).

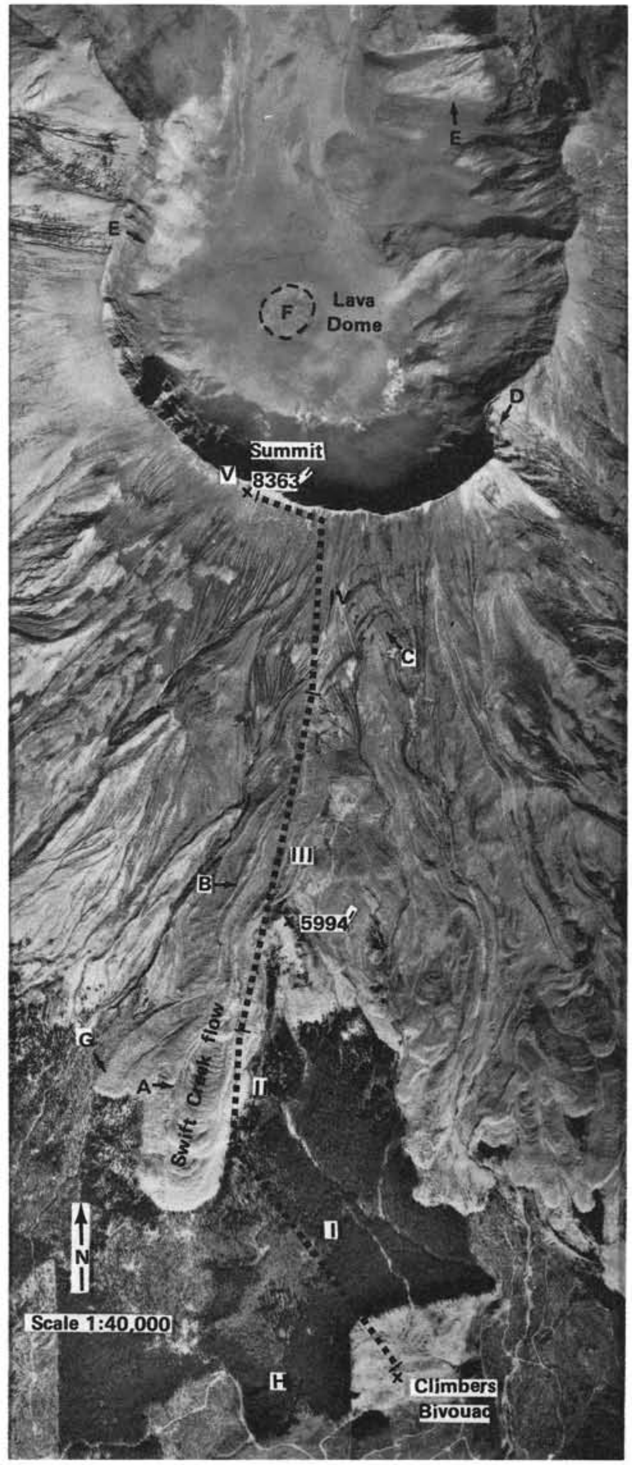

Figure 3. Aerial photograph of the Monitor Ridge climbing route, fall 1980. Route approximately located. Numbers I-V refer to segments of the route discussed in the text. A, lateral pressure ridges; B, lava levee; C, crevasses on Swift Glacier; D, top of Shoestring Glacier; E, contact between white ancestral Mount St. Helens dacite and younger pyroclastic and lava deposits; F, 1980 lava dome; G, margin of old andesite flow; H, point where Road 830 traverses margin of old andesite flow.

In addition, climbers must recall that Mount St. Helens is still an *active* volcano. Sudden explosive activity in the lava dome is possible and may not be predicted by scientists monitoring the volcano. In the case of eruption, the Forest Service recommends immediate descent from the mountain, avoiding gullies and ravines. If caught in an ash-fall, breathe through a moist cloth and protect your eyes.

During the winter, large snow cornices build out over the crater rim. The cornices may fail at any time, and climbers should avoid travel over them, even when roped-up.

The Mount St. Helens climbing experience changes radically as snow melts from the stratovolcano's cone. Early-season ascents (approximately pre-July or post-October) are largely over snow fields. While often plagued by bad weather, the early-season climb delights well-prepared mountaineers with exciting glissades, telemark skiing, and most importantly, ash-free conditions.

As the snow melts, an extremely dusty environment may be encountered. Climbers should protect cameras and other sensitive gear from swirling ash. At the summit, sudden intense "dust-devils" may rip hats from the heads of the unwary and coat everyone and everything with fine ash.

GEOLOGICAL HISTORY OF THE MOUNT ST. HELENS AREA

Tertiary rocks older than Mount St. Helens

The oldest rocks in the Mount St. Helens area record volcanic eruptions occurring during the Tertiary about 35 to 20 million years ago (Figure 4). The Tertiary volcanoes were unrelated to present-day Mount St. Helens and produced interbedded pyroclastic materials (tuffs) and lava flows. Also common are sandstone, conglomerate, and siltstone derived from erosion of the volcanic units during the Tertiary.

Most of the Tertiary volcanic rocks are andesites. Basalt and dacite are also present in lesser quantities. These three igneous rock types are typical products of volcanic arcs like the Cascade Range. Basalts are, generally, dark-colored rocks that are relatively fluid when molten. As a result, basalts often flow great distances and form low, broad shield volcanoes. Lighter colored dacites are products of more viscous magma and typically pile up to form steep lava domes or plugs subject to catastrophic collapse. Dacitic magma also tends to trap volcanic gases and therefore often produces explosive eruptions of pumice and ash. The physical and chemical properties of andesites are intermediate between those of basalt and dacite.

Numerous igneous intrusions also cut the Tertiary section. In many instances, the intrusions mark the location of the subsurface conduits through which magma rose to the Earth's surface during an eruption.

Millions of years intervened between the last eruption of the Tertiary volcanoes and volcanism related to Mount St. Helens. During that time, folding accompanying uplift of the Cascade Mountains tilted the Tertiary rocks eastward (Figure 4). The uplift, together with alpine glaciation during the last ice age 10,000 to 20,000 years ago, caused deep erosion and incision of the Tertiary rocks by rivers, streams, and ice.

Ancestral Mount St. Helens

Beginning about 40,000 years ago and continuing to about 2,500 years ago, explosive dacitic eruptions built (and destroyed) lava domes and possibly one or more stratovolcano cones on top of the eroded Tertiary rocks. The eruptions widely distributed volcanic ash over Washington. Volcanic activity was episodic with hundreds or even thousands of years between eruptions.

Characteristic products of ancestral Mount St. Helens include hornblende-rich dacite lava domes, pyroclastic flows, and lahar deposits. The Butte Camp area (Figure 1) contains an excellent example of the dacite lava domes. Additional light-colored lava domes of ancestral Mount St. Helens can be seen from the summit in the base of crater walls (Figure 5).

Pyroclastic flows—hot, gas-rich torrents of pumice, dense dacite fragments, and crystals—streamed into and filled valleys surrounding ancestral Mount St. Helens. Explosive eruptions may have caused large portions of volcanic cones or domes to collapse, causing debris avalanches. The debris avalanches and pyroclastic flows dammed drainages and created lakes like Spirit Lake. Rapid breaching of the dams, along with melting of snow or ice during eruptions, generated lahars (sediment-rich floods). Some of the lahars produced by ancestral Mount St. Helens were huge, inundating floodplains as far away as the Columbia River, more than 40 mi away.

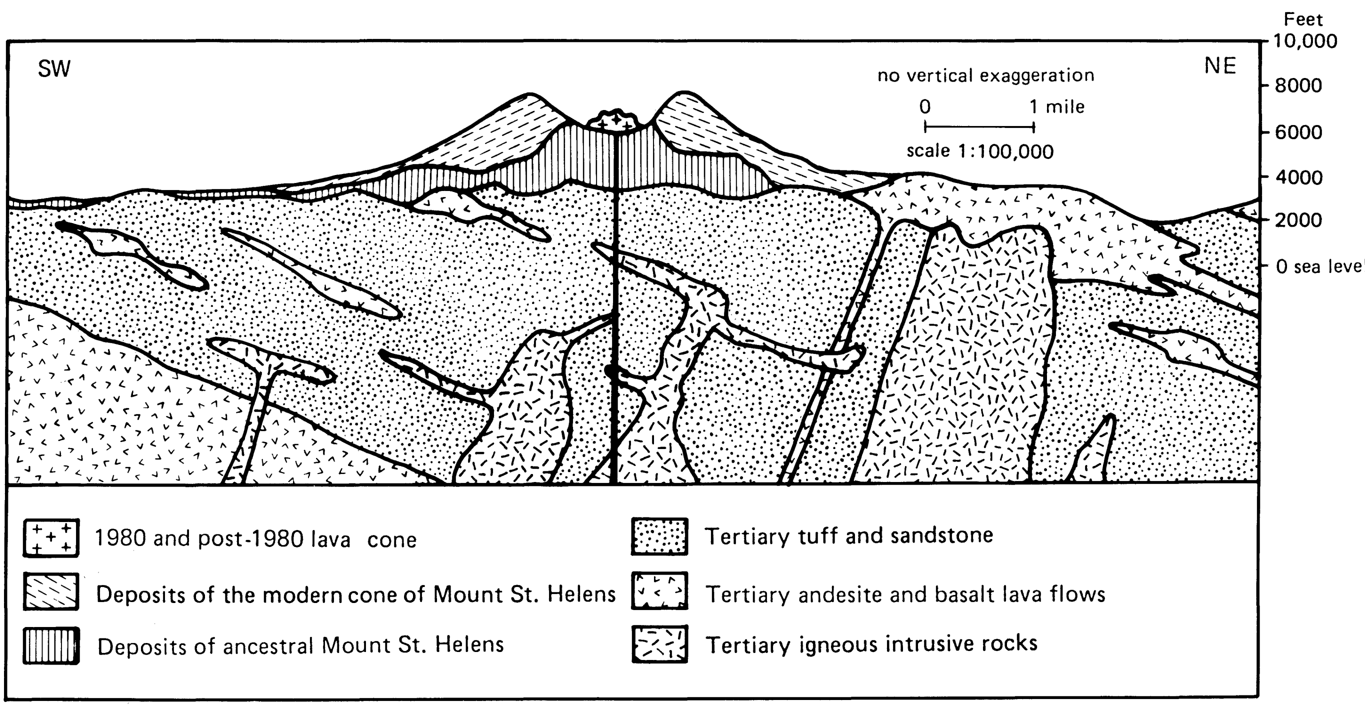

Figure 4. Geologic cross section through Mount St. Helens (modified from Evarts and others, 1987). Geologic units are discussed in text.

Figure 5. View northwest from crater rim showing west crater wall. Photograph taken August 7, 1987. Light-colored deposits at base of crater walls are dacite domes from ancestral Mount St. Helens. To the east, right, is the lava dome. Note ash clouds derived from small avalanches into the crater.

Building of the pre-1980 cone of Mount St. Helens

About 2,500 years ago, the present-day cone of Mount St. Helens began to grow. Because most of the cone was built after the extensive alpine glaciation of the last ice age (about 10,000 years ago), pre-1980 Mount St. Helens had a beautifully symmetrical profile. Neighboring older stratovolcanoes such as Mount Rainier or Mount Adams are heavily scarred from glacial erosion and therefore present steeper, more demanding climbing routes.

During this growth stage in the development of the volcanic center, both dacitic pyroclastic deposits and andesitic and basaltic lava flows were erupted. Once again, eruptions were episodic. Often, long dormant intervals occurred between periods of intense activity. Before 1980, the last eruptions of Mount St. Helens were between 1831 and 1857.

The Monitor Ridge route on Mount St. Helens passes almost entirely over products of the cone-building stage. Dacitic volcanism during this stage produced lava domes, pyroclastic flows, and lahars. Near the end of the climb, the route crosses such pyroclastic flows (see route segment IV below). Other dacite structures, such as the old summit dome and Goat Rocks dome on the north side of the mountain were casualties of May 18, 1980.

The lava flows of Mount St. Helens were extruded mostly from vents high on the south slopes of the volcano. The Monitor Ridge route takes advantage of the relatively smooth central flow channel of one of the andesite units, the Swift Creek flow (Figure 3).

Andesites, not as viscous as most dacites, are still relatively "sticky" compared to many basalts. At Mount St. Helens, the andesitic lavas form short, narrow, stubby flows with surfaces composed of blocky lava rubble. Beneath the rubble, the flow interior is massive with platy to roughly columnar jointing.

Lava levees—low walls of rubble which confined flowing lava into central flow channels—are common and well-exposed along the steep portions of Mount St. Helens andesite flows (see point B of Figure 3, Figure 6). On gentler slopes at the terminus of these flows, flowing lava piled up and formed lateral pressure ridges (point A of Figure 3).

One of the more fluid Mount St. Helens lava flows, the Cave basalt, flowed more than 9 mi from the volcano. The Cave basalt is a pahoehoe flow with smooth, ropy surface textures and numerous lava tubes. Lava tubes form from the roofing over of lava channels by flowing lava. During an eruption, molten basalt is carried from the vent area to the advancing toe of the flow via lava tubes. The longest and best known Mount St. Helens lava tube is Ape Cave, which is more than 11,000 ft long. Ape Cave is open for public exploration and is conveniently located near climbing routes (Figure 1). Climbers may want to bring a lantern for a quick caving experience after the ascent of the mountain.

The 1980 eruptions of Mount St. Helens

After more than 100 years of dormancy, Mount St. Helens resumed activity on March 20, 1980, with a swarm of earthquakes. Between late March and May 18, a dacitic magma body (cryptodome) was emplaced into the cone of the volcano, causing a significant "bulge" or swelling.

On May 18, a 5.1-magnitude earthquake triggered enormous debris avalanches on the north side of the mountain, and the "bulge" slid northward toward Spirit Lake. The debris avalanches exposed the magma body and abruptly reduced the confining pressure in the surrounding geothermal system. The cryptodome exploded, producing a destructive, northward-directed lateral blast that wiped out timber, wildlife, and the human beings caught within its 156-mi^2 extent.

Following the lateral blast, vertically directed ash clouds soared into the stratosphere, blanketing much of eastern Washington with volcanic ash. Ultimately, some of the ash traveled around the world. Pyroclastic flows also spread out through the breach in the cone and formed a thick pumice blanket on the north side of the mountain.

Lahars occurred on most of the rivers ringing Mount St. Helens. The largest, along the North Fork of the Toutle River, may have been produced by liquefaction of a portion of the debris avalanche by earthquakes. Lahars on the south side consisted of hot pyroclastic-flow material mixed with melted glacial ice, snow, and perhaps magmatic water.

Mount St. Helens was drastically altered by these volcanic events. The summit was lowered by more than 1,300 ft, and a new 1,900-ft-deep crater exposing the core of the cone was formed. Cherished climbing routes on the north side of the mountain, such as the Lizard and Dog's Head routes, were destroyed or severely altered. About 70 percent of the volume of glacial ice on the mountain vanished. All of two glaciers and most of a third were blasted apart or were carried in landslides into the North Fork Toutle River (see route segment IV for more discussion of the remaining glaciers on Mount St. Helens).

So far, the current eruptive cycle has produced only typical ex-

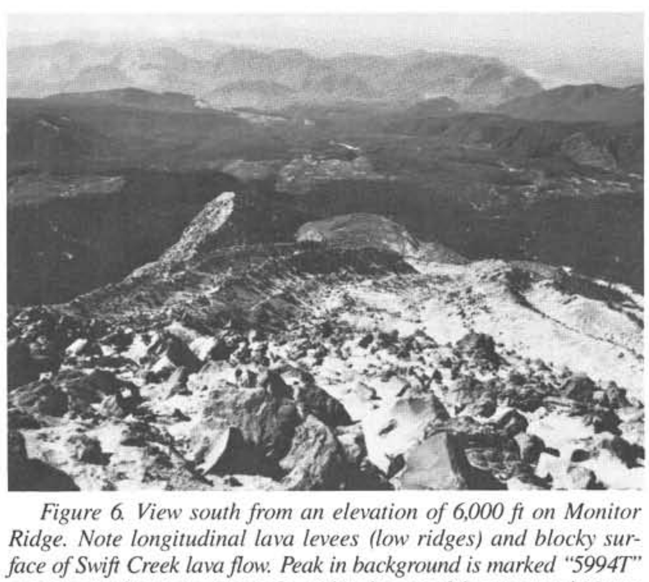

Figure 6. View south from an elevation of 6,000 ft on Monitor Ridge. Note longitudinal lava levees (low ridges) and blocky surface of Swift Creek lava flow. Peak in background is marked "5994T" on topographic map, Figure 2, and is the top of the ancestral Mount St. Helens andesite flow traversed in segment I of the climb. Toe of the Swift Creek flow is visible to the right of the peak.

plosive dacitic products such as pyroclastic flows, a debris avalanche, lahars, and lava domes. Table 1 illustrates eruptive activity since 1980. Lava dome growth (and occasionally, explosive destruction) has been the primary action on the volcano. Perhaps the dome will ultimately fill the crater and rebuild Mount St. Helens to its former (or a greater) height. Perhaps dome growth will stagnate, leaving the gaping crater. Other alternatives include explosive destruction of the dome—possibly producing further pyroclastic flows and lahars—or extrusion of andesite or basalt lava flows. Geologists are presently unable to determine which is more likely.

Table 1. *Eruptive activity at Mount St. Helens since May 18, 1980 (data from a summary of eruptive activity prepared by the U.S. Geological Survey, October 1986).*

Date	Explosive activity	Pyroclastic flows	Dome-building	Mud-flows
5/25/80	x			
6/12/80	x	x	x	
7/22/80	x	x		
8/07/80	x	x	x	
10/16/80	x	x	x	
12/27/80			x	
2/05/81			x	
4/10/81			x	
6/18/81			x	
9/06/81			x	
10/30/81			x	
3/19/82	minor		x	x
5/14/82			x	
8/18/82			x	
2/03/83	minor		x	x
2/83-2/84	continuous dome-building activity			
3/29/84			x	
6/17/84			x	
9/10/84			x	
5/30/85			x	
5/08/86			x	
10/21/86			x	

GUIDE TO THE GEOLOGY OF MONITOR RIDGE

In the following guide, segments of the climb to the summit of Mount St. Helens along the Monitor Ridge route are described. Figures 2 and 3 show the route and the segments, numbered I through V. After the name of each segment, the estimated distance and elevation gain are given. This guide is designed to be used during the ascent of the mountain.

Start: Climbers Bivouac

Climbers Bivouac, near the end of USFS Road 830 (Figure 1), is the starting point for most Mount St. Helens climbers. The bivouac area lacks water and developed camping facilities. An emergency telephone there provides a quick link to authorities in case of an accident.

Segment I. Climbers Bivouac to base of Monitor Ridge via the Ptarmigan Trail (0.9 mi, 260 ft)

The Ptarmigan Trail (Trail 216A) rises from Climbers Bivouac to the base of Monitor Ridge. The trail is on the hummocky surface of an ancient (ancestral Mount St. Helens) andesitic lava flow. Although not easily seen by the hiker, the steep margins and lobate form of the lava flow are easily recognized on a topographic map (Figure 2). The abrupt flow margin is also traversed and then ascended by Road 830 just before reaching Climbers Bivouac (point H on Figure 3).

The unnamed flow consists of several thick flow lobes of andesite. As the forest cover and deep soils suggest, the flow is older than the nearby sparsely vegetated lavas. While the precise age of the andesite is not known, it predates the 2,500-year-old or younger eruptive products of the cone of Mount St. Helens. This lava flow is exceptional in that it records a rare eruption of andesitic lava at a time when explosive dacitic volcanism dominated ancestral Mount St. Helens.

Segment II. Base of Monitor Ridge to beginning of the lava levees (0.7 mi, 800 ft)

At about 4,120 ft of elevation, the forest cover thins, and climbers enter meadows at the base of Monitor Ridge. Here, the well-maintained, gently ascending Ptarmigan Trail ends, and the first steep portion of the climb begins with a scramble up the toe of the Swift Creek lava flow. The route over the lava is marked with widely spaced red flagging. Beware of falling rocks set in motion by other climbers scurrying up steep slopes.

The ridge is composed of the andesitic Swift Creek lava flow. Formally named in 1983 for the adjacent drainage on the east, the Swift Creek flow was previously known as "The Mitten" because of its distinctive shape when viewed from the air (Figure 3) or on a topographic map (Figure 2). The climbing route traverses the 350- to 450-year-old andesite lava flow most of the way up the volcano.

The Swift Creek flow is typical of the many andesite lava flows on the south flank of Mount St. Helens. Erupted from vents high on the volcano, these relatively viscous lavas formed stubby, narrow block flows. The surface of a block lava flow is composed of angular chunks or rubble of andesite (Figure 6).

At its terminus, the Swift Creek flow is more than 200 ft thick. Lava streaming down the steep flanks of the cone ponded upon reaching gentler slopes. Distinctive crescent-shaped lateral pressure ridges (point A on Figure 3) mark the toe of the flow. Flow lobes (point G on Figure 3) record successive eruptions of lava—probably separated by no more than hours or days—and are responsible for the mitten shape of the flow. As many as six lobes are present in the Swift Creek flow.

While easily visible on an aerial photo, features such as pressure ridges and flow lobes may be a challenge to recognize while trudging up the mountain over loose blocks of andesite. The ridges and lobes are best viewed from above, either during a rest stop near the beginning of the next climbing segment or on the descent of the mountain (Figure 6).

Segment III. The lava levees of Monitor Ridge to upper pumice slopes (1.0 mi, 2,100 ft)

An abrupt steepening of slope at about 4,800 ft of elevation signals the end of the multi-lobed toe of the Swift Creek flow. From here to the probable vent area at 6,900 ft, the Swift Creek lavas are contained within a series of levees. The lava levees consist of longitudinal rubble walls, 6 ft or more in height, stretching for hundreds of yards along the flow (point B on Figure 3). As many as four distinct levees are visible along portions of the route (Figure 6). Travel in the central flow channel, particularly when it is snow-covered, is pleasant compared to that on the rugged toe of the flow.

The levees are the consequence of the flow of a viscous material—lava—down a slope. In order to move, the lava must form a layer deep enough to overcome resistance to motion. At the center of the flow, this is easily accomplished. Along flow margins, however, the lava thins, and a "dead zone" develops where stationary material accumulates to form walls. Construction of the walls or levees is accentuated by cooling of the lava. Blocks of congealed magma pile up at a much faster rate on the margins than in the central flow channel. The levees force the lava to occupy a narrower area than at the flow toe. Succeeding eruptions produce levees of different heights depending on the volume of lava extruded. Excellent examples of levees are common in the andesite flows of the south flank of Mount St. Helens (Figure 3).

At 5,280 ft of elevation, climbers may notice a U.S. Geological Survey (USGS) geodetic survey station. The station consists of a metal tower on which is mounted a prism used to reflect the laser light used in high-precision surveying. Many such sites on the volcano are resurveyed regularly, and the distances and angles between the stations are precisely calculated. The surveys are designed to detect swelling or collapse of the cone—a probable sign of magma injection into the stratovolcano. In March-May 1980, growth of such a "bulge" on the north side of Mount St. Helens led to the catastrophic eruption of May 18.

Do not disturb survey stations or any other monitoring equipment found on the volcano. The safety of climbers on Mount St. Helens depends on the ability of geologists to accurately detect signs of impending eruption.

At 5,800 ft, the highest point of the ancestral Mount St. Helens lava flow traversed in segment I is visible immediately east of the route (Figure 6). The prominent ridge has an elevation of 5,994 ft (Figures 2 and 3).

Between 6,600 and 6,800 ft of elevation, the lava levees narrow and coalesce. The vent for the Swift Creek lava flow probably lies within this area.

Segment IV. Upper pumice slopes to the summit (0.8 mi, 1,465 ft)

From about 6,800 ft of elevation to the crater rim at about 8,250 ft, the route traverses pyroclastic flow deposits (Figure 7). These flows were produced by the old summit dome of Mount St. Helens (destroyed on May 18, 1980) about 500 to 350 years ago. The pyroclastic flows are slightly older than the Swift Creek lava flow. Because of a thick cover of 1980 ash, features of the flows are not easily viewed by climbers at the time of writing.

At about 6,900 ft of elevation a hydrogen gas monitoring station was in place until not long ago. Monitor Ridge was named in 1983 after the hydrogen sensor. Operated for several years as an experiment in eruption prediction, the station has been removed by the USGS.

Hydrogen gas is present in most magmas. Because hydrogen gas is light and mobile in earth materials, anomalous quantities of the gas could signal the presence of hidden magma. Experiments at Mount St. Helens indicate that hydrogen monitoring is not as sensitive an indicator of impending eruptions as seismic activity, crater or dome deformation, and sulfur-dioxide gas concentration.

Figure 7. Climbers arriving at the crater rim. View east with Mount Adams in the background. The climbers are traversing pyroclastic flows covered with a thick layer of 1980-vintage ash.

Figure 8. View west of a climber descending the 8,365-ft summit of Mount St. Helens. Clouds of ash from debris avalanches obscure the crater walls.

The Monitor Ridge route passes close to three small glaciers between an elevation of 6,200 ft and the summit. From west to east, the glaciers are Dryer Glacier, a small unnamed glacier, and Swift Glacier (Figure 2). Between about 7,000 and 7,400 ft of elevation, the surface of the unnamed glacier forms a convenient snow-covered surface for glissades during descent of the mountain.

Dryer Glacier commemorates Thomas J. Dryer, an early Portland journalist and businessman. In 1853, Dryer led the first recorded party to climb the mountain and probably passed close to the glacier.

Normally, these glaciers are heavily covered with 1980-vintage ash and other volcanic debris and are usually difficult to detect. However, by late summer, crevasses in snow and ice may break through the overlying ash cover, revealing the presence of glacial ice (point C on Figure 3).

Prior to 1980, Mount St. Helens supported 11 named glaciers: Wishbone, Loowit, Leschi, Forsyth, Nelson, Ape, Shoestring, Swift, Dryer, Toutle, and Talus. The May 18 eruption removed about 70 percent of the ice volume on the volcano. Loowit and Leschi glaciers and nearly all of Wishbone were blasted away together with most of the snow-accumulation areas for Forsyth, Nelson, Ape, and Shoestring. Hot pyroclastic flows melted or eroded snow and firn from the surfaces of Shoestring, Nelson, and Ape Glaciers, producing the Muddy River, Pine Creek, and Smith Creek lahars.

The beheaded glaciers of Mount St. Helens may ultimately stagnate, retreat, and finally vanish. However, the insulating effect of the thick ash cover prolongs the existence of the glaciers. And at least one glacier, Shoestring, appears to have revived. Following a year (1981) in which the lower part of Shoestring was nearly stagnant and moving at less than 20 percent of its pre-eruption velocities, glacial ice has rapidly regenerated, and a wave of increased motion has begun moving down the glacier.

At about 8,250 ft of elevation, the crater rim is reached (Figure 8). Be sure to maintain a safe distance from the edge of the rim and avoid travel over cornices. Continue 0.2 mi west along the crater rim to the 8,365-ft summit of Mount St. Helens. The route passes over the top of Dryer Glacier (Figure 2). Glacial ice and small crevasses may be visible.

Segment V. Summit (End of guide)

In clear weather, three other nearby Cascade stratovolcanoes are visible from the summit. They are, to the south, Mount Hood, to the east, Mount Adams, and to the north, Mount Rainier.

On the crater rim to the east-northeast, note the cleft in the cone carved by Shoestring Glacier when the mountain was 1,300 ft taller (Figure 9).

Figure 9. View east of the crater rim. Mount Adams is in the background. To the left of the center of the photograph is a prominent valley that was carved by Shoestring Glacier when Mount St. Helens was 1,300 ft higher.

Avalanches. The crater rim is extremely unstable. Avalanches of rock and tephra cascade every few minutes into the crater, feeding large piles of talus that partially surround the lava dome. The avalanche activity decreases during the winter because ice tends to cement loose rubble on the crater walls. However, snow avalanches are common in the winter. Eruptive activity, such as dome growth, increases avalanching, as small earthquakes shake loose unstable portions of the crater walls. The extremely high avalanche potential makes any crater wall climbing excessively hazardous.

Following the May 18, 1980, eruption, large ice avalanches from beheaded glaciers frequently fell into the crater. As remaining glacial ice moved away from the rim due to glacier flow and melting, the ice falls diminished. Currently, the avalanches are dominantly composed of pyroclastic material and lavas from the crater rim and walls.

Lava dome. The lava dome dominates the view from the summit (see cover illustration). Composed of gray dacite with a rough, fractured surface and a dense, columnar-jointed interior, the 920-ft-high dome grows both by surface extrusion of new flow lobes and by swelling as new magma is injected internally. The dome is presently much larger than shown on available topographic maps or aerial photos (Figures 2 and 3).

USGS geologists and a host of instruments closely monitor the dome. The dome is "wired" to detect small earthquakes, changes in dome and crater dimensions, temperature, gas concentrations, and magnetic field changes. Climbers may see helicopters landing on or near the dome, and with binoculars, some of the instrument stations can be viewed.

The geologists primarily use crater and dome deformation rates, earthquake activity, and sulfur-dioxide gas concentrations to predict dome-building eruptions. Their success in anticipating major eruptions led to reopening Mount St. Helens to climbing.

The last dome eruption occurred on the evening of Octob er 21, 1986. An irregular lobe, still visible on the top of the dome (see cover illustration), was produced along with injection of magma into the interior of the dome. The new lobe is more than 800 ft long and 330 ft wide, and it added about 85 ft to the height of the dome. The eruption was heralded by swarms of small earthquakes. Emissions of sulfur dioxide increased from about 50 tons per day on October 20 to about 675 tons per day on October 21. Sulfur-dioxide concentrations quickly diminished after the eruption.

Perhaps of greater interest to climbers and hikers are the events of October 5, 1986. An earthquake on that night dislodged a large piece of the lava dome. The resulting dome explosion produced a pyroclastic flow that destroyed an instrument station north of the dome, partially melted telemetry cables, and sent an ash cloud to lightly dust Cougar, Woodland, and north Vancouver, Washington. This episode—which was not predicted by monitoring scientists—illustrates that small explosions, pyroclastic flows, or ash clouds may occur at any time within the crater.

Given current growth rates, the dome could rebuild Mount St. Helens to the former 9,677-ft elevation in about 200 years. However, many scenarios are possible, including stagnation of the dome and other eruptive features, explosion of the dome with attendant pyroclastic flows and lahars, or extrusion of andesite or basalt lava flows.

Acknowledgments

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RECOMMENDED READING

Beckey, F., 1987, Cascade alpine guide, climbing and high routes—1. Columbia River to Stevens Pass: [Seattle] The Mountaineers, 2nd edition, 337 p.

Brugman, M.M., and Post, Austin, 1981, Effects of volcanism on the glaciers of Mount St. Helens: U.S. Geological Survey Circular 850-D, 11 p.

Evarts, R.C., Ashley, R.P., and Smith, J.G., 1987, Geology of the Mount St. Helens area—Record of discontinuous volcanic and plutonic activity in the Cascade Arc of southern Washington: Journal of Geophysical Research, v. 92, no. B10, p. 10155-10169.

Lipman, P.W., and Mullineaux, D.R., eds., 1981, The 1980 eruptions of Mount St. Helens: U.S. Geological Survey Professional Paper 1250, 844 p., 1 plate.

Phillips, W.M., 1987, Geologic map of the Mount St. Helens quadrangle, Washington and Oregon: Washington Division of Geology and Earth Resources Open-File Report 87-4, 59 p., 1 plate.

Tilling, R.I., 1984, Eruptions of Mount St. Helens; past, present, and future: U.S. Geological Survey general-interest publication, 52 p. □

Oil and gas well records listed in new DOGAMI release

The Oregon Department of Geology and Mineral Industries (DOGAMI) has published an updated list of all available records and samples it keeps on oil and gas exploration wells drilled in Oregon.

The new report is entitled *Available Well Records and Samples of Onshore and Offshore Oil and Gas Exploration Wells in Oregon* and has been released as DOGAMI's Oil and Gas Investigation 16. It was compiled by DOGAMI Petroleum Geologist Dan E. Wermiel.

The 25-page publication lists the well records in two tables, one listing onshore, the other offshore well records. The tables provide such information as well and company names; date, depth, and location of the wells; types of available logs and samples; and literature references. The onshore records are grouped by county. An introduction includes descriptions of the legislative history and current nature of DOGAMI's recordkeeping. Additional tables provide a key to abbreviations, a list of commercial firms offering well histories and logs, and a list of selected DOGAMI publications on oil and gas. Finally, the report contains a glossary explaining the different types of logs and a list of the references to which the well-record tables are keyed.

The publication is the first printed product derived from newly established computerized data bases of DOGAMI's oil and gas files. This will, in the future, enable the Department to provide the public with continually updated information, both of the well records and of the literature references to them.

The new release, DOGAMI Oil and Gas Investigation 16, is available now at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. The purchase price is $5. Orders under $50 require prepayment. □

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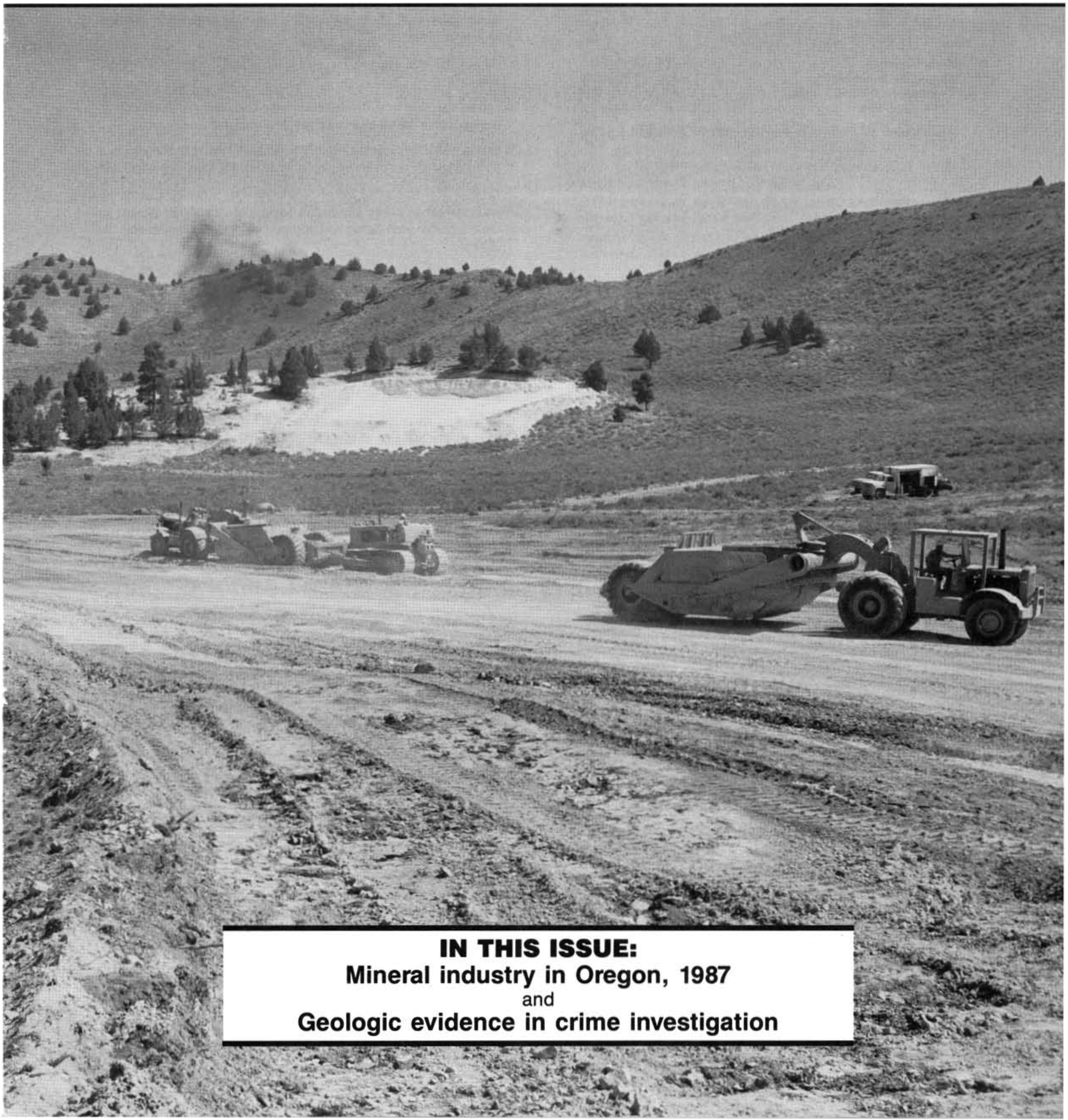

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and
Geologic evidence in crime investigation

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Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Eagle-Picher Minerals, Inc., operation in Malheur County, mining diatomaceous earth. Related article on Oregon's mineral industry in 1987 begins on next page.

Mining Awareness Week proclaimed

In recognition of mining's important contribution to the economy of Oregon, Governor Neil Goldschmidt, on March 17, 1988, issued a proclamation declaring the week of April 24-30 Mining Awareness Week in Oregon. We are proud to present our readers with the text of the Governor's proclamation.

PROCLAMATION

Whereas: The minerals extracted from the earth have opened doors to progress throughout history and are vital to the continuation of civilization; and

Whereas: Mineral discovery was an integral part of Oregon's history; and

Whereas: Mining will continue to make essential contributions to the economy of Oregon and the Nation; and

Whereas: Modern mining includes the best available reclamation technology to ensure beneficial subsequent use of mining sites; and

Whereas: The ability of the domestic mining industry to survive and prosper at home and in the international market is vital to the economic well-being and competitiveness of Oregon and the Nation;

Now, therefore, I, Neil Goldschmidt, Governor of the State of Oregon, hereby proclaim April 24-30, 1988, as

Mining Awareness Week

in Oregon, in recognition of mining, which created, established, and maintained our Nation's industrial cornerstone resulting in benefits to the entire world.

In witness whereof, I hereunto set my hand and cause the Great Seal of the State of Oregon to be affixed. Done at the Capitol in the City of Salem, State of Oregon, on the day, March 17, in the Year of our Lord, One Thousand Nine Hundred Eighty-Eight.

Neil Goldschmidt, Governor

Crater Rock Museum specimens featured in State Capitol display

Roxy Ann Gem and Mineral, Inc., of Medford supplied the display currently shown in the Oregon Council of Rock and Mineral Clubs (OCRMC) display case at the State Capitol in Salem. Installed by Wes and Dorothy Riley, the display features more than 50 specimens from the collection of the Crater Rock Museum owned by the Medford club. The museum, located next-door to the club's meeting hall, is a "must-see" for visitors to southern Oregon.

Roxy Ann's display at the Capitol shows materials from nine Oregon counties: Petrified wood rounds and limbs from Crook, Deschutes, Gilliam, Jackson, Malheur, and Sherman Counties; thundereggs from Crook, Harney, Jefferson, and Wasco Counties; sagenite agate from Jackson County; plume agate from Jefferson County; and Copco agate from Jackson County.

Polished thunderegg halves are shown on the top shelf of the case; sagenite, plume, and Copco agate specimens on the middle shelf; large rounds and small limbs of petrified wood on the lower shelf; and 18 miniature slabs of sagenite, plume, and Copco agate on the illuminated bottom of the case.

The display will remain in place until May 14, 1988, and will be followed by exhibits of rocks and minerals from Far West Lapidary and Gem of Coos Bay (May to September) and the Trail's End Gem and Mineral Club of Astoria (September to January).

—OCRMC news release

Exploration and mining activity in Oregon, 1987

by Len Ramp, Resident Geologist, Grants Pass Field Office, Oregon Department of Geology and Mineral Industries

SUMMARY

During 1987, the level of exploration and mining activity in Oregon increased over that of 1986. The value of nonfuel mineral production increased from $126 million in 1986 to $154 million in 1987, and the total mineral production including natural gas increased from $135 million in 1986 to $160 million in 1987. The drop in the total value of metal production due to the August 1986 shutdown of the Hanna nickel mine and the 1987 shutdown of the Hanna smelter near Riddle was more than offset by the increase in production of diatomite from the Eagle-Picher operation near Vale and the statewide rise in demand for construction materials such as sand and gravel and stone.

During 1987, 595 mine sites were active. Approximately 30 were metallic- and industrial-mineral mines, and the rest were mainly sand and gravel and stone operations. During the same period, a total of 37 metallic-mineral sites were explored by 29 separate companies. Some of the exploration projects were continued from the preceding year, and several new ones were added.

OREGON'S MINERAL PRODUCTION
MILLIONS OF DOLLARS

	ROCK MATERIALS (Sand & Gravel, Stone)	METALS & INDUSTRIAL MINERALS (Cement, Nickel, Pumice, etc.)	NATURAL GAS	TOTAL
1972	54	22	0	76
1973	55	26	0	81
1974	75	29	0	104
1975	73	33	0	106
1976	77	35	0	112
1977	74	35	0	109
1978	84	44	0	128
1979	111	54	+	165
1980	95	65	12	172
1981	85	65	13	163
1982	73	37	10	120
1983	82	41	10	133
1984	75	46	8	129
1985	91	39	10	140
1986	96	30	9	135
1987	102	52	6	160

Summary of mineral production in Oregon for the last 16 years. Data for 1987 derived from U.S. Bureau of Mines annual preliminary mineral industry survey and Oregon Department of Geology and Mineral Industries natural gas production statistics.

Mill at Greenback Mine, Josephine County (active mine site 11).

Table 1. *Active mines in Oregon, 1987*

Map no.	Data
	Industrial minerals
1.	Ash Grove Cement West (cement, limestone), sec. 11, T. 12 S., R. 43 E., Baker County. Company continued production of crushed limestone (marble) for refining beet sugar and production of cement from marble and shale mined by the plant site along Interstate Highway 84 near Durkee. Production is valued at about $25 million per year.
2.	Eagle-Picher Minerals, Inc. (diatomite), Tps. 19 and 20 S., Rs. 35, 36, and 37 E., Harney and Malheur Counties. The company operates a mill near Vale and produces diatomite, which is processed by air classification and flux calcining (partial fusion and agglomeration) and sold under the brand name of Celatom. Diatomite is used as a filter aid for water, beverages (beer), syrups, juices, edible oils, fuels, and pharmaceuticals.
3.	Teague Mineral Products (bentonite and zeolite), secs. 8, 28, and 29, T. 23 S., R. 46 E., Malheur County. Bentonite is used in drilling muds and as pet litter, as binder for hay pelletizing, and as a sealant for ponds, ditches, and solid-waste disposal sites. Clinoptilolite (zeolite), produced from a mine on Succor Creek, is used mostly for pet litter but also in odor-control products and as fungicide carrier and ammonia absorbent in aquarium systems. Clinoptilolite also readily absorbs radioactive cesium.
4.	Oil-Dri Production Company (diatomite), secs. 14, 21, and 23, T. 27 S., R. 16 E., Christmas Valley, northern Lake County. The company is continuing production of diatomite, which is packaged as pet litter for several companies under various brand names.
5.	Central Oregon Bentonite Company and Oregon Sun Ranch, Inc. (bentonite), sec. 4, T. 19 S., R. 21 E., Crook County. Both companies continued production of bentonite clay from adjacent properties near Clover Creek, a tributary of Camp Creek.
6.	Cascade Pumice and Central Oregon Pumice, Tps. 17 and 18 S., R. 11 E., in the Bend area, Deschutes County. Both continued production of screened pumice primarily for lightweight aggregate in concrete block manufacturing.
7.	CooSand Corporation (silica sand), sec. 34, T. 24 S., R. 13 W., Coos County. The company continued production of glass sand and abrasive sand from dunes. The sand is shipped by rail to Portland. Part is cleaned magnetically and used in the production of colored-glass containers such as beverage bottles, and part is used as air-blast sand and railroad traction sand.
8.	Bristol Silica and Lime Company (silica), sec. 30, T. 36 S., R. 3 W., Jackson County. Production of silica rock for decorative granules, abrasives, poultry grit, and filtration media continued. The company's adjacent dolomite deposit was explored, and equipment is being installed to produce dolomite in the near future. No lime was produced in 1987.

Bonanza Mining Company placer, Baker County (active mine site 22).

Table 1. *Active mines in Oregon, 1987—continued*

Map no.	Data
9.	Steatite of Southern Oregon (soapstone), secs. 10 and 11, T. 41 S., R. 3 W., Jackson County. Production of block soapstone for carving continued during the year.
10.	D and D Ag Lime and Rock Company (agricultural lime), sec. 20, T. 28 S., R. 5 W., Douglas County. The company worked the old Oregon Portland Lime Quarry and produced a small amount of agricultural lime during the year.
	Lode gold mines
11.	Greenback Mine, sec. 33, T. 33 S., R. 5 W., Josephine County. Geo Gold and Silver and Josephine County Partners optioned the property, revamped the mill, opened up the lower workings, and produced some gold. Operators pumped out the winze, laid track on the 900 level, and did sampling. About 200 tons of ore from the Hammersley Mine dump were reportedly processed through the Greenback Mill.
12.	Maid of the Mist Mine, sec. 4, T. 39 S., R. 4 W., Upper Applegate district, Jackson County. The mine is operated in a small way by three senior citizens, Art Goss, Dudley Smith, and Lou Kula, who have cleaned out old adits and started milling small quantities of ore with a small ball mill.
13.	Gold Blanket Mine, sec. 14, T. 38 S., R. 9 W., Illinois River district, Josephine County. Near-surface deposits consist of several small quartz veins and flat-lying mineralized shears in altered siltstone and chert of a volcaniclastic unit of Late Jurassic age. A small mill is used for minor production by claim owners. The operation is seasonal.
14.	Oregon King Mine (gold and silver), sec. 30, T. 9 S., R. 17 E., Ashwood district, Jefferson County. ORECO Enterprises, Inc., conducted a successful heap-leach operation. Winter shutdown and continued production in 1988 are planned.
15.	Lower Grandview (Thomason) Mine, sec. 6, T. 14 S., R. 37 E., Baker County. Operated in a small way by owner Art Cheatham, this seasonal operation employed three workers, used a small mill, and had modest production for the past several years.
16.	Pyx Mine, sec. 1, T. 10 S., R. 35 E., Greenhorn district, Grant County. The mine was worked on a seasonal basis by Myron Woodley. Small production was reported from near-surface pocket enrichment and underground veins. Ore was milled at Woodleys Mill in Sumpter.
17.	Virtue Mine, sec. 21, T. 9 S., R. 41 E., Virtue district, Baker County. The mine was worked by Keith Lyons and Jeff Young. Small production using Lyon's small custom mill in nearby Baker was reported. The mine was an important early-day producer from small high-grade veins. Total recorded production during 1862-1884, 1893-1899, and 1906-1907 was $2.2 million.

Open cut and adits at Gold Blanket Mine, Josephine County (active mine site 13).

Table 1. *Active mines in Oregon, 1987—continued*

Map no.	Data
18.	Golden Eagle Mine (Eagle Group), sec. 19, T. 9 S., R. 38 E., on Lake Creek, Baker County. Owner-operator Woody Allstead is working the small high-grade deposit using a closed-circuit portable mill. This operation shuts down during the winter due to snow.
19.	Iron Dyke Mine, sec. 21, T. 6 S., R. 48 E., on the Snake River, Baker County. Silver King Mines, Inc., produced 15,000 tons of ore averaging 3.5 percent Cu, 0.35 oz/ton Au, and 0.5 oz/ton Ag that was trucked 22 mi to be processed in the Silver King mill at Copper Cliffs Mine near Cuprum, Idaho. Eleven people were employed in this operation.
20.	Gold Ridge Mine, secs. 16 and 17, T. 12 S., R. 43 E., Baker County. Milton Mitchek, operator, had some production during the year using a small mill at the mine.
21.	Ruth Mine, sec. 27, T. 8 S., R. 5 E., North Santiam district, Marion County. Shiny Rock Mining Company milled ore and shipped flotation concentrates containing Au, Ag, Pb, and Zn to China.
Placer mines	
22.	Bonanza Mining Company placer, sec. 3, T. 7 S., R. 45 E., Pine Creek, Cornucopia district, Baker County. This placer mine, which was the state's largest placer operation in 1987, employs about 12 people and uses sound environmental practices. Manager-operator is Tom Bonn, mining engineer, who designed the equipment and operating plan. A truck-mounted grizzly, trommel, and sluice are used to wash the gold from the gravel.
23.	Goldwater, Inc., placer, T. 12 S., R. 38 E., on Pine Creek near Hereford, upstream from Oregon Highway 7, Baker County. A small-scale trommel and backhoe-loader are used, and the mine has been active for about six months each year for several years.
24.	Broken Pick placer, sec. 12, T. 13 S., R. 41 E., on Clarks Creek, Baker County. This small-scale operation has also been active for several years.
25.	Josephine Creek and tributaries, Josephine County, has three or four small operations in Tps. 38 and 39 S., R. 9 W.
26.	Sucker Creek placers, Tps. 39 and 40 S.,Rs. 6 and 7 W., Josephine County. These have three or four seasonal operations.
27.	Coffee Creek placer, sec. 7, T. 30 S., R. 2 W., Douglas County. This seasonal operation has been worked for several years.
28.	Coyote Creek placers, sec. 24, T. 33 S., R. 6 W., Josephine County. This placer is operated on a seasonal basis by Jack Smith.
29.	Lower Grave Creek (Skipper's placer), secs. 31 and 32, T. 33 S., R. 7 W., Josephine County. This is a small-scale seasonal placer.
30.	Galice area placers, Tps. 34 and 35 S., R. 8 W., Galice Creek, Rocky Gulch, Taylor Creek, and Peavine, Josephine County. All are small seasonal operations.

Broken Pick Mining Company placer mine on Clarks Creek in Baker County (active mine site 24).

Exploratory drilling at Quartz Mountain gold mine, Lake County (exploration site 25).

ACTIVITY

Metals

ORECO Enterprises conducted a heap-leach operation at the Oregon King gold-silver mine (active mine site 14 on map and in Table 1) in Jefferson County. Silver King Mines, Inc., mined gold, silver, and copper ore at the Iron Dyke Mine (active mine site 19) in Baker County.

The search continued for epithermal gold. These deposits are often associated with hot-spring deposits of siliceous sinter, jasperoids, opalite, and mercury. Host rocks are volcanic intrusive and extrusive rocks and tuffaceous and lacustrine sediments. The two principal areas of epithermal gold exploration activity include (1) the areas surrounding Vale in northern Malheur County near the eastern edge of the state, and (2) the Lakeview area in southern Lake County in the south-central part of the state. A few of the other areas that are being explored may also be classified as epithermal gold deposits.

Exploration activity included geochemical sampling, geological mapping, test drilling, and trenching. New claims were located, and previously staked claims were maintained.

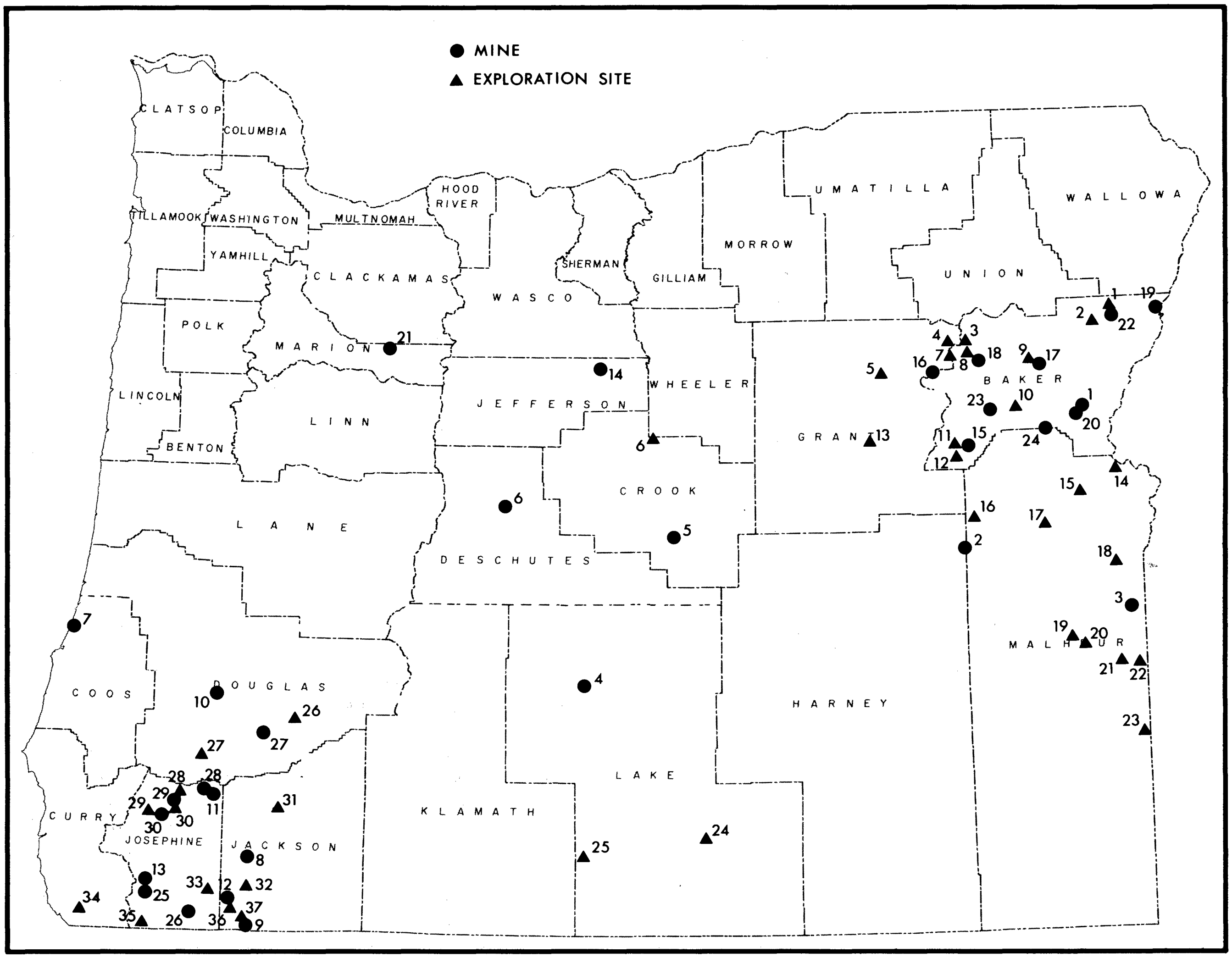
Volcanogenic sulfide deposits formed in submarine ophiolites and island-arc volcanic rocks are still being held and explored in southwestern Oregon. One example, the Turner-Albright Mine (exploration site 35 on map and in Table 2) in southern Josephine County, is held by Savanna Resources, who have drilled reserves of complex polymetallic sulfide ore with gold, silver, copper, zinc, and cobalt values. Recent ore-dressing work has been done by the U.S. Bureau of Mines on drill-core samples from this deposit.

Other volcanogenic sulfides are the Silver Peak Mine (exploration site 27) in southern Douglas County by Formosa Exploration, Inc., and the Goff Mine (exploration site 28) in northern Josephine County by AMSELCO (now known as BP America).

Exploration in the Baker area of northeastern Oregon was focused mainly on quartz veins and mineralized shear zones. The gold mineralization is genetically related to granitic intrusive rocks. The principal host rocks are argillite and chert of the Permo-Triassic Elkhorn Ridge Formation. A few of the deposits are in fractured hydrothermally altered zones in granitic intrusive rocks and narrow veins in gabbro and meta-andesite. Some attention is also still being paid to large areas of hydrothermal alteration in Tertiary volcanic rocks of the Western Cascades.

Industrial minerals

Industrial minerals continued to be a significant portion of the state's mineral production. Eagle-Picher Minerals, Inc. (active mine



EXPLANATION

ACTIVE MINES

1. Ash Grove Cement West (cement, limestone)
2. Eagle-Picher Minerals, Inc. (diatomite)
3. Teague Mineral Products (bentonite, zeolite)
4. Oil-Dri Production Company (diatomite)
5. Central Oregon Bentonite Company and Oregon Sun Ranch, Inc. (bentonite)
6. Cascade Pumice and Central Oregon Pumice (pumice)
7. CooSand Corporation (silica sand)
8. Bristol Silica and Lime Company (silica)
9. Steatite of Southern Oregon (soapstone)
10. D and D Ag Lime and Rock Company (agricultural lime)
11. Greenback Mine (gold)
12. Maid of the Mist Mine (gold)
13. Gold Blanket Mine (gold)
14. Oregon King Mine (gold, silver)
15. Lower Grandview (Thomason) Mine (gold)
16. Pyx Mine (gold)
17. Virtue Mine (gold)
18. Golden Eagle Mine (Eagle Group) (gold)
19. Iron Dyke Mine (gold, silver)
20. Gold Ridge Mine (gold)
21. Ruth Mine (gold, silver, lead, zinc)
22. Bonanza Mining Company placer (gold)
23. Goldwater, Inc., placer (gold)
24. Broken Pick placer (gold)
25. Josephine Creek and tributaries (gold)
26. Sucker Creek placers (gold)
27. Coffee Creek placer (gold)
28. Coyote Creek placers (gold)
29. Lower Grave Creek (Skipper's) placer (gold)
30. Galice area placers (gold)

EXPLORATION SITES AND AREAS

1. Cornucopia Mine (gold)
2. Dolly Varden Mine, Eagle Creek district (gold)
3. Meadow Lake (gold)
4. Baby McKee, Alpine and Davenport (gold)
5. Susanville Mine (Bull of the Woods) (gold)
6. Ochoco Mine (gold)
7. Bald Mountain-Ibex (gold)
8. Cracker Oregon Gold Mine (E and E) (gold)
9. Gray Eagle Mine, Virtue district (gold, antimony)
10. Dooley Mountain area (perlite)
11. Record Mine (gold)
12. Grouse Spring prospect (copper, silver)
13. Prairie Diggings prospect (gold)
14. Lackey prospect (gold)
15. Hope Butte (gold)
16. Castle Rock (gold)
17. Harper Basin Diatomite (diatomite)
18. Shell Rock Butte (gold)
19. Quartz Mountain (gold)
20. Red Butte (gold)
21. Bannock project (gold)
22. Mahogany project (gold)
23. Oregon-Idaho border area (gold)
24. Miners Draw-Coyote Hills (gold)
25. Quartz Mountain (gold)
26. Zinc Creek (gold)
27. Silver Peak Mine (gold, copper, zinc)
28. Hungry Hill-Goff Mine (gold, silver)
29. Howard Creek area (gold)
30. Almeda Mine (gold, silver)
31. Shamrock Mine, Hull Mountain area (copper, nickel, cobalt, platinum, gold)
32. Forest Creek area (gold)
33. Jones Marble (white marble)
34. Mount Emily area (gold)
35. Turner-Albright Mine (gold, copper, zinc, cobalt)
36. Palmer Creek area (gold)
37. Squaw Creek area (gold, copper)

Mining and mineral exploration in Oregon in 1987 (excluding sand and gravel and stone). Active mines are keyed to Table 1; exploration sites and areas are keyed to Table 2.

Table 2. *Exploration sites and areas in Oregon, 1987*

Map no.	Name	Location Sec./T.(S.)/R.	Commodity	Comments
1.	Cornucopia Mine	27/6/45 E. Baker County	Au (gold)	UNC Mining and Milling Corp.; volume sampling, core drilling, mapping, geochemistry, drifting.
2.	Dolly Varden Mine, Eagle Creek district	19,30/7/44 E. Baker County	Au	COMINCO American, Inc.; mapping, surface sampling, drilling.
3.	Meadow Lake	5/8/37 E. Baker County	Au	Chevron Resources; trenching, surface sampling, mapping.
4.	Baby McKee Alpine and Davenport	11/8/36 E. 14/8/36 E. Grant County	Au	Cable Cove Mining; portal and adit renovation, long-hole drilling.
5.	Susanville Mine (Bull of the Woods)	7,8/10/33 E. Grant County	Au	Widman Brothers; surface work and some rotary-hammer drilling.
6.	Ochoco Mine	29,30/13/20 E. Crook County	Au	Orbana Resources; core drilling.
7.	Bald Mountain-Ibex	3,4/9/36 E. Baker County	Au	American Copper Nickel holding property.
8.	Cracker Oregon Gold Mine (E and E)	32,33/8/37 E. Baker County	Au	Boise-Cascade; dump sampling and evaluation; contracted for 1,000 ft of new drift and crosscuts to vein.
9.	Gray Eagle Mine, Virtue district	7/9/41 E. Baker County	Au, Sb (antimony)	Morrison Knudsen Co.; surface sampling and mapping; drilling is planned.
10.	Dooley Mountain area	——/11,12/40 E. Baker County	Perlite	Supreme Perlite; continuing evaluation of perlite deposits in area.
11.	Record Mine	1,2/14/36 E. Baker County	Au	Golconda Resources Ltd.; drilling.
12.	Grouse Spring prospect	24,25/14/36 E. Baker County	Cu (copper), Ag (silver)	Manville Corp.; diamond drilling.
13.	Prairie Diggings prospect	33/13/32 E. Grant County	Au	GSR Goldsearch Resources, Inc.; 7,000 ft of drilling; applied for mining permits.
14.	Lackey prospect	22,27/15/45 E. Malheur County	Au	Permian Resources; drilling.
15.	Hope Butte	21/17/43 E. Malheur County	Au	Chevron Resources; drilling.
16.	Castle Rock	8,9/18/37 E. Malheur County	Au	Chevron Resources; surface sampling, mapping.
17.	Harper Basin diatomite	——/18,19/41,42 E. Malheur County	Diatomite	Manville Corp.; drilling.
18.	Shell Rock Butte	18/21/45 E. Malheur County	Au	Permian Resources; drilling.
19.	Quartz Mountain	6/25/43 E. Malheur County	Au	Chevron Resources; drilling.
20.	Red Butte	26,27,34,35/25/43 E. Malheur County	Au	Chevron Resources; hand trenching.
21.	Bannock project	11/26/45 E. Malheur County	Au	Chevron Resources; surface sampling, mapping.
22.	Mahogany project	25,26/26/46 E. Malheur County	Au	Chevron Resources; surface sampling.
23.	Oregon-Idaho border area	——/——/—— Malheur County	Au	Beaver Resources Ltd.; large area, aerial thematic mapping.
24.	Miners Draw-Coyote Hills	14,15,22,23/35/23 E. Lake County	Au	U.S. Minerals Exploration; 12 reverse circulation holes drilled.
25.	Quartz Mountain	26,27,34,35/37/16 E. Lake County	Au	Galactic Resources Ltd./Quartz Mountain Gold Corp. drilling, trenching, metallurgical testing, permitting.
26.	Zinc Creek	23/29/1 W. Douglas County	Au	Inland Gold; reconnaissance.
27.	Silver Peak Mine	23/31/6 W. Douglas County	Au, Cu, Zn (zinc)	Formosa Exploration, Inc.; mapping, sampling, core drilling, evaluation.
28.	Hungry Hill-Goff Mine	20,29,30/33/7 W. Josephine County	Au, Ag	AMSELCO/BP-America; renewed exploration permit with Josephine County.
29.	Howard Creek area	——/34/8,9 W. Josephine County	Au	Sawyer Consultants; exploration of large block claims, mapping, sampling.

Table 2. *Exploration sites and areas in Oregon, 1987—continued*

Map no.	Name	Location Sec./T.(S.)/R.	Commodity	Comments
30.	Almeda Mine	13/34/8 W. Josephine County	Au, Ag	Kennecott Exploration; completed evaluation of 1986 drilling, turned back to owners February 1987.
31.	Shamrock Mine, Hull Mountain area	19/34/2 W. Jackson County	Cu, Ni (nickel), Co (cobalt), Pt (platinum), Au	Freeport-McMoRan Gold Co.; drilled four holes, further work planned.
32.	Forest Creek area	——/38/3 W. Jackson County	Au	Freeport-McMoRan Gold Co.; reconnaissance on large claim block; seven holes drilled, then option dropped.
33.	Jones Marble	31/38/5 W. Josephine County	White marble	North Lilly Mining Co.; drilling on adjacent claims held by Morris.
34.	Mount Emily area	8/40/12 W. Curry County	Au	Mapping, geochemistry, drilling by Mount Emily Resources.
35.	Turner-Albright Mine	15,16/41/9 W. Josephine County	Au, Cu, Zn, Co	Savanna Resources Ltd. obtained drill core samples for U.S. Bureau of Mines; metallurgical testing of massive sulfide ore.
36.	Palmer Creek area	35/39/4 W. Jackson County	Au	Westley Mines-Nerco joint venture; geochemistry, mapping, drilling.
37.	Squaw Creek area	31,32.5,6,8/40,41/3 W. Jackson County	Au, Cu	Freeport-McMoRan Gold Co.; reconnaissance of large claim block.

site 2) completed its first full year of diatomite production from its operation in Harney and Malheur Counties. Oil-Dri Production Company (active mine site 4) continued to produce diatomite for pet litter and floor sweep. Teague Mineral Products Company (active mine site 3) produced bentonite and zeolites in Malheur County. Ash Grove Cement West (active mine site 1) continued cement production near Durkee and produced crushed limestone for sugar refining. Cascade Pumice and Central Oregon Pumice (active mine site 6) produced pumice near Bend, chiefly for lightweight aggregate used in concrete blocks. CooSand Corporation (active mine site 7) continued production of glass and abrasive sands from dunes in Coos County.

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

The Oregon Department of Geology and Mineral Industries is studying the industrial-mineral potential of the state. An evaluation of Oregon's talc deposits will be the first to be completed and will be published later this year. Other industrial minerals currently under study by the Department include limestone, bentonite, silica sand, and zeolites.

The Department released its first complete listing of mineral producers in the state (Open-File Report O-87-03, *Directory of Mineral Producers in Oregon*), which may be purchased from the Department for $5. □

Oregon Geology publication schedule to change

Since the earliest days of the Oregon Department of Geology and Mineral Industries, we have published a monthly magazine. In the interest of greater variety, cost containment, and better time management, we now plan to print six double issues of *Oregon Geology* each year instead of the twelve single issues you have been accustomed to receiving.

We asked for your opinions last year in the October issue and received generally supportive comments. Most of you who responded understood the need for change in these days of vast new amounts of information, increased demands on agency staff, more data, changing priorities, fewer dollars, and rapidly changing technology.

We have the same loyalty to you that you have demonstrated to us over the years with your subscriptions to the magazine and letters and comments to us. You can rest assured that you will receive at least the same number of pages in a year's subscription that you received under the old system. Our plan is to give you a better blend of material in a single issue and occasionally to present you with interesting types of articles that space constraints precluded with the old format.

We in Oregon are surrounded by some of the most interesting geology to be found anywhere in the world. New and complicated techniques are helping geologists understand our geologic heritage to a degree that was never possible until now. We are also just starting to identify new, hitherto unrecognized mineral resources that lie within our state's boundaries. Some of this information is first announced or released in *Oregon Geology.* Some of it would be lost forever if it were not printed on the pages of this magazine. It is our intention to use this bimonthly format to continue to inform you, our readers, about the best and latest news of the geology of Oregon.

Watch for the May/June issue. □

Former Board member R.W. deWeese dies

Raymond W. "Bill" deWeese, prominent Portland businessman and member of the Governing Board of the Oregon Department of Geology and Mineral Industries from 1969 to 1977, died of a heart attack on Monday, March 7, 1988, in his office in Portland.

Until his retirement in 1970, deWeese worked for Esco Corporation, where he had been Vice President for marketing and a member of the Board for 30 years, retiring in 1970. He also founded several companies, including Odyssey Productions, Inc.; Catheter Technology Corporation; Synektron; and Asia Pacific. He was active in community affairs, serving on the Portland School Board for many years and on the boards of several companies, including Cascade Corporation, Oregon Metallurgical Corporation, and PacWest Bancorp.

DeWeese is survived by his wife Kuniko; sons Douglas, Alexander, and David; daughter Ann Thompson; and three grandchildren. □

Murder, soil, and rocks: Geologic evidence in crime investigation

by Charles A. Tracy, Professor of Administration of Justice, Portland State University, Portland, Oregon, and Michael T. Long, Forest Engineering Geologist, Willamette National Forest, Eugene, Oregon

The battered body of Stephanie Bryan was placed in a shallow hillside grave by her murderer, who carelessly neglected to either clean his boots or dispose of them. Almost one year later, in 1957, Burton Abbott was convicted and executed for her murder, primarily as the result of the testimony of Dr. Paul L. Kirk, a pioneer American criminalist at the University of California at Berkeley, who was able to convince the jury that the tiny bits of clay and gravel on Abbott's boots came from the grave site. (For a general description of this case, see deFord, 1966).

Dr. Kirk's testimony was based on the concept of using scientific knowledge and scholarly deduction to solve crimes, an idea first expressed to Western readers a century ago by Arthur Conan Doyle's Sherlock Holmes. In his first episode, *A Study in Scarlet*, which was published in 1887, Dr. Watson lists twelve areas of knowledge used by Holmes in his practice as a consulting detective. One of these areas was geology, which permitted him to "tell at a glance different soils from each other." Forensic geology was established!

It took 17 more years, however, before this new field moved from fictional to factual murder cases. In 1904, a German chemist, Dr. Georg Popp, linked a murder suspect to the crime scene by matching crystals of hornblende and quartz found in a sample of sand on a handkerchief near the body with similar minerals taken from under the fingernails of the suspect. Dr. Popp was also able to determine that the specific variety and size distribution of quartz and hornblende crystals on the suspect's trousers corresponded to those in the loamy soil where the body of the victim was found.

Popp firmly established the value of geologic evidence in 1908, when he was able to place a murder suspect at the crime scene, as well as to destroy his alibi, by tracing his movements during the day of the murder. On the sole of one of the suspect's shoes was a small amount of layered soil. One layer consisted of red clay mixed with splintery quartz crystals and mica, comparable to the soil where the body had been found. A second layer contained carbon, brick dust, and concrete fragments—consistent with components of soil at a location where the suspect's bloody trousers had been found. The suspect claimed to have been working during the day of the crime in a field located a considerable distance from where the murder had occurred. The soil in this field was found to be largely composed of "porphyry" (sic). (Popp may have been referring to sand grains composed of two minerals, i.e., quartz and hornblende.) However, no trace of this material was found on the suspect's shoe. The suspect was convicted, again largely because of Popp's expert testimony. Later, after the murderer's death sentence was commuted to life imprisonment, he corroborated Popp's conclusions (Thorwald, 1967).

More recently, in 1983, geologic evidence played an important role in the penalty phase of a California murder trial (Rapp, 1987). Tiny rock clasts found in the defendant's automobile were identified by state geologists as being the same as rock clasts located at a gravel pit where the body of a murder victim had been found. Even though the defendant was not being tried for this particular murder, the geologic evidence was part of the prosecutor's argument to the jury that the defendant's past violent activities justified the death penalty—which he received.

The value of soil and rock fragments as physical evidence in crime investigations is based on the probability of two samples originating from the same location. Unfortunately, few statistically valid studies on the variability of soil have been conducted. The findings from those studies that have been reported seem to support the notion that natural variations are highly probable. For example, a study during the late 1970's in southern Ontario, Canada, found that the probability was less than 1 in 50 chances of finding two soil samples that were the same in color and mineral properties, when they originated from two different locations 1,000 ft apart (Saferstein, 1977).

The natural potential for soil and rock fragments to be useful as physical evidence is limited by the ability of the forensic scientist to determine whether two samples are from the same source. Mistakes are made, however. A 1976 study of crime labs in the United States found 35 percent of 93 labs that agreed to test two samples from two different geographical locations came to the wrong conclusion of common origin (Peterson, 1983).

Nevertheless, the value of geologic evidence has been validated over the past 80 years by the work of such scientists as Popp and Kirk, and it will continue to play an important role in solving crimes and convicting criminals (Murray and Tedrow, 1975). Indeed, before his trial, Burton Abbott expressed to a cellmate fear only of Paul Kirk's expert testimony, even though he went to his death in San Quentin's gas chamber still denying that he had murdered Stephanie Bryan.

Note: A two-day forensic-science conference will be held in the Portland metropolitan area on June 13 and 14, 1988. Those readers who would like more information on the conference or who are interested in expanding their knowledge about forensic sciences are invited to contact Dr. Charles A. Tracy at Portland State University, PO Box 750, Portland OR 97207, phone (503) 464-4014.

REFERENCES CITED

DeFord, M.A., 1966, Murderers sane and mad: London, Abelard-Schuman, Ltd., p. 27-33.

Murray, R.C., and Tedrow, J.C.F., 1975, Forensic geology: Earth sciences and criminal investigation: New Brunswick, Rutgers University, 217 p.

Peterson, J.L., 1983, The crime lab, *in* Klockars, K.B., ed., Thinking about police: New York, McGraw Hill Book Co., p. 195.

Rapp. J., 1987, Forensic geology and a Colusa County murder: California Department of Conservation, Division of Mines and Geology, California Geology, v. 40, no. 7, p. 147-153.

Saferstein, R., 1977, Criminalistics: Englewood Cliffs, Prentice-Hall, p. 63-64.

Thorwald, J., 1967, Crime and science: New York, Harcourt, Brace, and World, p. 235-252. □

More USGS topographic maps now available

The U.S. Geological Survey (USGS) map catalog for the State of Oregon now lists a total of 1,911 7½-minute (scale 1:24,000) maps that will eventually be printed for the state. Over 1,400 of these maps are in print and are now available at the Portland business office of the Oregon Department of Geology and Mineral Industries (DOGAMI). *(Continued on page 46,* ***Maps)***

OIL AND GAS NEWS

Gas storage project drilling planned

Oregon Natural Gas Development Corp. has applied for five drilling permits as part of the natural gas storage project at Mist Gas Field, where gas is injected and stored in the depleted Bruer and Flora Pools. Four of the applications are for injection-withdrawal wells, and one is for an observation-monitor well. Observation-monitor wells are generally used to monitor gas levels and pressures in the storage reservoirs, while injection-withdrawal wells are used to add gas to and remove gas from the storage reservoirs. There are currently two injection-withdrawal and six observation-monitor wells at the gas storage project.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
401	Oregon Nat. Gas Dev. IW 42C-10 36-009-00235	NE¼ sec. 10 T. 6. N., R. 5. W. Columbia County	Application; 2,600.
402	Oregon Nat. Gas Dev. IW 22D-10 36-009-00236	NW¼ sec. 10 T. 6. N., R. 5. W. Columbia County	Application; 2,600.
403	Oregon Nat. Gas Dev. OM 43B-10 36-009-00237	SE¼ sec. 10 T. 6. N., R. 5. W. Columbia County	Application; 3,000.
404	Oregon Nat. Gas Dev. IW 33D-3 36-009-00238	SE¼ sec. 3 T. 6. N., R. 5. W. Columbia County	Application; 2,900.
405	Oregon Nat. Gas Dev. IW 23B-3 36-009-00239	SW¼ sec. 3 T. 6. N., R. 5. W. Columbia County	Application; 2,800.

□

State Map Advisory Council publishes first annual report

The State Map Advisory Council for Oregon (SMAC) has released its first annual report, a summary of its activities and accomplishments in 1987. The Council was established by Governor Neil Goldschmidt by Executive Order on July 11, 1987.

The 54-page report was produced under the chairmanship of Deputy State Geologist John D. Beaulieu and published by the Oregon Department of Geology and Mineral Industries as Open-File Report O-88-01. It lists the members of the Oregon SMAC and its committees for maps, geographic information systems, and land records. The release further contains reports on meetings of the committees of SMAC.

The Oregon SMAC is the lead governmental body in Oregon for mapping discussions. It consists of representatives from federal and state agencies, local government, and private industry. Its purpose is to focus computerized mapmaking activities in Oregon and to prevent duplication of efforts.

The new release, *First Annual Report of the State Map Advisory Council for Oregon, 1987,* is available now at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. The purchase price is $5. Orders under $50 require prepayment. □

TO THE EDITOR

AVALANCHE HAZARDS FOR CLIMBERS AT MOUNT ST. HELENS NOTED

The March article regarding the geology of the Monitor Ridge climbing route on Mount St. Helens provides a new dimension to an ascent of the mountain.

One additional item should be added to the section on climbing hazards, however. Slab avalanches can and do occur on the slopes adjacent to Monitor Ridge. On the weekend of March 12, a very large slab avalanche occurred on the Swift Glacier, starting at about 7,500 ft and traveling a mile to about 5,000 ft in elevation.

Climbers should pay close attention to snow-slab buildup and should climb on the ridge crest. Skiers are especially at risk, as the better ski descents are in bowls adjacent to the ridge. These bowls can be subject to avalanche hazard during and after snowfall or wind-driven snow deposition. At this time of year, the hazard is also increased by hot, sunny weather, making slopes with southern exposure unstable by noon.

Climbers should always call the avalanche forecast before climbing. The number is (503) 221-2400.

—Dennis L. Olmstead
Oregon Department of Geology and Mineral Industries

PALEONTOLOGIST REMEMBERED

I was very interested in the article on paleontology in Oregon published in the December 1987 issue of *Oregon Geology.* In particular the paragraph about Charles E. Weaver brought back good memories. I was an undergraduate student at the University of Washington 1942-46, and Charles Weaver was the professor of paleontology.

The reason that he spurned the automobile was that he was color-blind and not allowed to drive a car. He could recognize only yellow, and when he used colored chalk on the blackboard he had to ask the class what color he was using.

His walking was legend, and we heard that he had walked the entire north and west coasts of the Olympic Peninsula and often had such a large pack that he had to lie down on the beach to slip into it and then have a couple of Indians lift him up with the pack on his back.

He seldom used a textbook, and all his lectures were dictated. He would come to class and ask a student what the last sentence was that he gave in the previous lecture and then would start out that day's lecture from the last sentence of the previous day's lecture.

Wilbert R. Danner
Professor of Geology
University of British Columbia

NOTE

The article "Paleontology in Oregon" in the December 1987 issue of *Oregon Geology* included, on the front cover of the issue, a photo of Ralph Chaney and a woman we had not been able to identify. Former Oregon State Geologist Ralph Mason tells us it is Ethel I. Sanborn, then paleobotanist at Oregon State College in Corvallis. □

(Maps continued from page 45)

By 1991, the USGS plans to have the entire set of maps in print and will be phasing out the old 15-minute (scale 1:62,500) maps within the next ten years. A photo-revision program for existing quadrangle maps is in progress, and the newly revised maps are continuously released.

DOGAMI also sells 15-minute, 1:250,000 topographic, and other USGS geologic maps along with all DOGAMI publications at the Portland business office. The USGS map catalog is available free, over-the-counter from the Portland office and from any other map dealer who sells USGS maps. It may also be ordered by mail from the USGS, Box 25286, Federal Center, Denver, CO 80225. □

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Geologic map of Oregon west of 121st meridian (U.S. Geological Survey Map I-325). 1961	6.10		
Geologic map of Oregon east of 121st meridan (U.S. Geological Survey Map I-902). 1977	6.10		
Landforms of Oregon (relief map, 17x12 in.)	1.00		
Oregon Landsat mosaic map (published by ERSAL, OSU). 1983	$8.00 over the counter, $11.00 mailed		
Geothermal resources of Oregon (map published by NOAA). 1982	3.00		
Geological highway map, Pacific Northwest region, Oregon/Washington/part of Idaho (published by AAPG). 1973	5.00		
Mist Gas Field Map, showing well locations, revised 1987 (DOGAMI Open-File Report O-88-2, ozalid print)	5.00		
Northwest Oregon, Correlation Section 24. Bruer & others, 1984 (published by AAPG)	5.00		
Mining claims (State laws governing quartz and placer claims)	1.00		
Back issues of *Ore Bin*	50¢ over the counter; $1.00 mailed		
Back issues of *Oregon Geology*	75¢ over the counter; $1.00 mailed		
Index map of available topographic maps for Oregon published by the U.S. Geological Survey	1.50		

Separate price lists for open-file reports, geothermal energy studies, tour guides, recreational gold mining information, and non-Departmental maps and reports will be mailed upon request. The Department also sells Oregon topographic maps published by the U.S. Geological Survey.

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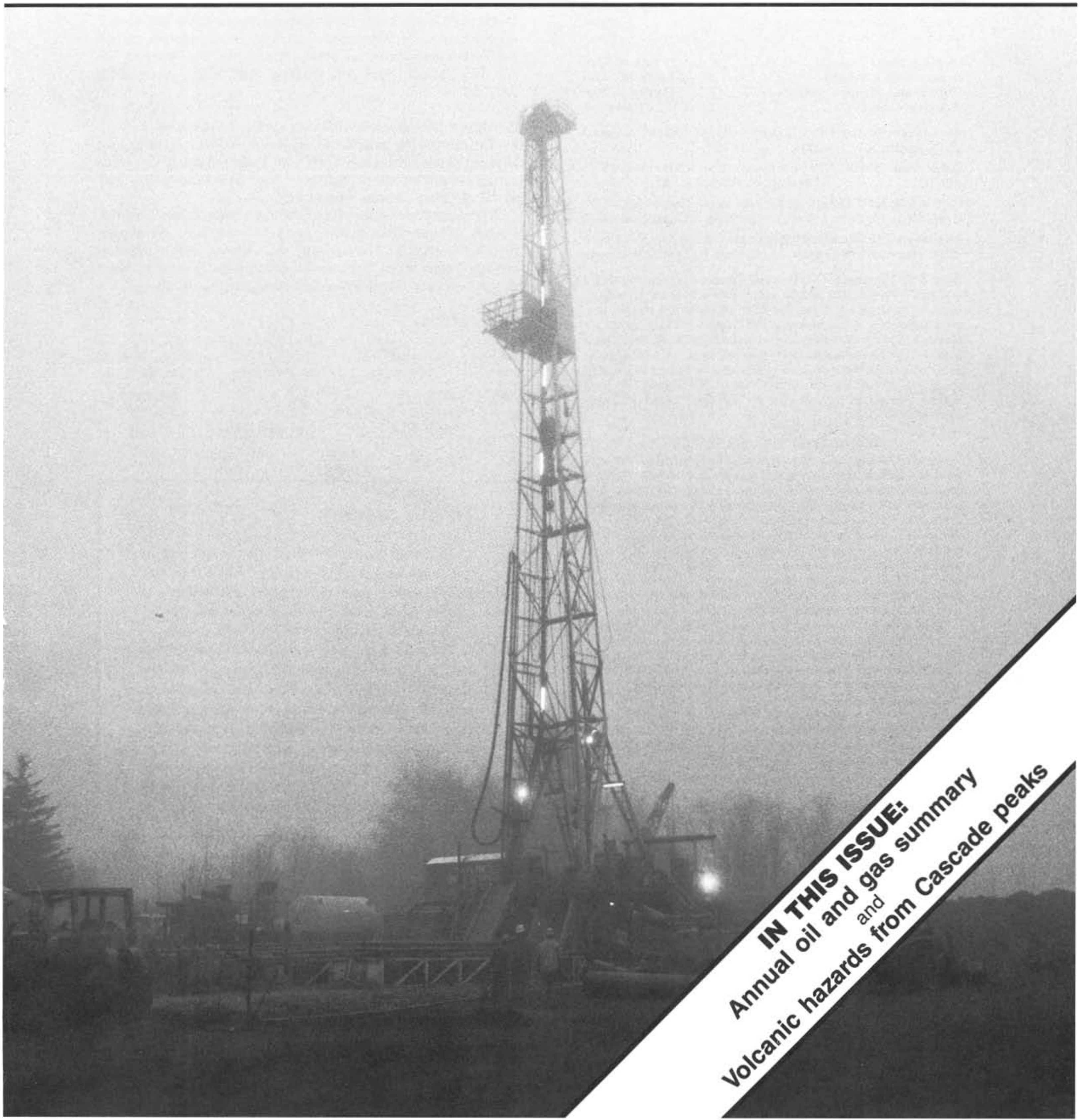

IN THIS ISSUE:
Annual oil and gas summary
and
Volcanic hazards from Cascade peaks

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Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. If manuscript was prepared on common word-processing equipment, a file copy on 5¼-in. diskette may be submitted in addition to the paper copies. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors,* 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of the bibligraphic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Preparations to flow-test the well ARCO Foster 42-30-65, one of the seven new natural gas producers of 1987 in the Mist Gas Field, Columbia County, Oregon. Annual summary of oil and gas exploration and development in Oregon in 1987 begins on next page.

OIL AND GAS NEWS

MMS offshore conference

The Minerals Management Service (MMS) will hold a conference in Portland on May 23-25, 1988, to discuss recommendations for environmental studies prior to the scheduled 1992 Lease Sale No. 132. The MMS is conducting several studies as part of its Environmental Studies Program in preparation for the scheduled 1992 lease sale off Oregon and Washington. The conference will enable participants to hear about ongoing studies and to recommend further studies. For information and registration materials, contact Bio/Tech Communications, MMS-OCS Conference Planners, 600 SW 10th Avenue, Suite 418, Portland, OR 97205, phone (503) 245-7377.

Northwest Petroleum Association spring symposium

The oil and gas potential of southwestern Washington and the adjacent Outer Continental Shelf will be the subject of this year's spring symposium of the Northwest Petroleum Association, May 18-20, at Ocean Shores, Washington.

The symposium begins with a field trip on May 18 from Portland, Oregon, to Ocean Shores, Washington, and concludes with another field trip on May 20. The field trips will examine Eocene reservoir sands and other strata. For more information see the announcement of the Northwest Petroleum Association later on in this issue.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
406	ARCO Columbia Co. 44-27-65 36-009-00240	SE¼ sec. 27 T. 6 N., R. 5 W. Columbia County	Application; 2,150.

□

To our readers

This issue is a historic first: It is the first regular two-month issue of *Oregon Geology* which from now on will appear every other month. For the rest of volume 50, the numbering of the issues will indicate this by double numbers: 5/6, 7/8, 9/10, 11/12.

The size of the issue corresponds to that of two monthly issues—24 instead of 12 pages; the amount of information you receive is the same as before, more, in fact, if you consider that of the 24 pages only two pages take up our list of available publications, compared to four pages in two separate issues.

If the longer interval between issues affects your need for prompt information, please feel free to write or call the Department with your requests.

CONTENTS

Oil and gas exploration and development in Oregon, 1987

by Dan E. Wermiel, Petroleum Geologist, and Dennis L. Olmstead, Petroleum Engineer, Oregon Department of Geology and Mineral Industries

ABSTRACT

Oil and gas leasing in Oregon in 1987 remained at about the same level as during 1986. During 1987, nearly 700,000 federal acres were terminated or relinquished, leaving 762,521 acres in 1,045 parcels under lease at year's end. Counties with the most activity were Umatilla, Crook, and Morrow. There were 160,000 state acres terminated during the year, leaving 109,107 acres under lease at year's end, with the majority of that acreage located in Clatsop County.

Twenty applications for permits to drill were issued during 1987. Nine exploratory wells, one reentry of a suspended well, one redrill, and five gas-storage wells were drilled by four operators, about the same level of drilling activity as during 1986. Of these wells, all but the reentry were in the Mist Gas Field in Columbia County. There were seven new gas completions, all drilled by ARCO Oil and Gas Company.

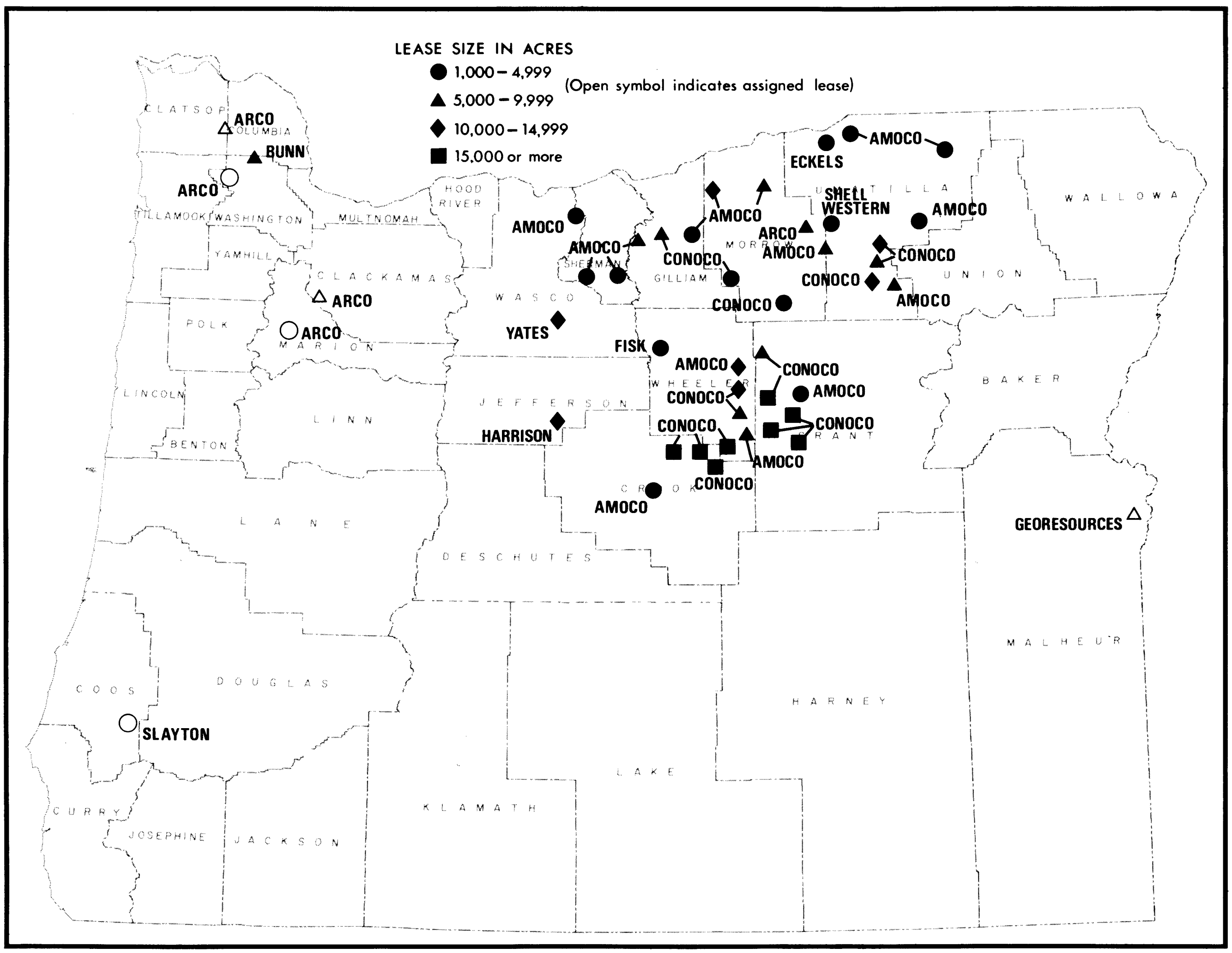
Production in 1987 totaled 3.8 billion cubic feet (Bcf) of gas, down from 4.6 Bcf produced during 1986. Total value for the gas produced was $5.5 million.

Oregon Natural Gas Development Corporation continued drilling at the natural-gas storage project at Mist Gas Field, where the depleted Bruer and Flora Pools are being used for gas-storage purposes. A total of 4 Bcf was injected during 1987.

The Oregon Department of Geology and Mineral Industries (DOGAMI) will conduct a review of permitting, drilling, and development rules during 1988.

LEASING ACTIVITY

During 1987, leasing in Oregon remained at a low level, following a similar year in 1986. Applications were filed for about 93,000 acres of federal land, mostly in the Simultaneous Oil and Gas (SOG) program, which reoffers previously relinquished leases. Of this total, 2,000 acres were in the Over-the-Counter program. The oil-and-gas leasing map shows this acreage as well as 245,000 acres for which Conoco applied in the December 1987 SOG filing and 118,500 acres for which Amoco applied. During the year, leases on 102,732 acres (58 parcels) were issued. Some of this acreage is from 1987 filings, and some was from 1986 or earlier filings. Counties with the most activity were Umatilla, Crook, and Morrow. In 1987, nearly 700,000



Major areas of oil and gas leasing activity in Oregon, 1987. Map shows acreage applied for, issued, and assigned. Most of it is federal acreage. Withdrawals and terminations are not shown. Data courtesy Greater Columbia LANDATA.

Table 1. *Oil and gas permits and drilling activity in Oregon, 1987*

Permit no.	Operator, well, API number	Location	Status, depth (ft) TD=total depth PTD=proposed TD RD=redrill
180 Rework	Oregon Nat. Gas Dev. IW 32d-10 36-009-00082	NE¼ sec. 10 T. 6 N., R. 5 W. Columbia County	Completed, service well; TD: 2,171.
358D	Damon Petroleum Corp. Stauffer Farms 35-1 Deepening 36-047-00020-80	NW¼ sec. 35 T. 4 S., R. 1 W. Marion County	Abandoned, dry hole; TD: 2,752.
364	Oregon Nat. Gas Dev. OM 12c-3 36-009-00201	NW¼ sec. 3 T. 6 N., R. 5 W. Columbia County	Completed, service well; TD: 3,156.
367	Oregon Nat. Gas Dev. OM 14a-3 36-009-00204	SW¼ sec. 3 T. 6 N., R. 5 W. Columbia County	Completed, service well; TD: 3,200.
372	Oregon Nat. Gas Dev. OM 32b-11 36-009-209	NE¼ sec. 11 T. 6 N., R. 5 W. Columbia County	Completed, service well; TD: 3,205.
373	Oregon Nat. Gas Dev. IW 33c-3 36-009-00211	SE¼ sec. 3 T. 6 N., R. 5 W. Columbia County	Completed, service well; TD: 2,772.
377	ARCO Oil and Gas Co. Longview Fibre 11-31-64 36-009-00214	NW¼ sec. 31 T. 6 N., R. 4 W. Columbia County	Completed, gas; TD: 1,745.
378	ARCO Oil and Gas Co. Columbia County 24-26-65 36-009-00215	SW¼ sec. 26 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 2,400.
379	ARCO Oil and Gas Co. Columbia County 11-7-65 36-009-00216	NW¼ sec. 7 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 3,800.
380	ARCO Oil and Gas Co. Columbia County 11-34-65 36-009-00217	NW¼ sec. 34 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 1,950.
381	ARCO Oil and Gas Co. Columbia County 23-18-65 36-009-00218	SW¼ sec. 18 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 3,600.
382	ARCO Oil and Gas Co. Columbia County 32-26-65 36-009-00219	NE¼ sec. 26 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 2,200.
383	ARCO Oil and Gas Co. Columbia County 42-9-65 & Redrill 36-009-00220 36-009-00220-01	NE¼ sec. 9 T. 6 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 2,850, RD: 2,840.
384	ARCO Oil and Gas Co. Columbia County 24-26-65 36-009-00221	SW¼ sec. 26 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 2,000.
385	ARCO Oil and Gas Co. Columbia County 22-27-75 36-009-00222	NW¼ sec. 27 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 2,300.
386	ARCO Oil and Gas Co. Columbia County 31-34-65 36-009-00223	NE¼ sec. 34 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 2,344.
387	ARCO Oil and Gas Co. Columbia County 31-27-65 36-009-00224	NE¼ sec. 27 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 6,700.
388	LEADCO, Inc. CC-Jackson 22-17 36-009-00225	NW¼ sec. 17 T. 5 N., R. 4 W. Columbia County	Abandoned, dry hole; TD: 2,318.
389	LEADCO, Inc. CC-Jackson 23-17 36-009-00226	SW¼ sec. 17 T. 5 N., R. 4 W. Columbia County	Permit issued; PTD: 2,500.
390	ARCO Oil and Gas Co. CFI 31-1-65 36-009-00227	NE¼ sec. 1 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 2,100.
391	ARCO Oil and Gas Co. Columbia County 34-4-65 36-009-00228	SE¼ sec. 4 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 3,382.
392	ARCO Oil and Gas Co. Longview Fibre 32-20-65 36-009-00229	NE¼ sec. 20 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 2,850.
393	ARCO Oil and Gas Co. Columbia County 21-35-65 36-009-00230	NW¼ sec. 35 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 1,924.
394	ARCO Oil and Gas Co. Foster 42-30-65 36-009-00231	NE¼ sec. 30 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 2,658.
395	Hutchins and Marrs GP 1 36-011-00024	SW¼ sec. 14 T. 30 S., R. 10 W. Coos County	Permit issued; PTD: 6,000.

Wellhead at the ARCO Columbia County 31-27-65, which was drilled to a total depth of 6,700 ft, making it the deepest well drilled during 1987.

acres were terminated or relinquished, leaving 762,521 acres in 1,045 parcels under lease at year's end. Rental income during the year on federal land was $581,107.

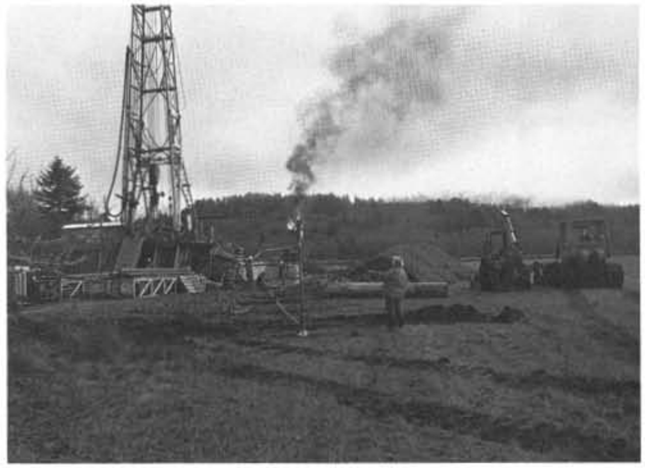
The SOG lease program was ended in December, and Over-the-Counter leases were changed to include a competitive bidding process in 1988.

The Division of State Lands held no lease sales of state land during 1987 and had only one application, which was for 800 acres. Nearly 160,000 acres were terminated during the year, leaving 109,107 acres under lease on December 31. Clatsop County has more state land under lease than any other county.

No counties held lease sales in 1987; however, 14,000 acres taken during the July 1986 Columbia County lease sale were assigned to ARCO Oil and Gas Company.

DRILLING

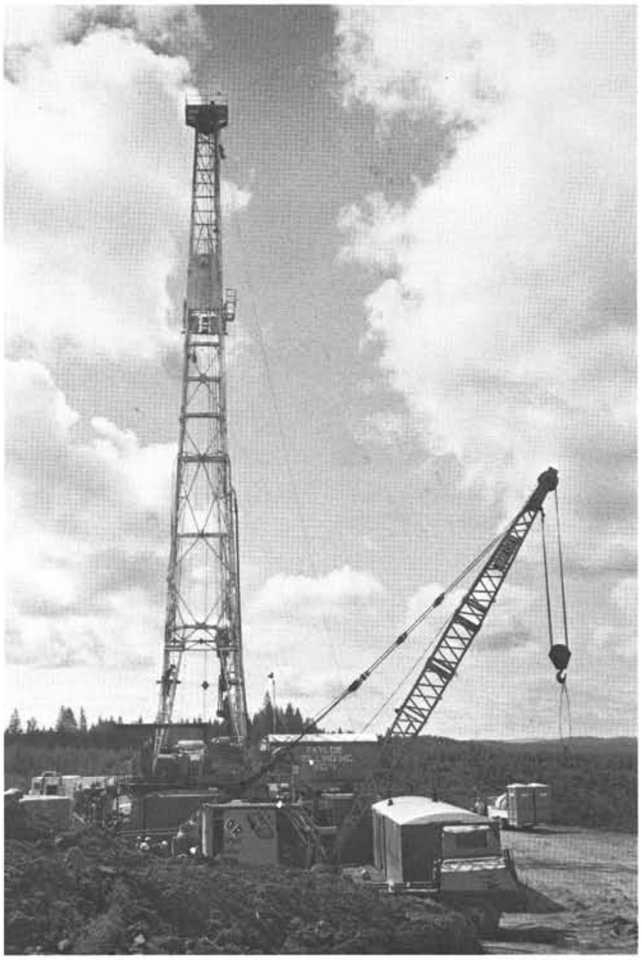
Nine exploratory oil and gas wells, one reentry of a suspended well, one redrill, and five gas-storage wells were drilled in the state in 1987. This amount of drilling is similar to the level of drilling activity during 1986. All but one of the wells were drilled within



Dorothy Foster, royalty owner, lighting the flare at the flow test of the ARCO Foster 42-30-65 well.

Table 2. *Canceled and denied permits, 1987*

Permit no.	Operator, well, API number	Location	Issue date	Cancellation date	Reason
297	Hutchins and Marrs GP 1 36-011-00021	NE¼ sec. 14 T. 30 S., R. 10 W. Coos County	7-25-85	7-25-87	Permit canceled; expired.
298	Tenneco Oil Company Columbia County 11-28 36-009-00144	NW¼ sec. 28 T. 6 N., R. 10 W. Columbia County	6-11-85	6-11-87	Permit canceled; expired.
300	Tenneco Oil Company Columbia County 33-28 36-009-00146	SE¼ sec. 28 T. 6 N., R. 5 W. Columbia County	6-11-85	6-11-87	Permit canceled; expired.
302	Tenneco Oil Company Columbia County 42-28 36-009-00148	NE¼ sec. 28 T. 6 N., R. 5. W. Columbia County	-	-	Permit denied; irregular location.
314	ARCO Oil and Gas Company Scherf 41-21 36-009-00160	NE¼ sec. 21 T. 6 N., R. 5 W. Columbia County	6-20-85	7-1-87	Permit canceled; expired.
346	ARCO Oil and Gas Company CFI 23-9 36-009-00187	SW¼ sec. 9 T. 5 N., R. 4 W. Columbia County	1-31-86	1-31-87	Permit canceled; expired.
352	ARCO Oil and Gas Company Columbia County 44-27 36-009-00191	SE¼ sec. 27 T. 6 N., R. 5 W. Columbia County	3-11-86	3-12-87	Permit canceled; expired.
353	ARCO Oil and Gas Company Longview Fibre 43-4 36-009-00192	NE¼ sec. 4 T. 5 N., R. 5 W. Columbia County	3-28-86	3-28-87	Permit canceled; expired.
354	ARCO Oil and Gas Company Columbia County 44-6 36-009-00193	SE¼ sec. 6 T. 6 N., R. 5 W. Columbia County	3-28-86	3-28-87	Permit canceled; expired.
355	ARCO Oil and Gas Company Columbia County 31-7 36-009-00194	NE¼ sec. 7 T. 6 N., R. 5 W. Columbia County	3-28-86	3-28-87	Permit canceled; expired.
359	ARCO Oil and Gas Company CFI 21-22 36-009-00196	NW¼ sec. 22 T. 5 N., R. 4 W. Columbia County	5-20-86	5-20-87	Permit canceled; expired.
363	Oregon Natural Gas Dev. OM 44d-3 36-009-00200	SE¼ sec. 3 T. 6 N., R. 5 W. Columbia County	7-3-86	7-7-87	Permit canceled; expired.
370	ARCO Oil and Gas Company CFI 12-5 36-009-00207	NW¼ sec. 5 T. 6 N., R. 5 W. Columbia County	7-18-86	7-18-87	Permit canceled; expired.



Rigging up in preparation to spud the ARCO Longview Fibre 11-31-64 well.

the boundaries of the Mist Gas Field, a pattern that has continued since the field discovery in 1979. The other well was an unsuccessful attempt by Damon Petroleum Corporation to reenter and deepen a previously drilled well in the Willamette Valley near Hubbard in Marion County. Although the operator experienced mechanical difficulties and the well was plugged before deepening was accomplished, it indicates a continued interest in the Willamette Valley, where wells have been drilled each year since 1979.

Twenty permits to drill were issued in 1987 (Table 1), down from thirty in 1986. Twelve expired permits were canceled, and one permit was denied during the year (Table 2).

Four operators were active in the state last year. ARCO Oil and Gas Company was most active, drilling eight exploratory wells and one redrill, with seven successful completions at the Mist Gas Field. Oregon Natural Gas Development Corporation drilled five wells as part of the natural-gas storage project at Mist Gas Field. LEADCO, Inc., drilled a dry hole at Mist Gas Field, and Damon Petroleum reentered its 1986 Marion County well.

Total footage drilled for the year, including the gas-storage wells, was 42,665 ft, which is an increase from 39,740 ft in 1986. The average depth for exploration and development wells was 2,896 ft, 11 percent deeper than the 2,600-ft average depth in 1986. The deepest well drilled during the year was a 6,700-ft well drilled by ARCO Oil and Gas Company at Mist Gas Field. This was a relatively rare test of the deeper sediments at Mist. The well was dry at total depth but productive from the Clark and Wilson sand, which remains the only producing reservoir at the field.

DISCOVERIES AND GAS PRODUCTION

The Mist Gas Field experienced seven new producers, which sets a record for the number of new pool discoveries in a single year at Mist. ARCO Oil and Gas Company is the operator of these wells, which include Columbia County 11-34-65, Columbia County 21-35-65, Columbia County 31-27-65, Columbia County 31-34-65, Columbia County 34-4-65, Foster 42-30-65, and Longview Fibre 11-31-64. The cumulative initial flow rate for these seven wells is 10 to 12 million cubic feet (MMcf) of gas per day. This brings the number of completed wells at Mist Gas Field to twenty wells, all operated by ARCO Oil and Gas Company, of which ten were producing gas, four were shut-in, and all but one of the new wells were awaiting connection to gas pipeline at year's end. One producing well, Tenneco Columbia County 41-28, was plugged during the year due to gas depletion.

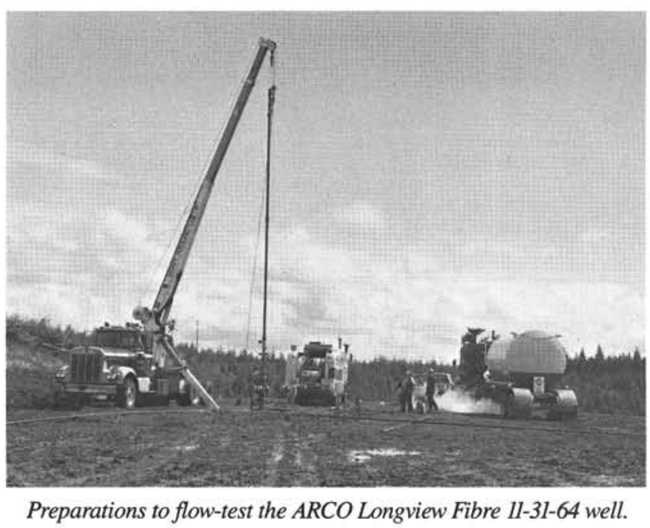
Gas production for the year totaled 3.8 Bcf, a decrease from the 4.6 Bcf produced in 1986. The cumulative field production through the end of 1987 was 31.7 Bcf. The seven new gas wells add an additional 11 to 14 Bcf of reserves to the field. The total value for the gas produced for the year was $5.5 million, down from the $9.2 million produced during 1986. Gas production should increase for 1988 with the connection to gas pipeline of the new producers discovered during 1987. ARCO estimates that daily production at Mist should increase from the 1987 rate of 10 MMcf of gas per day to about 15 MMcf of gas per day upon connection of the new wells.

STORAGE PROJECT

Oregon Natural Gas Development Company began drilling at the natural-gas storage project at Mist Gas Field during 1986. This drilling continued in 1987 with the drilling of three additional observation-monitor wells and two injection-withdrawal wells. Pipeline gas will continue to be injected and stored in the depleted Flora and Bruer Pools. Observation-monitor wells are used to monitor the gas levels and pressures in the storage reservoir, and injection-withdrawal wells are used to add gas to and remove gas from the storage reservoir. During 1987, a total of 4 Bcf was injected at the natural-gas storage project, 1.6 Bcf into the Flora Pool and 2.4 Bcf into the Bruer Pool. Stored gas will be withdrawn for sale later this year.

OTHER ACTIVITY

The Northwest Petroleum Association (NWPA) remained active during 1987, with membership standing at 140 at year's end. At the monthly meetings, papers covering oil and gas-industry-related subjects such as leasing, geology, and economics were presented. A symposium, including a field trip, was held in Bend to discuss the hydrocarbon potential of central Oregon's pre-Tertiary rocks.



Preparations to flow-test the ARCO Longview Fibre 11-31-64 well.

The Oregon Department of Geology and Mineral Industries (DOGAMI) did not undertake law or rulemaking in 1987 but will conduct a triannual rule review during 1988.

Last year, two offshore planning bills, Senate Bill 606 and Senate Bill 630, passed the legislature. SB606 provides for hard-mineral exploration in state waters under the direction of the Division of State Lands. SB630 establishes the Oregon Ocean Resource Management Task Force and requires the group to write a master plan to manage Oregon's ocean resources. DOGAMI is a member of the task force and a consultant to the Division of State Lands.

The Mist Gas Field map (Open-File Report O-88-2) has been updated to January 1988 and is available from DOGAMI for $5. Other publications in the Oil and Gas Investigations Series are also available, including OGI-16, *Available Well Records and Samples of Onshore and Offshore Oil and Gas Exploration Wells in Oregon.* A publication list is presented on the last page of this issue of *Oregon Geology.*

ANTICIPATED 1988 ACTIVITY

The coming year appears to have some significant activity in store for Oregon.

ARCO Oil and Gas Company has received a drilling permit for a proposed 9,000-ft wildcat well in eastern Oregon's Columbia Basin, about 6 mi northeast of Heppner in Morrow County. This well will drill through the rocks of the Columbia River Basalt Group to test underlying Tertiary rocks, which are interpreted to have favorable conditions for hydrocarbon generation and entrapment. ARCO Oil and Gas Company also plans to continue its drilling program at Mist Gas Field.

Oregon Natural Gas plans to drill five more wells, four injection-withdrawal wells and one observation-monitor well, at the natural-gas storage project at Mist Gas Field.

NWPA will hold its annual symposium on the central Washington coast during May. Details may be obtained from the NWPA, P.O. Box 6679, Portland, OR 97228-6679. □

State and counties receive share payments from BLM

For the fiscal year ending September 30, 1987, Oregon counties have received a total of $2,885,470 as their share of "Payments in Lieu of Taxes" distributed by the U.S. Bureau of Land Management (BLM) to offset fiscal impacts of tax-exempt federal lands within local government boundaries.

BLM Oregon-Washington State Director Bill Luscher said that Malheur County was the largest Oregon recipient with $641,084, trailed by Lane County with $325,379, Harney County with $305,539, and Lake County with $212,463.

BLM administers the payment program because it is the largest single federal land management agency, with responsibility for more than 300 million acres of public lands across the nation. BLM manages 15.7 million acres in Oregon.

Tax-exempt federal lands include many different types of land that can have fiscal impacts on the governmental units surrounding them. These payments help local government provide fire and police protection, search-and-rescue operations, road construction, and other vital services. The recipients may use the funds for any governmental purpose.

—*BLM News*

BLM presents the Badlands

There are places in the U.S. Bureau of Land Management's (BLM) Prineville district where hiking is possible all year. Particularly in winter, when a lot of people head west from Bend to Mount Bachelor to ski, a few head east to the Badlands.

The Badlands is a 32,000-acre area in the High Lava Plains province and is located 12 mi from Bend, just north of U.S. Highway 20. It is readily accessible regardless of weather conditions, according to Berry Phelps, recreation planner. The area contains rolling hills of western juniper and deeply fractured basalt outcroppings that look like giant lava blisters.

The Badlands is not only a place to go to escape but also a good place to get lost. Once you are out in the Badlands, the entire area looks very much the same, and it is easy to become disoriented. Even though the area is not extremely large, it is still a good idea to carry a map and a compass. Maps of the Badlands are available at BLM's Prineville district office (P.O. Box 550, 185 East Fourth Street, Prineville, OR 97754, phone (503) 447-4115).

Much of the area is very sandy. An attempt to drive off established roads and getting stuck could turn a visit into more of an outdoor experience than originally planned. That is why BLM recommends hiking rather than driving.

BLM has studied the Badlands area to determine its suitability for wilderness. Because of the unique natural values in the area, BLM plans to recommend it for wilderness designation.

—*Adapted from Brian Cunninghame, BLM News*

Historic China Ditch remembered

The U.S. Bureau of Land Management's (BLM) Roseburg district and the National Advisory Council on Historic Preservation are working together to protect the China Ditch, a hydraulic-mining feature in the North Myrtle Creek area.

The China Ditch was dug during the early 1890's to bring water from the Cavitt Creek drainage to hydraulic-mining operations. The name comes from the Chinese laborers who worked on the project. Although the developers promised substantial economic benefits for the area, the results fell far short of their predictions. The project was abandoned in 1894, after approximately 26 mi of the ditch was built.

BLM currently manages 10 mi of the ditch. The immediate focus is on lessening logging impacts. Future goals include an inventory of associated historic sites and development of an interpretive plan.

—*Isaac Barner, BLM News*

EOMA offers scholarship

Eastern Oregon Mining Association (EOMA), the Baker-based miners' advocate organization, is now accepting scholarship applications from college students whose field of study is mining, announced EOMA President Chuck Chase.

Available this year, as in previous years, is a $500 scholarship to a student who lives in eastern Oregon, a region determined by EOMA directors to be east of the Cascade Mountains and north and south to the state's boundary lines.

Eligible, said Chase, are students starting their third or fourth year in a college or university which offers a degree in a mining-related field. The student must have declared his or her major field of study in a mining-related subject.

The financial award will go to the individual who has demonstrated an aptitude for excelling in the field of mining. The $500 will be awarded to the selected student at a fall meeting of EOMA.

Deadline for applications is June 1. Those interested should contact EOMA, Attention Scholarship, P.O. Box 932, Baker, OR 97814.

—*EOMA news release*

Volcanic hazards from High Cascade peaks

by John Eliot Allen, Emeritus Professor of Geology, Portland State University, 97207-0751

INTRODUCTION

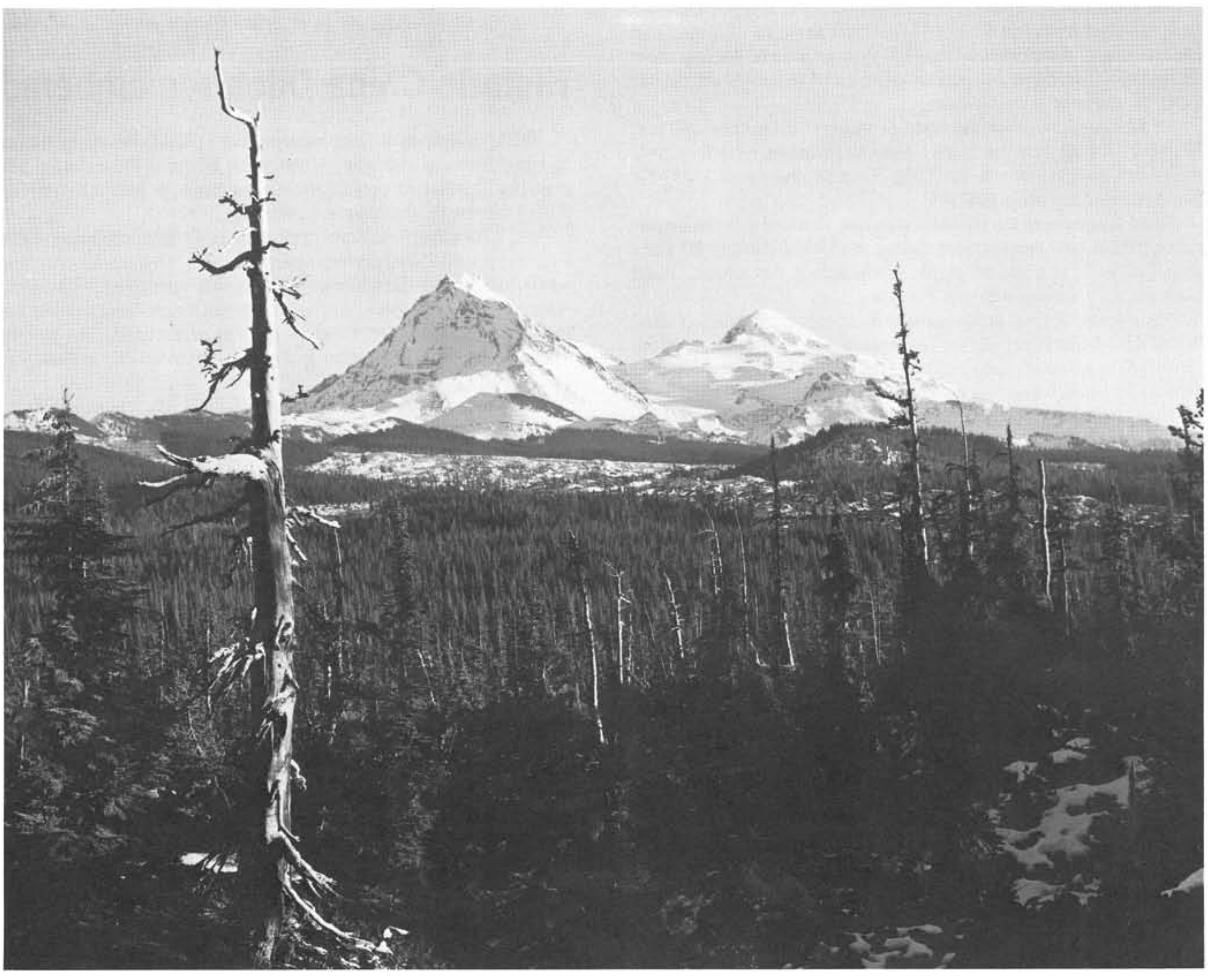
My interest in High Cascade volcanoes began while I climbed most of them during college. At Berkeley, I studied under the pioneer volcanologist Howell Williams, and my first job out of school was as Ranger Naturalist at Crater Lake, where I wrote my first professional paper on the domes around the north rim of the lake (Allen, 1935). For six months after June 1980, I served at the request of the U.S. Geological Survey (USGS) as chairman of a committee that validated the scientific credentials of visitors into the Mount St. Helens "Red Zone."

When in 1981 the Smithsonian Institution's Tom Simkin and others published *Volcanoes of the World: A regional directory, gazetteer, and chronology of volcanism during the last 10,000 years*, I was fascinated with the different kinds of information that could be extracted from it, and this paper eventually resulted. Unless otherwise noted, statistical data given here were derived from that work (Simkin and others, 1981).

VOLCANIC HAZARDS

Most volcanoes that cause hazards to human affairs occur above zones where a plate of oceanic crust is being "subducted," or shoved down, beneath a continental plate to a depth where its contained water causes melting of formerly solid rock to produce magma (gas-charged molten rock) that then works its way to the surface. These magmas contain large amounts of water vapor and are hence highly explosive. Oceanic volcanoes, such as those that eventually formed Hawaii and Iceland, although much more numerous, are mostly submarine, and their very liquid lavas do not produce explosive activity.

Subduction zones surround the Pacific Ocean and have produced the "Ring of Fire" chains of volcanoes in the Philippines, Japan, Kamchatka, the Aleutian Islands, Alaska, the Cascades, Mexico and central America, and the Andes in South America. An eastward "loop" in the chain supports the volcanoes in the West Indies, and another series of loops off the main line in the western Pacific has produced the volcanoes in the East Indies.



North and Middle Sisters, in the central Oregon High Cascades. View is to the southeast. Foreground is covered by lava flows. Photo courtesy Oregon State Highway Division.

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

The United States is the third most volcanically active country in the world, containing 58 volcanoes that have erupted 471 times since 1700 A.D. Around the Pacific "Ring of Fire," only Japan and Indonesia can boast (or lament!) more.

Of the 58 active volcanoes in the United States, the Aleutian Islands contain the largest number, with 26 volcanoes that have erupted 200 times. The rest of Alaska comes in second, with 17 volcanoes that have erupted 117 times. Since 1750, there is only one period of 10 years (1854 to 1864) when a volcano did not erupt somewhere in the Aleutians or in Alaska.

The Hawaiian islands have only four volcanoes that have been active during historical time, but they have erupted 114 times. Since 1732, there have been only three periods of six years each when one of the Hawaiian volcanoes did not erupt. Fortunately for most of us, the "lower 48" comes in a poor third in the number of volcanoes, with nine that have erupted a total of 40 times since 1750.

EXPLOSIVITY OF VOLCANIC ERUPTIONS

The violence of an eruption can be indicated by the Volcanic Explosivity Index (VEI) (Simkin and others, 1981; Newhall and Self, 1982), which is calculated by measurements of the volume of ejecta; the height of the cloud column; and adjectival terms used by the observers, such as "gentle," "explosive," "severe," "violent," and "cataclysmic." On the VEI scale, 1 is small, 2 is moderate, 3 is moderate to large, 4 is large, and 5 is very large. The scale continues on up to 8, but no eruption in the last 10,000 years has been assigned a VEI of 8, and only one has been assigned a VEI of 7: the Tambora eruption of 1815.

The rest of the 471 eruptions in the U.S. during the last 10,000 years have VEI's of less than 4. This does not include dozens of small cinder cones in Oregon, California, Nevada, and New Mexico, many of which have given off basaltic lava flows covering up to 20 or more square miles.

Table 1. *Casualties and VEI's for some selected historic volcanic eruptions (partly from Simkin and others, 1981, and New York Times, 1969)*

Date	Volcano	VEI	Comments	People killed
79	Vesuvius	5	Pompeii and Herculaneum (ash)	2,000+
1669	Etna	3	Catania (lava)	20,000+
1783	Laki	4	Iceland (gases)	⅕ of population
1815	Tambora	7	Indonesia (tsunamis)	12,000
1883	Krakatau	6	Sunda Straits (tsunamis)	36,000+
1902	Pelee	4	Martinique (nuee ardente)	30,000+
1963	Agung	4	Bali (nuee ardente)	1,500+
1980	St. Helens	3	Washington (nuee ardente)	60?
1985	Ruiz	3?	Colombia (mud flow)	15,000

Table 2. *Rating of U.S. volcanoes according to explosivity. Eruptions during the last 10,000 years. In eruption dates, a minus sign means B.C.*

VEI 6	Crater Lake (-4650) White River, Alaska (525) Novarupta, Alaska peninsula (1912)	13 other eruptions worldwide from 11 volcanoes
VEI 5	White River, Alaska (310) St. Helens, Washington (-1900?, 1500, 1980)	31 other eruptions worldwide from 25 volcanoes
VEI 4	Rainier, Washington (-300?) Newberry Volcano, Oregon (big obsidian flow) (315) Mono Craters, California (810) Inyo Craters, California (910, 1240) Pogromni, Aleutian Islands (1795) Isanotski, Aleutian Islands (1825) Augustine, Alaska (1883, 1976) Spurr, Alaska (1953)	121 other eruptions worldwide from 54 volcanoes

The dating of Holocene but prehistoric eruptions is usually by means of carbon-14 radioactive dating of organic material within the ash layers or beneath lava flows. Such work has been done at only a few volcanoes, so there must have been many more eruptions of less well-studied volcanoes than are listed in Simkin and others (1981).

There are more than 3,000 volcanoes in the Cascade Range that have erupted during the last five million years (Hammond, personal communication, 1987). The greater Portland area contains nearly 50 volcanoes which erupted probably more than half a million years ago (Allen, 1975).

During the 17 years between 1843 and 1860, there was a burst of activity in the Cascades with 21 eruptions; during only six years (three periods of two years each) were there no eruptions. Some geologists have speculated that we may now be entering another such spell of activity.

Mount Tabor, one of the many small extinct volcanoes in the Portland area. This excavated cinder cone serves as an outdoor theater.

Few of the 14 High Cascade volcanoes in the United States are extinct, although such eroded matterhorns as Three Fingered Jack, Mount Washington, and Mount Thielsen might be so considered.

It is no wonder that since the eruption of Mount St. Helens in 1980 the team of USGS geologists at the Cascades Volcano Observatory in Vancouver, Washington, has been working overtime to explore and monitor Mount St. Helens, with some work also being done at the other volcanoes in the range.

PREDICTION

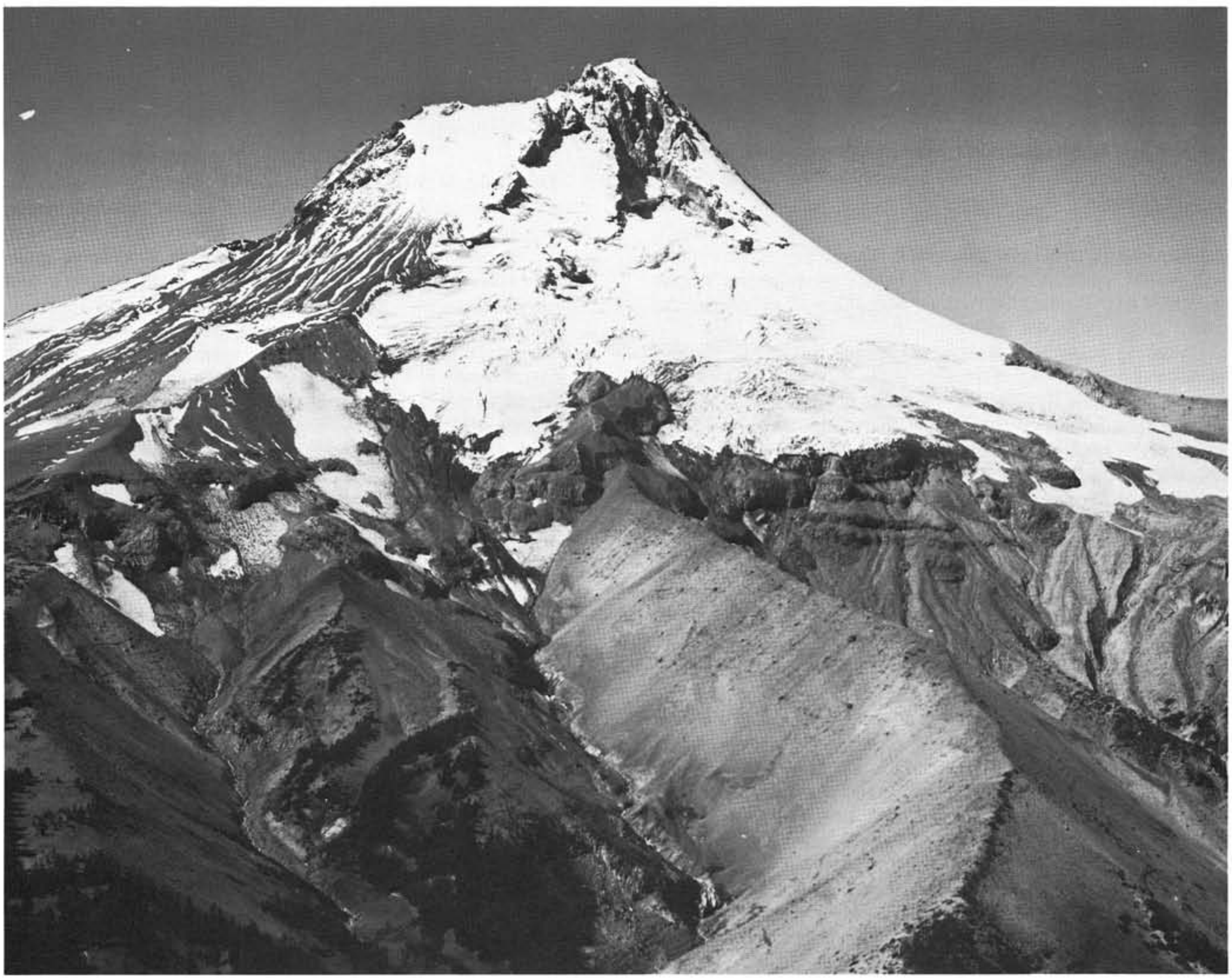
In retrospect, the catastrophic eruption of Mount St. Helens, disastrous as it was, has still had some positive results, since it led to the establishment of the volcano observatory at Vancouver. The extensive USGS program includes mapping and monitoring the Cascade volcanoes that are judged to be most likely to erupt.

Detailed mapping of the geology results in information as to what happened in the past, which, in turn, can result in predictions as to what may happen in the future. Networks of seismographs or tiltmeters have been deployed around several of the Cascade peaks—the seismographs to detect small earthquakes caused by movements of magma and the tiltmeters to detect possible swelling caused by intrusion of magma below the surface. On Mount St. Helens, gravity changes and gas emissions are also being monitored.

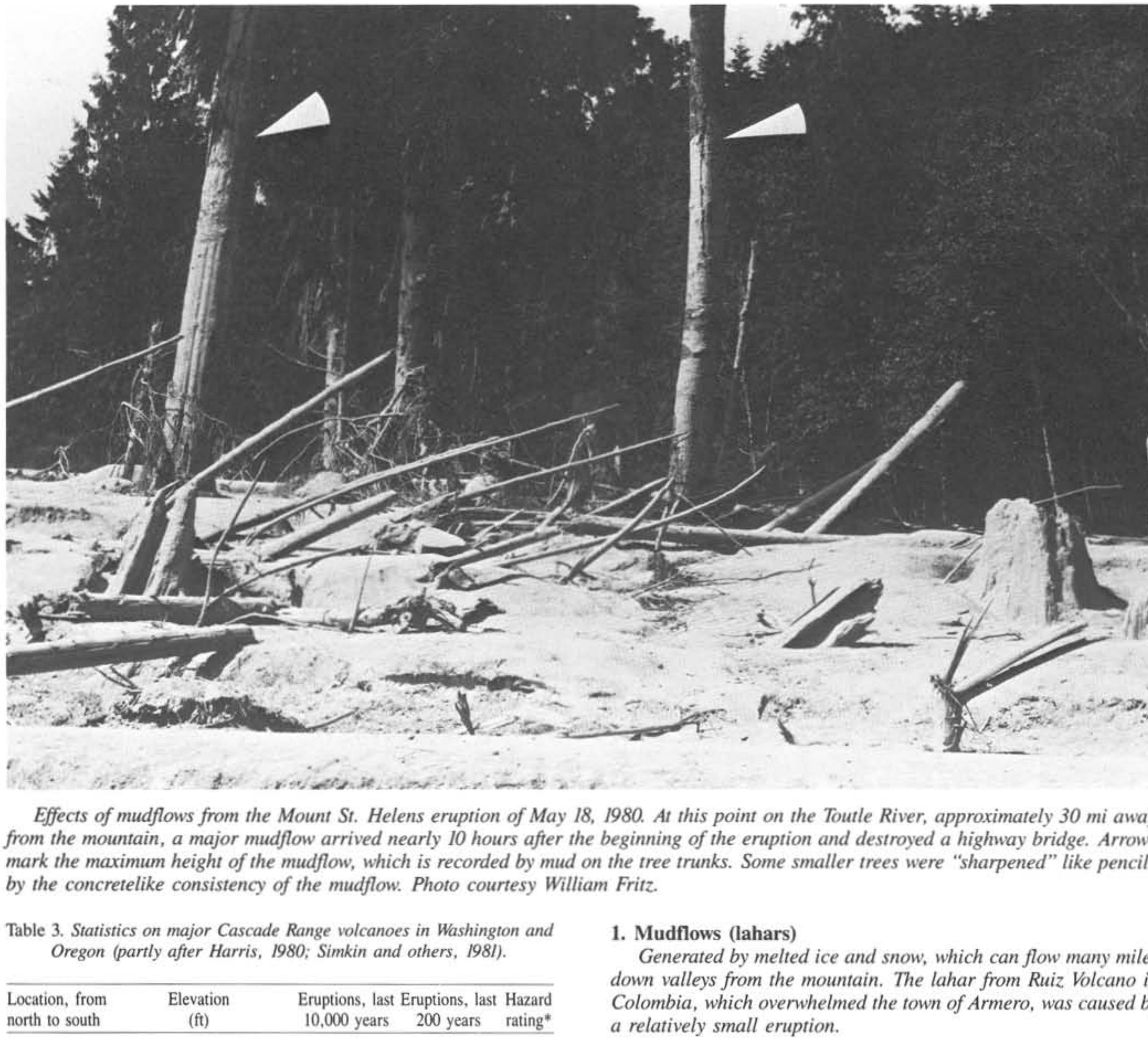
An important but often overlooked consideration for communities near potentially active volcanoes is the development of plans to be activated in the event of an eruption. Such plans include decisions on evacuation of residents; transportation routes; emergency housing, food, water, and sanitation; and ways of dealing with interruptions in communication, transportation, power, and other essential services. Concerned residents should encourage civil authorities to develop appropriate plans.

The USGS geologists may be able to provide a few weeks' or days' warning, but this is not time enough to develop a well-organized plan involving all the government agencies that could help cope with such a disaster. When Mount St. Helens erupted, there was nearly two months' warning, only because the great blast was preceded by numerous earthquakes and small eruptions. We might not be so lucky again!

Work done since 1981 by USGS scientists (Driedger and Kennard, 1986) has shown that most of the larger peaks contain more ice and snow than did Mount St. Helens. They are, therefore, even more susceptible to large mudflows in case of a volcanic eruption. The method of determining the amounts of snow and ice on the four volcanoes studied consists of mapping the areas of snow and ice with aerial photographs and then measuring the depth of the snow and ice at selected locations with a backpack radar unit so that volumes could be estimated.



Mount Hood, seen in late September from the east, showing canyons deeply eroded into volcanic deposits below Newton Clark Glacier. Photo courtesy Oregon State Highway Division.



Effects of mudflows from the Mount St. Helens eruption of May 18, 1980. At this point on the Toutle River, approximately 30 mi away from the mountain, a major mudflow arrived nearly 10 hours after the beginning of the eruption and destroyed a highway bridge. Arrows mark the maximum height of the mudflow, which is recorded by mud on the tree trunks. Some smaller trees were "sharpened" like pencils by the concretelike consistency of the mudflow. Photo courtesy William Fritz.

Table 3. *Statistics on major Cascade Range volcanoes in Washington and Oregon (partly after Harris, 1980; Simkin and others, 1981).*

Location, from north to south	Elevation (ft)	Eruptions, last 10,000 years	Eruptions, last 200 years	Hazard rating*
Baker, Wash.	10,750	12	9	B
Glacier Peak, Wash.	10,436	5	0	C
Rainier, Wash.	14,410	18	7	A
Adams, Wash.	12,307	?	2	D
St. Helens, Wash. (post-1980)	8,364	33	11	B
Hood, Oreg.	11,245	9	6	A
Jefferson, Oreg.	10,495	2	0	B
North Sister, Oreg.	10,094	4	0	B
South Sister, Oreg.	10,354	1	0	B
Newberry Crater, Oreg.	7,984 (Paulina Peak)	13	0	A
Mazama, Oreg.	(11,000?)	1	0	B
McLoughlin, Oreg.	9,510	1	0	C
Shasta, Calif.	14,163	19	1	A
Lassen Peak, Calif.	10,457	4	1	C

*According to population living within 20 mi: A = >2,500, B = 1,500-2,500, C = 500-1,500, D = <500

TYPES OF VOLCANIC HAZARDS

Hazards are discussed in the order of probable extent of risk to the populace, as follows:

1. Mudflows (lahars)

Generated by melted ice and snow, which can flow many miles down valleys from the mountain. The lahar from Ruiz Volcano in Colombia, which overwhelmed the town of Armero, was caused by a relatively small eruption.

Mount Rainier: About 5,700 years ago, the Osceola mudflow came 65 mi down the White River Valley from Mount Rainier and inundated 125 mi² of the Puget lowlands now occupied by the cities of Kent, Auburn, Sumner, and Puyallup to a depth of up to several hundred feet (Harris, 1980).

Glaciers on Mount Rainier cover more than 35 mi² and contain 156.2 bcf of ice and snow (34 times that of Mount St. Helens) that would make a cube slightly more than a mile on a side. Mudflows caused by melted snow and ice came 70 mi down the valley beyond Auburn about 6,000 years ago and 30 mi to Orting about 500 years ago. In historic times, mudflows have occurred most often in the valleys of the White, Nisqually, and Mowich Rivers and in Tahoma and Kautz Creeks.

The present population of the area once covered by mudflows from Mount Rainier now numbers in the hundreds of thousands, and another Osceola-type event would have even more disastrous effects than the recent overwhelming of the town of Armero by mudflows from Ruiz Volcano in Colombia that killed 20,000 people.

Mount St. Helens: Since 2500 B.C., mudflows have come down the various valleys around the mountain at least 10 times. During the 1980 eruption, an estimated 4.6 bcf of that volcano's snow and glacier ice was melted. This would make a cube measuring 1,663 ft on a side that would cover 64 average-size city blocks!

The melting of the snow and ice produced the large mudflows that caused havoc and destruction for many miles down the Toutle and Cowlitz Rivers and into the Columbia River, where shipping was prevented from reaching Portland for several weeks while six dredges cleaned out the filled channel at a cost of many millions of dollars. Several years of dredging in the Cowlitz Valley was necessary in order to prevent future flooding from the filled river channel.

Mount Hood: For two reasons, Mount Hood in Oregon is now perhaps our riskiest volcano: (1) it has a record of repeated activity, and (2) mudflows could affect thousands of people living in the upper Hood River Valley and along 30 mi of the Sandy River. The 12.3 bcf of ice and snow of the nine glaciers on Mount Hood (nearly three times that of Mount St. Helens) covers about 5.2 mi^2 and would make a cube 2,302 ft on a side. This is equal to more than half the water normally stored behind Bonneville Dam. Most of the topography on the lower slopes and down the valleys is the result of a series of mudflows and pyroclastic flows that occurred during an eruptive period about 12,000-15,000 years ago.

During the last half million years, at least six mudflows from the mountain have come all the way down the Sandy River to the Columbia River, and mudflows have repeatedly poured into the upper Hood River Valley. It is fortunate that Portland is protected from mudflows from Mount Hood by the deep canyon of the lower Sandy River gorge. The upper Sandy and Hood River Valleys are not so protected.

The Three Sisters: The Three Sisters (North, Middle, and South Sisters) contain 5.6 bcf of ice and snow, a cube 1,775 ft on a side. This is about a quarter of the water normally held behind Bonneville Dam. There are five major glaciers covering 3.2 mi^2. The towns of Sisters, Redmond, and Bend (population 20,000) lie less than 25 mi away.

Mount Shasta: Mount Shasta contains 4.7 bcf of ice and snow, a cube 1,675 ft on a side, slightly more than Mount St. Helens. About 80 percent of the ice on Mount Shasta is in the headwaters of Mud, Ash, Whitney, and Bolam Creeks and the McCloud and Shasta Rivers. In the past, mudflows have traveled as much as 16 mi down these drainages. The towns of Weed and Mount Shasta (population 6,000) lie within 10 mi of the volcano.

Table 4. *Volumes of ice and snow on selected High Cascade volcanoes. Volumes are given in billions of cubic feet (bcf). After Driedger and Kennard, 1986.*

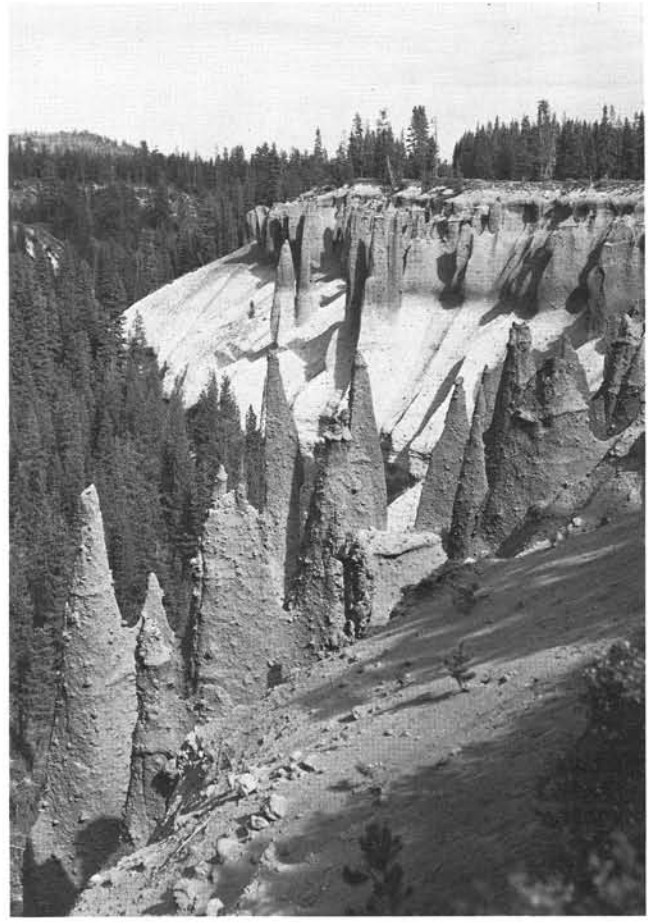
Mount Rainier	156.2 bcf
Mount Hood	12.3 bcf
Three Sisters (North, Middle, and South Sisters)	5.6 bcf
Mount Shasta	4.7 bcf
Mount St. Helens	4.6 bcf

2. Pyroclastic flows (nuees ardentes)

Blasts containing hot gas and ash, advancing at more than a hundred miles per hour, that may travel for tens of miles and cover areas of more than 100 mi^2 near the volcano.

Mount St. Helens: On May 18, 1980, at 8:32 a.m., a cloud of hot gas and ash burst from the north flank of the mountain and raced north, west, and east to level 125 mi^2 of primeval forest. Even though earlier rumblings and small explosions had led to restrictions on access to the area, some 60 people lost their lives in this eruption.

Mount Mazama (Crater Lake): The largest pyroclastic eruption in Oregon within the last 10,000 years occurred about 6,800 years ago, when the top of Mount Mazama collapsed after the outpouring of cubic miles of pumice and ash (Bacon, 1983).



The Pinnacles, remnants of pyroclastic flows (mainly ash flows) that filled the drainages surrounding Mount Mazama during its climactic eruption. In this hot ash deposit, vapor phase alteration from hot gases escaping to the surface through fumaroles locally crystallized the ash to create these resistant pinnacles (Bacon, 1983). Artifacts discovered beneath deposits show that human beings were inhabiting this region prior to the eruption. Photo courtesy Oregon Highway Division.

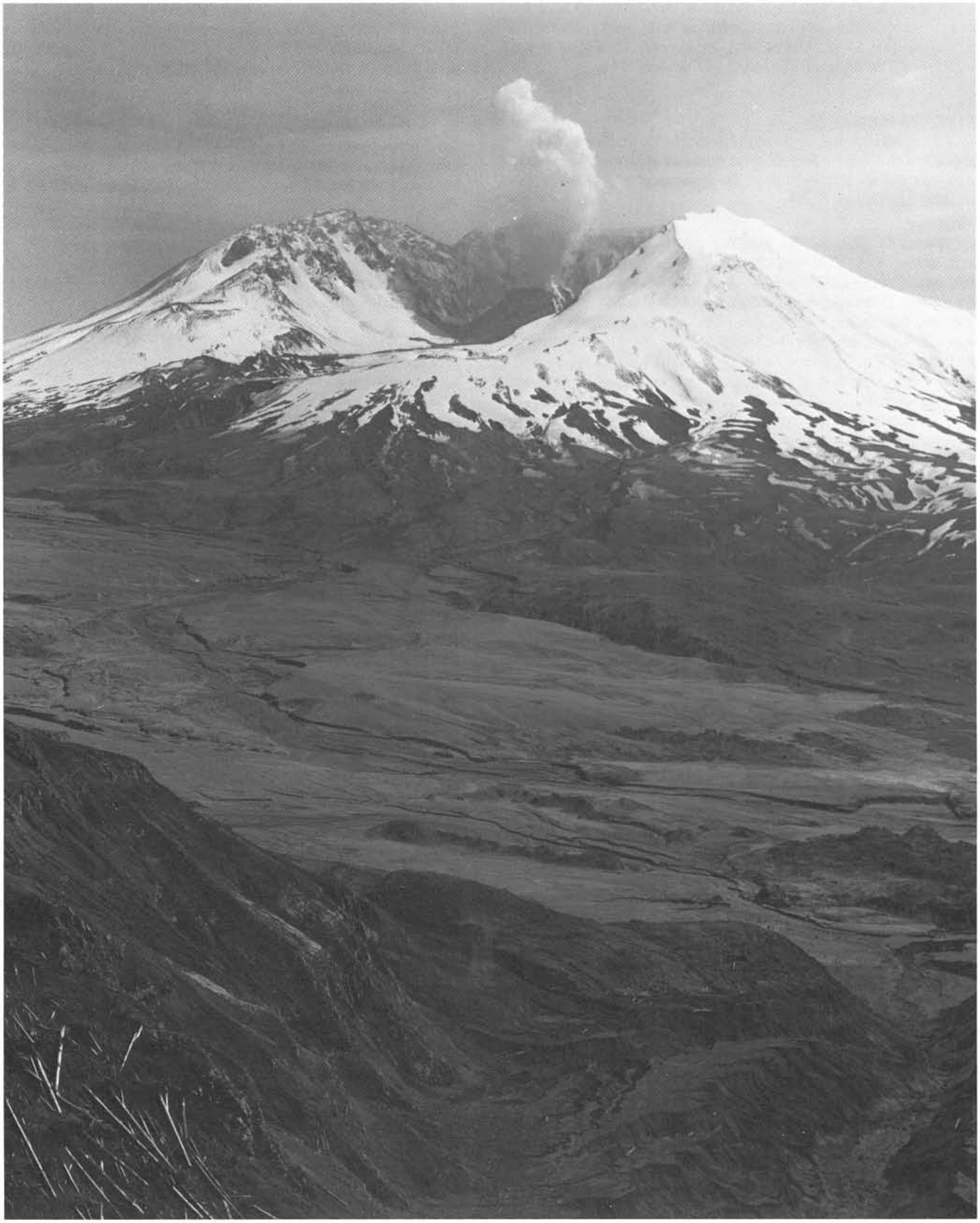
Lassen Peak: The main eruption of Lassen Peak in 1915 was a similar "burning cloud" that came down the north slopes of the mountain and devastated several square miles of forest.

Mammoth Lakes: Prehistoric eruptions produced the caldera at Mammoth Lakes, California, depositing the Bishop Tuff to a depth of several hundred feet. In recent years, the caldera has been showing signs of renewed magmatic activity (swarms of small earthquakes).

3. Debris avalanches (landslides)

Gravity falls and flows induced by earthquakes accompanying a volcanic eruption. They may travel down a valley for several miles, burying all before them to depths of several hundred feet.

Mount St. Helens: The 1980 eruption of Mount St. Helens was initiated by an earthquake that started a landslide on the north side of the mountain. The landslide, in turn, exposed the magma vent below and turned into a debris avalanche containing two thirds of a cubic mile of debris that came down the mountain at nearly 170 mi/h and eventually covered more than 21 mi^2 for as much as 13 mi down the Toutle River valley. Only half a dozen of the world's more than 75 identified debris avalanches are known to exceed this volume (Lipman and Mullineaux, 1981).



Mount St. Helens, the dome, and the May 18, 1980, debris avalanche, as seen from Coldwater Ridge. Photo courtesy of Lyn Topinka, U.S. Geological Survey, David A. Johnston Cascades Volcano Observatory.

Mount St. Helens is composed largely of domes of very viscous dacite. Some other Cascade volcanoes are composed of andesite, which is less viscous. The most fluid lava is basalt, which frequently flows down valleys like water and poses little hazard to life, even in the Hawaiian Islands, since the flows progress slowly enough to be avoided, and the general area of potential hazard can be deduced from the topography in time for evacuation.

All of the relatively recent flows in North America, with the exception of Paricutin, Mexico, are prehistoric. In the western United States, many of the flows were erupted less than 3,000 years ago, as at the Craters of the Moon, Idaho, and the McCartys and Carrizozo flows in New Mexico. In the Cascades, young rhyodacites were erupted at South Sister, Newberry Crater, and Medicine Lake, and basalts were erupted at McKenzie Pass (Belknap Crater) and near Santiam Junction. The Parkdale lava flow in the upper Hood River Valley is about 7,000 years old.

WHAT SHOULD BE DONE BEFORE A VOLCANO ERUPTS

By geologists and geophysicists:

1. Study the volcano and map hazardous zones and rate them as to degree of potential danger.

2. Monitor the potentially active volcano for such preliminary warning signs as earthquakes, swelling, tilting, and gas emissions.

By local, county, state, and federal authorities:

1. Discourage development within identified hazardous zones.

2. Plan ahead for possible volcanic activity: (A) Establish detailed plans for evacuation, rescue, hospitalization, and emergency housing. (B) Coordinate local, county, state, and federal plans. (C) Review and update these plans at regular intervals.

3. When the volcano shows signs of activity, set up "Red" and "Blue" zones to restrict the public access. Upgrade or enlarge these zones as potential activity becomes more hazardous, and notify the public so people can prepare to evacuate.

By the media:

1. Publicize hazard zones and emergency plans.

2. Publicize escape routes and means of dealing with damage (ash fall, especially).

GLOSSARY (Adapted from Foxworthy and Hill, 1982, and Bates and Jackson, 1987)

Ash fall-----Volcanic ash (fine pyroclastic material, sometimes including larger pumice fragments) that has fallen through the air from an eruption cloud.

Debris avalanche-----A rapid and usually sudden sliding or flowage of unsorted masses of rock and other material. In the 1980 eruption of Mount St. Helens, that included fragmented cold and hot volcanic rock, water, snow, glacier ice, trees, and some hot pyroclastic material.

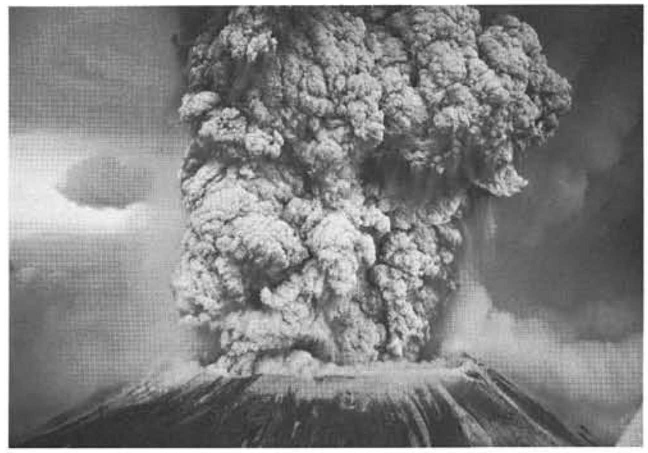
Lahar-----Mudflow originating on the flank of a volcano.

Mudflow-----A flowage of water-saturated earth material with a high degree of fluidity during movement. A less saturated and fluid mass is often called a debris flow.

Nuee ardente (French for "glowing cloud")-----A swiftly flowing, turbulent gaseous cloud, hot and sometimes incandescent, with the characteristics of a pyroclastic flow in its lower portion and capable of very high speed. Sometimes used synonymously with "pyroclastic flow," "ash flow," or "glowing avalanche."

Pyroclastic-----Pertaining to fragmented (clastic) rock material formed by a volcanic explosion or by ejection from a volcanic vent.

Pyroclastic flow-----Lateral flowage of a turbulent mixture of hot gases and unsorted pyroclastic material (volcanic fragments, crystals, ash, pumice, and glass shards). Often used synonymously with "ash flow" and "nuee ardente."



Mount St. Helens in eruption on May 18, 1980. Photo courtesy of Austin Post, U.S. Geological Survey, David A. Johnston Cascades Volcano Observatory, Glaciology Project.

REFERENCES CITED AND SELECTED READINGS

Allen, J.E., 1935, Structures in the dacitic flows at Crater Lake, Oregon: Journal of Geology, v. 44, no. 6, p. 737-744.

———1975, Volcanoes of the Portland area, Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 37, no. 9, p. 145-157.

Bacon, C.R., 1983, Eruptive history of Mount Mazama and Crater Lake caldera, Cascade Range, U.S.A.: Journal of Volcanology and Geothermal Research, v. 18, p. 57-115.

Bates, R.L., and Jackson, J.A., eds., 1987, Glossary of geology: Alexandria, Va., American Geological Institute, 788 p.

Blong, R.J., 1984, Volcanic hazards, a sourcebook on the effects of eruptions: New York, Academic Press, 424 p.

Crandell, D.R., 1980, Recent eruptive history of Mount Hood, Oregon, and potential hazards from future eruptions: U.S. Geological Survey Bulletin 1492, 81 p.

Crandell, D.R., Miller, C.D., Glicken, H.X., Christiansen, R.L., and Newhall, C.G., 1984, Catastrophic debris avalanche from ancestral Mount Shasta volcano, California: Geology, v. 12, no. 3, p. 143-146.

Crandell, D.R., and Mullineaux, D.R., 1978, Potential hazards from future eruptions of Mount St. Helens volcano, Washington: U.S. Geological Survey Bulletin 1383-C, 26 p.

Decker, R., and Decker, B., 1981, Volcanoes: New York, Freeman and Co., 244 p.

Driedger, C.L., and Kennard, P.M., 1986, Ice volumes on Cascade volcanoes: Mount Rainier, Mount Hood, Three Sisters, and Mount Shasta: U.S. Geological Survey Professional Paper 1365, 28 p.

Foxworthy, B.L., and Hill, M., 1982, Volcanic eruptions of 1980 at Mount St. Helens: The first 100 days: U.S. Geological Survey Professional Paper 1249, 125 p.

Harris, S.L., 1980, Fire and ice: The Cascade volcanoes (rev. ed.): Seattle, Wash., Mountaineers-Pacific Search Press, 316 p.

Lipman, P.W., and Mullineaux, D.R., eds., 1981, The 1980 eruptions on Mount St. Helens, Washington: U.S. Geological Survey Professional Paper 1250, 844 p.

Macdonald, G.A., 1975, Hazards from volcanoes, *in* Bolt, B.A., Horn, W.L., Macdonald, G.A., and Scott, R.F., eds., Geological hazards: New York, Springer, p. 63-131.

Newhall, C.G., and Self, S., 1982, The volcanic explosivity index (VEI): An estimate of explosive magnitude for historical volcanism: Journal of Geophysical Research, v. 87, p. 1231-1238.

New York Times, 1969, Encyclopedic almanac 1970: New York, New York Times Book and Educational Division, p. 388-392.

Sheets, P.D., and Grayson, D.K., eds., 1979, Volcanic activity and human ecology: New York, Academic Press, 644 p.

Simkin, T., Siebert, L., McClelland, L., Bridge, D., Newhall, C., and Latter, J.H., Volcanoes of the world (Smithsonian Institution): Stroudsburg, Pa., Hutchinson Ross, 233 p.

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

A satellite radar study of the structures in the Madras area, Jefferson County, Oregon

by D.H. Vice, Consulting Geologist, 449 Hart-Albin Building, Billings, Montana 59101

One of the new remote-sensing techniques developed in the past ten years is satellite radar imagery. Because of this technique's newness and the limited access, most geologists are not familiar with its advantages and disadvantages. One of the advantages is that the imagery provides a synoptic view of a large area, such as the Madras-Hay Creek area of central Oregon. This synoptic view can indicate structures that have not been recognized in standard or high-altitude air photos or in Landsat images.

A study of Seasat satellite radar imagery covering the Madras-Hay Creek area of central Oregon (see facing page) shows several lineaments that suggest the presence of regional structures. Some of these structures have been described previously (Peck, 1964; Swanson, 1969). Others have not been noted on published maps and reports of the area and may not have been recognized because of the stratigraphic discontinuity and lack of marker beds within the Clarno Formation.

The Seasat radar imagery (SAR Revolution 595) has an approximate scale of 1:500,000 (1 in. = 7.89 mi). This ascending revolution traverses Oregon from south-southeast to north-northwest.

The major lineaments visible within the Seasat radar imagery include a possible extension of the Mitchell fault (Little Willow Creek lineament) and a series of anticlines in the Hay Creek area. Other lineaments present in the radar imagery are the Dry River, Gateway, and Axehandle-Horse Heaven features.

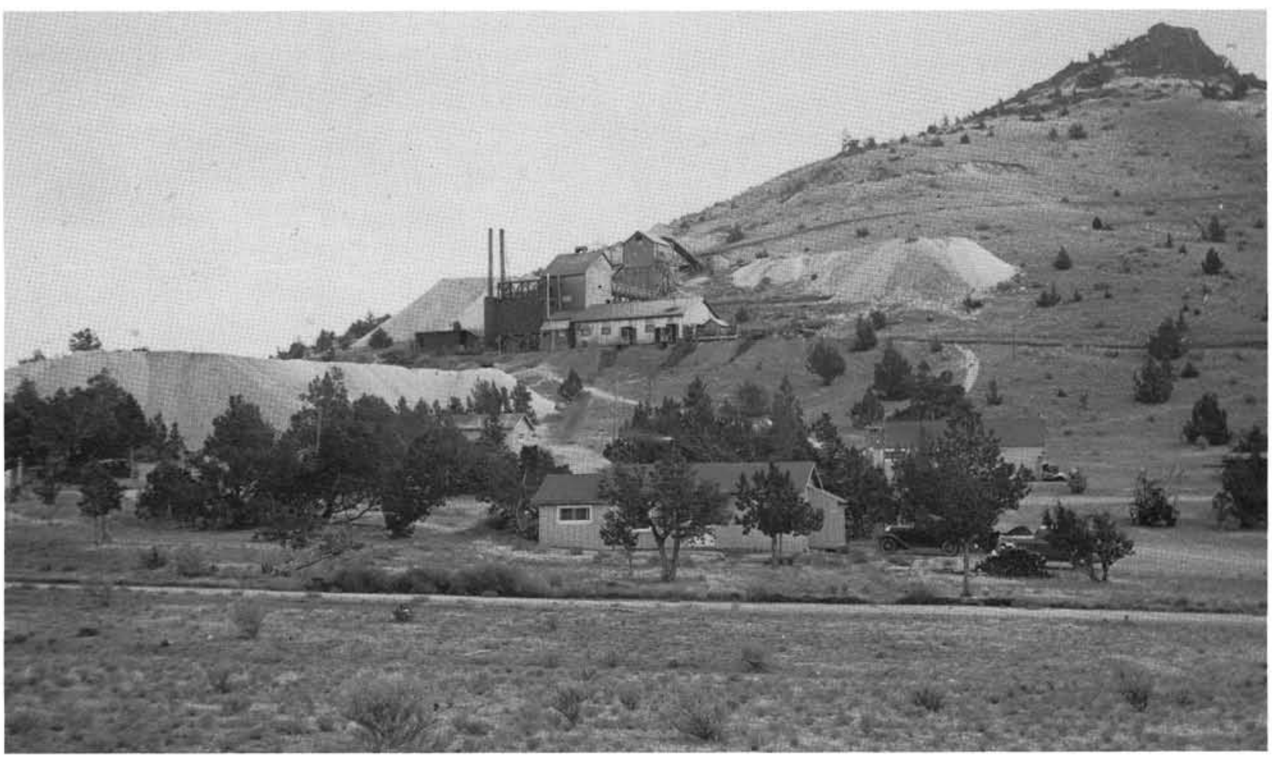
The Little Willow Creek lineament is a discontinuous east-west-trending feature that follows segments of the Deschutes River. The eastern segment of this lineament follows the lower Little Willow Creek and includes short portions of the Trout Creek drainage to the east. The western segment follows the lower portion of Seekseequa Creek. The significance of the lineament is uncertain, because no faults that correlate with the lineament have been mapped in the area.

In the Hay Creek area, the Little Willow Creek lineament appears to offset a secondary, north-trending linear feature that follows Hay Creek. This Hay Creek lineament has a distance of approximately 1½ mi (8,000 ft), separating segments on either side of the Little Willow Creek lineament. If this later feature represents a fault, then considerable movement has occurred along the structure.

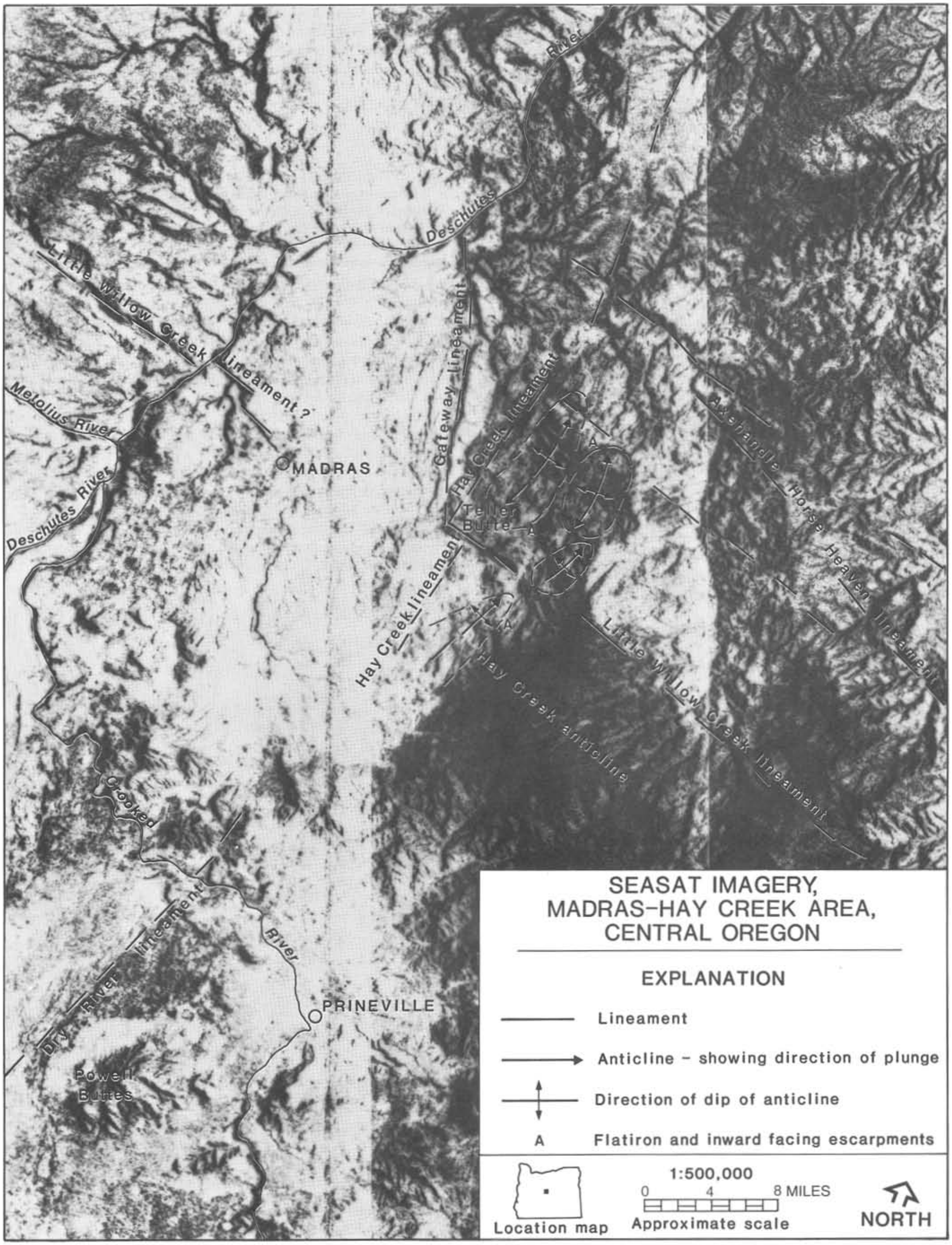
Four anticlines are present in the Hay Creek area. Three of these anticlines occur north of the Little Willow Creek lineament. These structures have a northerly trend. The one structure south of the Little Willow Creek anticline has a north-northeasterly trend. These structures are identifiable within the radar as anticlines because of the presence of steep, inward-facing escarpments and flatirons. Swanson (1969) mapped the structure south of the Little Willow Creek lineament.

The Axehandle-Horse Heaven lineament is poorly defined by the alignment of a series of short drainage segments. The Oregon King Mine, the Axehandle Mine, and the Horse Heaven Mine are all located along this lineament. Swanson (1969) shows a broad zone of silicic and andesitic domes and small intrusives along the same trend.

*(Continued on page 66, **Seasat**)*



Historical photograph of the Horse Heaven mercury mine, east of Madras, Oregon, where mercury was mined and retorted between 1934 and 1944 and between 1955 and 1958. This is one of several mines located along the Axehandle-Horse Heaven lineament.


SEASAT IMAGERY,
MADRAS-HAY CREEK AREA,
CENTRAL OREGON
EXPLANATION
Lineament
Anticline - showing direction of plunge
Direction of dip of anticline
A Flatiron and inward facing escarpments
1:500,000
0 4 8 MILES
Approximate scale
Location map
NORTH
Deschutes River
Little Willow Creek lineament ?
Metolius River
Deschutes River
MADRAS
Gateway lineament
Hay Creek lineament
Teller Butte
Hay Creek lineament
Hay Creek anticline
Little Willow Creek lineament
Axehandle-Horse Heaven lineament
Crooked River
Dry River lineament
PRINEVILLE
Powell Buttes

(*Seasat*, *continued from page 64*)

The Dry River lineament is based on the straight segment of its drainage from the Powell Buttes to its mouth at the Crooked River.

The five lineaments shown in the Seasat satellite radar suggest the presence of regional structures. This is particularly true with the Little Willow Creek and Hay Creek lineaments that are associated with four anticlines. The suggestion of regional structure is also true with the Axehandle-Horse Heaven lineament that is associated with several mercury mines and one base-metal mine. The large size of these lineaments often makes them difficult to recognize in standard or high-altitude air photos, because this type of imagery does not have a synoptic view. Although Landsat imagery provides a synoptic view, the color and tonal changes can often mask regional lineaments. Also, Landsat imagery does not emphasize relief the way satellite radar does. In summary, Seasat radar provides an inexpensive tool for regional structural studies. This technique can provide an alternative to Landsat imagery.

REFERENCES

Peck, D.L., 1964, Geologic reconnaissance of the Antelope-Ashwood area, north-central Oregon: U.S. Geological Survey Bulletin 1161-D, 26 p.

Swanson, D.A., 1969, Reconnaissance geologic map of the east half of the Bend quadrangle, Crook, Wheeler, Jefferson, Wasco, and Deschutes Counties, Oregon: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-568. □

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that we feel are of general interest to our readers.

A STRATIGRAPHIC-GEOCHEMICAL STUDY OF THE TROUTDALE FORMATION AND SANDY RIVER MUDSTONE IN THE PORTLAND BASIN AND LOWER COLUMBIA RIVER GORGE, by Rodney Duane Swanson (M.S., Portland State University, 1986)

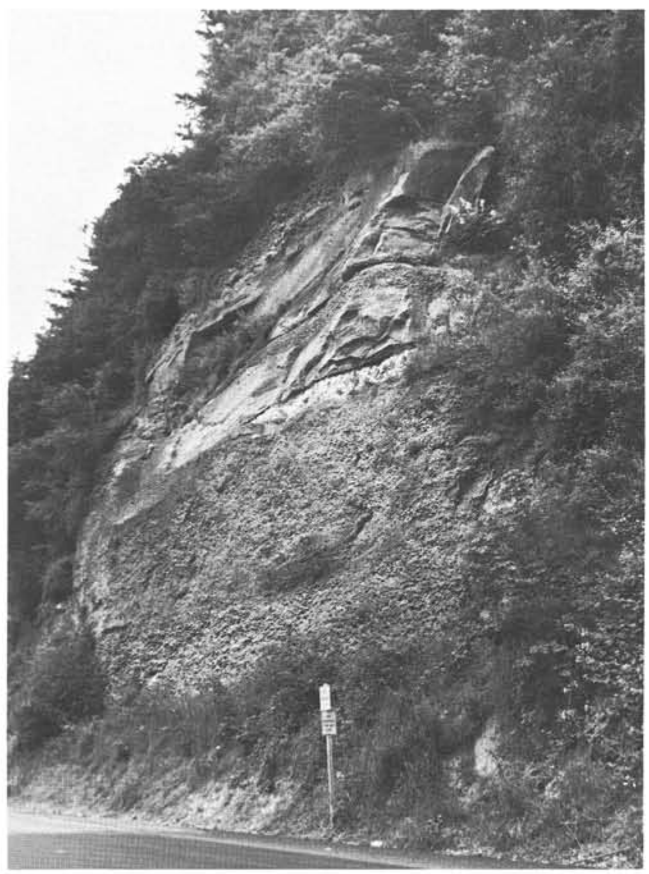
Hyaloclastic sediment forms an identifiable stratigraphic interval within the Troutdale Formation that can be traced from the Bridal Veil channel to the Portland basin. Hyaloclastic sediments, penetrated by wells in northeast Portland and composed chiefly of vitric sands interbedded with muds, sandy muds, and gravels, correlate with the upper member of the Troutdale Formation. These beds are characteristic of the informal upper member of the Troutdale Formation in the Bridal Veil channel of the ancestral Columbia River and the type area of the Troutdale Formation exposed along the Sandy River. Fluvially deposited hyaloclastic beds within the upper Troutdale Formation are interpreted to be the result of interaction of Cascadian basaltic lavas with an ancestral Columbia River. Glass clasts taken from well and outcrop samples have nearly identical trace and minor element geochemical content as determined by instrumental neutron activation analysis.

Based on similar major oxide geochemical content, the upper member Troutdale Formation hyaloclastic sediment is derived from Pliocene (5-2 m.y. B.P.) High Cascades high-alumina basalts found between the Hood River Valley and the Bull Run area. Trace and minor element data for High Cascade group basalts along the Washington side of the Columbia River area show a similarity between basalts near Underwood Mountain and hyaloclastic separates. Vitric material from a gravel 100 m below the main body of upper Troutdale Formation hyaloclastic sediment is tentatively correlated with basalts of the Simcoe Volcanics in south-central Washington, based on major oxide content. Age dates for the Simcoe basalts range from 2(?)-7.5 m.y. B.P. The latest Pliocene and early Pleistocene Boring Lavas, K-Ar dated at 1.3 and 2.5 m.y. B.P., which intrude and overlie the Troutdale Formation in the Portland area, are not source rocks for Portland area Troutdale Formation hyaloclastites, based on differing trace and minor element concentrations.

In the Portland basin, hyaloclastic beds are interbedded with intervals of nonhyaloclastic sediment. Upper Troutdale Formation exposed in the lower Columbia River Gorge is dominated by hyaloclastic sands and gravels. In the Portland basin, up to 900 ft of Troutdale Formation basaltic gravel overlies the hyaloclastic interval that defines the base of the upper Troutdale Formation.

Trace element contents of Sandy River Mudstone and lower Troutdale Formation sediment are similar. Addition of High Cascades lava-derived sediment to the upper Troutdale Formation is indicated by higher Cr, Co, Fe, and Sc concentrations. Q-F-L plots show a similarity between the Sandy River Mudstone and the lower Troutdale Formation and a higher amount of lithic material in upper Troutdale Formation sediments in the well area. Modern lower Columbia River sediment plots within the range of the upper and lower Troutdale Formation in a Q-F-L plot.

Formation of the Portland basin was in progress at the time of Columbia River basalt deposition. Deformation probably continued through deposition of the post-Columbia River basalt Pliocene sediment in the basin. Along the eastern margin of the Portland basin, the Troutdale Formation appears to be gently dipping toward the west. Locally, however, upper Troutdale Formation hyaloclastic sediment is offset approximately 150 m downward from Prune Hill, Washington, to the Blue Lake area, 2 mi to the southwest, on the Oregon bank of the Columbia River.



Upper member of the Troutdale Formation, consisting of conglomerate and sandstone. Outcrop at Stark Street bridge in Portland, Oregon.

THE STRATIGRAPHY AND STRUCTURE OF THE COLUMBIA RIVER BASALT GROUP IN THE SALMON RIVER AREA, OREGON, by Martin Stuart Burck (M.S., Portland State University, 1986)

Approximately 16 km^2 of Columbia River basalt are exposed in the Salmon River area to the south and to west of Mount Hood, Oregon. A maximum composite basalt section composed of 15 flows and totaling 461 m is exposed in discontinuous areas of outcrop.

The Columbia River basalt in the Salmon River area belongs to the Grande Ronde Basalt and the Frenchman Springs Member of the Wanapum Basalt. The Grande Ronde Basalt section (six flows) was mapped as two chemically distinct units referred to as low-MgO (older) and high-MgO (younger) Grande Ronde Basalt. At least one interfingered flow of the Prineville chemical type occurs within the low-MgO section. The Prineville flow represents the oldest Columbia River basalt exposed in the Salmon River area.

The Frenchman Springs section (eight flows) is represented by four distinct chemical units referred to as the basalt of Ginkgo, the basalt of Silver Falls, the basalt of Sand Hollow, and the basalt of Sentinel Gap.

Stratigraphic division of the Columbia River basalt units was based on geochemistry determined by INAA for trace elements and by X-ray fluorescence spectrometry for major oxides. The definition of geochemical units was aided by stratigraphic position, texture, and phenocryst/glomerocryst abundance.

The Grande Ronde Basalt and the Frenchman Springs Basalt originated in the Columbia Plateau and flowed westward through the Cascade Range along a 72-km-wide tectonic depression. The Prineville flow is chemically similar to flows that originated near the Bowman Dam (formerly the Prineville Dam) located 70-80 km to the southeast.

The distribution of Columbia River basalt in the Salmon River area was controlled by structures that developed gradually. The formation of these structures began during the incursion of the Grande Ronde Basalt and consisted of northeast-trending folds and a northwest-trending fault zone that displays components of strike-slip and vertical displacement. This approximately N 30° W-trending fault zone extends the entire length (30 km) of the Salmon River area.

The Ginkgo intracanyon flow may have passed through the Salmon River area within the projected continuation of the Mount Hood-The Dalles syncline. Rapid infilling by subsequent flows restored the low relief nature of the basalt surface by the end of Frenchman Springs time.

Persistent north-south compressional stresses resulted in the development of large-scale folds that were imprinted by the existing, continually developing small-scale folds. Continual length-shortening resulted in northeast-trending thrusts and high-angle-reverse faults along the weakened limbs of anticlinal structures. Thrust faults are associated with extensive breccias and may show up to 122 m of stratigraphic displacement.

The northwest-trending (predominantly N 30° W) fault zone exists along the western edge of the Salmon River area. Northeast-trending structures appear to terminate against it. The regional, right-lateral, strike-slip sense of motion along this zone is masked in the Salmon River area, where terminated anticlines and synclines create a vertical sense of displacement. The N 30° W structural zone was active throughout the history of structural development in the Salmon River area and has a complimentary relationship with the northeast-trending structures. The prominent overall northwest trend of the basalt outcrop pattern in the Salmon River area is related to the presence of the northwest-trending structures located along its western edge.

Northeast-trending normal faults are the youngest structures recorded by the tectonic history of the Columbia River basalt in the Salmon River area. This relationship was determined where normal faults cut previously formed thrust breccias. The late-forming normal faults are not related to the predominant, northeast-trending structures and indicate a fluctuation in the regional compressive-stress pattern that may exist today. Normal faulting may also be related to the emplacement of semidiscordant sills of silicic volcanic material observed within the basalt section and other intrusive features such as the Still Creek pluton located 1.5 km to the northeast.

THE ENGINEERING GEOLOGY OF THE FOUNTAIN LANDSLIDE, HOOD RIVER COUNTY, OREGON, by Susanne L. D'Agnese (M.S., Portland State University, 1986)

The Fountain Landslide, located along I-84, 5 km east of Cascade Locks, Oregon, has moved periodically for over thirty years. Aerial photographs taken prior to recorded movement of the landslide show the headscarp of a large preexisting landslide. In 1952, a cut was made into the toe of the landslide to straighten Highway 30. The recorded movement history begins at this time. Stabilization procedures in the late 1950's focused on dewatering the slide mass. Movement had nearly stopped by 1957. A deeper cut was made into the toe of the landslide in 1966 to widen the highway to the four-laned I-80N (later renamed I-84). Accelerated movement resulted. The Oregon State Highway Division removed 264,000 m^3 of material from the head of the movement zone. Accelerated movement continued. The Oregon State Highway Division then began intense research of the landslide. Research included core logs, slope inclinometers, and the ground-water data. The western portion of the slide mass was unloaded more extensively in 1970 (1.2 million m^3). This later unloading slowed down the movement, but it continues periodically.

The oldest unit found in the area is a volcaniclastic unit. It is found only in core logs in the southwest portion of the slide. The basalts of the Columbia River Basalt Group are found intact and as talus in the study area. Quartz diorite intrusives younger than the Columbia River Basalt Group are found at the surface and at depth along the entire length of the toe of the landslide. Wind River lava crossed from Washington, dammed the Columbia River, and was deposited within the study area.

The slide mass consists primarily of Columbia River Basalt Group talus and Wind River lava talus. The slip plane consists primarily of rocky mudstone. The ground-water table is elevated over the intrusive at the toe of the landslide and over the volcaniclastic unit at the head. Surface cracks and scarps indicate that the slide mass moves northward, drops at the head, and heaves at the toe.

A slope-stability analysis of the Fountain Landslide showed that the instability here is the result of elevated ground-water and the removal of material at the toe for highway construction. It also showed that the eastern portion is more stable than the western portion. The differences in the stability result from the addition of fill at the toe and a lower ground-water table in the eastern portion. The development of the prehistoric slide resulted when the dam of Wind River lava was removed, and lateral support for the deposit was lost.

This study shows that it is essential to have adequate geologic information prior to construction or remedial design for any preexisting landslide to avoid stability problems.

PETROGRAPHY AND PROVENANCE OF SANDSTONES FROM THE OTTER POINT FORMATION, SOUTHWESTERN OREGON, by Robert W. Goodfellow (M.S., University of Oregon, 1987)

The Otter Point Formation of southern Oregon is a melange consisting of sheared mudstones and sandstone with included coherent blocks of sandstone and mudstone, chert, pillow basalt, glaucophane schist, and serpentinite. The formation is exposed in both the Gold Beach and Sixes River tectonostratigraphic terranes. Petrographic study of Otter Point sandstones was carried out to determine provenance of the sandstones and to investigate differences and similarities in compositional modes of sandstones in the two terranes.

Sandstones from the Otter Point Formation in the Gold Beach terrane are predominantly quartz-poor lithic wackes. Mean framework compositional modes for Otter Point sandstones are Q7-F17-L36 at the type locality, Q12-F19-L48 at Cape Blanco, and Q7-F17-L46 at the Miller Creek locality. Source rocks for Otter Point sandstones are interpreted to be primarily basalts and andesites that were derived from an island arc. Sediments were probably deposited in a back-arc basin within a marginal sea located between the arc and the North American continent.

Otter Point sandstones from the Sixes River terrane are predominantly quartz-rich, feldspathic wackes that have mixed sources including volcanic, plutonic, and metamorphic rocks. Sediments were derived from both continental and magmatic-arc source areas. Otter Point sandstones in the Sixes River terrane were deposited within, or adjacent to a subduction complex at the North American continental margin.

Collision of the arc with the continent resulted in chaotic mixing of sediments and the formation of a melange, as well as juxtaposition of both terranes. Chert and oceanic basalt were incorporated into the melange of both terranes during the collision event.

PETROGRAPHIC AND GEOCHEMICAL CHARACTERISTICS OF BEDDED CHERTS WITHIN THE JURASSIC OTTER POINT FORMATION, SOUTHWESTERN OREGON, by Sheila A. Monroe (M.S., University of Oregon, 1987)

Bedded cherts of the Late Jurassic Otter Point Formation of southwestern Oregon crop out as erosional remnants. The chert bodies consist of chert beds 2-5 cm thick interbedded with thin (0.1-1.0-cm) shale partings. The cherts are commonly dark reddish brown or pale green. They are composed primarily of radiolarian tests and micro$_6$crystalline quartz. Radiolarians are best preserved in the argillaceous, dark reddish-brown cherts.

Otter Point cherts are interpreted to have formed at intermediate water depths. Absence of calcareous debris, relatively high concentrations of impurities when compared to DSDP cherts and porcellanites, low Ce anomalies, and intermediate MnO/TiO_2 ratios in the cherts suggest that they were deposited at a moderate distance from shore, possibly in a marginal sea. This nearshore basin was located about 30° north of the Late Jurassic/Early Cretaceous paleoequator.

U/Pb GEOCHRONOLOGIC AND PETROLOGIC STUDIES IN THE BLUE MOUNTAINS TERRANE, NORTHEASTERN OREGON AND WESTERNMOST-CENTRAL IDAHO: IMPLICATIONS FOR PRE-TERTIARY TECTONIC EVOLUTION, by Nicholas Warren Walker (Ph.D., University of California, Santa Barbara, 1986)

Numerous erosional inliers in the extensive Cenozoic-age volcanic and sedimentary blanket of northeastern Oregon and west-central Idaho reveal a lithologically diverse and structurally complex assemblage of Late Paleozoic to Late Mesozoic age rocks of oceanic affinity.

This assemblage includes tectonically juxtaposed, variably deformed and metamorphosed Permo-Triassic volcanic-plutonic complexes and related sedimentary rocks, ultramafic-mafic-silicic igneous suites, polymict melange tracts, and thick sequences of Upper Triassic to Upper Cretaceous volcaniclastic sediments. Numerous undeformed mesozonal gabbroic to granodioritic plutons of Late Jurassic to Early Cretaceous age cross-cut these older rocks, indicating that juxtaposition of the older components took place prior to emplacement of the plutons.

Field, petrologic, and U-Pb geochronologic investigation of igneous and metamorphic components of this region demonstrate that the Permo-Triassic Seven Devils Group was constructed, at least in part, within and upon a Late Carboniferous basement whose protolith was plutonic. Geochemical data suggest this basement is of oceanic origin.

Commencing in the Early Permian and continuing sporadically through the Late Triassic, the basement was penetrated by plutons and dike swarms ranging in composition from gabbronorite to trondhjemite. Geochemical evidence indicates these plutonic bodies were generated from a source depleted in LIL elements and are of oceanic affinity.

Together, the metamorphic basement and plutons compose the crystalline infrastructure to the stratigraphically and structurally overlying Seven Devils Group. A Late Triassic ductile shear zone of unknown displacement affecting these rocks records translation in the thermally softened arc infrastructure.

Regional U-Pb geochronologic data from pre-Jurassic igneous and meta-igneous components throughout this region reveal an age range of plutonic activity of 279 Ma to 215 Ma. This fact, considered in concert with field evidence, paleomagnetic evidence, and paleontologic data, supports the conclusion that, although there are distinct structural/stratigraphic blocks within this region, they are vestiges of a single, ensimatic convergent margin system that was magmatically and tectonically active intermittently from Early Permian to Early Cretaceous time. This kindred assemblage is collectively referred to as the "Blue Mountains Terrane."

Structural telescoping of this convergent margin system took place prior to the emplacement of undeformed Late Jurassic-Early Cretaceous plutons. Accretion to the continental margins occurred subsequent to pluton emplacement and was accomplished by translational movement during the Cretaceous.

GEOCHEMISTRY OF THE EUREKA-EXCELSIOR GOLD-LODE DEPOSIT AND ASSOCIATED GREENSTONES AND METASEDIMENTARY ROCKS, CRACKER CREEK DISTRICT, BAKER COUNTY, OREGON, by Craig Paul Calder (M.S., Eastern Washington University, 1986)

Sixty-seven samples of altered and unaltered metasedimentary rocks, greenstones, and quartz-carbonate vein collected from Cracker Creek district, Oregon, were analyzed for Ag, Au, Cu, Rb, Tl, and Zn. Data on major and minor oxides, SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, TiO_2, MnO, P_2O_5, H_2O, and CO_2, were obtained for altered and unaltered rocks. In addition, unaltered greenstones were analyzed for Ba, Cr, Sr, Y, and Zr. The metasedimentary rocks include upper Paleozoic to Mesozoic cherts and argillites, whereas greenstones are low-K tholeiites in composition.

The elements K, Rb, and Tl are enriched in hydrothermally altered greenstones by factors of 11, 18, and 24, respectively, in comparison to unaltered greenstones. These enrichment trends demonstrate that Tl is concentrated more in hydrothermal fluids than either Rb or K. Enrichments of H_2O, CO_2, and MgO, with depletions of SiO_2 and Na_2O, are noted in the chloritic alteration zone of the greenstones. The cherts and argillites are less prone to alteration than the greenstones due to their high silica content. Increase in mean Tl contents by factors of 2.6 and 1.8 for argillites and cherts respectively occur in the hydrothermally altered metasedimentary rocks.

The $K/Tl \times 10^4$ and Rb/Tl ratios are more effective than the abundances of individual elements for separating the unaltered and altered rocks. These ratios show a decrease in values from unaltered to altered samples, with the lowest values in the quartz-carbonate vein. The $K/Tl \times 10^4$ ratio shows a more significant depletion in comparison to the Rb/Tl ratio. The enrichment of Tl over K and Rb in hydrothermally altered wall rocks and vein samples is demonstrated in

Tl-Rb-K plots, with unaltered samples clustering near the K apex and altered rocks and vein samples plotting closer to the Tl apex.

Thallium is enriched with respect to K and Rb in the paragenetically later carbonate sulfide-rich phase, which contains the highest concentrations of Au and Ag. The Au/Ag ratios of the sulfide-rich ore range from 1:2 to 1:30, with higher base metal values associated with the lower ratios.

The vein and hydrothermally altered wall rocks contain abundant carbonate. The most common and pervasive alterations are carbonatization, sulfidization, and sericitization. The narrow argillic shear zone in contact with the vein is occasionally of ore grade, with the highest gold values most commonly observed in the footwall. The vein is composite with quartz deposition predominating in the early stages, followed by greater proportions of carbonate, muscovite, and disseminated sulfides in the later stages. Ore minerals include pyrite, chalcopyrite, a mineral of the tetrahedrite-tennantite series, and electrum.

STRATIGRAPHY, PETROLOGY, AND PROVENANCE OF THE CRETACEOUS GABLE CREEK FORMATION, WHEELER COUNTY, OREGON, by Stephen W. Little (M.S., Oregon State University, 1987 [compl. 1986])

The Mitchell inlier in north-central Oregon contains the largest exposure of Cretaceous marine sedimentary rocks in this region. Nearly 9,000 ft of Albian-Cenomanian rocks are exposed along the flanks of the Mitchell anticline. The Cretaceous section rests unconformably on Permian(?) metasedimentary rocks and is unconformably overlain by Tertiary volcanic rocks. The Cretaceous rocks have previously been divided into the Hudspeth and Gable Creek Formations. The Hudspeth Formation consists of thick sequences of hemipelagic mudstone that contain subordinate siltstones and thin beds of turbiditic sandstone. The Gable Creek Formation is composed of numerous isolated sequences of coarse conglomerate, pebbly sandstone, and sandstone. This study concentrates on the stratigraphy and petrologic composition of the Gable Creek conglomerates.

The Gable Creek conglomerates are composed of a heterogeneous assemblage of volcanic rocks, chert, plutonic rocks, and lesser amounts of sedimentary and metamorphic rocks. The petrologic composition of the conglomerates can be accurately reflected by means of pebble-count analysis. Pebble counts provide a valuable tool for quantifying conglomerate composition and documenting compositional variations within the 70-mi^2 Cretaceous outcrop area. Cluster analysis of the pebble count data confirms the presence of two major conglomerate petrofacies within the inlier. The striking compositional contrasts between the two petrofacies may be due to primary differences in sediment composition or secondary, post-depositional changes. Statistical correlation values reveal that conglomerate composition is fairly uniform within each of the two petrofacies. Petrologic composition also remains nearly constant within each of the major conglomerate units but exhibits random variations upward through the stratigraphic section.

The Cretaceous rocks at Mitchell were deposited in a deep marine basin sometimes referred to as the Ochoco basin (Odiorne, written comm., 1985). The Ochoco basin may have extended into southwestern Oregon, where Cretaceous rocks of the Hornbrook Formation are exposed. Several small Cretaceous inliers in central Oregon represent nonmarine and shallow marine environments of deposition that flanked the basin margins.

This study supports the interpretation of the Cretaceous rocks at Mitchell as submarine turbidites as suggested by Kleinhans (1984). The Gable Creek rocks were deposited in submarine channels by various sediment gravity-flow processes in a base-of-slope or proximal-fan setting. The Gable Creek units are arranged into thinning- and fining-upward sequences that may be the result of progressive channel abandonment. The correlative Hudspeth rocks are interpreted as submarine levee, overbank, and interchannel deposits associated with the Gable Creek channels. The geometry of the Cretaceous rocks is defined by a series of stacked channel-levee-interchannel sequences.

Cliff-forming member of Gable Creek Formation at Mitchell, Oregon. Light-colored streaks are lenses of channel sands within conglomerates.

Paleocurrent data from the Cretaceous section yield a dominant southwesterly direction of sediment transport and a subordinate northwesterly trend. Variations in paleocurrent orientation may reflect several directions of sediment input, overbank deposition, and channel abandonment. The Gable Creek conglomerates have source areas located to the southeast, east, and northeast of Mitchell within the late Paleozoic and early Mesozoic accreted terranes in eastern Oregon. The provenance of the conglomerates is widespread and includes the island-arc rocks of the Seven Devils Group, rocks of the dismembered oceanic crustal terrane, forearc strata of the John Day inlier, and the Jurassic plutons in northeastern Oregon. A previously undescribed tuffaceous unit within the Gable Creek Formation probably marks a short-lived episode of mid-Cretaceous volcanic activity in the source area.

THE GEOLOGY AND PETROLOGY OF THE CHETCO COMPLEX, KLAMATH MOUNTAINS, SOUTHWESTERN OREGON, by Karla Louise Urbanowicz (M.S., University of California, Davis, 1986)

The Chetco Complex forms part of the Western Jurassic Belt of the Klamath Mountains in Oregon. The complex contains ultramafic and mafic plutonic rocks that are chemically and mineralogically consistent in both northern and southern exposures. Ultramafic plutonic rocks commonly exhibit porphyroclastic textures, and gabbroic to dioritic rock types show massive to foliated textures. Whole-rock chemistry for the suite indicates differentiation with an early Fe enrichment during cumulate crystallization, followed by silica and alkali enrichment along calc-alkaline trends. The cumulate assemblage includes olivine, pyroxene, plagioclase, and spinel. Plutonic rocks include two-pyroxene gabbros, hornblende quartz diorites, minor tonalites, and a late-stage hornblende anorthite pegmatite.

Evidence exists for high-grade subsolidus reactions involving the cumulate assemblage, with amphibole as an important phase.

*(Continued on page 70, **Abstracts**)*

Geologist named Reed College president

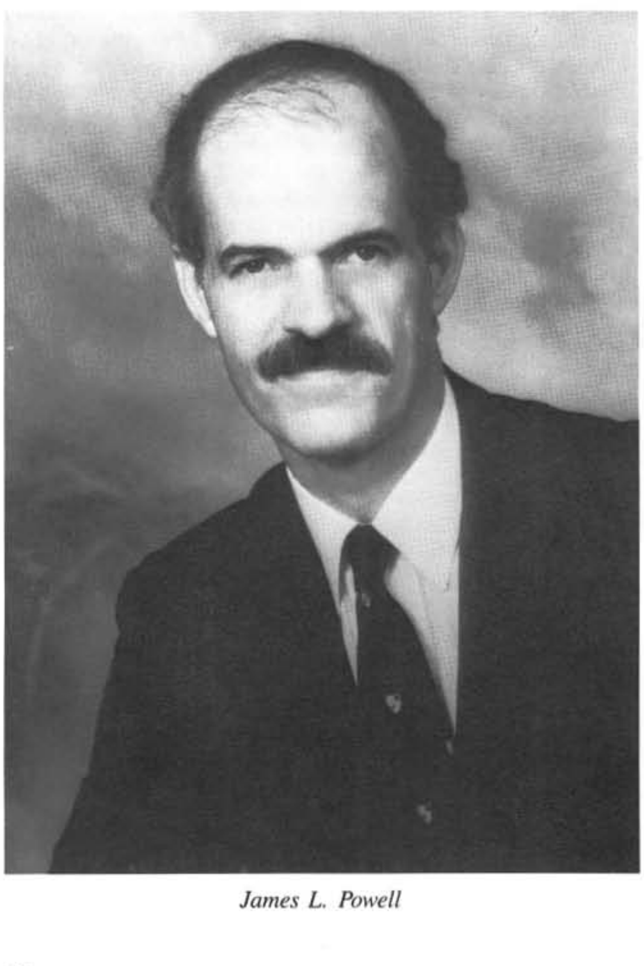
The Board of Trustees of Reed College in Portland, Oregon, has announced the selection of 51-year-old geologist James Lawrence Powell as the next president of this private college.

Powell is currently the president of Franklin and Marshall College in Lancaster, Pennsylvania, where he has served in that function since 1983. He will assume his new responsibilities in August 1988, succeeding Paul E. Bragdon, who leaves the presidency to become Oregon Governor Neil Goldschmidt's Assistant for Education.

A nationally respected scholar in the area of science education, Powell has published in the field of geochemistry over a period of nearly 25 years. He also has delivered recent papers and presentations on computing in liberal education, computer-intensive campuses, prudent college management, and the tenure system.

Powell earned his doctoral degree in geochemistry at the Massachusetts Institute of Technology in 1962 and served as teacher and administrator at Oberlin College before he joined Franklin and Marshall College. Among the awards and honors he has received are an LH.D. (doctor of humane letters) degree from Tohoku University, Japan, in 1986 and an Sc.D. (doctor of science) degree from Oberlin College in 1983.

Powell currently serves the cause of higher education on a national level by actively participating in a significant number of educational organizations. He is, among other things, the only representative from a liberal arts college on the National Science Board, the policy-making body of of the National Science Foundation; he is a director of EDUCOM, a university group for advancing the uses of technology in higher education; and he serves on the board of governors of the Institute for European Studies.



James L. Powell

Powell is married to Joan Hartman, who has taught political science at the Claremont Graduate School, at Oberlin, and at Franklin and Marshall. She has worked at the Congressional Research Service and the U.S. Department of the Interior, which she still serves as a consultant. Powell is the father of three children, Marla, 20; Dirk, 17; and Joanna, 1; and enjoys the music of Mozart, reading biographies and mysteries, running, backpacking, and fly-fishing.

—Reed News

Northwest Petroleum Association announces symposium

The oil and gas potential of southwestern Washington and the adjacent Outer Continental Shelf (OCS) will be examined at the annual spring symposium held by the Northwest Petroleum Association on May 18-20, 1988, at Ocean Shores, Washington.

The purpose of the meeting will be to summarize current stratigraphic and structural models as well as recent drilling, seismic, and leasing activity. There will be a full day of talks on May 19 and pre- and post-meeting technical field trips.

Attention has recently been drawn to the area considered for study because of the Washington State lease sale, the proposed upcoming OCS sale, the regional seismic project of the U.S. Department of Energy, and the search for another Mist Gas Field.

For further information on lodging, recreation, and car rental and to obtain the necessary registration form, contact Gay Preator, Weyerhaeuser Company PC 2-31, Tacoma, WA 98477, phone (206) 924-2624; or Ocean Shores Chamber of Commerce, Ocean Shores, WA 98569, phone (206) 289-2451.

—NWPA news release

(***Abstracts**, continued from page 69*)

Mineral assemblages and textures indicate that initial crystallization occurred at water-undersaturated conditions at temperatures >1,300° and pressures <10 kb, followed by deformation and crystallization under hydrous conditions, with amphibole as part of the stable assemblage.

Gneissic rocks containing primarily hornblende and plagioclase are abundant around the perimeters of the complex. The foliated rock is chemically similar to massive gabbroic and dioritic plutonic rocks in TiO_2, CaO, FeO*, and MnO contents, but trends toward lower Al_2O_3 and higher MgO, Na_2O, and $^{87}Sr/^{86}Sr$ values. Amphibole compositions in gabbroic and gneissic portions of the complex are magnesio-hornblendes, with Al^{IV} contents indicating similar crystallization temperatures. Higher temperatures are indicated for amphiboles in the cumulate portions of the complex. Lamprophyre dikes containing the high-temperature amphibole kaersutite are found crosscutting ultramafic units. The foliated portions of the complex containing hornblende plagioclase gneiss are probably derived from the gabbrioc to dioritic sequence during an episode of deformation with increased water activity. Similar trends in element depletions are noted in oceanic environments, where hydrothermal metamorphism and deformation affects upper and lower portions of the crust.

Values for TiO_2 are consistently low (<1 percent) for the plutonic suite, except for anomalous amphibolite rocks entrained below the Josephine Peridotite sheet. Initial $^{87}Sr/^{86}Sr$ ratios for the nongneissic rocks in the suite are in the range found for volcanic-arc rocks. The chemical trends in the Chetco Complex indicate affinities to calc-alkaline island-arc tholeiites. However, similar mineral assemblages and highly deformed rock textures are also found in modern oceanic transform faults and back-arc basins, which should also be considered as a possible analogue for the Chetco Complex. □

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Basalt hydrovolcanic deposits near Owyhee Reservoir
Well logging of oil and gas wells in Oregon
Blowhole near Black Butte Ranch

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COVER PHOTO

View to the southeast across Dry Creek (see article beginning on next page). The stratigraphy in foreground, in ascending order: Second tephra deposit, lacustrine to fluvial sediments, sequence of 12 basalt flows, fluvial sediments, and local caps of intracanyon basalt. Knob in intermediate distance at left side of photograph and ridge in center of photograph are Dry Creek Buttes. Location of vent area for third tephra deposit, a maar, is the low hill immediately to right of Dry Creek Buttes. Photograph by Leonard Farr, Department of Geology, Portland State University.

OIL AND GAS NEWS

Northwest Petroleum Association symposium

The annual symposium and field trips of the Northwest Petroleum Association were held May 18-20, 1988, in western Washington. Meetings were held at Ocean Shores, Washington. Two field trips were conducted this year, one in the Chehalis Basin between Chehalis and Ocean Shores to look at Tertiary marine sands, and one along the Olympic Peninsula coast to see late Tertiary units, structural relationships, and hydrocarbon seeps.

The one-day symposium featured nine speakers plus a dinner talk on Mount St. Helens. Papers covered such topics as the Astoria and Grays Harbor Basins, volcanic stratigraphy, mineral exploration on Weyerhaeuser lands, Olympic Peninsula accretionary terrane, and the Oregon-Washington Outer Continental Shelf planning area. The symposium was attended by about 55 persons.

Minerals Management Service conference

The Minerals Management Service (MMS) held its Conference-Workshop on Recommendations for Studies in Washington and Oregon Relative to Offshore Oil and Gas Development on May 23-25, 1988, in Portland, Oregon. A similar conference was held in 1976, but the latest meeting served as a much-needed update for the MMS to develop an understanding of research needs and priorities for the Washington and Oregon planning area. Lease Sale No. 132 for the Outer Continental Shelf off the two states is scheduled for 1992, and the Environmental Studies Program for the area is already underway.

Twenty speakers gave reviews of the state of the art in various scientific disciplines on the first day of the conference. The second day was spent with nine different discipline-oriented subgroups to develop recommendations to the MMS for additional studies in preparation for the lease sale and for tracking the effects of the sale.

Industry interest in Lease Sale No. 132 is still unknown. The Request for Interest, required for Frontier Areas, will be issued in November 1989 and is the next milestone in the process. This step will help to determine whether there is sufficient industry interest to continue to the Call for Information.

Drilling begins at Mist Gas Field

Oregon Natural Gas Development has begun drilling at the natural-gas storage project at the Mist Gas Field in Columbia County. Well IW 33D-3, located in SE¼ sec. 3, T. 6 N., R. 5 W., was spudded on May 19 and has a proposed total depth of 2,900 ft.

This is the second injection-withdrawal well in the depleted Flora Pool which is now being used for gas-storage purposes. An injection-

*(Continued on page 94, **Oil and gas**)*

CONTENTS

Basalt hydrovolcanic deposits in the Dry Creek arm area of the Owyhee Reservoir, Malheur County, Oregon: Stratigraphic relations

by Michael L. Cummings and Lawrence P. Growney, Department of Geology, Portland State University, Portland, Oregon 97207*

ABSTRACT

Basalt hydrovolcanic deposits occur at three stratigraphic levels and are interbedded with fluvial and lacustrine felsic volcaniclastic sediments south of the Dry Creek arm of the Owyhee Reservoir. The earlier formed hydrovolcanic deposits were partially to totally buried by felsic detritus before subsequent basalt hydrovolcanic eruptions.

The three lithologic associations found within the hydrovolcanic deposits are (1) explosion breccias containing blocks of basalt and sediments of underlying units within a matrix of lithic fragments and palagonitized basalt glass; (2) interbedded, poorly bedded to massive deposits composed of juvenile basalt glass and lithic fragments; and (3) moderately to well-bedded, planar to cross-bedded vitric and lithic lapilli tuffs.

A diatreme is exposed beneath the uppermost deposit of basalt tephra, and the walls of the diatreme widen upward toward the paleosurface. Basalt scoria breccias with a matrix of altered basaltic glass and blocks of country rock occupy the diatreme and are cut by irregularly shaped intrusions and dikes. Calcite and zeolites are cements in all hydrovolcanic deposits. Calcite veins to 0.5 m wide are common in the lower two tephra sequences.

The first hydrovolcanic deposit is interpreted as a tuff cone; the second has features characteristic of a tuff cone near its base but grades upward to features that are more similar to those of a tuff ring; the third is a tuff ring that has characteristics of a maar and contains interbedded basalt flows and palagonite within the crater.

INTRODUCTION

Tuff rings, tuff cones, and maars are formed by hydrovolcanic eruptions produced by the interaction of rising magma with surface and/or ground water. The resulting hydrovolcanic deposits are varied depending upon the availability of water and the depth at which the magma intersects water (Fisher and Waters, 1970; Wohletz and Sheridan, 1983; Lorenz, 1985). The characteristics and formation mechanisms of these deposits are presented by Fisher and Waters (1970), Lorenz (1973), and Wohletz and Sheridan (1983) and reviewed by Lorenz (1985). In the Pacific Northwest, maars, tuff cones, tuff rings, and cinder cones of Pleistocene and younger age are present in the High Lava Plains of central Oregon (Lorenz, 1970; Heiken, 1971) and in the Snake River Plain in Idaho (Womer and others, 1980, 1982).

These topographic features and those from such sites as the Rio Grande Rift in New Mexico (Seager, 1987) and the classic localities in the Eifel region of Germany (Lorenz, 1973) are relatively young features that are partially eroded and that occur as craters and associated ejecta deposits. However, hydrovolcanic deposits south of the Dry Creek arm of the Owyhee Reservoir in Malheur County are interbedded with felsic volcaniclastic sediments of the Miocene Deer Butte Formation (Kittleman, 1962; Kittleman and others, 1965). Earlier formed hydrovolcanic deposits were partially to totally buried by felsic volcaniclastic sediments before subsequent hydrovolcanic eruptions. These deposits and enclosing volcaniclastic sediments are presently exposed in valleys and canyons that are tributary to Dry Creek and the Owyhee River. In this paper, we describe the sedimentary and volcanic features and stratigraphy of the hydrovolcanic deposits located south of Dry Creek arm and the implications of these deposits for the volcanic and sedimentary history of the Owyhee area.

SEDIMENTARY AND VOLCANIC FEATURES OF HYDROVOLCANIC DEPOSITS

Stratigraphy and lithology

Three stratigraphically distinct basalt tephra deposits have been identified south of the Dry Creek arm of the Owyhee Reservoir (Figure 1). The deposits are interbedded with felsic volcaniclastic sediments. Thickness variations in the tephra deposits within the map area suggest that deposits from numerous eruptive centers coalesce within each stratigraphic level. However, since our mapping has been on a reconnaissance basis, we are not certain of the number of centers that contributed to each stratigraphic level.

The general stratigraphic sequence and geologic map of the area are illustrated in Figure 1. The base of the first basalt tephra deposit is not exposed in the study area. It is overlain by lacustrine felsic volcaniclastic sediments that grade upward into fluvial sediments. Trees rooted in the fluvial sediments occur as casts and molds in the base of the second hydrovolcanic deposit. In the western part of the study area, the second sequence of tephra deposits directly overlies those of the first. Lignitic paludal sediments immediately overlie the second basalt tephra and grade upward into fluvial backswamp facies. A sequence of at least 12 basalt flows lacking sedimentary interbeds overlies these sediments. The lowermost flows form a thick pillow-palagonite complex in the area of Dry Creek. South of Dry Creek, the lower flows are significantly thicker than the upper flows in the sequence. Fluvial, fine-grained sands and siltstones that contain fish scales and leaf fossils were deposited over the basalt flows before the third hydrovolcanic eruption. The third basalt tephra deposit is overlain by, and thins and grades laterally into, the felsic fluvial sediments.

A diatreme is exposed in the third eruptive center. In the area of the diatreme, the underlying stratigraphy is disturbed by faults and medium-grained basalt intrusions. Upward, the walls of some of the intrusions flare outward, and these intrusions grade into dense and scoriaceous basalt clasts in a palagonitized matrix. The upward flaring of the diatreme cuts out stratigraphic units, including the basalt-flow sequence and the overlying and underlying felsic volcaniclastic sediments, to form a crater. The morphology of the crater is characteristic of maar volcanoes. Fine-grained basalt dikes at various orientations occur within the faulted area that contains the irregularly shaped intrusions. At least two north-trending dikes are present in what is believed to be the center of the diatreme. These dikes and surrounding country rocks are silicified and contain disseminated pyrite. The dikes may have been feeders for the basalt flows that occupy the crater of the maar. Approximately 100 vertical m of the diatreme are exposed along the walls of tributary canyons to the main north-trending canyon in the study area.

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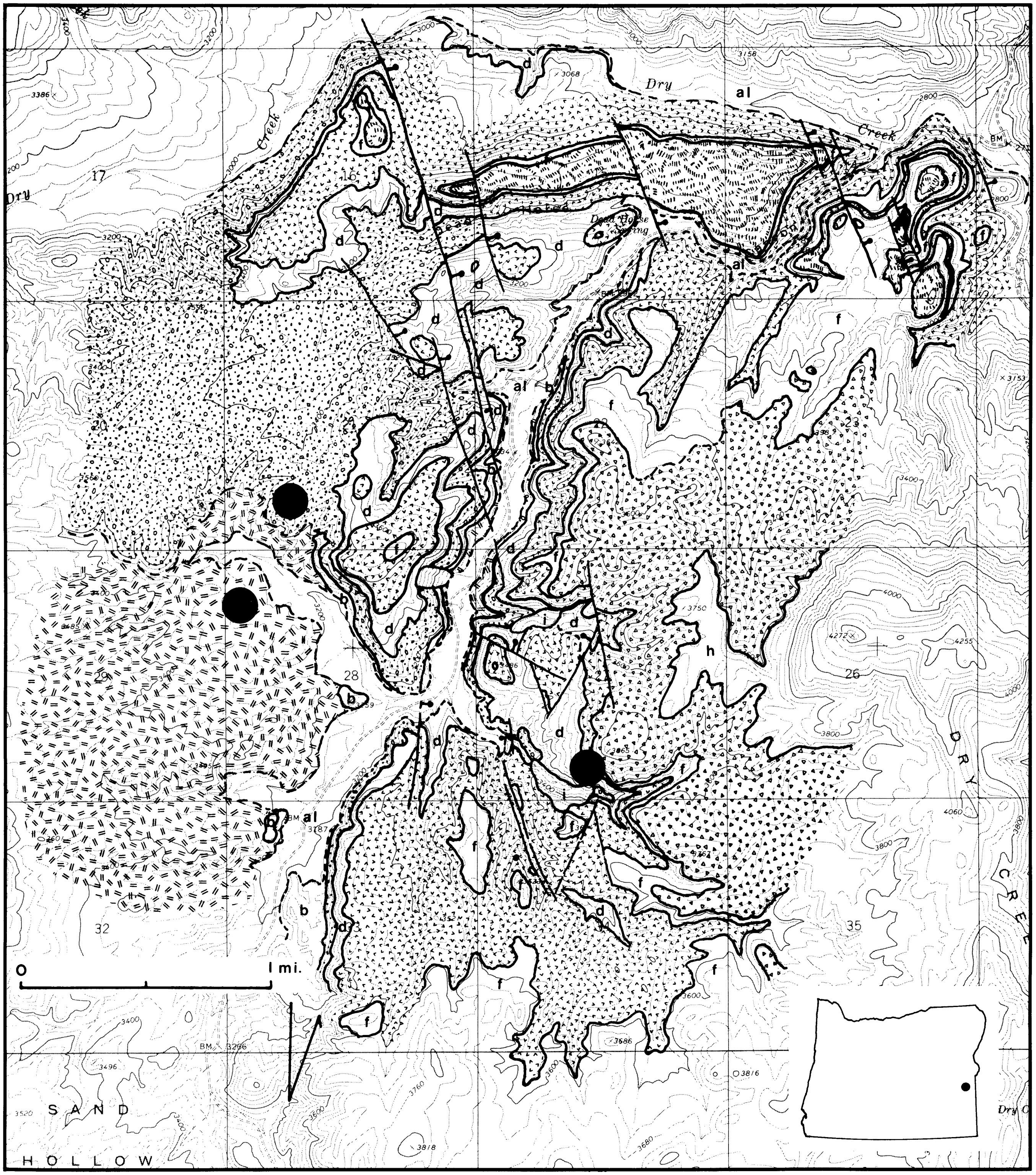

Figure 1. Geologic map of the area south of the Dry Creek arm of the Owyhee Reservoir, Malheur County, Oregon. The large black circles represent approximate locations of inferred/observed vent areas. Explanation of stratigraphic units on facing page.

EXPLANATION

al — **Alluvium**--Unconsolidated alluvial deposits along stream channels

Intracanyon basalt flows--Columnar-jointed (lower) to chaotic internal morphology, locally invasive into sediments (upper)

h — **Felsic fluvial volcaniclastic sediments**--Interlayered and underlying intracanyon basalt flows. Composed of medium- to fine-grained sandstones and siltstones

Third basalt tephra deposit--Morphology of crater indicates a maar surrounded by a tuff ring. Basalt flows interlayered with palagonite occur in crater area. Irregularly shaped intrusions, breccias, and dikes cut the stratigraphy in diatreme exposed in canyons cut into crater area

i — Basalt to gabbro intrusions within the diatreme of the maar

f — **Felsic fluvial volcaniclastic sediments**--Tree-leaf fossils in overbank deposits, fish scales in cross-laminated, medium- to fine-grained sandstones

Basalt flow sequence--Up to 12 basalt flows that range from 20 to 3 m thick. Lower flows are pillowed at the base in the Dead Horse Creek Canyon area and form a thick pillow-palagonite complex along the north wall of Dry Creek Canyon. Sequence thins onto flank of second basalt tephra deposit

d — **Felsic fluvial volcaniclastic sediments**--Thin lignite seams in lower, backswamp-dominated facies. Channel facies are more common in upper part of unit

Second basalt tephra deposit--Well-exposed deposits of poorly bedded lahar and surge deposits to well-bedded vitric, lithic lapilli tuffs. Crystalline rhyolite lapilli fragments are common, especially in upper part of tephra deposit

b — **Lacustrine sediments grading upward to fluvial felsic volcanic sediments**--Pelecypods common in lacustrine deposits; gastropods and pelecypods near top of lacustrine deposits; gastropods in fluvial deposits. Basalt detritus common near contact with first basalt tephra deposit

First basalt tephra deposit--Interbedded, poorly bedded to massive deposits of juvenile basalt glass; lithic fragments are abundant. Lahars and block and ash flows common

In the case of the second hydrovolcanic deposit, all exposed materials were deposited upon the contemporary surface. The relation between the deposits of the first eruptive center and the contemporary surface is not known, because the base of the deposit is not exposed in the study area.

Within the three basalt tephra deposits, we have differentiated three lithologic associations on the basis of bedding features, clast sizes, and overall geometry. These are (1) explosion breccia containing blocks of basalt and sediments from underlying units within a matrix of lithic fragments and palagonitized basalt glass; (2) interbedded, poorly bedded to massive deposits composed of juvenile basalt glass and lithic fragments; and (3) moderately to well-bedded, planar to cross-bedded vitric and lithic lapilli tuffs. The three lithologic associations are systematically distributed relative to both the location of the vent and stratigraphic level within the deposits. The approximate thicknesses and general characteristics of these associations for each of the three tephra deposits are presented in Table 1.

The explosion breccia (first lithologic association) is exposed only in the maar. These chaotic deposits contain blocks from underlying stratigraphic units within a matrix of rock fragments and palagonite. Field relations suggest that the materials were deposited at the approximate level of the paleosurface adjacent to the eruptive vent. A wide range of sizes and compositions of clasts includes blocks of dense and scoriaceous basalt from the underlying basalt flow sequence and volcaniclastic sediments. Blocks of basalt and amygdaloidal basalt are up to 1 m in diameter and display distinct reaction rims that are up to 5 cm wide (Figure 2). The deposits are at least 25 m thick in the maar. They are pervasively altered, and calcite and zeolite veining is common.

The second lithologic association, interbedded, poorly to massive bedded deposits composed predominantly of juvenile basalt glass, includes three types of deposits (A, B, and C). The A type contains block and ash-flow breccias overlain by glass-rich materials with large-scale cross-bedding (Figure 3). These deposits locally occupy channels within underlying deposits. Clasts within the block and ash-flow breccias include basalt; scoriaceous basalt, and, especially in the second tephra deposit, clasts of purple-gray, flow-banded rhyolite. These rhyolite clasts are rounded and seldom larger than 8 cm in diameter.

The B type consists of unsorted to poorly sorted deposits that locally occupy channels within older deposits. These deposits are similar to the block and ash-flow breccia deposits of the A type but lack the upper cross-bedded deposits. The bedding and sorting characteristics and geometry of the deposits indicate that the A type was formed as base-surge deposits, whereas the B type was formed as lahars.

The A and B types are interstratified with the C type: poorly to moderately well-bedded, porous deposits of irregularly shaped clasts of glass, scoria, and dense basalt (Figure 4). Ballistic stones of scoriaceous and dense basalt form bedding sags within the bedded deposits.

These three types of deposits (A, B, and C), which occur proximal to inferred vents and are particularly common in the first and second hydrovolcanic deposits, are less abundant proximal to the vent of the maar.

The third lithologic association, the moderately to well-bedded, planar to cross-bedded, vitric to lithic lapilli tuffs, occurs stratigraphically high in the tephra deposits and extends to the greatest distance from the vents. The moderately well-bedded deposits contain beds up to 15 cm thick of glassy, coarse lithic and vitric lapilli interbedded with finer grained, more prominently bedded vitric lapilli. In coarser grained beds, primary porosity was high, and the various basalt fragments form the framework of the bed. Bedding planes are at low angles and are seldom clearly distinguished. The diffuse bedding planes are locally wavy, but internal sedimentary textures within the beds have not been observed. Ballistic stones up to 12 cm in

Figure 2. Rounded to angular blocks of massive and scoriaceous basalt and cobbles of felsic volcaniclastic sediments in a matrix of basalt glass and rock fragments. Reaction rims around blocks are up to 5 cm wide. Calcite and zeolite veining cuts the matrix. Photograph is of the explosion breccia (first lithologic association) near the vent of the third tephra deposit. Photograph by Leonard Farr, Department of Geology, Portland State University.

diameter form asymmetric bedding sags within these deposits. The stones are usually dense basalt as illustrated in Figure 5.

Where the deposits of the third lithologic association are moderately to well bedded, bedding planes are planar and range from low-angle cross to parallel. Beds are up to 5 cm thick, and bedding planes are distinct. The clasts within a bed are of approximately similar grain size but are of a different size in the sub- and superjacent beds. Grain sizes range from ash to lapilli up to 1 cm in diameter. Clasts consist of palagonitized basalt glass and sparse scoria. Accretionary lapilli up to 1 cm in diameter occur in beds containing scoriaceous basalt glass, ash-size fragments of basalt glass, and agglutinated basalt glass. Figure 6 illustrates the fine-scale concentric layering in the lapilli. Within the second tephra deposit, rhyolite clasts are common to abundant, especially stratigraphically high in the deposit. These rhyolite clasts are illustrated in Figure 7.

Figure 8 illustrates low-angle laminated vitric-lithic tuff that occurs near the stratigraphic top on the flank of the second tephra deposit. Similar deposits are also locally present in the first tephra deposit. However, those within the second deposit contain abundant angular to rounded rhyolite lithic fragments within bedded palagonite. Although rhyolite lithic fragments occur throughout the stratigraphy of the second deposit, they are particularly common in these materials.

The color of the tephra deposits changes from the brown color that is common near the vent to a pale olive green in the distal deposits. Bedding planes in these distal deposits are parallel, and beds are commonly less than 0.5 cm thick. The grain size is commonly distinctly different between adjoining beds but uniform within the bed. Clasts range in size from ash to fine lapilli. The lateral distance traversed from the vent to the most distal deposits is approximately 2.5 km, as measured in the uppermost hydrovolcanic deposit. The tephra deposits grade into, and are interdigitated with, laterally contemporaneous felsic volcaniclastic sediments. Fine-grained basaltic detritus composed of glass and rock fragments occurs within the felsic sediments.

Although the distal deposits grade laterally outward into felsic volcaniclastic sediments, the overall stratigraphic relation between the felsic detritus and tephra deposits is transgressive. These sedimentary deposits partially to totally buried the tephra before the next hydrovolcanic eruption.

In addition to the three lithologic associations observed in the three tephra deposits, basalt flows are present in the vent area of the maar. These basalt flows are from 1.5 to 2 m thick and are interbedded with palagonite units of similar thicknesses. The interbedded sequence of flows and palagonite is bounded by massive, unsorted deposits, and flows may be locally invasive into such deposits. The basalt flows are aphanitic and contain xenoliths of medium-grained, holocrystalline basalt, as illustrated in Figure 9. As indicated, the basalt flows occur within the crater of the maar; however, isolated pods and lenses of basalt occur within a breccia in the northern flank of the maar. These pods and lenses are rootless and display radial cooling fractures. The matrix lacks clearly defined bedding. It is believed that the matrix consists of disturbed, originally bedded deposits of the third lithologic association.

Alteration and cementation

The tephra deposits are pervasively altered. All primary basalt glass has been converted to clay minerals, and the porosity is partially to totally infilled with calcite and zeolites. Where calcite is particularly abundant, the tephra deposits form steep cliffs and pillars. Calcite veins form anastomosing networks that are oriented along north to north-northwest trends. Zones containing numerous veins are up to 1 m wide, and individual veins contained therein are up to 20 cm wide.

Color anomalies that are red in contrast to the overall brown to olive-green color of the tephra deposits occur near or within the vent areas. Examination of rocks from within the color anomalies suggests that oxidation of the basalt glass and leaching of the glass generated secondary porosity. A green secondary mineral, believed to be celadonite, is deposited within the secondary pores. The distribution of leached areas and precipitated celadonite is irregular but may be more prominent along north-trending fractures.

Within the diatreme of the maar, the basalt dikes and surrounding sediments contain disseminated pyrite where silicified. These silicified zones have been observed only within the diatreme.

DISCUSSION

The tephra deposits in the stratigraphic section south of Dry Creek are well exposed in the canyons of the area. In addition, the interfingering field relations between basalt tephra and felsic volcaniclastic sediments provide an opportunity to examine evidences of the dynamics of the depositional system in which the tephra was

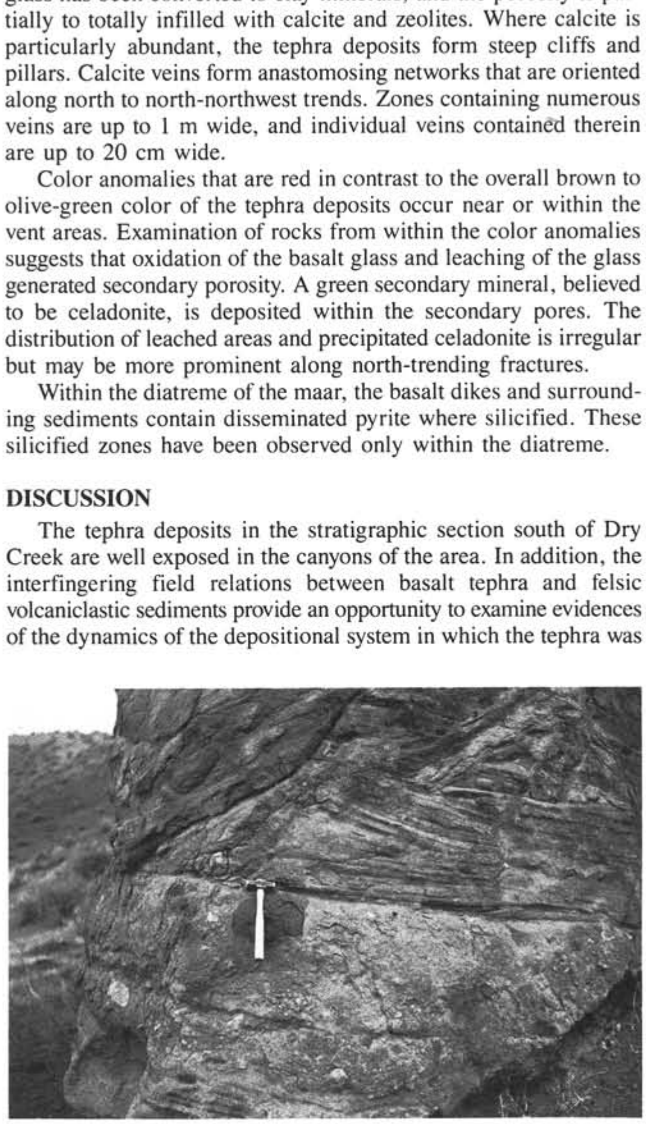

Figure 3. Block and ash-flow breccia overlain by vitric lapilli tuff with sparse lithic fragments and large-scale cross-bedding. Left of center of the photograph, moderately to poorly bedded basalt vitric tuff occupies a channel within the cross-bedded sequence. This photograph illustrates the A type of the second lithologic association within deposits of the first tephra deposit.

Figure 4. Porous lapilli tuff composed of basalt glass and sparse basalt scoria and basalt clasts. Beds of similar deposits occur within the second and, to a lesser extent, the third lithologic associations. The mechanical pencil is 12.5 cm long.

formed. The tephra deposits were produced by interactions of the hydrologic and magmatic systems in the basin in which the Miocene Deer Butte Formation accumulated. These interactions will be examined in relation to (1) the character of the eruptions that produced the tephra, (2) the paleohydrologic conditions of the basin, and (3) the spatial and stratigraphic distribution of similar basalt tephra deposits in the Owyhee region.

The vertical and horizontal distribution of the three lithologic associations described above varies among the three tephra deposits. The first tephra deposit contains mainly deposits of the second lithologic association: interbedded, poorly bedded to massive deposits composed of juvenile basalt glass and lithic fragments. The second tephra deposit contains deposits of the second lithologic association near the inferred vent area but is characterized by deposits of the third lithologic association (moderately to well-bedded planar to cross-bedded vitric and lithic lapilli tuffs) throughout most of its stratigraphy. The third tephra deposit, the maar, contains deposits of the first lithologic association near the vent (explosion breccia containing blocks of basalt and sediments from underlying units within a matrix of lithic fragments and palagonitized basalt glass) overlain primarily by deposits of the third lithologic association. This maar also contains lava flows interlayered with palagonite within the crater. Field relations suggest that these flows overtopped the north rim of the crater and became mixed into the deposits of the third lithologic association on the north flank of the maar.

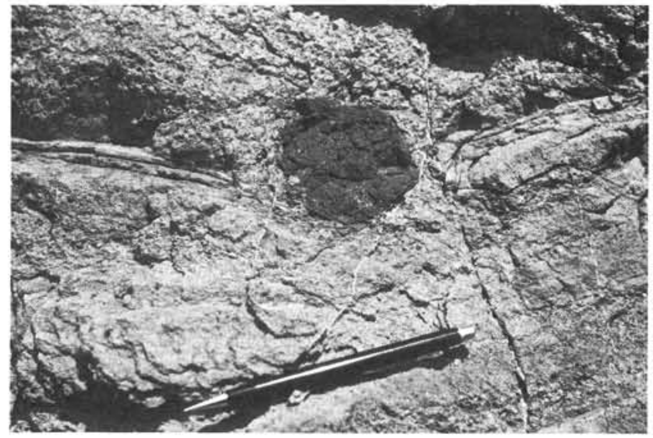

Figure 5. A bedding sag within moderately to well-bedded lapilli tuff of the third lithologic association as it occurs within the second tephra deposit. The mechanical pencil is 12.5 cm long.

Wohletz and Sheridan (1983) related the bedding and geomorphic characteristics formed by hydrovolcanic eruptions to the character of the eruption phenomena. Thickly bedded deposits containing abundant ballistic fall, massive surge bed forms, and lahar deposits are characteristic of tuff cones. Tuff cones tend to form under conditions where eruption clouds are poorly inflated and deposits are wet, cohesive, and massive. Such deposits are similar to those of the second lithologic association in the Dry Creek tephra deposits. Thinly bedded deposits that have traveled farther from the vent are deposited from highly inflated eruption clouds characteristic of tuff rings (Wohletz and Sheridan, 1983). The deposits are drier and less cohesive than the deposits of tuff cones. These deposit characteristics are similar to those of the third lithologic association identified in the Dry Creek tephra deposits. The initial deposits of tuff rings are reported to be explosion breccias formed near the vent. Such explosion breccias are similar to the first lithologic association in the Dry Creek deposits.

On the basis of the sedimentary characteristics of the deposits, the first tephra deposit is interpreted to be a tuff cone. The second tephra deposit has characteristics of a tuff cone during its early eruptive history but contains deposits more similar to a tuff ring higher in its stratigraphy. The morphology of the crater indicates that the third tephra deposit is a tuff ring formed around a maar, the crater of which was filled by basalt flows.

An evolution in the paleohydrologic conditions in the sedimentary basin at the time of the hydrovolcanic eruptions is inferred by the progressive changes in the characteristics of each successively younger tephra deposit. Basalt hydrovolcanic eruptions occur either in settings that contain abundant ground and/or surface water as in the Eifel region of Germany (Lorenz, 1973) or where abundant ground and/or surface water can be shown to have existed in the past as in the High Lava Plains of central Oregon (Heiken, 1971; Allison, 1979). Lorenz (1973) noted that in the Eifel, maar deposits formed in the bottoms of fluvial valleys, whereas cinder cones formed where eruptions occurred on valley slopes or the tops of ridges. Wohletz and Sheridan (1983) indicate that tuff cones of Quaternary age were erupted in areas where surface water was located above the vent, whereas tuff rings typically formed in areas where surface water above the vent was absent. The tuff rings, however, required abundant surface or ground water that could enter the vent during eruption.

The systematic changes in the lithologic associations in the three tephra deposits of the Dry Creek area indicate evolving hydrologic conditions in the basin. The first deposit, a tuff cone, is interpreted

Table 1. *Approximate thicknesses and general characteristics of lithologic associations for the three tephra deposits*

Tephra unit	Lithologic association*	Thickness	General characteristics
Tephra 3	---	14 m	Aphanitic basalt flows up to 1.5 m thick interlayered with reddish-brown palagonite in layers of similar thickness. Basalt is locally invasive into block breccias along the east rim of the crater. Xenoliths of crystalline olivine basalt approximately 3 mm in diameter occur in the flows.
	3	25 m	Planar to cross-bedded, vitric lapilli tuffs. Grain sizes within beds are uniform but different from overlying and underlying beds. Bed thickness ranges from 1 to 30 cm. Pods and lenses of aphanitic basalt occur in disturbed materials on the north rim of the crater. Pods have chilled margins and radial fracture patterns.
	1	25 m	Chaotic mixture of blocks including basalt, scoriaceous basalt, and felsic volcaniclastic sediments occurring in a matrix of fine palagonitized basalt glass, felsic detritus, and lithic fragments. Veins of calcite and zeolites are common. Blocks are up to 2 m in diameter and have alteration rinds over 3 cm thick in clasts of nonvesicular basalt.
Tephra 2	3	30-50 m	Moderately to well-bedded vitric-lithic lapilli tuffs. Coarse-grained beds are up to 30 cm thick; granule-size clasts occur in beds outward from the vent where bedding thickness is up to 5 mm. Accretionary lapilli up to 1 cm in diameter are common in well-bedded materials. Large-scale cross-bedding occurs in the upper 10 m of the deposits near the vent area. Graded bedding occurs as fining-upward sequences, and load casts occur where coarse-grained layers occur over fine-grained layers.
	2	20-30 m	Massive, unsorted block-and-ash deposits up to 1.5 m thick interlayered with porous vitric lapilli tuff. Beds of lapilli tuff are up to 30 cm thick. Ballistic stones of dense and scoriaceous basalt form bedding sags in bedded layers. Ballistic stones are at least 12 cm in diameter. Accidental inclusions include purple-gray rhyolite, dense basalt, and scoriaceous basalt.
Tephra 1	3	6+ m	Large-scale, low-angle cross-bedding to tabular cross-beds up to 1 m thick occurring near the top of the deposits. Cobbles up to 10 cm in diameter occur in matrix-supported to clast-supported, discontinuous conglomerate beds that are up to 35 cm thick. Cobbles are basalts of various textural types. Small felsic chips are locally present. Bedding types and lithologies include planar-bedded conglomerates and tabular cross-bedded, laminar, and low-angle large-scale cross-bedded siltstones to coarse-grained sandstones.
	2	40+ m	Block and ash-flow breccias overlain by large-scale cross-bedded deposits. Block and ash-flow breccias are up to 1.5 m thick, and cross-bedded materials are up to 2 m thick. Channels are common. Unsorted, massive block and ash units are also present. Poorly bedded, porous vitric lapilli tuffs display bedding sags produced by ballistic stones. One ballistic stone is over 1 m in diameter and produced a bedding sag extending 60 cm below the base of the clast.

* See discussion on stratigraphy and lithology in text.

Figure 6. Three parallel beds containing accretionary lapilli from the second lithologic association in deposits of the second tephra deposit. The photograph shows the concentric layering characteristic of accretionary lapilli. The mechanical pencil is 11.5 cm long.

Figure 7. Subangular to subrounded rhyolite clasts (light-colored) within well-bedded vitric-lithic lapilli tuff. The clasts are typically less than 2 cm in length. These clasts are within surge deposits that are near the top of the deposits of the second tephra deposit.

to have formed under conditions where abundant water was available. These conditions may have been met by eruption within a shallow lake or a broad, low-gradient fluvial valley characterized by high water tables and swampy conditions. The second deposit displays characteristics suggesting that throughout the eruption an adequate supply of water was available to produce violent hydrovolcanic explosions. However, the rate of water coming into contact with the rising magma decreased as the eruption continued (Fisher and Waters, 1970; Walker, 1984). The third deposit, a tuff ring around a maar, suggests that water did not enter the system at a fast enough rate to continue violent eruptions and that the eruption cloud was relatively dry. The dikes and irregularly shaped intrusions within the diatreme and the later eruption of basalt flows into the crater further indicate that magma output exceeded water inflow. Lorenz (1975, 1985) indicates that if the water supply is stopped during eruption, magma may enter the diatreme or be erupted into the crater.

This hydrologic evolution is also indicated by the felsic volcaniclastic sediments and basalt flows that are interlayered with the hydrovolcanic deposits. The sediments between the first and second tephra deposits indicate that a lacustrine environment was established immediately after eruption of the first tuff cone. These sediments grade upward into cross-bedded fluvial deposits that immediately underlie the deposits of the second tuff cone. The lignite deposits that immediately overlie the deposits of the second tephra deposit and the extensive deposits of the backswamp facies suggest abundant ground water but potentially no standing bodies of water, such as lakes. Immediately below the sequence of 12 basalt flows, small- to medium-size channel and levee facies are more common. A lake apparently developed in the area of Dry Creek, since the lower basalt flows of the sequence that overlies these sediments form a pillow-palagonite complex exposed in the cliffs along Dry Creek. The lower flows also have pillowed bases along Dead Horse Canyon, 1 km south of Dry Creek. However, pillows have not been observed in the lower flows south of Dead Horse Canyon. Fluvial sediments overlie the basalt flows. Cross-bedded, fine-grained sandstones and associated siltstones contain fish scales, and siltstones locally contain tree leaves. These sediments are believed to represent a moderately to well-drained landscape with stream valleys and low-relief interfluves. The tuff ring of the third tephra deposit was deposited upon these sediments, and the maar and diatreme was cut into these sediments and the underlying basalt flow sequence. The progression in the volcaniclastic sediments corroborates the patterns of paleohydrologic evolution inferred from the characteristics of the hydrovolcanic deposits.

The distribution, areal extent, and stratigraphic context of similar hydrovolcanic deposits in the Deer Butte Formation are, at present, unknown. The stratigraphy north of the Dry Creek arm overlies that portion of the stratigraphy that contains the hydrovolcanic deposits south of the Dry Creek arm. Although our map coverage north of Dry Creek extends for 1.5-3 km, the hydrovolcanic deposits are not present within this portion of the stratigraphic section.

However, hydrovolcanic deposits appear to be common within the stratigraphy of the area between Dry Creek and Red Butte and may be an important component of the lower portion of the Miocene Deer Butte Formation. The descriptions of measured sections between Dry Creek and the Red Butte area (Johnson, 1961; Kittleman, 1962; and Kittleman and others, 1965) suggest that hydrovolcanic deposits are present within this area. Evans (1986) reports basalt lahar deposits in stream valleys immediately southeast of Red Butte. Abbe and Cummings (1987) describe fissurelike features at least 1 km in length that have been infilled by felsic volcaniclastic sediments overlain by glass-rich basalt detritus, basalt blocks, and blocks of surrounding sedimentary rocks. These features were interpreted to have been dilatant fissures at the time of sedimentation and hydrovolcanic eruptions in the area.

Since hydrovolcanic eruptions require a specific set of hydrologic conditions, hydrovolcanic deposits (or their absence, where basalt flows are present) may provide a useful method of reconstructing hydrologic evolution of the sedimentary basin during deposition of the Deer Butte Formation. Whether the hydrovolcanic deposits are restricted to a particular stratigraphic interval within the Deer Butte Formation or occur at different stratigraphic levels will be investigated during further mapping.

Recognition of hydrovolcanic deposits and the presence of silicified and pyrite-bearing dikes within the diatreme of the third tephra deposit and color anomalies within the first tephra deposit draw attention to the economic potential of these deposits. Lorenz (1985) reviewed the characteristics of diatremes and briefly pointed out examples of economic mineralization found in these settings. The interaction of the erupting magma with ground water can produce diatremes that progressively migrate to deeper crustal levels as eruption continues. The diatremes may form to depths of 2-2.5 km below the surface. Wolfe (1980, 1986) examined diatremes associated with various forms of explosive volcanism. Hydrovolcanic eruptions at Taal volcano in the Philippines are examined as a mechanism for formation of breccia pipes. The hydrovolcanically formed breccias of the diatreme and crackle zones that extend into the country rock surrounding the diatreme are readily altered by circulating hydrothermal solutions. The processes that produce economically mineralized diatremes and examples of precious-metal and base-metal mineralized diatremes are described in relation to the processes of formation.

Walden (1986) reports tuffs deposited by maar volcanism in the Miocene Sucker Creek Formation in the Coal Mine Basin area near the Idaho-Oregon border. D. Guilbert (personal communication, November 1987) reports possible basalt hydrovolcanic deposits southeast of Rockville near the Idaho-Oregon border. These reports suggest that basalt hydrovolcanic deposits may be present in several formations in the Owyhee region. The necessary hydrologic conditions to form hydrovolcanic eruptions apparently occurred at different times and in different parts of the Owyhee region throughout the Miocene.

CONCLUSIONS

The presence of three basalt tephra deposits at three stratigraphically distinct levels within the felsic volcaniclastic sedimentary deposits exposed south of the Dry Creek arm of the Owyhee Reservoir suggests several conclusions.

1. Basalt hydrovolcanic eruptions were an important geologic process that accompanied felsic volcaniclastic sedimentation.

2. The first tephra deposit has characteristics of a tuff cone; the second of a tuff cone that grades upward into sediments more characteristic of tuff rings; the third tephra deposit is a tuff ring surrounding a maar. A series of basalt flows was erupted into this maar crater.

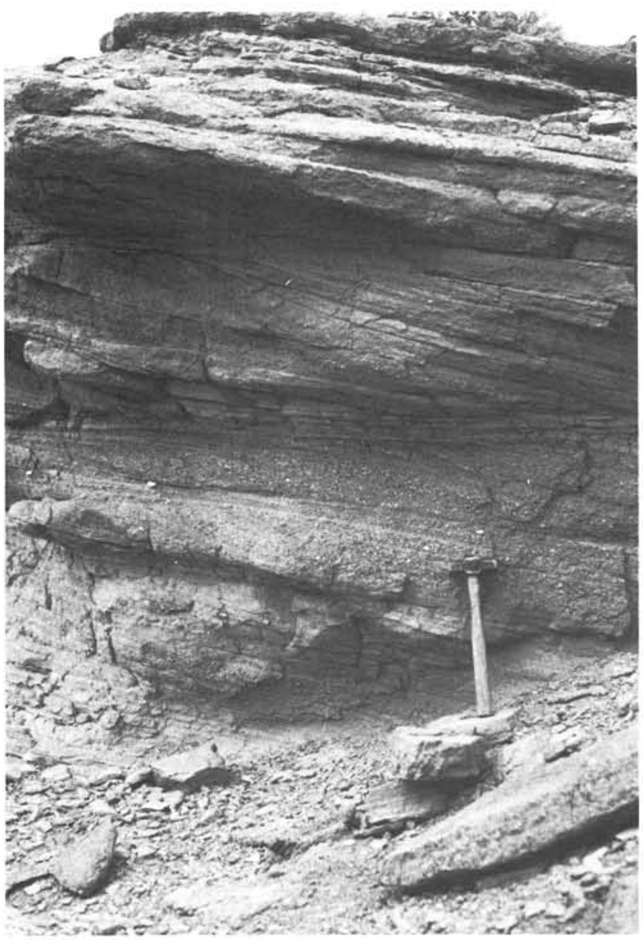

Figure 8. Low-angle, large-scale cross-bedding within palagonitized vitric-lithic lapilli tuff of the second lithologic association. The photograph illustrates the deposits from near the top of the deposits of the second tephra deposit.

Figure 9. Photomicrograph of the basalt flows within the crater of the third tephra deposit. The basalt flows contain xenoliths of well-crystallized olivine basalt that are up to 3 mm in diameter. The nonporphyritic basalt flows contain a groundmass of extremely fine grain size. Field of view is 5 mm.

3. The changes in bedding, lithology, and lithologic associations among the hydrovolcanic deposits and the depositional environments represented by the interdigitated felsic volcaniclastic sediments indicate evolution in the hydrology of the basin during sedimentation. This evolution led from standing surface water and abundant ground water to moderate relief and less ground-water availability as sedimentation continued.

4. Basalt hydrovolcanic deposits are apparently common within the Deer Butte Formation exposed south of Dry Creek, but whether the deposits are restricted to a specific stratigraphic interval is still under investigation. Basalt hydrovolcanic deposits also appear to be common in the Miocene section of the Owyhee region.

5. The diatremes formed during hydrovolcanic eruptions are excellent targets for mineral exploration and should be examined with care.

ACKNOWLEDGMENTS

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REFERENCES CITED

Abbe, T., and Cummings, M.L., 1987, Results of preliminary mapping in the Deer Butte Formation, Owyhee region, Oregon [abs.]: Pacific Northwest Metals and Minerals Conference, Portland, Oregon, Abstracts, p. 26.

Allison, I.S., 1979, Pluvial Fort Rock Lake, Lake County, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 7, 72 p.

Evans, C.S., 1986, The geology, geochemistry, and alteration of Red Butte, Oregon; a precious metal-bearing paleo hot spring system: Portland, Oreg., Portland State University master's thesis, 133 p.

Fisher, R.V., and Waters, A.C., 1970, Base surge bed forms in maar volcanoes: American Journal of Science, v. 268, no. 2, p. 157-180.

Heiken, G.H., 1971, Tuff rings: Examples from the Fort Rock-Christmas Lake Valley basin, south-central Oregon: Journal of Geophysical Research, v. 76, no. 23, p. 5615-5626.

Johnson, A.M., 1961, Stratigraphy and lithology of the Deer Butte Formation, Malheur County, Oregon: Eugene, Oreg., University of Oregon master's thesis, 144 p.

*(Continued on page 94, **Dry Creek**)*

Well logging of oil and gas wells in Oregon

by Bill Diggons, Schlumberger Educational Services, 5000 Gulf Freeway, Houston, Texas 77252-2175

This is the second in a series of articles on the oil and gas industry that have been written for *Oregon Geology* by people who work in various occupations within the industry itself. The first article, "Oil and Gas Exploration for the Nongeologist," by Wesley G. Bruer, appeared in the August 1986 issue of *Oregon Geology*. This second article tells how subsurface geophysical techniques are used to analyze oil and gas wells. Future articles, which will appear at irregular intervals in upcoming issues of *Oregon Geology*, will discuss such topics as leasing. *—Editor*

INTRODUCTION

Wireline logging has been used to analyze exploratory oil and gas wells in Oregon since the 1950's. These services are vital to the exploration and development process of Oregon's hydrocarbon resources. The following article describes how wireline logging serves the petroleum industry.

At the Mist Gas Field, most of the wireline logging is done by Schlumberger and Welex. Schlumberger owes its start to experiments in the early 1900's by Conrad Schlumberger, a French physicist, and his brother Marcel, a mechanical engineer, who demonstrated that electrical measurements on the earth's surface can map the earth's substructure. Later, in the twenties, they proved that measuring tools based on similar methods, when lowered into an oil well with an electrical conducting cable called a "wireline," could identify oil-bearing formations. This technique evolved into the business of "wireline logging," giving the oil industry the closest thing to an X-ray in the search for oil and natural gas. Today, Schlumberger and other oilfield companies assist in the drilling, location, production, and maintenance of oil and gas reservoirs.

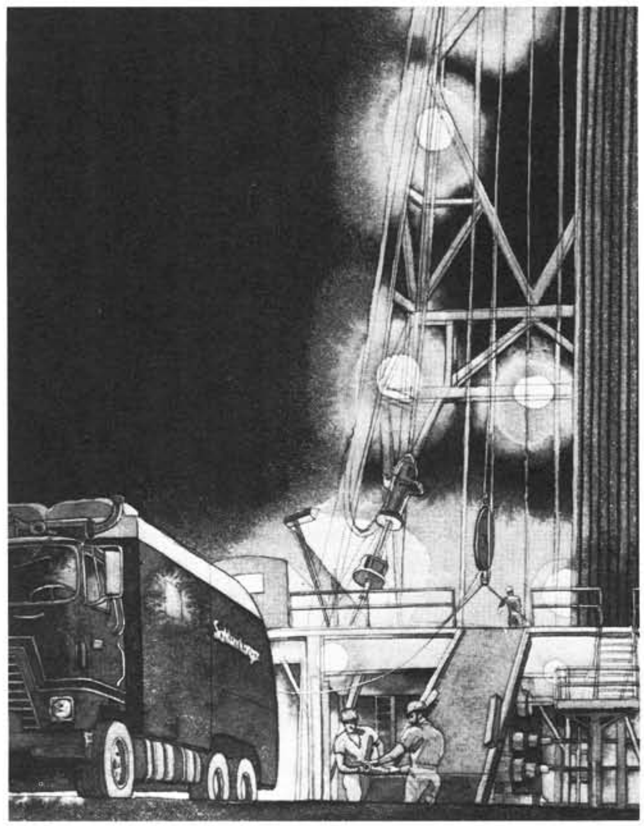
Once a promising geological area has been located by surface geological and geophysical surveys, a well is drilled. While drilling is in progress, a drilling analysis service, combining surface and downhole measurements, is provided to improve drilling efficiency and safety and to monitor hole direction. Periodically, drilling is interrupted to evaluate the well by means of wireline logging. When the logs indicate hydrocarbons, a drillstem test shows how much oil and gas will flow, confirming the discovery.

If results are positive, a heavy steel casing is cemented into the borehole to prepare the well for production. This casing keeps the hole from collapsing and isolates the productive formations. Then, explosive charges are detonated in the borehole, blasting cylindrical holes through the casing and cement deep into the productive zone, allowing oil and gas to flow into the well. For production, a length of small-diameter tubing is run inside the casing to the depth of the productive hole. Oil and gas flow to the surface through this tubing. When the rock formation is tight, fluids are pumped into the reservoir with enough force to split the rocks and open additional flow channels to increase production.

At this point, the production is tested at various flow rates, while pressure measurements are made downhole and at the surface. These data are needed to evaluate the production potential of the field.

The producing life of a well may span decades. At regular intervals, reservoir performance is monitored. Additional wireline logs are run and compared with the original logs to show changes in reservoir status.

Not all of the hydrocarbons in a reservoir can be produced by natural flow or pumping. Primary production may recover only part of the original hydrocarbons in place. Wireline logging assists in enhanced recovery techniques until the well is finally plugged and abandoned.



Preparing for a logging operation on a wellsite. The wireline cable is unwound from the truck onto the rig floor.

A CLOSER LOOK AT WIRELINE LOGGING

When a well is drilled, very little information is available to the geologist standing at the top of a hole several thousand feet deep and only a few inches in diameter. He must be able to distinguish rock layers downhole that can be less than 6 in. thick. Often, there is scant evidence that the drill has penetrated an oil or gas reservoir. This is where wireline logging provides invaluable information.

Drilling is interrupted periodically so that a computerized mobile laboratory, called a "CSU," can lower measuring instruments to the bottom of the drill hole on an armored electrical cable called a "wireline." These instruments, encased in a slim cylindrical tool known as a "sonde," are then pulled slowly back to the surface, measuring continuously the physical paramaters of the rock formations through which they pass. The data are transmitted on the wireline to the CSU surface laboratory, where measurements are recorded on a magnetic tape and on a graph called a "log." Properly interpreted, these logs give a complete picture of subsurface formations—how deep, how thick, and how porous they are, and how much oil and gas they contain.

WIRELINE TODAY

Today, wireline services are as vital to oil and gas exploration and production as the X-ray is to medical diagnosis. They now include electromagnetic, acoustic, and nuclear measurements and are recognized as the most reliable and scientifically accurate method for locating and evaluating oil and gas reservoirs. Yet, this service represents no more than 5 percent of the total cost of drilling a well.

Wireline services are needed throughout the productive life of a well. One category, openhole services, provides logging information in newly drilled wells. Production or cased-hole services, on the other hand, are offered after a steel casing has been set and cemented into the wellbore prior to production. In addition, the wellsite mobile laboratory provides a computer interpretation of downhole data at the well, thus facilitating decision making.

LOGGING THE OPEN BOREHOLE

Downhole logging tools, the instruments that take the measurements, must withstand the "pressure-cooker" environment at the bottom of a well, where temperatures can exceed 400°F and pressures range above 10,000 psi.

Typically, the sonde crammed with sensors and electronics will consist of a cylindrical steel tube that is 20 to 40 ft long. The measurements record the physical properties of the rocks, their lithology, and their fluid content.

Electrical and electromagnetic measurements

An electrical current is sent into the formation, and resistance to current flow is measured. When the pores of a rock are filled with saltwater, the resistance to current flow is low; if they are filled with hydrocarbons, resistance is high. Thus, electric logs are the basic measurement for locating hydrocarbons. Sometimes oil is found with fresh water or low-salinity water whose resistance to current flow is also high, so another tool was developed to determine the proportion of water in pores of the rock, regardless of the salinity of the water. This is done through dielectric measurements using radio-frequency currents.

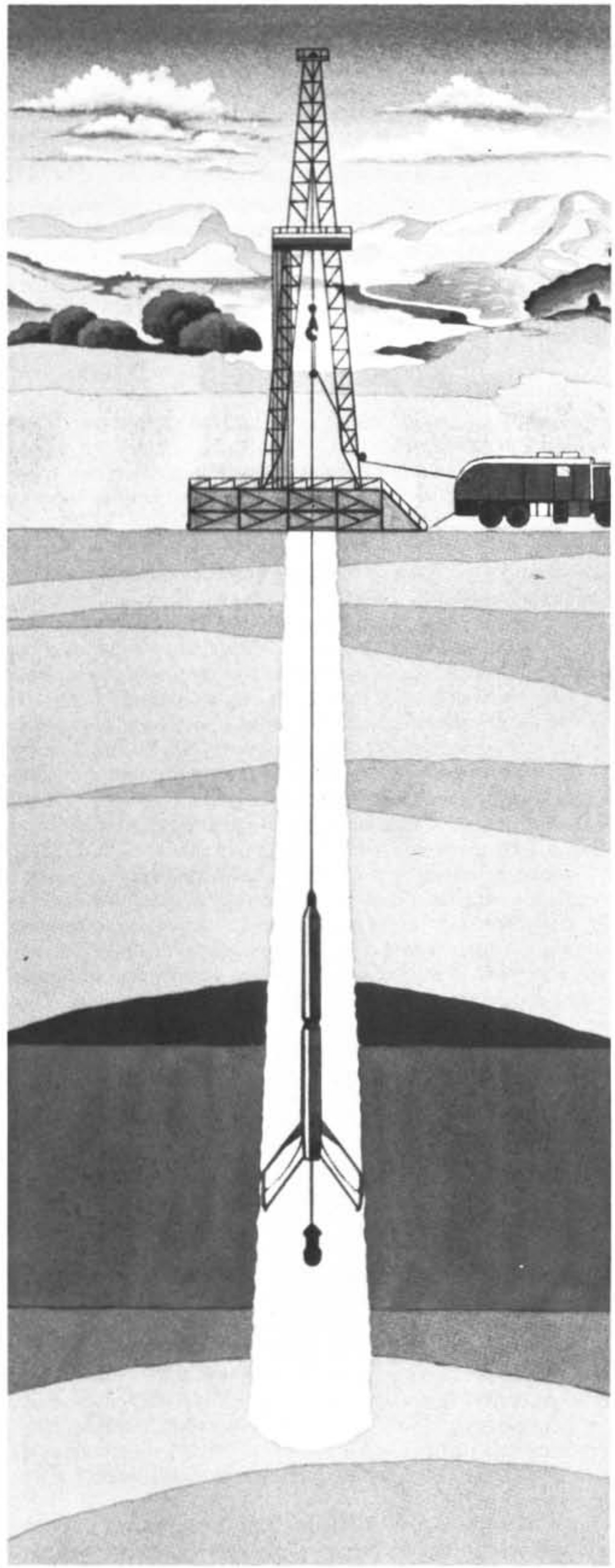
Acoustic measurements

Sonic tools transmit a sound wave and measure how long the sound wave takes to travel through the rock formations, how much of the signal is lost in transit, and how the shape of the wave has been modified. These measurements tell much about the structure and lithology of the rock, its porosity, and its fluid content. This information is used in formation evaluation, for fracture detection and completion design, and for refining surface seismic data through offset-seismic profiling. Acoustic signals at ultrasonic frequencies can resolve microstructures of rocks, while subsonic frequencies assist in borehole seismic investigations covering thousands of feet.

When high-energy sound waves are transmitted into the earth from the surface, they can be detected by a logging tool in the borehole. These downhole measurements provide information about geological structure at a great distance around and beneath the borehole. This technique, called "Vertical Seismic Profiling," is an important link between wireline logging data and the surface seismic exploration that precedes drilling.

Nuclear measurements

Nuclear tools investigate the atomic structures of rocks by measuring their interaction with nuclear particles. They help determine the lithology, porosity, and fluid composition of the formation. One of



Periodically, drilling is interrupted to evaluate the well by means of wireline logging with a logging tool called a "sonde." When the logs indicate hydrocarbons, a drillstem test shows how much oil and gas will flow, confirming the discovery.

these nuclear measurements detects natural formation radioactivity to locate shales. A second gauges the reaction of the formation to gamma rays or neutrons emitted by a source within the logging tool. The atoms of the chemical elements within rock, oil, and water react uniquely with the nuclear particles and indicate rock density and hydrogen content. Spectrographic analysis identifies elemental components of the formation.

Stratigraphic information

Information gathered by another tool called a "dipmeter" helps define reservoir structure. Dipmeters combine multiple electrical resistivity measurements with gyroscopes and other "navigation" devices to measure the direction and angle, or dip, of each rock layer penetrated by the wellbore. They are also used to create "electrical images" of the borehole wall—similar to core photographs. These data help the geologist define the depositional environment of the field and can be crucial in determining where to drill the next well.

Sample taking

Several types of wireline tools actually retrieve rock or fluid samples from the well for laboratory analysis. The Repeat Formation Tester, an advanced sample taker, collects fluids from reservoir rocks and measures formation pressure. The pressures at which these fluids enter the tool and the types of fluids recovered help define the ability of the formation to produce oil and gas.

PROBING BEHIND THE CASING

Once hydrocarbons have been located in commercial quantities, a steel casing is set from the surface to the bottom of the borehole and is cemented in place. This maintains the integrity of the wellbore and isolates productive formations from one another. Wireline services that are used extensively after holes are lined with steel casing are called "production" or "cased-hole services." Here are the most important applications for cased-hole services:

1. Bring a newly drilled well to production (well completion). Production services in a newly drilled well include the following:

   a. Perforating by explosive charges that blast cylindrical holes through the casing and deep into the reservoir rock to allow oil and gas to flow into the wellbore and up to the surface.

   b. Acoustic measurements that determine how solidly the casing is cemented into the borehole.

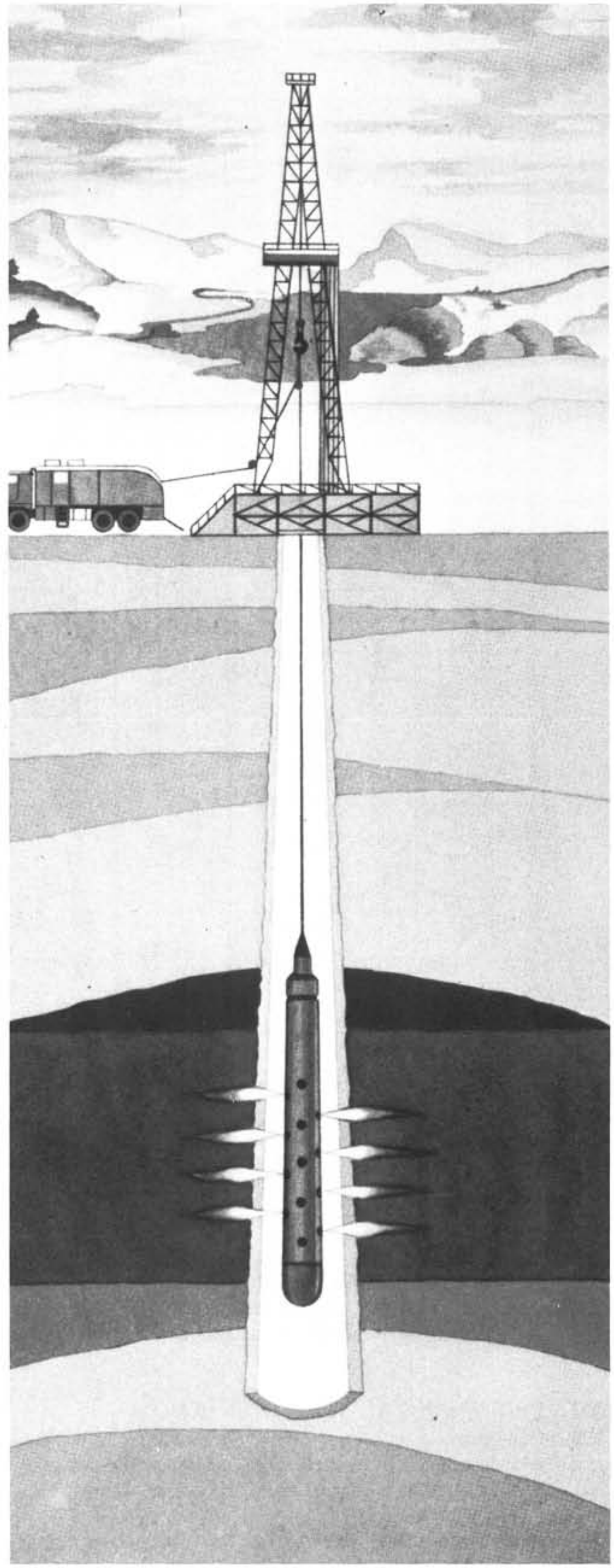
   c. Base logs that determine the initial oil or water saturation so that, later in the producing life of the well, comparisons can be made with similar logs to monitor the movement of fluids in the reservoir.

   d. Measurements made while the well is producing to determine how much each individual reservoir zone contributes to production.

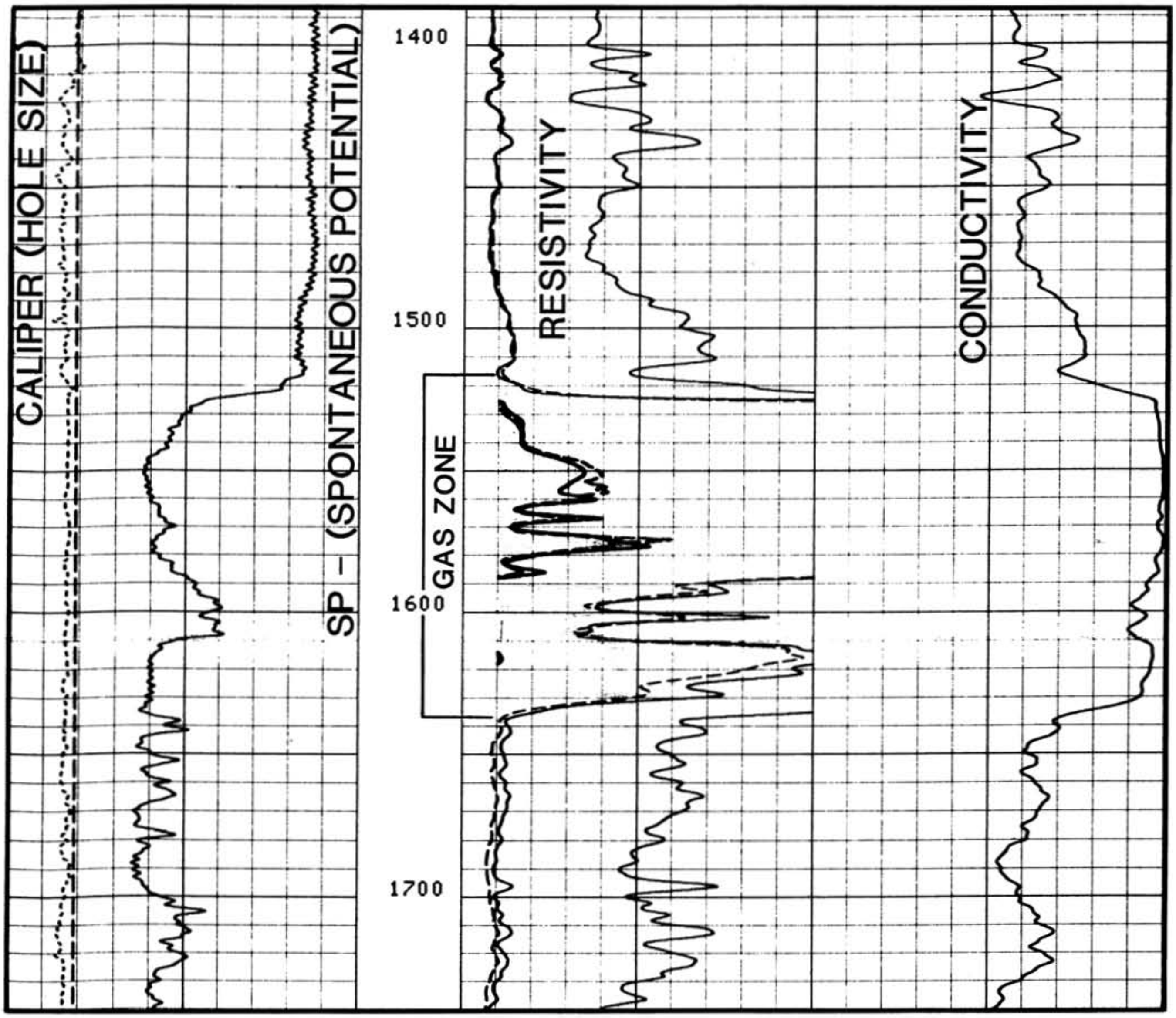
2. Evaluate old wells. Wireline production services using acoustic and nuclear techniques can help locate behind-casing oil- and gas-bearing zones that were bypassed in wells either because no logs were recorded or because the logging program was insufficient.

3. Repair an old well to improve production (workover). After many years, producing wells can develop problems that require repairs. Again, wireline production services can determine the flow profile in the well and the water saturation behind the casing so zones producing unwanted water can be shut off. Also, acoustic measurements can check whether old cement in the annulus still provides an adequate hydraulic seal. Depending on the diagnosis, a workover program is set up. This could include wireline services to perforate the casing, either to squeeze additional cement into the annulus between the casing and rock formations or to produce oil and gas from remaining zones.

4. Monitor the performance of a reservoir. Wireline production services can be run periodically in producing wells to monitor the



Perforating the well. Explosive charges are detonated in the borehole, blasting cylindrical holes through the casing and cement deep into the productive zone, thereby allowing oil and gas to flow into the well.



Representative electric log from ARCO's Busch 14-15 well in the Mist gas field, showing the gas zone in the Clark and Wilson sand. Horizontal lines indicate depth. Vertical lines record electrical properties of fluids in the pore spaces of the rock. These properties indicate probable location of hydrocarbons.

performance of the reservoir and the effectiveness of the well completion. Flow, saturation, and pressure profiles are measured to show remaining reserves, water encroachment, and reservoir production efficiency.

DATA PROCESSING AND INTERPRETATION

In an interactive process requiring an interpretation expert, data acquired by downhole logging tools are translated by computers into useful parameters such as reserves, fluid content of formations, lithology, and rock porosity.

There are two primary levels of data processing and interpretation. The first is at the wellsite for immediate decision making; the second, at field log-interpretation centers or in offices, provides more in-depth analysis of the field data. Communications by satellite transmission between the logging truck at the wellsite and the log data processing centers bring together these levels of analysis and permit well operators away from the scene to participate in wellsite decisions.

CONCLUSION

The role of wireline logging in the petroleum industry has been primarily formation evaluation in which the fundamental questions to be answered are the location of hydrocarbon-bearing formations and an estimation of the amount of hydrocarbon in place. A variety of downhole measurements yields answers to the questions in both open and cased holes. Today, the emphasis in the oil and gas industry is on using cost-effective technologies to maximize production from reservoirs and establish the most economical means of managing reservoir reserves. Wireline logging services contribute to every step of reservoir development from seismic surveys to the final reservoir engineering. □

Mysterious blowhole near Black Butte Ranch

by Larry Chitwood, Geologist, Deschutes National Forest, 1645 Highway 20 East, Bend, Oregon 97701

On December 26, 1987, a cross-country skier discovered a cloud of steam rising out of a small hole in the ground. The area around the hole appeared to have sunk. The site, on Deschutes National Forest land (sec. 16, T. 14 S., R. 9 E.) is near Black Butte Ranch (see location map on next page). The parents of the skier, residents of Black Butte Ranch, immediately contacted the Sisters District Ranger, who quickly convened a small group including this author to look at the site.

Under 4 in. of snow, an area of about 25 ft by 50 ft had subsided by up to 3 ft. Within this area were three holes or pits, each about 3-4 ft across. One (the northernmost) was gently blowing warm, moist air of 58 °F into the cold winter air of 25 °F, producing a small cloud of condensed moisture. Depth of the blowhole was 7 ft, but since the top of the hole had subsided 2 ft, total depth was 9 ft. Foundering slabs of frozen soil 4-8 in. thick produced a miniature landscape of ridges, steep slopes, cracks, and tilted small trees.

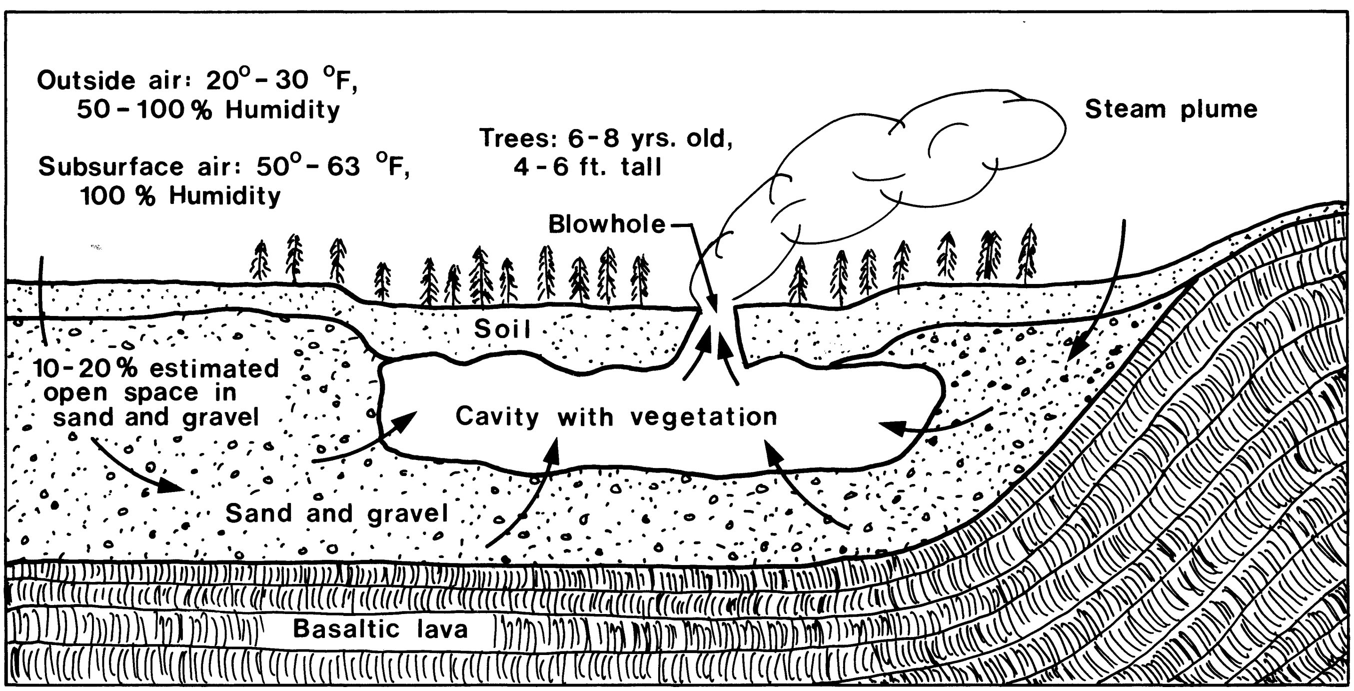
The site was notable for supporting a thick concentration of 6- to 8-yr-old ponderosa pines growing in a strikingly rectangular pattern of about 25 ft by 80 ft. The subsidence area and holes were within this rectangle. Timber harvest in the late 1970's removed most trees at this site and in the vicinity.

The area is a late Pleistocene basaltic lava field of low hills, with sand and gravel filling in many of the low areas of the field. During the latest Wisconsin glaciation, outwash rivers from glaciers north of the Three Sisters flowed through the low areas of the lava field and deposited sand and gravel. The subsiding area is within one of these deposits of sand and gravel.

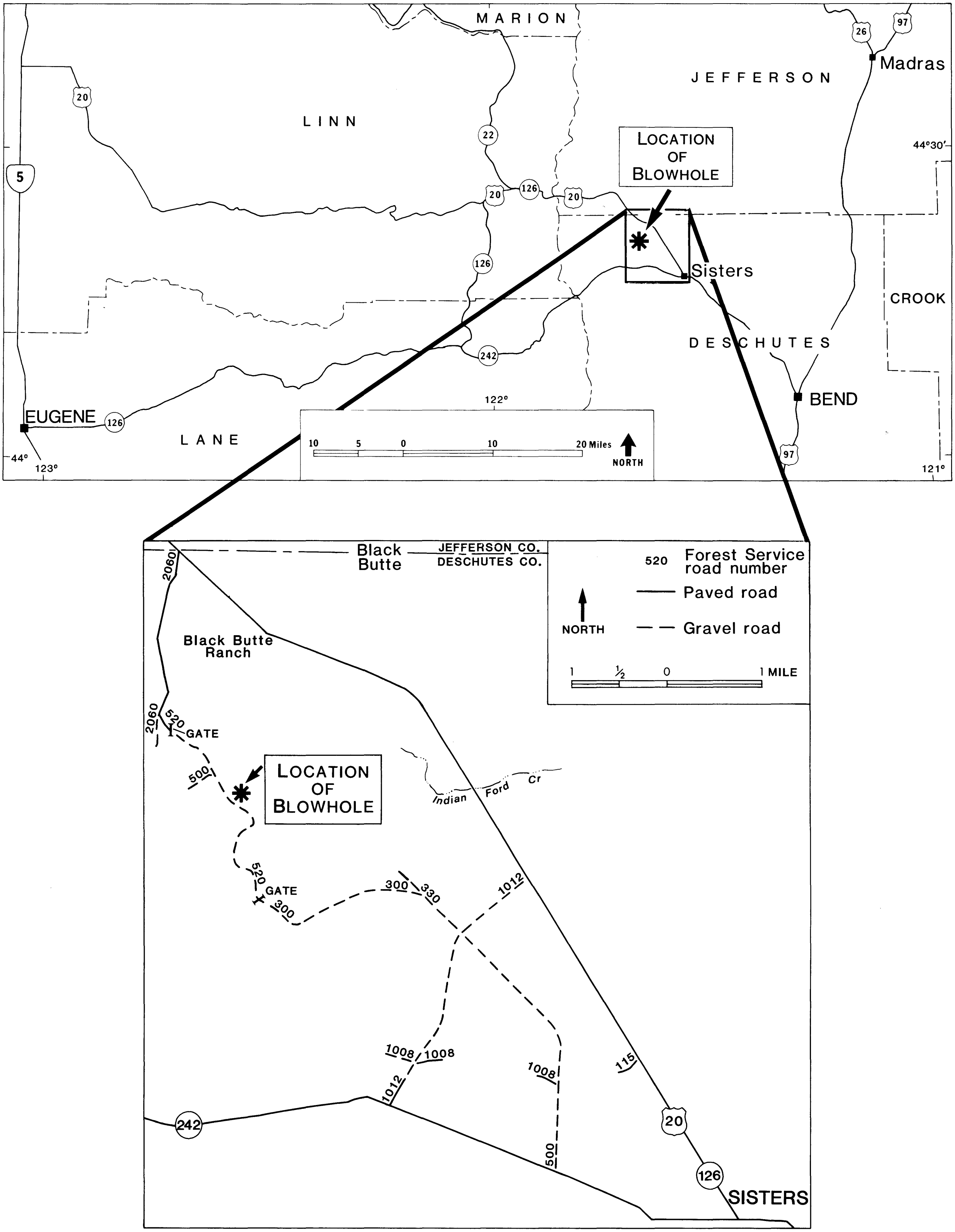
During several weeks of observing and monitoring, the blowhole attracted the most attention. The steam plume and thick coatings of frost on the small pines demonstrated high humidity of the underground air. The air smelled slightly of moist, organic soil. Temperatures of the air were recorded regularly for several weeks and ranged from 50° to 62 °F. A startling temperature of 67 °F, which was reported on January 4, 1988, prompted a quick trip to the site to discover that the glass tube of the thermometer suspended in the blowhole had slipped upwards in its frame by 10°. An air sample taken on January 5 and analyzed by Century Testing Labs of Bend, Oregon, indicated atmospheric composition: oxygen, 20.8 percent; carbon monoxide, <20 ppm; and carbon dioxide <0.2 percent.

During visits by several people, the blowhole was always observed to be blowing, never drawing. The volume of air flowing out varied from almost imperceptible amounts to an estimated 1,000 ft^3 per minute. This is contrary to the flow of air usually observed in caves and water wells in central Oregon. These routinely blow and draw due to changes in atmospheric pressure. When underground air space is large, the pressure within this space attempts to equilibrate with that of the atmosphere through wells and cave openings. Barograph records from December 29, 1987, to January 6, 1988, showed that atmospheric pressure was highly changeable. Consequently, airflow at the blowhole was independent of barometric pressure, indicating that the underground air space accessible through the blowhole was small.

The origin of the subsidence and blowhole had to relate to the existence of subsurface cavities in either (1) the sand and gravel, or (2) the underlying lava, or (3) both. The most likely possibility for creating cavities in sand and gravel is a man-made excavation backfilled with vegetation and soil. In lava, the most likely possibility at this site is a collapsing lava tube. Cavities in both the sand and



Schematic drawing of blowhole system, with arrows showing movement of air. Cool, dense outside air sinks into the ground over a wide area surrounding the blowhole and displaces warmer, less dense subsurface air in open spaces in sand and gravel. Subsurface air moves into vegetation-filled cavity and escapes through blowhole. Escaping subsurface air is saturated with moisture (100 percent humidity). In cool outside air, moisture condenses into steam plume. No steam plume was observed when outside air temperature exceeded 40° F. Data collected January through March 1988.



Map showing location of blowhole.

gravel and the lava could be tectonically induced: a deep crack or fissure could be opening. This possibility suggests impending volcanic activity. All three possibilities were seriously considered, but impending volcanic activity was considered to be highly unlikely.

As the subsidence incident developed, people who visited the site began to express their desires for a preferred outcome of the investigation. Certainly the most popular was that of a collapsing lava tube. Here, imagination and scientific interest could be served simultaneously. The backfilled-excavation idea was not popular; it was untidy and suggested unfinished business. The prospect of volcanism was most unpopular and frightening, since the site was very close to a developed area.

Only after snow melted from the site in February was the origin of the subsidence and blowhole confirmed. Fresh, gray, unweathered clasts of gravel were scattered over the entire surface of the 25-ft by 80-ft area that was so clearly marked by the rectangle of young trees. On the surface beyond the rectangle were yellow to tan gravel clasts typical of the upper 3 ft of soil in this area. Clearly, the subsidence site had been excavated to a depth of at least 9 ft, backfilled most likely with logging slash (tree branches, limbs, and tops) and/or stumps, then thinly covered with a homogenized mixture of topsoil, sand and gravel. The thin covering of soil had collapsed into the open spaces of the buried vegetation. The rectangle of young trees marks the excavated area, and the trees germinated and thrived in the disturbed soil. The subsidence occurred only days or weeks before December 26, because the ground had only recently frozen and had subsequently broken up during subsidence.

When the blowhole formed, it acted like a chimney; in fact, one might call it an artesian air well. The relatively warm, moist underground air rose out of the hole into the cold winter air to form a thin steam plume. Air escaping from the hole was probably replaced by air drawn from the moist, fine web of interstitial passages in the surrounding sand and gravel. This local circulatory system was too small to be affected by barometric pressure changes but large enough to provide sustained heat from past summers to drive the convecting system.

Thus, several weeks of systematic observation brought the puzzle of the blowhole to a conclusion that neither satisfied the most popular expectations nor supported imaginative ideas of a frightful volcanic eruption. The blowhole was indeed the result of the imperfect backfilling of an old excavation and did not represent a threat to anyone.

Residents of central Oregon are generally aware that the remarkable landscape of this area was produced mainly by volcanism and glaciation. Occasionally, when a weather front approaches the Cascades, people are quick to notice "banner clouds" at the tops of volcanic peaks. These give the striking appearance of a steam eruption in progress and, far away as they are, inspire imaginative visions of volcanic activity. But when strange clouds rise in one's own backyard, concerns are immediate and serious and need responsible actions and answers. □

Watershed enhancement progresses

The 1987 Legislature created the Governor's Watershed Enhancement Board and provided it with $500,000 in grant money. The money is to be used during a two-year period to help Oregonians improve severely degraded streamside areas and associated uplands. One of the criteria for funding is that a project would demonstrate the benefits of watershed enhancement to the public. Benefits can be decreased streambank erosion, improved water quality, and, in some areas, the return of year-round streamflow.

With its meeting in May, the Board concluded the grant award period; applications for funding improvement projects are no longer accepted. The Board received 60 applications from private individuals, organizations, and government agencies and, since February 1988, has awarded over $370,000 to 17 projects. The Board will request additional grant money from the 1989 Legislature for continuing the program through 1991.

The following describes the five projects approved for funding at the Board's May meeting:

1. The Lakeview Soil and Water Conservation District plans to rehabilitate 6 mi of the Chewaucan River above the City of Paisley in Lake County. The Chewaucan River is tributary to Lake Abert. The project includes juniper and rock riprap, instream rock placement, vegetation planting, and a livestock control program. The project is an extension of similar improvements completed by the USDA Forest Service and the Oregon Department of Fish and Wildlife on other reaches of the river. State, federal, and local agencies and the landowner are cooperating in the project. Volunteer labor will be provided by the Paisley Future Farmers of America. Funds granted are $21,700.

2. The Siskiyou Wheelmen, a volunteer group, will rehabilitate a road bank severely degraded by motorcycle and bike riding. The group, in cooperation with the USDA Forest Service, will place physical barriers on the cut slopes to minimize the amount of sediment flowing into the Ashland Creek watershed and into Reeder Reservoir. The reservoir is the City of Ashland's municipal water supply. Funds granted are $1,450.

3. The U.S. Bureau of Land Management will implement a livestock management program to exclude cattle migration into the Whitehorse Creek basin. The project site is in southeastern Oregon near the border of Malheur and Harney Counties. Volunteer groups, such as the Oregon Natural Resources Council, the Izaak Walton League, Trout Unlimited, the National Wildlife Federation, and the Wilderness Society will provide up to 60 percent of the installation work. Funds granted are $18,000.

4. The Lincoln Soil and Water Conservation District will carry out a project that is part of the 1987 Devil's Lake Coordinated Resource Management Plan. The project consists of fencing streambanks on Rock Creek to exclude cattle and allow riparian vegetation to become established. The riparian zone filters out and accumulates erosion sediments and nutrient runoff from Rock Creek which are major sources of pollution to Devil's Lake. Many government agencies, private landowners, and organizations are cooperating in the project. Funds granted are $3,000.

5. The Grant Soil and Water Conservation District was given partial funding for its watershed enhancement project on the upper South Fork John Day River. The $80,000 project is aimed at rehabilitation of 9 mi of stream to prevent erosion and includes fencing, vegetation planting, bank shaping, and structures for water management. The project also includes plans for fish habitat improvement and range improvement by brush control, fencing, and seeding. Funds granted are $10,000.

The Board also has approved about $43,000 for a public-awareness and education program. Planned for this program and aimed at a variety of audiences are speaking tours and slide presentations on watershed enhancement benefits.

—News release of the Governor's Watershed Enhancement Board

Current deposition of metals on sea floor has ancient counterpart

Sulfides being deposited on the sea floor at ocean spreading centers are thought to be modern equivalents of on-land massive sulfide deposits formed tens to hundreds of millions of years ago and containing some of the world's largest deposits of base metals, according to a U.S. Geological Survey (USGS) scientist.

Sulfides are mineral compounds characterized by the linkage of sulfur with metallic elements. Many of the known on-land sulfide deposits have been mined for gold and silver.

"Modern-day analogs to these ancient deposits of copper, zinc, and lead may be currently forming along the ridge crests of spreading centers on the ocean floor, where Earth's crust is being pulled apart and volcanic material is welling up from below to fill the void," says USGS geologist Randolph A. Koski.

Spreading centers where sulfide deposition is occurring include areas in the U.S. Exclusive Economic Zone (EEZ) off the West Coast, such as the Gorda Ridge. U.S. jurisdiction over the EEZ was proclaimed in 1983, including rights to mineral recovery from the ocean floor.

Koski says that the study of how these modern sulfide deposits are forming could help in exploration for onshore deposits. "The study of modern sea-floor sulfides at mid-ocean ridges provides insight into the structural settings and hydrothermal processes that favor sulfide deposition," Koski says. "For instance, we now know that variations in occurrence and composition of these hydrothermal sulfides along ridge crests are largely controlled by sub-sea-floor porosity and structure as well as the nature of fluid-wallrock interactions." He explains that getting a better understanding of what causes and controls the deposition of sulfides on the ocean floors will give us a better understanding of how the now-onshore deposits were formed in ancient seas and what the best places are to explore for onshore sulfide deposits.

Koski is one of three USGS scientists each presenting a series of Bradley lectures at major USGS centers around the nation in 1988. He was selected for the honor by the USGS assistant chief geologist for the Western Region, with headquarters in Menlo Park, California. Similarly, two other scientists were selected as Bradley lecturers: Robert Schuster from the Central Region (headquarters in Denver, Colorado) and Bruce Wardlaw from the Eastern Region (headquarters in Reston, Virginia).

The lectures were named in honor of Wilmot Hyde Bradley, who worked for the USGS from 1920 to 1969 and who served the longest term, from 1944 to 1959, of any USGS chief geologist since the agency was established 109 years ago. The purpose of the Bradley lectures is to make USGS scientists and others aware of significant research and activities of the USGS Geologic Division.

—USGS news release

UNR issues call for papers

The Mining and Engineering Division of the University of Nevada-Reno (UNR) Continuing Education Program has announced a symposium on engineering geology and geotechnical engineering and issued a call for papers.

The Engineering Geology and Geotechnical Engineering 25th Anniversary Symposium, sponsored by the UNR Civil Engineering and Geological Sciences Departments and the Division of Continuing Education, will be held March 20-23, 1989, on the UNR campus in Reno.

Papers are requested for the following topics: Waste management and design for nuclear and chemical waste; geophysical and in-situ methods of site characterization; geotechnical applications of geostatistics and probability; engineering solutions to geologic hazards; earthquake engineering; foundation engineering; highway materials and pavement design; and case histories. Other topical areas of geotechnology will be welcome.

Preliminary abstracts (one-page limit) are due August 15, 1988, to Dr. Bob Watters, Proceedings Editor, Mackay School of Mines, University of Nevada-Reno, Reno, NV 89557, phone (702) 784-6069.

For further information about the symposium, contact Engineering Symposium, Division of Continuing Education, University of Nevada-Reno, Reno, NV 89557-0024, phone (702) 784-4046.

—UNR news release

Coos Bay collection on display at State Capitol

The display case of the Oregon Council of Rock and Mineral Clubs (OCRMC) at the State Capitol in Salem is currently filled with an exhibit installed by Bert Sanne and Cecelia Haines representing the Far West Lapidary and Gem Society of Coos Bay. More than 100 separate items, all from Bert Sanne's own extensive collection, exemplify rocks from 11 Oregon counties.

Featured on the center shelves of the display case are a working rhodonite clock—pink rhodonite from Josephine County—and lighted lamps made from Carey plume and polka dot agate and encased in myrtlewood frames. The top shelves display Biggs jasper, Graveyard Point plume agate, Blue Mountain jasper, Crook County limb casts, and petrified-wood cabochons. Lower shelves show rough, tumbled, and faceted Oregon sunstones, Holley Blue specimens and two Holley Blue rings, sagenite, Paiute jasper, Vistaite, thunder eggs from Crook, Wheeler, and Malheur Counties, Stinking Water Mountain wood, carnelian, and Eagle Rock and Priday plume agates.

The display will remain in place until September and will be followed by an exhibit furnished by the Trail's End Gem and Mineral Club of Astoria.

—OCRMC news release

U.S. Geological Survey funds Oregon earthquake study

In March 1988, the Oregon Department of Geology and Mineral Industries (DOGAMI) was awarded a $75,000 grant for the continuation of its earthquake studies through 1988. The grant comes from the National Earthquake Hazard Reduction Program that is administered by the U.S. Geological Survey (USGS).

"In recent months, the earthquake potential in Oregon has been increasingly in the news," said DOGAMI geologist Ian Madin, who works in the Department's earthquake study project. "This increased awareness in the public," he said, "reflects new geological research that suggests that earthquake hazards in Oregon may be greater than we previously believed."

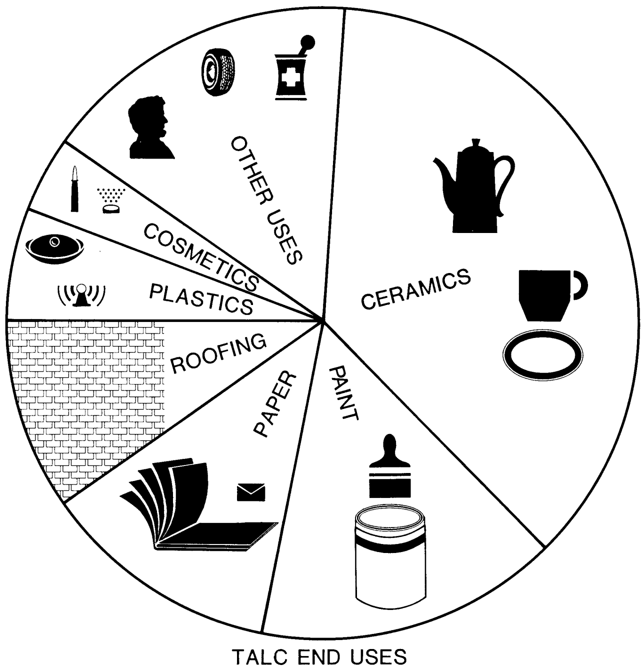
The grant was awarded for the continuation of a multi-year, joint DOGAMI-USGS program begun in November 1987 with an initial grant of $25,000. The program seeks to define and reduce earthquake hazards in the Portland metropolitan area through geologic research and mapping and by encouraging public and private hazard mitigation efforts.

The program is planned to continue through 1991, and an additional $300,000 in USGS funding is proposed for 1989-1991.

—DOGAMI news release

First report on talc in Oregon available

A comprehensive report on talc in Oregon, its formation, occurrences, and uses, has been published by the Oregon Department of Geology and Mineral Industries (DOGAMI). The study is intended to serve as a basis for further study and development of talc as an industrial-mineral resource in Oregon's economy.



Pie diagram from cover of Special Paper 18 shows industrial uses of talc.

Investigations of talc in Oregon, by DOGAMI geologists Mark L. Ferns and Len Ramp, has been released as DOGAMI Special Paper 18. It is the first comprehensive report devoted to this commodity alone and includes the results of two years of field study by the authors, as well as some information that so far had been available only in unpublished DOGAMI files. The 52-page report identifies and describes more than 100 separate talc occurrences in the state. Numerous tables present a variety of analyses of samples to characterize the deposits and their economic potential.

Until now, the only commercial use of Oregon talc has been the production of carving-grade soapstone. However, the report identifies occurrences that may have economic potential for other uses also.

The new report is now available at the DOGAMI office in Portland. The price is $7. Orders under $50 require prepayment.

—DOGAMI news release

Oregon SMAC publishes user guide

The Geographic Information Systems (GIS) Committee of the Oregon State Map Advisory Council (SMAC) has published a guide for access to, and information about, organizations in Oregon that are involved in computer-stored geographic data.

Oregon Geographic Information Systems User Reference Guide is a brochure listing 28 federal, state, local, and private agencies and organizations, their addresses and contact persons; in addition, it presents summaries of the kinds of computer hardware and software these organizations use, the geographic areas they cover, and the nature of the mapping data they generate. The list of participating organizations includes such bodies as, for example, the State Department of Transportation, the U.S. Army Corps of Engineers, Benton County Public Works, and Portland General Electric Company.

The guide was produced from information contained in the index to digital mapping data that is found under ORMAP in the Oregon State Library's on-line Public Access Catalog. It provides general information about an area of technology resources that changes continually and rapidly. With it, the GIS Committee hopes to promote the effective use of geographic information technology and to enhance the management of Oregon's natural and social environment.

More detailed information about ORMAP is available from Dick Myers, State Library, phone (503) 378-4368; and about hard-copy maps, aerial photography, and other indexes from Glenn Ireland, U.S. Geological Survey, phone (503) 231-2019. □

Analyses of sediment-samples from continental shelf released

The elements titanium and chromium were among the most abundant of 26 elements analyzed in a study of sediment samples from the continental shelf off the coast of Oregon and northernmost California, according to a report released by the Oregon Department of Geology and Mineral Industries (DOGAMI).

Elemental content of heavy-mineral concentrations on the continental shelf off Oregon and northernmost California, by L.D. Kulm and C.D. Peterson of Oregon State University (OSU), has been released as DOGAMI Open-File Report O-88-4. It was funded in part by the U.S. Minerals Management Service through the Bureau of Economic Geology, University of Texas at Austin, Continental Margins Program, and administered by DOGAMI. Additional funding was provided by the OSU Sea Grant Program and the Oregon Division of State Lands.

The 29-page report presents the results of Instrumental Neutron Activation Analysis (INAA) of 73 sediment samples selected mostly from the OSU College of Oceanography archives. The samples had been taken from the top 40 centimeters of sand and mud sediments on the ocean floor in water depths between 17 and 200 meters.

According to the report, the highest chromium values, up to 7 weight percent of the opaque-mineral concentrate, were found on the inner shelf from Coos Bay, Oregon, to northern California. The largest quantities of titanium, up to 23 weight percent of the opaque-mineral concentrate, were found on the inner shelf between Tillamook and Cape Blanco, Oregon. However, the deposits have not been drilled, and complete evaluation would require deeper sampling.

Concentrations of heavy minerals, such as chromium-bearing chromite and titanium-bearing ilmenite, and of heavy metals, particularly gold and platinum, have been known to occur in coastal regions onshore as placer deposits and black sands. They were mined for gold as early as 1850 and for chromite and ilmenite in 1943, during mineral shortages of World War II. The concentrations of heavy minerals found in the surface sediments of the continental shelf suggest that there may be similar ancient beach placers deeper down in the shelf sediments as well.

The new release, DOGAMI Open-File Report O-88-4, is available at the DOGAMI Portland office. The price is $5. Orders under $50 require prepayment.

—DOGAMI news release

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that we feel are of general interest to our readers.

THE MESOZOIC STRATIGRAPHY, DEPOSITIONAL ENVIRONMENTS, AND TECTONIC EVOLUTION OF THE NORTHERN PORTION OF THE WALLOWA TERRANE, NORTHEASTERN OREGON AND WESTERN IDAHO, by Patrick M. Goldstrand (M.S., Western Washington University, 1987)

Mesozoic rocks exposed along the Snake River in the northern Wallowa terrane represent portions of a volcanic island and associated intra-arc sedimentary basins within the Blue Mountains island arc of Washington, Oregon, and Idaho. In the northern portion of the Wallowa terrane, rock units include the Wild Sheep Creek, Doyle Creek, and Coon Hollow Formations, the Imnaha intrusion (informal name), and the Dry Creek stock (informal name).

The volcanic rocks of the Ladinian to Karnian Wild Sheep Creek Formation show two stages of evolution, an older dacitic phase (lower volcanic facies) and a younger mafic phase (upper volcanic facies). The two volcanic facies are separated by turbidites of the argillite-sandstone facies. The two magmatic phases that occur in the Wild Sheep Creek Formation may by represented by the compositional changes from older quartz diorite to younger gabbro in the Imnaha intrusion. The Imnaha intrusion may be a subduction-related pluton and is a likely source for the Wild Sheep Creek volcanic rocks. Interbedded with the upper volcanic facies are debris flows (sandstone-breccia facies) and carbonate platform deposits (limestone facies). Sedimentary structures in the Wild Sheep Creek Formation indicate a shoaling to subaerial volcanic island to the south and southeast.

The Karnian Doyle Creek Formation consists of epiclastic turbidites with interbedded vitric tuffs. Quartz diorite clasts in this formation indicate uplift and erosion of part of the Imnaha intrusion during the later emplacement of the gabbroic portion of the intrusion.

Between the Early and Late Jurassic (Oxfordian), the northern Wallowa terrane was uplifted and tilted. Clastic rocks of the Coon Hollow Formation represent transgressional nearshore to offshore (sandstone-conglomerate facies) and progradational outer-fan to mid-fan environments (flysch facies). Radiolarian chert clasts in the flysch facies indicate a different source for this unit than the underlying stratified rocks of the Wallowa terrane.

Paleocurrent data and radiolarian fossils suggest that the Baker terrane was the source for the chert clasts. This chert source constrains the timing of the amalgamation of the Wallowa and Baker terranes to the Oxfordian. The amalgamation of these terranes during the Late Jurassic may be associated with initial accretion of the Blue Mountains island-arc complex with the western margin of North America. Uplift and extension was associated with this collisional event, and hornblende-diorite dikes and sills intruded the Wallowa terrane. After this intrusive event, compression and regional metamorphism to the lower greenschist facies occurred during the Late Jurassic. Also associated with the collisional event was the intrusion of a pyroxene-hornblende diorite stock (Dry Creek stock), which intruded the Wallowa terrane to shallow depths and has a K-Ar age of 139.5 ± 2.1 Ma.

Accretion was complete by the Early Cretaceous with the suturing of the terranes of North America by plutons associated with the Wallowa Batholith. 130-Ma plutons which intrude the Blue Mountains island arc show 66° of clockwise rotation which may be related to Basin and Range extension.

Although the Wallowa and Wrangellia terranes formed in different tectonic environments, paleomagnetic and faunal evidence suggests a spatial relationship between the two terranes during the Late Triassic. The Wallowa terrane may represent a volcanic arc originally situated to the east of the Wrangellia back-arc. If the terranes traveled with the Farallon Plate, the Wallowa terrane docked before and north of the Wrangellia terrane, and subsequent oblique convergence of the Kula and North American Plates initiated Sumatra-type strike-slip faulting to move Wrangellia outboard and northward of the Wallowa terrane.

TEXTURAL AND MINERALOGICAL CHARACTERISTICS OF ALTERED GRANDE RONDE BASALT, NORTHEASTERN OREGON: A NATURAL ANALOG FOR A NUCLEAR WASTE REPOSITORY IN BASALT, By Paul M. Trone (M.S., Portland State University, 1987)

Altered flows that are low-MgO chemical types of the Grande Ronde Basalt crop out in the steep walls of the Grande Ronde River canyon near Troy, Wallowa County, Oregon. The alteration effects in these flows are being investigated as a natural analog system to a high-level nuclear waste repository in basalt. The flows within the study are referred to as the analog flow, in which the alteration effects are the strongest, and the superjacent flow. The analog flow crops out at Grande Ronde River level, and a roadcut-outcrop is developed in the flow-top breccia of this flow. The two flows have been divided into flow zones based on intraflow structures observed in the field and primary igneous textures observed in this section. These zones include, from the base upward, the flow-interior, transition, and flow-top breccia zones of the analog flow, the interflow contact zone, and the flow-interior and flow-top breccia zone of the superjacent flow. The intraflow structures and textures of the transition and interflow contact zones are atypical of Grande Ronde Basalt flows. The transition zone is transitional in textures between the flow-interior zone and flow-top breccia zone and includes holocrystalline spines mantled with fused *in situ* breccias. The interflow contact zone reflects the dynamic interaction during the emplacement of the superjacent flow manifested as invasive basalt tongues; clasts shed from tongues, pipe vesicles, and tree molds; and pockets of breccia caught up in the base of the superjacent flow.

The characteristics of the porosity are distinct among flow zones. In the flow-interior zones the porosity is dominated by horizontal platy and vertical joint-related fractures. Vesicles and diktytaxitic cavities are a very minor contribution to the overall porosity and are somewhat isolated in contrast to the fractures, which are highly interconnected.

Low within the transition zone the porosity is similar to the flow-interior zone. High in the zone, the porosity includes vesicles in resorbed clasts and surrounding incipient breccia clasts. The porosity and extent of interconnection increases laterally outward from the spines in the fused *in situ* breccia as interclast voids increase in size and abundance.

The flow-top breccia zone and brecciated portion of the interflow contact zone are the most porous zones due to large interclast voids. Vesicles and diktytaxitic cavities are the porosity in these flow zones.

In the solid portion of the interflow contact zone the porosity is provided by platy fractures, large flattened vesicles, tree molds, and pipe vesicles.

Secondary minerals occur as replacements of primary phases and as precipitated phases in primary porosity. The variety of secondary minerals precipitated in vesicles and diktytaxitic cavities from aqueous solutions is greatest in the flow-top breccia and interflow contact zones and includes clay minerals, zeolites, silica minerals, and carbonate. The clay minerals include smectite and celadonite; zeolites include clinoptilolite, phillipsite, and chabazite; silica minerals include quartz, chalcedony, opal-CT lepispheres, and opal-CT; and the carbonate is calcite. The paragenetic sequence is clay minerals→silica minerals→zeolites→carbonate→silica minerals→clay minerals. The individual mineral species differ among the two flow zones. Celadonite, chalcedony, and quartz are the major secondary minerals in the interflow contact zone, whereas smectite, clinoptilolite, and opal-CT are the major minerals occurring in the flow-top breccia zone.

The differences in the secondary mineral suite, assemblages, and parageneses among the flow-top breccia and interflow contact zones are attributed to solution-composition differences. Assuming the basalt is inert to altering solutions, and the solution composition is not influenced by the relative proportions of glass and crystalline phases in the basalt or water/rock ratios, the differences in solution composition are reasonably explained if a thermal gradient is assumed present during alteration. A geothermal gradient, even if elevated above the assumed present-day gradient, is not sufficient to produce the alteration effects. An elevated gradient related to the cooling of superjacent flow is necessary.

RADIOLARIA FROM THE OTTER POINT COMPLEX (OREGON) AND THE VOLCANO-PELAGIC STRATA ABOVE THE COAST RANGE OPHIOLITE (CALIFORNIA), by Christopher L. Garey (M.S., University of Texas at Dallas, 1987)

Radiolaria from the Otter Point complex (southwestern Oregon) indicate that the unit ranges in age at least from late Kimmeridgian (Late Jurassic) to Berriasian-earliest Hauterivian (Early Cretaceous). The studied radiolaria, when analyzed from a paleolatitudinal perspective, indicate that portions of the Otter Point were deposited in near-equatorial waters. Many new radiolarian forms are presented and described from Otter Point cherts and limestone.

Radiolaria from the volcano-pelagic strata associated with the Coast Range ophiolite near Black Mountain, Sonoma County, California, indicate that the tuffaceous beds there are folded synclinally. The radiolaria were analyzed from a paleolatitudinal standpoint, and relative ages of the faunas from these analyses indicate the attitudes of the beds. All samples containing radiolaria from this locality were determined to be from Zone 2 of Pessagno (Kimmeridgian), and many new forms are presented and described.

STRATIGRAPHY AND STRUCTURE OF THE WESTERN TROUT CREEK AND NORTHERN BILK CREEK MOUNTAINS, HARNEY COUNTY, OREGON, AND HUMBOLDT COUNTY, NEVADA, by Scott Alan Minor (M.S., University of Colorado, 1986)

The area of study, which is 325 km^2 in extent, is located in the western Trout Creek and northernmost Bilk Creek Mountains along the Oregon-Nevada border, within the northwestern Basin and Range province.

The oldest rocks in the area consist of Cretaceous metamorphic and granitic intrusive rocks, which are nonconformably overlain by a 1,400-m-thick, 15.6-15.8-m.y. -old volcanic/pyroclastic sequence. More than 80 basaltic flows comprise the lower 750 m and, on the basis of a magnetostratigraphic study, have been correlated with the Steens Basalt. The upper part of the sequence primarily consists of four compositionally zoned ash-flow tuff sheets that vented from nearby calderas. The youngest (13.4-15 m.y.?) Tertiary rocks in the area consist of a thick (1,300 m) sequence of tuffaceous and conglomeratic sedimentary rocks.

A north-northwest-trending structural grain, which characterizes the study area, is expressed by numerous, closely spaced (<2 km), relatively large-displacement (1-3 km), north-northwest-striking normal faults and north-northwest-striking tilted fault blocks. Locally north-northeast-trending normal faults are present that truncate, are truncated by, or curve into faults of the other trend, indicating an equivalent age. Most of the north-northwest-trending faults dip from 25° to 60° at the surface, and many are inferred to be listric faults. Fault-to-bedding angles indicate that some of these faults were tilted to lower angle dips during deformation. Fault-slip data from small-displacement faults suggest that nearby major faults have experienced largely dip-slip displacement. The spatial distribution of tilted fault blocks, which dip as much as 60°, defines a broad, structurally disrupted anticlinal uplift with an axis that trends north-northwest and plunges towards the north-northwest. The directions of dip and the concavity of listric faults are toward the core of the anticline. Minor deformation occurred in the southwestern part of study area 15.8 m.y. ago during eruption of the basaltic flows. Major uplift and faulting occurred throughout the area about 14-15 m.y. ago; deformation may have continued intermittently up to recent time. Stresses associated with both the shallow emplacement of magma along a north-northwest-trending zone of weakness and Basin-Range regional extension may have caused the deformation.

PALEOCURRENT ANALYSIS OF THE CRETACEOUS MITCHELL FORMATION, NORTH-CENTRAL OREGON, by Craig A. Sandefur (M.S., Loma Linda University, 1986)

Cretaceous sedimentary rocks of north-central Oregon, known as the Hudspeth and Gable Creek Formations and here informally subsumed under the name "Mitchell Formation," are potential petroleum-source and reservoir rocks. Thus, determining their extent under the cover of Tertiary volcanic rocks is of great importance to future petroleum exploration in the southern half of the Columbia basin. The direction of sediment transport has been previously studied by several workers with contradicting results and conclusions. The primary objective of this research was to expand the paleocurrent analysis using both macro- and micro-fabric to provide additional evidence of sediment-transport direction. This information allows a better prediction of the extent, thickness, and petroleum potential of the marine Cretaceous rocks.

From field study of both sedimentary structures and gross lithology my work reconfirms that these sediments are part of a subsea fan complex consisting of fan-apron-facies turbidites and mudstones (Hudspeth mudstone facies) and channel-facies conglomerates and sandstones (Gable Creek sandstone-conglomerate facies). Sole marks, flute casts, pebble imbrication, and alignment of plant fragments indicate that sediment transport was generally from south to north into a northeast-southwest elongate basin. These results suggest that the greatest potential for petroleum production from Cretaceous sediments in north-central Oregon lies in restricted rift-type basins such as those in the surrounding area of Mitchell.

MATURATION, DIAGENESIS, AND DIAGENETIC PROCESSES IN SEDIMENTS UNDERLYING THICK VOLCANIC STRATA, OREGON, by Neil S. Summer (M.S., University of California-Davis, 1987)

Data from three drill holes in Oregon in areas where sediments are mantled by thick sequences of volcanic rocks suggest that the sediments were subjected to an unusual diagenetic history. Anomalous, near-constant maturation levels in sedimentary sequences over 4,000 ft thick indicate that the levels of thermal maturation in organic matter below the volcanic cover were sufficiently high to have generated hydrocarbons.

Study of the mineral diagenesis of these sediments shows that they have been transformed to low-grade metamorphic rocks equivalent to the zeolite facies. The diagenetic mineral assemblage, consisting of sphene, chlorite, illite, and quartz, is nearly constant throughout the drillholes studied and corresponds to temperatures of about 170° -190 °C. The consistency of the authigenic mineral assemblage in four different rock types can be interpreted to be the result of the movement of geothermal fluids through the strata. A hydrothermal mechanism is considered to be the most effective form of thermal input. Isothermal temperature fields can result from the influx of heat from a perched geothermal aquifer flowing in an overlying porous stratum with the steady-state geothermal gradient. These isothermal conditions may have lead to the anomalous vitrinite-reflectance profiles and the common authigenic mineral assemblage.

The cooling of extrusive volcanic material and the exothermic hydration reactions associated with the altering volcanic material can also be considered viable mechanisms of thermal input, resulting in constant maturation profiles. The lavas and tuff could not only have supplied heat to the sediments upon cooling but could have provided aquifer horizons that allowed extensive lateral flow of thermal fluids. The most likely source of thermal fluids would be intrusive bodies possibly associated with a pre-eruptive, intrusive stage of Columbia River basalts. Thus heat from the intrusives would have caused regional effects that extended far beyond those of the solely conductive metamorphic effects.

Nearly all of the published and unpublished vitrinite reflectance data from sediments overlain by thick volcanic strata in Oregon and Washington have anomalous near-constant profiles. This implies a systematic phenomenon which has broad implications for oil and gas exploration in the Pacific Northwest. Relatively organic-poor sedimentary sequences may provide significant amounts of hydrocarbon due to the fact that much larger volumes of thermally mature rock are involved. In addition, migration vectors may be assessed by study of the fossil hydrology and authigenic mineralization of the volcanically-lidded basins of the Pacific Northwest. □

***(Dry Creek**, continued from page 82)*

Kittleman, L.R., Jr., 1962, Geology of the Owyhee Reservoir area, Oregon: Eugene, Oreg., University of Oregon doctoral dissertation, 174 p.

Kittleman, L.R., Green, A.R., Hagood, A.R., Johnson, A.M., McMurray, J.M., Russell, R.G., and Weeden, D.A., 1965, Cenozoic stratigraphy of the Owyhee region, southeastern Oregon: Eugene, Oreg., University of Oregon Museum of Natural History Bulletin 1, 45 p.

Lorenz, V., 1970, Some aspects of the eruption mechanism of the Big Hole maar, central Oregon: Geological Society of America Bulletin, v. 81, no. 6, p. 1823-1829.

———1973, On the formation of maars: Bulletin Volcanologique, v. 37, no. 2, p. 183-204.

———1975, Formation of phreatomagmatic maar-diatreme volcanoes and its relevance to kimberlite diatremes, *in* Ahrens, L.H., Dawson, J.B., Duncan, A.R., and Erlank, A.J., eds., Physics and chemistry of the Earth 9: Oxford, UK, Pergamon Press, p. 17-27.

———1985, Maars and diatremes of phreatomagmatic origin: A review: Geological Society of South Africa Transactions, v. 88, p. 459-470.

Seager, W.R., 1987, Caldera-like collapse at Kilbourne Hole maar, New Mexico: New Mexico Geology, v. 9, no. 4, p. 69-73.

Walden, K.D., 1986, A stratigraphic and structural study of Coal Mine Basin, Idaho-Oregon: East Lansing, Mich., Michigan State University master's thesis, 70 p.

Walker, G.P.L., 1984, Characteristics of dune-bedded pyroclastic surge bedsets: Journal of Volcanology and Geothermal Research, v. 20, no. 3/4, p. 281-296.

Wohletz, K.H., and Sheridan, M.F., 1983, Hydrovolcanic explosions II. Evolution of basaltic tuff rings and tuff cones: American Journal of Science, v. 283, no. 4, p. 385-413.

Wolfe, J.A., 1980, Fluidization versus phreatomagmatic explosions in breccia pipes: Economic Geology, v. 75, no. 7, p. 1105-1109.

———1986, Breccias related to explosive volcanism: Journal of Southeast Asian Earth Sciences, v. 1, p. 63-79.

Womer, M.B., Greeley, R., and King, J.S., 1980, The geology of Split Butte—a maar of the south-central Snake River Plain, Idaho: Bulletin Volcanologique, v. 43, no. 3, p. 453-471.

———1982, Phreatic eruptions of the Eastern Snake River Plain of Idaho, *in* Bonnichsen, B., and Breckenridge, R.M., eds., Cenozoic geology of Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 453-464. □

***(Oil and gas**, continued from page 74)*

withdrawal well is used to add gas to and remove gas from the storage reservoir. Oregon Natural Gas Development plans to drill five gas-storage wells at Mist this year.

In addition, ARCO began exploratory drilling at Mist during June, the start of a multi-well program planning six to twelve wells with depths generally of 2,000-3,500 ft.

Operations begin at Morrow County well

ARCO has begun drilling preparations at the Hanna 1 drill site located in the NE¼ sec. 23, T. 2 S., R. 27 E., Morrow County, about 6 mi northeast of Heppner. This is a proposed 9,000-ft wildcat well in eastern Oregon's Columbia Basin and will drill through rocks of the Columbia River Basalt Group to test underlying Tertiary rocks which are interpreted to have favorable conditions for hydrocarbon generation and entrapment.

View south from Peak 3238, showing approximate drill site for the ARCO Hanna 1 well, 6 mi northeast of Heppner in Morrow County.

DOGAMI plans Tyee Basin natural-gas study

The Oregon Department of Geology and Mineral Industries (DOGAMI) plans to conduct a 5-year study of the natural-gas resource potential of the Tyee Basin in western Douglas and eastern Coos Counties. This area has geologic similarities to the producing Mist Gas Field area in Columbia County. The study will investigate the geologic factors in the Tyee Basin that are necessary for gas generation and entrapment.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
407	ARCO Columbia Co. 24-9-64 36-009-00241	SE¼, sec. 9 T. 6 N., R. 4 W. Columbia County	Application, 2,260.
408	ARCO Claruth-Franbea-Willna 12-15-64, 36-009-00242	NW¼, sec. 15 T. 6 N., R. 4 W. Columbia County	Application, 2,225.
409	ARCO Benson 14-7-64 36-009-00243	SW¼, sec. 7 T. 6 N., R. 4 W. Columbia County	Application, 2,175.
410	ARCO CFI 23-16-64 36-009-00244	NW¼, sec. 16 T. 6 N., R. 4 W. Columbia County	Application, 1,775.

□

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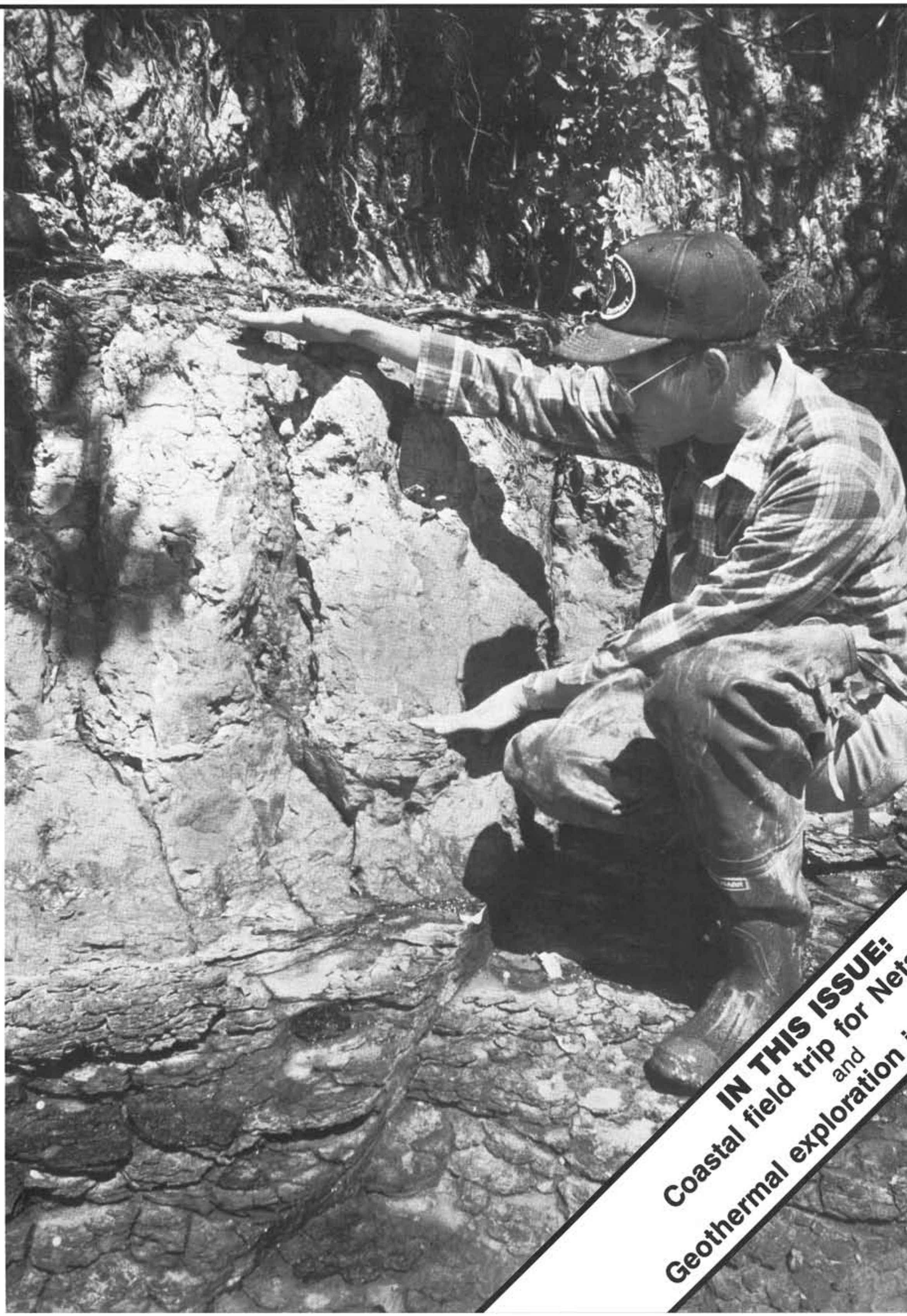

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and
Geothermal exploration in Oregon, 1987

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Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Coauthor Mark Darienzo kneeling on a buried forest horizon and using his hands to indicate two other buried horizons above the first at Netarts Bay. Article and field trip guide beginning on next page present evidence of episodic abrupt coastal subsidence associated with convergent margin seismicity along the Oregon coast.

MLR announces changes in rules and procedures

As a result of recent legislative action (Oregon House Bills 2039 and 2041) and resultant changes in Division 30 rules, the following changes for holders of mining permits administered by the Mined Land Reclamation Program (MLR) of the Oregon Department of Geology and Mineral Industries have come into effect:

1. Bond reduction. If a permit holder (a) has conducted a mining operation at a permitted site for a minimum of 10 years without any substantial violations and (b) can demonstrate the financial ability to perform the reclamation required in the approved reclamation plan, then the permit holder is eligible to apply for a reduction in bond by an amount not to exceed 50 percent of the actual cost of reclamation estimated for the eventuality that the Department were to perform the reclamation.

The Department and industry interpret the condition of "no substantial violation" to mean that the operator has not willfully violated the approved reclamation plan or any operating provision of the pertinent statutes (ORS 517.750 - 517.900) and has a record of quick corrective response when notified of a noncompliance. It is not the intent of the Department to deny bond reductions to eligible applicants on the basis of procedural violations. However, continued procedural violations, at some point, might constitute a "substantial violation" and create a situation in which an operator would not be eligible or have such eligibility revoked.

Essentially, the bond reduction process is intended to encourage responsible operation, and the best indication of that is the test of time. The Department considers Oregon fortunate to have many responsible operators and operations.

The second criterion for eligibility, demonstrated financial capability to perform the required reclamation, is interpreted by the Department and industry in the following manner: Initially, the Department regards as sufficient testimony for credit-worthiness that an operation is currently bonded by a surety company or a letter of credit from a bank for the approved cost of reclamation. If the permit holder has a cash bond with the Department, a credit check may be required.

Permit holders who believe they are eligible for bond reduction are to notify the MLR office (see first inside page of this issue for address and phone number) at the time they submit their renewal payment. The Department will then review the bond calculations, make its decision on whether the permit holder qualifies, and establish the reduced bond amount.

Prior to any bond reduction, the Department will ensure that the bond is adequate to cover the cost of reclamation as proposed in the approved reclamation plan. In the past, there were per-acre ceilings on the cost of reclamation. According to the new House Bill 2041, the bond is set at the cost of completing the approved reclamation plan, including expected costs to the Department in contracting the work. The permit holder will be consulted by the Department in the process of determining bonding calculations and may appeal the resulting estimate of the bond to the State Geologist and the Department Board of Governors.

2. Renewal fee reduction. For those operators who have completed the approved reclamation plan, including all topsoil replacement and seeding, at the proper time and are waiting for vegetation establishment, the Department may reduce the renewal fee to $100.

3. Inspection fees. In addition to the annual fee, an additional fee of up to $100 may be assessed by the Department for inspection of sites where (a) mining is conducted without a valid operating permit, or (b) a surface mining operation has been abandoned, or (c) mining is conducted outside the permitted area.

(Continued on page 115, MLR)

Coastal neotectonic field trip guide for Netarts Bay, Oregon

by C.D. Peterson and M.E. Darienzo, College of Oceanography, and M. Parker, Department of Geology, Oregon State University, Corvallis, Oregon 97331

INTRODUCTION

This field trip guide summarizes the geologic evidence of episodic abrupt coastal subsidence that is recorded in late Holocene salt marshes and in uplifted late Pleistocene terrace deposits of Netarts Bay, northern Oregon (Figure 1). Similar records of abruptly buried marsh horizons have been identified in several other northern Oregon bays, including Alsea Bay, Nestucca Bay, Siletz Bay (Darienzo and Peterson, 1987), Salmon Bay, and Nehalem Bay (Grant and McLaren, 1987). However, the marsh sequences at Netarts Bay presently provide the longest and most unambiguous records of tectonic strain accumulation and strain release in coastal northern Oregon during late Holocene time (0-3,300 years B.P.). This is also the first coastal site in northern Oregon that has been observed to record multiple events of abrupt coastal subsidence in terrace deposits of late Pleistocene age.

In this field trip guide, we outline the general tectonic setting of coastal Oregon and briefly discuss some of the controversies concerning convergent margin seismicity in the southern Cascadia margin. This field trip guide contains detailed core logs of the marsh sequences of late Holocene age in Netarts Bay, which include some seven events of tidal-marsh burial. Since tidal marshes grow within a restricted range of mean sea level, their episodic burials provide a record of the accumulation and release of vertical tectonic strain. The approximate ages of the seven marsh burial events in Netarts Bay are provided by ^{14}C dating analyses of the buried peat horizons. Finally, we describe several field locations at Netarts Bay, both on the modern marsh and along exposed Pleistocene terraces, where wetland burial events can be observed directly in the geologic sections.

This field trip guide is an outcome of a coastal neotectonics field trip to Netarts Bay in May 1988 that was sponsored by the College of Oceanography and the Department of Geology at Oregon State University. The field trip was attended by staff and students from Oregon State University, the University of Oregon, and the Oregon Parks and Recreation Division, which manages the Cape Lookout State Park at Netarts Bay. We thank the field trip participants for their questions, observations, and field trip photographs that we have incorporated into this guide.

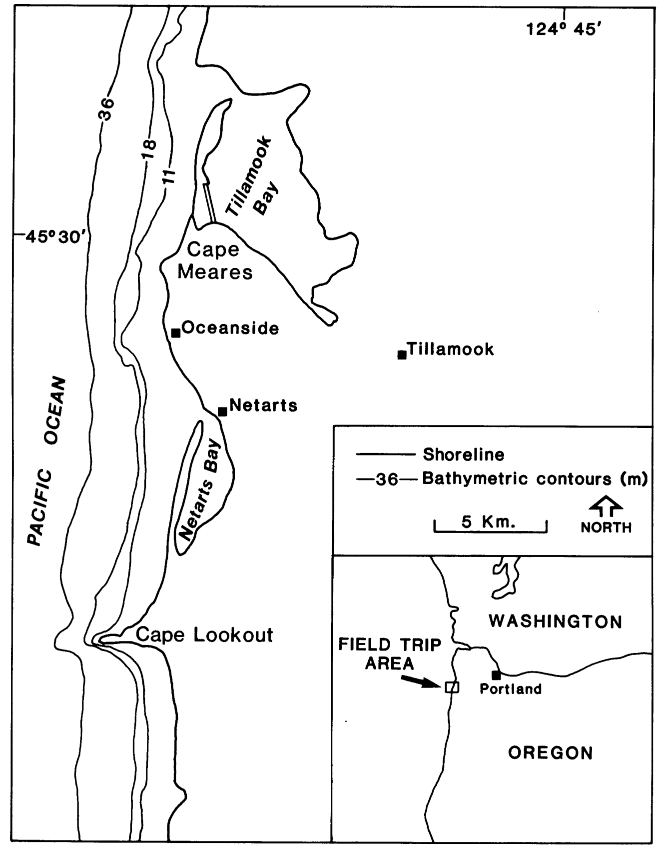


Figure 1. Map of study site. The field area is located some 55 km due west of the Portland metropolitan area (inset). Netarts Bay is situated between two headlands, Cape Lookout and Cape Meares, and is protected from the ocean by a barrier spit that extends nearly to the northern end of the coastal lagoon.

TECTONIC SETTING OF COASTAL OREGON

The Cascadia continental margin extends approximately 1,000 km from the Queen Charlotte Islands in southern British Columbia to Cape Mendocino in northern California (Figure 2). This continental margin comprises the region that is bounded to the west by the young oceanic Juan de Fuca Plate and to the east by the continental North American Plate. The nature of plate convergence along this margin is controversial. Recent studies of deep, small-scale seismicity in the northern Cascadia margin of Washington define the geometry of a descending subcrustal slab, confirming the subduction of the Juan de Fuca Plate under the North American Plate (Crosson and Owens, 1987; Weaver and Baker, 1988). In contrast, locked-plate deformation is indicated along the coast of northernmost California by folding and thrusting of Pleistocene and Holocene sequences (Carver and Burke, 1987). These belts of deformation are attributed to west-east plate convergence and to northward migration of the adjacent Mendocino triple junction, which is the conjunction of the Mendocino fracture zone and the San Andreas fault (Figure 2). The transition between the fold and thrust belts in northern California and the active plate subduction in Washington must occur somewhere along the Oregon coast, but where?

Although western Oregon comprises about a third of the Cascadia subduction zone, it has not experienced a substantial subduction zone earthquake in historical time. In fact, historic seismicity in the Juan de Fuca Plate has consistently shown north-south compression (Rogers, 1983; Weaver and Smith, 1983). The lack of large-scale subduction seismicity has been attributed to either terminated subduction or aseismic slip of the underthrusting plate. However, the historical record (<200 years of aseismicity) might be too short to rule out coseismic subduction processes (Heaton and Kanamori, 1984). Past events of large-scale subduction zone seismicity (Chile, 1960; Alaska, 1964) have produced rapid coastal subsidence associated with vertical tectonic strain release (Heaton and Hartzell, 1986). Multiple events of abrupt coastal subsidence have been reported from wetland burial sequences of late Holocene age in southwest Washington (Atwater, 1987). These wetland records con-

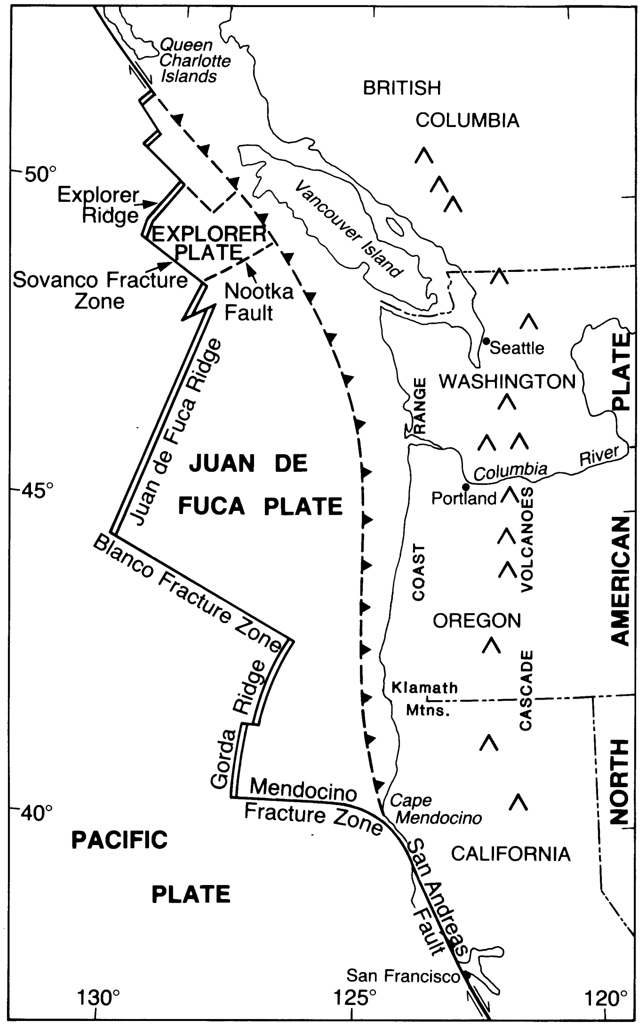


Figure 2. Tectonic map of the Cascadia Margin. Convergence of the Juan de Fuca oceanic plate with the North American continental plate occurs between the Queen Charlotte Islands in southern British Columbia and the Mendocino triple junction in northern California. A transition from plate subduction in the northern part of the margin to locked-plate deformation in the southern part of the margin probably occurs in Oregon.

firm active subduction tectonics and argue for coseismic strain release in the northern Cascadia margin. The question that immediately arises is, has the southern Cascadia margin experienced similar subduction strain release events in late Holocene time?

GEOLOGIC SETTING OF NETARTS BAY

Netarts Bay is located some 55 km due west of the Portland metropolitan area, on the west slope of the northern Oregon Coast Range (Figure 1). The field site is isolated from the Tillamook Bay drainages to the east by a resistant sandstone ridge that bridges two topographic highs comprised of Columbia River Basalt Group flows. These basalt flows form two coastal headlands, Cape Lookout and Cape Meares, to the south and north of Netarts Bay, respectively. Differential coastal erosion during Pleistocene high stands of sea level produced the Netarts embayment between the two capes. Sand trapped between the headlands during the Holocene transgression apparently formed the present sand spit barrier of Netarts Bay (Figure 3). Estuarine deposits within Pleistocene terrace sections on the east side of Netarts Bay indicate a protected depositional setting in late Pleistocene time as well. These young Pleistocene deposits are probably correlated with the Whisky Run terrace, dated at about 83,000 years B.P. (West and McCrumb, 1988). Although northwest-trending fault sets cut Tertiary rocks to the east of Netarts Bay, no faults have been observed in exposed Quaternary terraces along the bay shoreline.

Netarts Bay was chosen for our work on late Holocene changes in relative sea level on the basis of its unique physiography and hydrography (Darienzo, 1987). The salt marsh at the southern end of Netarts Bay is protected from ocean storms by the barrier sand spit that extends to the northern end of the bay (Figure 1). In addition, the marsh is unaffected by river flooding, since only minor tributaries enter this coastal lagoon. Records of episodic high-marsh burial by intertidal mud flats or of rapid marsh progradation over bay tidal flats should document changes of relative mean sea level and not effects of extreme climatic conditions. Since global sea level has not varied greatly within the last few thousand years (Clark and Lingle, 1979), any dramatic changes in local sea level should reflect vertical tectonic movements of the coastal region.

LATE HOLOCENE MARSH RECORDS IN NETARTS BAY

The late Holocene stratigraphy of the Netarts marsh has been documented in cores 4-5 m in length that have been taken along two transects that cross the length and width of the marsh system (Figure 4). The marsh core sites were surveyed into a temporary tide gauge station to reference all core horizons to local mean tide level (MTL). Two types of cores, including continuous cores (5-7.5 cm in diameter) and 1-m-interval cores (2.5 cm in diameter), were recovered at the marsh core sites. The 1-m-interval cores were used primarily to establish accurate depths of stratigraphic horizons, since the continuous cores averaged about 10 percent compaction during coring of the soft sediments. The continuous cores were used for detailed sediment and microflora analyses, which are currently being compiled for publication. Radiocarbon dating of the buried peats from returned core samples was performed by Beta Analytic, Inc., using standard pretreatment leaches to remove potential contaminants. Peat dates are adjusted by $^{12}C/^{13}C$ ratios, and all sample dates are calibrated by ^{14}C reservoir fluctuations (Stuiver and Reimer, 1986).

The preliminary results of the marsh coring and sample analytical work are shown in marsh stratigraphic sections trending west-east (Figure 5a) and north-south (Figure 5b). The stratigraphic sections document a series of repeating marsh burial sequences that are easily traced thoughout the marsh system. A typical burial sequence starts with a peat horizon that is overlain by a capping layer of sandy or silty sediments that is, in turn, overlain by finely laminated bay muds that grade upward into another peat horizon (Figure 6). Stratigraphic correlations across the marsh core sites show that the buried marsh horizons generally thin or are sometimes completely missing toward the central part of the Netarts marsh. The most complete records of marsh burial events are contained in cores from the bay margins, sites 5, 7, and 10, where rapid sedimentation and minimal erosional disturbance encourage quick marsh recovery from episodic burial.

A total of some seven marsh burial events are recorded in the upper 5 m of the Netarts marsh. Only the first and third buried horizons are generally visible in exposed sections of tidal creek cuts, between core sites 11, 8, and 12, or along the northern marsh scarp near core site 9 (Figure 4). The low organic muds covering the buried peat horizons vary from 0 cm to 100 cm in thickness. The vertical distances between the tops of successive peat horizons are also variable, ranging from 25 cm (between burial events 2 and 3 in core 7) to 175 cm (between burial events 4 and 5 in core 11). In some cases, a buried peat horizon is directly overlain by finely laminated muds, as shown by the second buried marsh horizon near zero-m depth (MTL) in cores 5, 7, and 10, and by the fifth and sixth buried peats at about 2.5-m depth (MTL) in cores 5, 10, 11, and 13 (Figures 5a,b). This buried peat couplet is anomalous in several respects and requires additional study before its origin can be interpreted.

Figure 3. Netarts Bay. View to north of Netarts Bay, spit, and ocean from field trip stop 1.

EVIDENCE OF ABRUPT COASTAL SUBSIDENCE IN MARSH RECORDS

The multiple sequences of peat burial by bay muds in the Netarts marsh cores document a process of episodic rise and fall of relative sea level due to vertical tectonic forcing. The buried peat layers in Netarts Bay were formed in high marsh settings at supratidal elevations. Many of these buried peat layers contain fresh-water diatom assemblages. Since Netarts Bay is a salt-water lagoon, the fresh-water microflora must represent fresh-water ponding on supratidal marshes during rainy periods. In contrast, the finely laminated muds that overlie the buried peat horizons contain marine-brackish diatom assemblages, which indicate that these muds were deposited at intertidal to subtidal elevations. The high marsh horizons must have subsided at least 1 m relative to the corresponding sea level to be buried by the tidal-flat muds. The measured vertical distances between several buried marsh horizons (<1 m) indicate some coastal emergence by tectonic strain accumulation between strain release events.

Significantly, the transitions between high marsh peats and overlying barren sediments in the first four burial sequences are extremely abrupt, usually occurring over distances of several millimeters (Figures 5a,b). The sediment-capping layers above three of the upper four buried marshes also indicate very rapid subsidence and initial burial. The sediment-capping layers are typically rich in sand and lack any evidence of traction current deposition by ripple or dune migration. They appear to have been deposited out of suspension from highly turbulent flows. Individual sediment-capping horizons do vary in thickness from one core site to the next but can be traced across the full extent of the marsh system. The widespread distribution of the thin capping layers indicates a system-wide mechanism of sand and silt transport over the broad marsh surfaces. Such a large-scale sheetflood could be produced only by a very rapid change in sea level, possibly associated with a tsunami or internal basin seiche, following an abrupt subsidence event.

RADIOCARBON AGES OF BURIED MARSH HORIZONS

The radiocarbon ages of the buried marsh (BM) horizons from adjacent core sites 5 and 11 range from the most recent at about 400 years B.P. (BM sequence 1) to 3,300 years B.P. (BM sequence 7) as shown in Figure 7. The age of the marsh layer must predate the actual marsh burial, so the marsh dates represent maximum radiocarbon ages of past subsidence events. Both the tops and bottoms of marsh layers in BM sequences 1, 3, and 4 were dated to bracket radiocarbon ages of the burial events and to estimate duration of marsh recovery from successive burial events. The greatest duration in radiocarbon age between burial events is on the order of 1,000 years (between BM horizons 4 and 5), while the shortest interval is possibly less than 100 years (between BM horizons 3 and 4 and between BM horizons 5 and 6). In addition, the first buried marsh (BM 1) was dated at three locations in site 5, and the three dates—top = 370 ± 60 radiocarbon years B.P. (RCYBP), middle lower = 690 ± 110 RCYBP, and bottom = $1,240 \pm 80$ RCYBP—demonstrate the potential age range of a single marsh unit.

Radiocarbon age reversals are apparent between the top and bottom of BM 3, between BM horizons 5 and 6, and between the bottom of the modern marsh and top of BM 1 (Figure 7). Such reversals might result from descending roots or organic fluids that transport radiogenically young carbon across marsh units. While

NETARTS BAY SALT MARSH CORE SITES

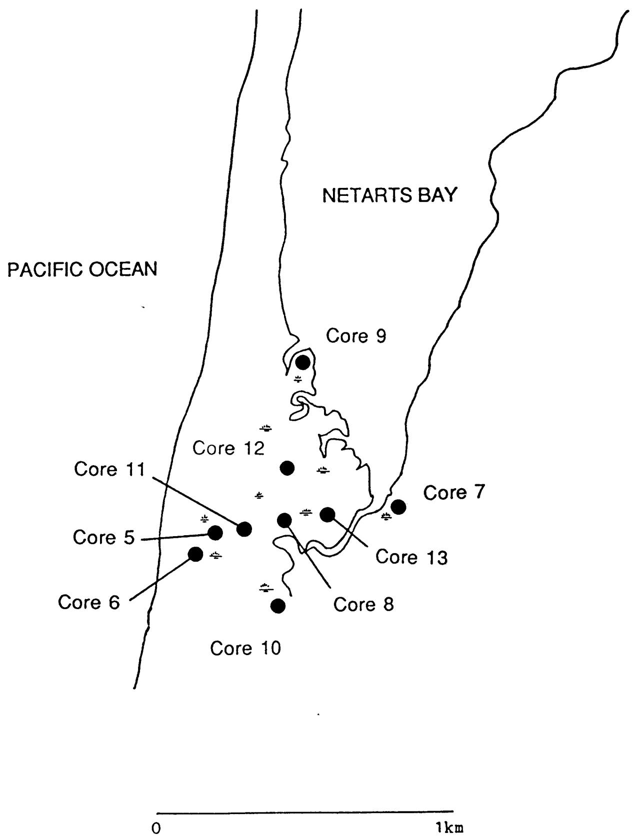


Figure 4. Map of selected core sites in southern marsh system of Netarts Bay. Core sites were chosen to form two transects that cross the full width of the marsh system from west to east and from north to south.

radiocarbon dating of the buried marsh horizons has obvious limitations in absolute age resolution, it does set important constraints on the timing and frequencies of past strain release events. Events of abrupt tectonic strain release have occurred throughout the late Holocene, and the observed recurrence intervals are clearly quite variable. Longer records of Holocene marsh burials are needed to better understand the tectonic cycles of strain accumulation and strain release in this part of the Cascadia margin.

EPISODIC MARSH BURIAL IN TERRACE DEPOSITS OF LATE PLEISTOCENE AGE

Protected tidal-basin deposits in uplifted terraces along the eastern side of Netarts Bay show evidence of multiple coastal subsidence events in late Pleistocene time. The Pleistocene terrace deposits pinch out against sedimentary and volcanic units of Tertiary age to the east of the Netarts embayment (Figure 8). However, 5- to 10-m-thick sections of the terrace deposits are locally well exposed along the southeast shoreline of Netarts Bay. The terrace deposits vary from estuarine deposits in the northern exposures near Whiskey Creek to fluvial channel-fill gravels and colluvial debris in the southern exposures near Austin Creek (Figure 8). A small mudflow deposit also occurs in the terrace section near Austin Creek and further denotes the processes of downslope mass transport in the vicinity of the high-relief volcanic units at the south end of Netarts Bay. The northern exposures of estuarine deposits are characterized by laminated tidal-flat muds with intervening layers of organic-rich material (Figure 9). The organic layers can be traced continuously along distances of at least 100 m, and they locally contain tree trunks rooted in place (Figure 10).

Some three to five organic-rich layers are observed within three 4-m vertical sections near Whiskey Creek (T1, T2) and Wee Willie's Restaurant (T3), as shown in Figure 9. The lower contacts between the organic layers and underlying laminated muds are gradational, while the upper contacts between the organic layers and the overlying muds are consistently abrupt (Figure 11). Sand-rich capping layers were not observed above the buried organic layers in the terrace outcrops. The alternations between bay muds and at least two wetland forest horizons are very striking and are similar in appearance to buried wetland soils in deposits of late Holocene age in southwestern Washington (Atwater, 1987). The magnitudes of coastal subsidence required to bury the wetland forest horizons with bay muds in the exposed late Pleistocene sections are certainly greater than those required to bury the tidal-marsh horizons in the sequences of late Holocene age of the Netarts marsh. The probable age of the Pleistocene terrace deposits (at least 83,000 years B.P.) precludes the use of ^{14}C dating to estimate the recurrence intervals between the burial events.

CONCLUSIONS

1. The protected tidal marshes of the Netarts coastal lagoon provide an ideal setting for the recording of vertical tectonic movements associated with convergent-margin strain accumulation and strain release.
2. The late Holocene record of marsh stratigraphy contains evidence of some seven separate events of coastal subsidence, as documented by supratidal marsh burial under intertidal bay muds. Sharp contacts above five of the buried marsh horizons indicate very abrupt burial.
3. At least four of the late Holocene burial events are associated with sediment-capping layers, which are interpreted to have been deposited out of suspension from catastrophic sheetfloods over the subsided marsh system.
4. The evidence of episodic coastal subsidence in Netarts Bay and from nearby estuaries documents multiple events of rapid tectonic strain release associated with active subduction processes in northernmost Oregon during late Holocene time.
5. The processes of tectonic strain accumulation and rapid strain release that are recorded in the late Holocene marshes of Netarts Bay can be traced back to late Pleistocene time in adjacent bay terrace deposits.
6. At least two events of wetland forest burial by bay muds in the exposed late Pleistocene sections required greater magnitudes of vertical subsidence than has been observed in late Holocene sequences of tidal marsh burial in Netarts Bay.

ACKNOWLEDGMENTS

Radiocarbon dating of selected peat horizons in the initial pilot study of late Holocene sea-level changes in Netarts Bay was supported by the Oregon State University Sea Grant College Program. Funding for the investigation of episodic tectonic strain release in Netarts Bay was provided by the U.S. Geological Survey, under the National Earthquake Hazards Reduction Program, Grant Number 14-08-0001-G1512. The Oregon Department of Geology and Mineral Industries assisted with figure drafting and photographic reproductions used in this field trip guide. We thank Tariq Jaswal for his contribution of several field trip photographs used in this guide.

FIELD TRIP STOPS 1-5

Access to Netarts Bay, Tillamook County, is by the Three Capes Scenic Route, a loop west of State Highway 101 between Pacific City in the south and Tillamook in the north. All field trip stop locations are along this Scenic Route and are shown in Figure 12.

Bring: small shovel, rubber boots or waders, and tide table.

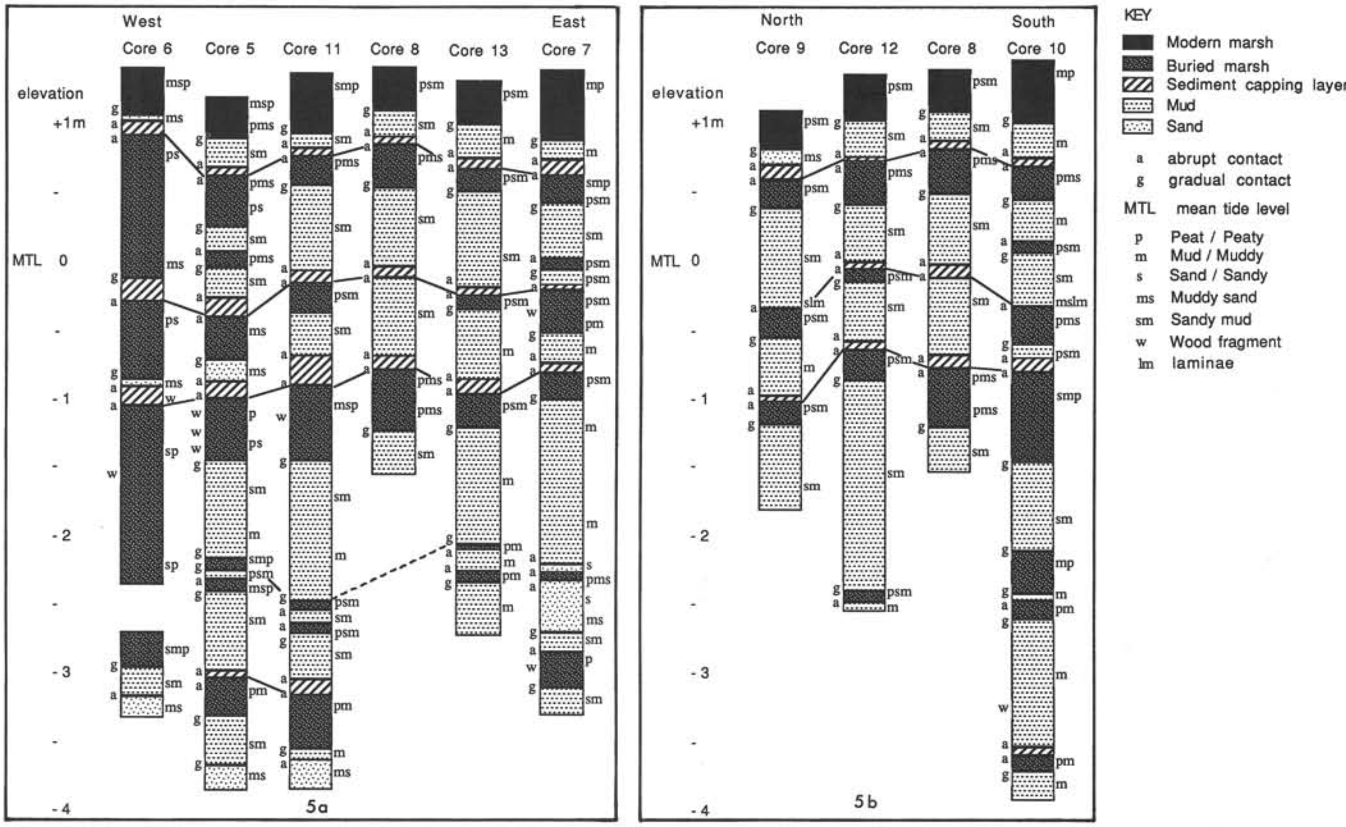
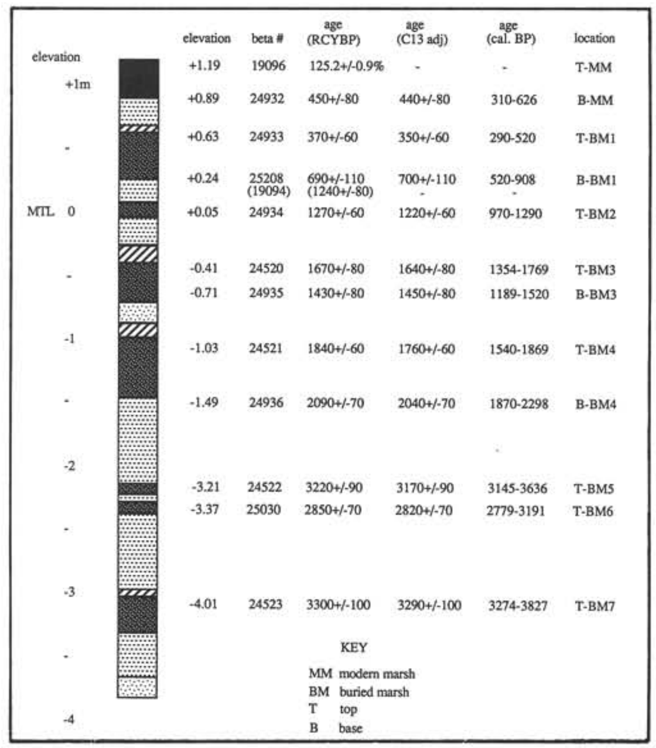


Figure 5. Core logs and stratigraphic correlations between core sites are shown in Figures 5a (west-east transect) and 5b (north-south transect). The types of contacts between depositional units are shown on the left of each core log, while the sediment composition is shown on the right (see key for definitions). At least seven distinct marsh horizons are apparent in the late Holocene stratigraphic sections.

Figure 6. Mark Darienzo (right) and Bob Yeats, Department of Geology, Oregon State University, looking at buried marsh layer in interval core from Netarts Marsh.



elevation	beta #	age (RCYBP)	age (C13 adj)	age (cal. BP)	location
+1.19	19096	125.2+/-0.9%	-	-	T-MM
+0.89	24932	450+/-80	440+/-80	310-626	B-MM
+0.63	24933	370+/-60	350+/-60	290-520	T-BM1
+0.24	25208 (19094)	690+/-110 (1240+/-80)	700+/-110 -	520-908 -	B-BM1
+0.05	24934	1270+/-60	1220+/-60	970-1290	T-BM2
-0.41	24520	1670+/-80	1640+/-80	1354-1769	T-BM3
-0.71	24935	1430+/-80	1450+/-80	1189-1520	B-BM3
-1.03	24521	1840+/-60	1760+/-60	1540-1869	T-BM4
-1.49	24936	2090+/-70	2040+/-70	1870-2298	B-BM4
-3.21	24522	3220+/-90	3170+/-90	3145-3636	T-BM5
-3.37	25030	2850+/-70	2820+/-70	2779-3191	T-BM6
-4.01	24523	3300+/-100	3290+/-100	3274-3827	T-BM7

KEY
MM modern marsh
BM buried marsh
T top
B base

Figure 7. Core log and radiocarbon dates from core sites 5 and 11. Buried marsh horizons range in radiocarbon age from about 400 years to about 3,300 years B.P. Calibrated ages are based on sample two sigma deviations about ^{14}C calibration curves established from tree-ring data (Stuiver and Reimer, 1986).

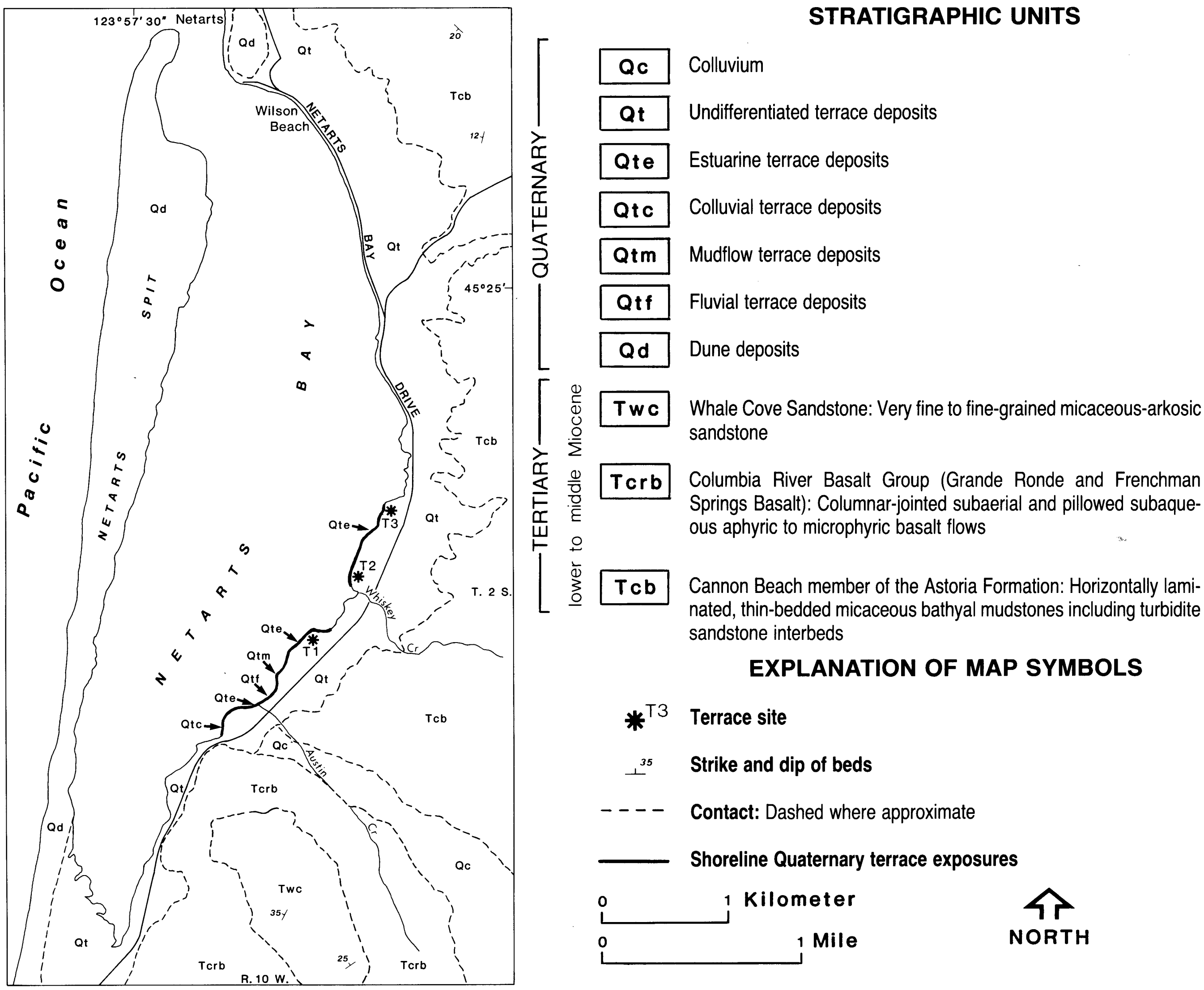


Figure 8. Preliminary geologic map of the Netarts Bay area and late Pleistocene terraces. The terrace deposits shift from interlayered wetland horizons and laminated bay muds to the north of Whiskey Creek (see Figure 9) to fluvial and colluvial deposits in the southernmost terrace exposures, which are adjacent to high-relief volcanic units. Mapped by M. Parker.

STOP 1: Anderson's Viewpoint, north of parking lot for Cape Lookout trailhead and south of Cape Lookout State Park.

From this site, one can look north to Netarts Bay. Netarts Bay is a shallow coastal lagoon located within a littoral cell bounded by Cape Meares to the north and Cape Lookout to the south. The bay is separated from the Pacific Ocean by a long narrow sand spit. The geology of the surrounding area is summarized in Figure 8. The salt marsh at field trip stops 2 and 3 is located at the southern end of the bay and is partially visible from this viewpoint. Pleistocene terrace outcrops (stops 4 and 5) are located on the southeastern side of the bay.

STOP 2: Tidal creek cuts in Netarts Bay salt marsh

Park vehicle in day use area at Cape Lookout State Park and walk to the salt marsh through the campground. Easiest access to the marsh is via campsite B-44. Wear rubber boots and watch out for small channel cuts hidden by the tall marsh vegetation. The lowest tide of the day is the best time to view the stratigraphy along the creek banks.

The marsh surface is relatively flat and occupies a narrow elevational zone (1-1.5 m above mean tide level) within the bay. The marsh is a high marsh containing plants such as *Deschampsia* (tufted hairgrass), *Juncus* (rush), and *Potentilla* (silverweed). Proceed to the tidal creek near core site 8 (Figure 4). At low tide, the first and possibly third buried marsh horizons will be visible. At core site 8, the second and third buried marshes are absent. Only the sediment-capping layer is associated with the third burial event at this location, and it is recognized by a thin layer (about 10 cm thick) of alternating mud and sand laminae. The second buried marsh was not present in any of the interior core sites (Figures 4, 5a,b). The sediment-capping layer immediately above the first buried marsh horizon is locally entrenched in the tidal creek bank due to differential erosion of this sand-rich layer.

If the present marsh surface dropped abruptly by 1 m, its surface elevation would then be very close to the elevation of the barren tidal flats just north of core site 9. A rapid displacement of coastal water masses in association with the abrupt coastal subsidence could scour available sand and silt and redeposit these sediments in an anomalous capping layer above the subsided marsh horizon. Mud

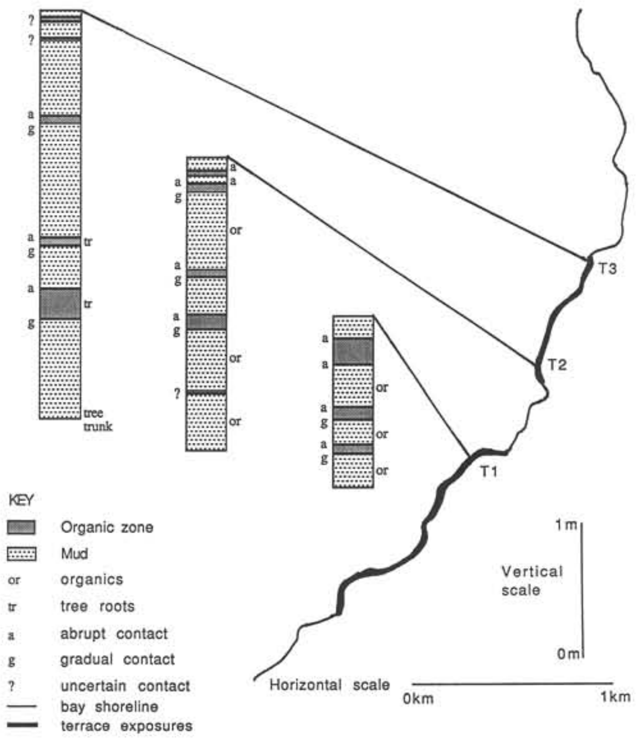


Figure 9. Preliminary stratigraphic sections of buried wetland horizons in terrace deposits exposed along the southeast margin of Netarts Bay (see Figure 8). A total of five burial sequences are observed at terrace sites T2 and T3. Rooted trees are associated with two to three buried horizons in the exposed Pleistocene sections.

and silt laminae would be deposited by the tides and by wind-wave action, and this would eventually raise the tidal flat to an elevation where marsh plants could recolonize the bay muds. Tectonic emergence between subsidence events could accelerate the low marsh progradation and its subsequent transition to a high marsh setting.

STOP 3: Marsh scarp at marsh/tidal-flat boundary

Proceed through gate at northwestern end of campground (no vehicle access) and follow dirt road north. The road narrows and becomes a trail. Continue walking until you reach the most northwestern part of modern marsh scarp (Figure 13). This point can be recognized by a "no hunting" sign along the bay edge 30-40 m east of the trail. From the sign, walk southeast to the marsh scarp.

At low tide, the first and possibly the third buried marsh horizons will be visible. At core site 9 (Figure 4), the second buried marsh was not present (Figure 5b), and it is likely absent along much of the northern scarp. The sediment-capping layer above the first buried marsh is usually visible as a differentially eroded layer of muddy sand and can be followed along most of the scarp. Occasionally, the sediment-capping layer is found intact in relatively protected pockets. X-radiographs of this capping layer indicate a lack of any small-scale cross-bedding or plane bed striations.

The 1-m-high scarp cutting the modern marsh and the first burial horizon is present along nearly the entire northern boundary of the salt marsh system. The scarp is an erosional feature formed by local wave and current action. The presence of an erosional scarp and absence of a progradational marsh front (except along the eastern side of the bay spit) suggest that rapid tectonic emergence is not presently occurring at Netarts Bay.

STOP 4: Pleistocene terrace outcrops near Whiskey Creek

Drive north to Wee Willie's Restaurant. Access to the bay shoreline and terrace exposures is via a trail through the salt marsh at the northern end of Wee Willie's parking lot. Walking south along the tidal flat to Whiskey Creek is possible during low tide. The late Pleistocene terrace outcrops are located both north and south of Whiskey Creek, with the best exposures of buried wetland forest horizons to the north of Whiskey Creek. This stop includes T1 and T2 on Figures 8 and 9.

Alternating layers of laminated mud and of dense organics are visible in the exposed terrace sections. Two of the organic layers at T2 locally contain protruding tree trunks and roots. The dense organic layers are buried Pleistocene wetlands that apparently range from incipient marshes (very thin organic layers) to forested soil horizons. The upper contact of each of the organic layers with the overlying laminated bay muds is sharp, indicating abrupt subsidence and rapid burial rather than gradual subsidence. However, no sediment-capping layer (e.g., sand layer) is present immediately above the dense organic layers.

Figure 10. Terrace outcrop 2, with Bob Yeats sitting on buried tree trunk in wetland soil horizon.

Figure 11. Three organic layers buried by terrace deposits (unit T1) of late Pleistocene age in Netarts Bay. Uppermost layer is partially obscured by vegetation at field notebook (18 cm high, for scale).

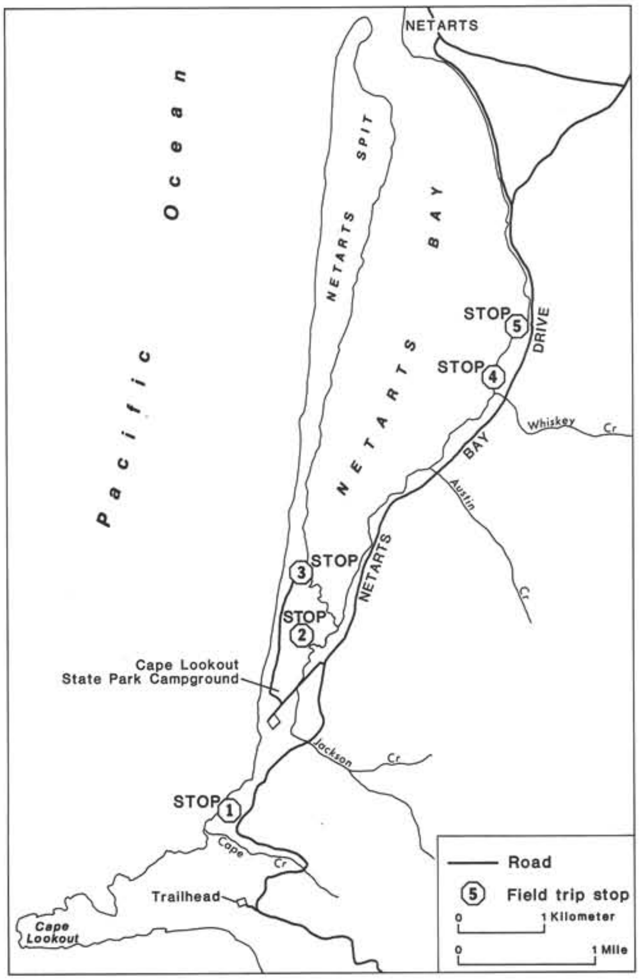


Figure 12. Location of field trip stops 1-5.

STOP 5: Pleistocene terrace outcrop near Wee Willie's Restaurant

Walk back to the tidal flat and terrace exposures north of Wee Willie's Restaurant. This stop includes T3 on Figures 8 and 9.

At low tide, numerous tree stumps are exposed on the modern tidal flat. A few of the tree stumps are close to the base of the vertical terrace exposure. Trenching through the thin cover of modern muds will expose the base and roots of the tree trunks that are rooted in the Pleistocene terrace deposits. The tree stumps on the tidal flat are in situ and are remnants of Pleistocene forest horizons exhumed during erosion and retreat of the bay cliff. Tree roots can be seen protruding out of an additional organic-rich layer about 1 m above the base of the bay cliff. Several additional organic-rich layers of varying thickness are also visible above the wetland forest horizons. In all cases, the organic-rich layers have abrupt upper contacts and gradual lower contacts with intervening laminated bay muds.

REFERENCES CITED

Atwater, B.F., 1987, Evidence for great Holocene earthquakes along the outer coast of Washington State: Science, v. 236, p. 942-944.

Carver, G.A., and Burke, R.M.,1987, Late Holocene paleoseismicity of the southern end of the Cascadia subduction zone [abs.]: EOS, v. 68, no. 44, p. 1240.

Clark, J.A., and Lingle, C.S., 1979, Predicted relative sea-level changes (18,000 years B.P. to present) caused by late-glacial retreat of the Antarctic Ice Sheet: Quaternary Research, v. 11, no. 3, p. 279-298.

Crosson, R.S., and Owens, T.J., 1987, Slab geometry of the Cascadia subduction zone beneath Washington from earthquake hypocenters and teleseismic converted waves: Geophysical Research Letters, v. 14, p. 824-827.

Darienzo, M.E., 1987, Late Holocene geologic history of a Netarts Bay salt marsh, northwest Oregon coast, and its relationship to relative sea level changes: Eugene, Oreg., University of Oregon master's thesis, 94 p.

Darienzo, M.E., and Peterson, C.D., 1987, Episodic tectonic subsidence recorded in late Holocene salt marshes, northwest Oregon [abs.]: EOS, v. 68, no. 44, p. 1469.

Grant, W.C., and McLaren, D.D., 1987, Evidence for Holocene subduction earthquakes along the northern Oregon coast [abs.]: EOS, v. 68, no. 44, p. 1239.

*(Continued on page 117, **Netarts Bay**)*

Figure 13. View to the south of bay flats and marsh scarp at field trip stop 3.

Geothermal exploration in Oregon, 1987

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

LEVEL OF GEOTHERMAL EXPLORATION

Introduction

In 1987 there was no new geothermal gradient drilling in the young volcanic rocks of the High Cascades. There was, however, moderate activity at Newberry Crater. The amount of leased land declined on both U.S. Bureau of Land Management (USBLM) and USDA Forest Service (USFS) lands. The total amount of Federal land leased for geothermal resources has declined annually by small amounts since the peak in 1983.

Drilling activity

Figure 1 shows the number of geothermal wells drilled and geothermal drilling permits issued from 1970 to 1987. No new permits were issued, and only two new geothermal-gradient wells were drilled. Table 1 lists the Department of Geology and Mineral Industries (DOGAMI) permits for geothermal drilling that were active in 1987. The decrease in drilling resulted from poor market conditions for electric power and from other factors, such as the termination of the U.S. Department of Energy (USDOE) program that provided matching funds for temperature-gradient drilling and appeals filed as part of the regulatory process concerning the California Energy Company, Inc., (CECI) drilling project near Crater Lake.

The USDOE program had focused on exploration of the High Cascades, Newberry volcano, and Medicine Lake volcano in California. This focus resulted in the completion of temperature-gradient holes northwest of Mount Jefferson, on the flanks of Mount Mazama (Crater Lake area), and at Newberry Crater. No new solicitations are planned for this program. One contract with CECI for drilling at Mount Mazama remains active.

Two temperature-gradient wells were drilled by GEO-Newberry Crater, Inc., a subsidiary of Geothermal Resources International, Inc., on the east and southwest flanks of Newberry volcano. Both holes were permitted to 5,000 ft, but the actual total depth drilled and other data from the holes are proprietary.

Figure 2 shows the number of geothermal prospect-well permits issued and wells drilled from 1970 to 1987. No wells have been drilled or permits issued since 1984 for shallow (less than 2,000 ft) temperature-gradient work. This trend is a result of the shifting focus of exploration from eastern Oregon to the Cascade Range, where deeper temperature-gradient wells are required to penetrate the "rain curtain."

Leasing

The consolidation of land holdings continued in 1987 as the total leased acreage of Federal lands decreased by about 12 percent (Table 2; Figure 3). This decrease in leased lands was the result of a 56-percent decline in USBLM noncompetitive leases, coupled with a 10-percent rise in USFS noncompetitive leases (Table 2). This decrease marks the fourth straight year of decline since the total leased acreage peaked in 1983.

A total of 119 leases are pending on USFS lands in Oregon. The majority of these leases (60) are awaiting preparation of environmental assessments or environmental impact statements. There are no leases pending on USBLM lands in Oregon.

Figure 4 is a graph of the annual total amount of monies received by the Federal Government from geothermal leasing in Oregon. The graph covers the period from 1974, when leasing was initiated, to the present. Sources of income included in the graph are filing fees, rental on competitive and noncompetitive leases, and bonus bids. Income from geothermal leasing peaked in 1980 at $1,701,189 and has declined steadily since then to its present level of about $475,000.

KGRA sales

No KGRA lands were offered for bid in 1987.

In December, USFS canceled its application to withdraw 2,330 acres in the Sparks Lake-Devils Lake Recreation Area and 2,291 acres in the Bachelor Butte and Todd Lake Recreation Areas. This action opens those areas for mining. The lands had been open to leasing.

Direct-use projects

The direct use of relatively low-temperature geothermal fluids continued in 1987 at about the same level as over the last several years. Most of the activity is centered in Klamath Falls and Vale.

In Vale, the successful Oregon Trail Mushroom Company, which commenced full-scale operations in 1986, continues to operate using water from a 107 °C aquifer for heating and cooling. The operation annually produces 2.3 million kg of mushrooms that are marketed in Spokane and Seattle, Washington; Salt Lake City, Utah; and the Treasure Valley area in Idaho (Geo-Heat Center, 1987). Other users at Vale include Ag-Dryers (a grain-drying facility) and a greenhouse operation. Hawley Meat Packing is no longer using the Vale geothermal aquifer.

The Oregon Department of Water Resources completed field work for a report on the hydrogeology of the developed geothermal aquifer at Vale. The report, which is in final review, will be published during 1988.

In Klamath Falls, the city continued to wrestle with the problem of defective piping installed in the district heating system. The heating

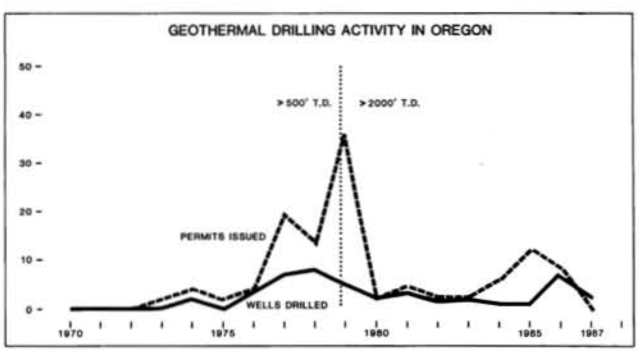


Figure 1. Geothermal well drilling in Oregon. Vertical line indicates time when definition of geothermal well was changed to a depth greater than 2,000 ft (610 m).

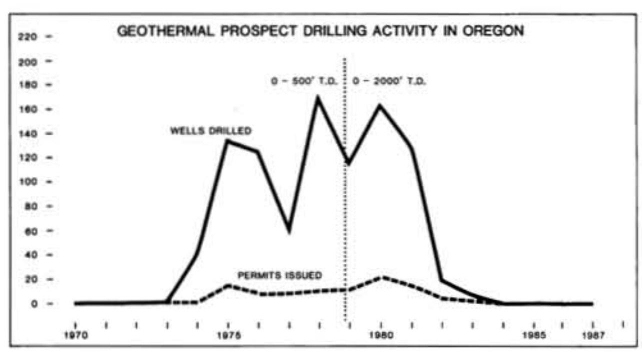


Figure 2. Geothermal prospect-well drilling in Oregon. Vertical line indicates time when definition of prospect well was changed to a depth of less than 2,000 ft (610 m).

system consists of two loops. The main loop serves the downtown area. A smaller loop, constructed in 1986 with support from a U.S. Housing and Urban Development grant, serves a residential sector (Michigan Street). The residential loop is operating satisfactorily, but the downtown loop has not operated for over three years due to defective fiberglass piping. In 1987, the city completed engineering plans for the replacement of the defective piping. Actual replacement now awaits the results of legal action.

Table 1. *Active permits for geothermal drilling in 1987*

Permit no.	Operator, well, API number	Location	Status, total depth (m)
116	California Energy Co. MZI-11A 035-90014	SW¼ sec. 10 T. 31 S., R. 7½ E. Klamath County	Suspended; 413.
117	California Energy Co. MZII-1 035-90015	SE¼ sec. 13 T. 32 S., R. 6 E. Klamath County	Suspended; 148.
118	GEO* N-1 36-017-90013	SW¼ sec. 25 T. 22 S., R. 12 E. Deschutes County	Suspended; 1,387.
124	Thermal Power Co. CTGH-1 36-047-90002	SE¼ sec. 28 T. 8 S., R. 8 E. Marion County	Suspended; 1,463.
125	GEO* N-2 36-017-90018	SW¼ sec. 29 T. 21 S., R. 12 E. Deschutes County	Suspended; confidential.
126	GEO* N-3 36-017-90019	NE¼ sec. 24 T. 20 S., R. 12 E. Deschutes County	Suspended; 1,219.
127	California Energy Co. CE-NB-3 36-017-90020	NW¼ sec. 16 T. 22 S., R. 13 E. Deschutes County	Suspended; 1,325.
128	California Energy Co. CE-NB-1 36-017-90021	NW¼ sec. 16 T. 22 S., R. 12 E. Deschutes County	Canceled.
129	California Energy Co. CE-NB-4 36-017-90022	SE¼ sec. 4 T. 21 S., R. 12 E. Deschutes County	Suspended; 1,225.
130	Trendwest, Inc. Olene Gap 1 36-035-90016	NW¼ sec. 35 T. 39 S., R. 10 E. Klamath County	Canceled.
131	GEO* N-4 36-017-90023	NE¼ sec. 35 T. 21 S., R. 13 E. Deschutes County	Suspended; confidential.
132	GEO* N-5 36-017-90024	NE¼ sec. 8 T. 22 S., R. 12 E. Deschutes County	Suspended; confidential.
133	GEO* N-6 36-017-90025	SW¼ sec. 6 T. 21 S., R. 13 E. Deschutes County	Canceled.
134	GEO* N-7 36-017-90026	NE¼ sec. 3 T. 22 S., R. 14 E. Deschutes County	Canceled.

* GEO-Newberry Crater, Inc.

The Geothermal Advisory Committee in Klamath Falls is considering engineering and financial alternatives in order to bring those users of geothermal fluids who discharge effluent to the surface into compliance with the Klamath Falls Geothermal Code. The code requires that, by 1990, all geothermal waters used in the city must be reinjected. In a related action, the Oregon Institute of Technology (OIT) made plans to drill an injection well in order to eliminate surface discharge from the OIT geothermal system. The well will be drilled in the summer of 1988, and all surface discharge from the OIT campus is expected to cease in 1989.

As reported in the Geo-Heat Center *Quarterly Bulletin*, eight Klamath Falls homeowners completed a residential heating district at a cost of $148,000. The closed-loop distribution system includes a 277-m production well and a 610-m injection well along with associated pumps, heat exchangers, and piping. The production well provides approximately 80 gpm of 84 °C fluid that is reinjected at 71 °C. Water is provided to individual homes at approximately 81 °C (Geo-Heat Center, 1987).

In La Grande, Union County, the New Jersey-based company BBC Brown Boveri District Heating and Cooling, Inc., has contracted with Hot Lake Company to supply pipeline equipment and financial assistance for the recreational vehicle resort geothermal project at Hot Lake. The system will pipe 85 °C water 2,500 ft from the Hot Lake artesian well to the resort. After heating mineral baths and other buildings at the resort, the effluent will be piped a further 300 ft to proposed greenhouses. The objective of Brown Boveri District Heating and Cooling is to show how cost-effectively a small district heating system can meet heat and hot-water needs with minimum temperature loss and environmental impact. Financial assistance to Hot Lake Company will take the form of a grant to defray first-year costs of equipment that Brown Boveri is supplying to the project (Geothermal Resources Council, 1987b).

In Lakeview, the binary-cycle electrical generating station set up several years ago remains idle. The City of Lakeview terminated its agreement with Brown, Vence, and Associates, the firm that initiated the formation of a geothermal franchise in the city. The city is still interested in the development of a district heating system.

In the Bend, Redmond, Prineville, and Madras areas of central Oregon and in the Willamette Valley, there was considerable activity in 1987 in the installation of ground-water heat pumps. The Oregon

Table 2. *Geothermal leases in Oregon in 1987*

Types of leases	Numbers	Acres
Federal leases in effect:		
Noncompetitive, USFS	226	429,149.15
Noncompetitive, USBLM	10	11,121.52
KGRA, USFS	1	360.00
KGRA, USBLM	12	25,999.73
Total leases issued:		
Noncompetitive, USFS	334	651,068.55
Noncompetitive, USBLM	266	406,157.79
KGRA, USFS	8	11,924.61
KGRA, USBLM	62	118,307.85
Total leases relinquished:		
Noncompetitive, USFS	108	221,919.40
Noncompetitive, USBLM	256	395,036.27
KGRA, USFS	7	11,564.61
KGRA, USBLM	50	92,308.12
Lease applications pending	119	——

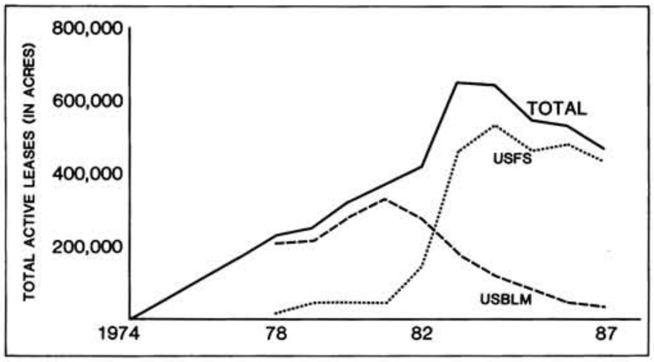


Figure 3. Active geothermal leases on Federal lands in Oregon from the inception of leasing in 1974 through December of 1987.

Department of Energy certified 36 residential tax credits in 1987, most of them for the installation of such systems. At the present time, a tax credit of up to $1,500 is available for each residence. The amount of the tax credit is based on energy savings, not the cost of the system.

The ownership of Jackson Hot Springs in Ashland, Oregon, has changed. At the present time, Jackson Hot Springs is still being run as a resort, though the new owners are reportedly considering other direct-use applications.

DOGAMI RESEARCH

DOGAMI geologists completed compilation of the McKenzie Bridge 15-minute quadrangle during 1987. Original field mapping was completed in 1986. Belknap, Foley, Terwilliger, and several unnamed hot springs occur in the area, which encompasses the transition zone between the High Cascades and Western Cascades near South Sister. The map will be published during 1988 (Priest and others, 1988).

Two geologic maps, each encompassing the area of a standard 15-minute quadrangle, were published in 1987. These maps cover the transition zone between the High Cascades and Western Cascades from about Breitenbush Hot Springs to just south of the junction of Highways 126 and 20. The maps were published in DOGAMI's Geological Map Series as GMS-46, *Geologic Map of the Breitenbush River Area, Linn and Marion Counties, Oregon* (Priest and others, 1987c), and GMS-47, *Geologic Map of the Crescent Mountain Area, Linn County, Oregon* (Black and others, 1987).

The geologic mapping was completed with USDOE support and was aimed at defining the geologic context of major hydrothermal systems in the Cascade Range. The three maps delineate a major zone of faulting that starts near the elbow of the North Santiam River and continues south to the headwaters of Horse Creek in the McKenzie Bridge quadrangle (Figure 5). The Western Cascades are uplifted relative to the High Cascades at this faulted boundary (Taylor, 1980; Brown and others, 1980; Priest and others, 1982, 1983). Belknap Hot Springs and adjacent unnamed hot springs are located on this fault zone (Priest and others, 1982, 1983). No major fault has been mapped through Breitenbush Hot Springs.

In 1986, DOGAMI received a grant from USDOE to complete a geologic study of the Breitenbush-Austin Hot Springs hydrothermal area, including a detailed analysis of the Thermal Power Company drill hole CTGH-1. CTGH-1 is a 1.46-km-deep hole drilled in the High Cascade Range northwest of Mount Jefferson in 1986 (Figure 5). D.R. Sherrod of the U.S. Geological Survey (USGS) is cooperating with DOGAMI to coordinate and partially write an open-file report. Geologic mapping of approximately 15 mi^2 around the site was completed by Sherrod and R.M. Conrey (Washington State University) in 1987. The final report will contain the geologic map and an analysis of cores and cuttings from the CTGH-1 hole and surrounding holes, as well as hydrothermal-alteration studies by T.E.C. Keith and K.E. Bargar of the USGS and an analysis of temperature and heat-flow data by D.D. Blackwell of Southern Methodist University. An open-file report that synthesizes the data in terms of a geothermal model for the Breitenbush-Olallie Butte area will be published in October 1988.

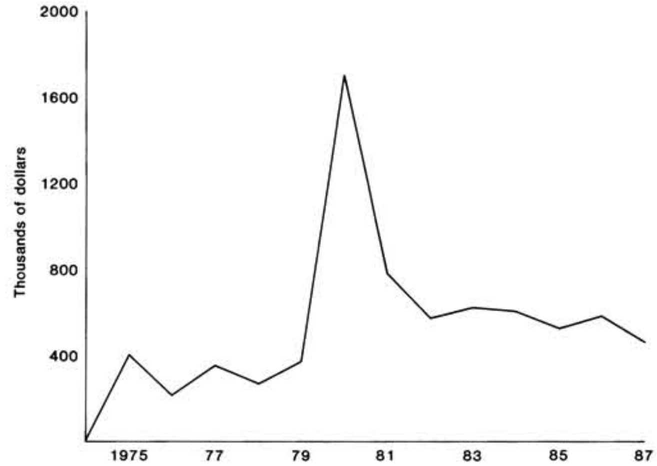


Figure 4. Federal income from geothermal leases in Oregon from the inception of leasing in 1974 to the present.

In July 1987, DOGAMI staff met in Bend, Oregon, with representatives of USFS, USBLM, and interested scientists to select potential drill sites for the Program for Scientific Drilling in the Cascades (PSDC). The main purpose of the drilling program is to investigate the thermal regime of the Cascade Range volcanic axis. Secondary objectives are to examine the rate and composition of volcanism occurring in the central portion of the Cascades during the last several million years. Three sites were identified near Santiam Pass for the first stage of drilling. Two of the sites are near Blue Lake, and the third is on Cache Creek (Figure 6). Drilling is expected to begin in late summer or early fall of 1988 at one of the sites. The proposed depth for this initial stage of drilling is 2,100 ft. Details of the PSDC plan were described in an open-file report published by DOGAMI in 1987 (Priest and others, 1987a). A nontechnical summary of the plan is also available upon request.

In 1987, DOGAMI published four other maps of interest to the geothermal community. Three maps by G.A. Smith (University of New Mexico) provide detailed 1:24,000-scale coverage of the Deschutes Basin (Smith, 1987a-c). The fourth map, published at the same scale, is E.M. Taylor's map of the northwest quarter of the Broken Top 15-minute quadrangle (Taylor, 1987; Figure 5).

ACTIVITIES OF OREGON WATER RESOURCES DEPARTMENT

The Oregon Water Resources Department (OWRD) continued its low-temperature geothermal program that includes monitoring of the resources in Vale, the Klamath Falls area, and Lakeview.

A report on the hydrogeology of the developed geothermal aquifer at Vale has been completed and is in final review. The report describes the geology and hydrology of the developed geothermal aquifer and documents some of the temperature and pressure changes that have resulted from development.

Monitoring of the geothermal aquifer in Klamath Falls shows that water levels have been declining at a rate of approximately 0.3 m per year since about 1975. In 1985, the City of Klamath Falls passed the Geothermal Management Act in order to eliminate, by 1990, the wasteful discharge of geothermal water that is presumably causing the decline. In November 1987, the Oregon Water Resources Commission was presented with an OWRD staff report describing the Klamath Falls decline and its implications. The report recommended

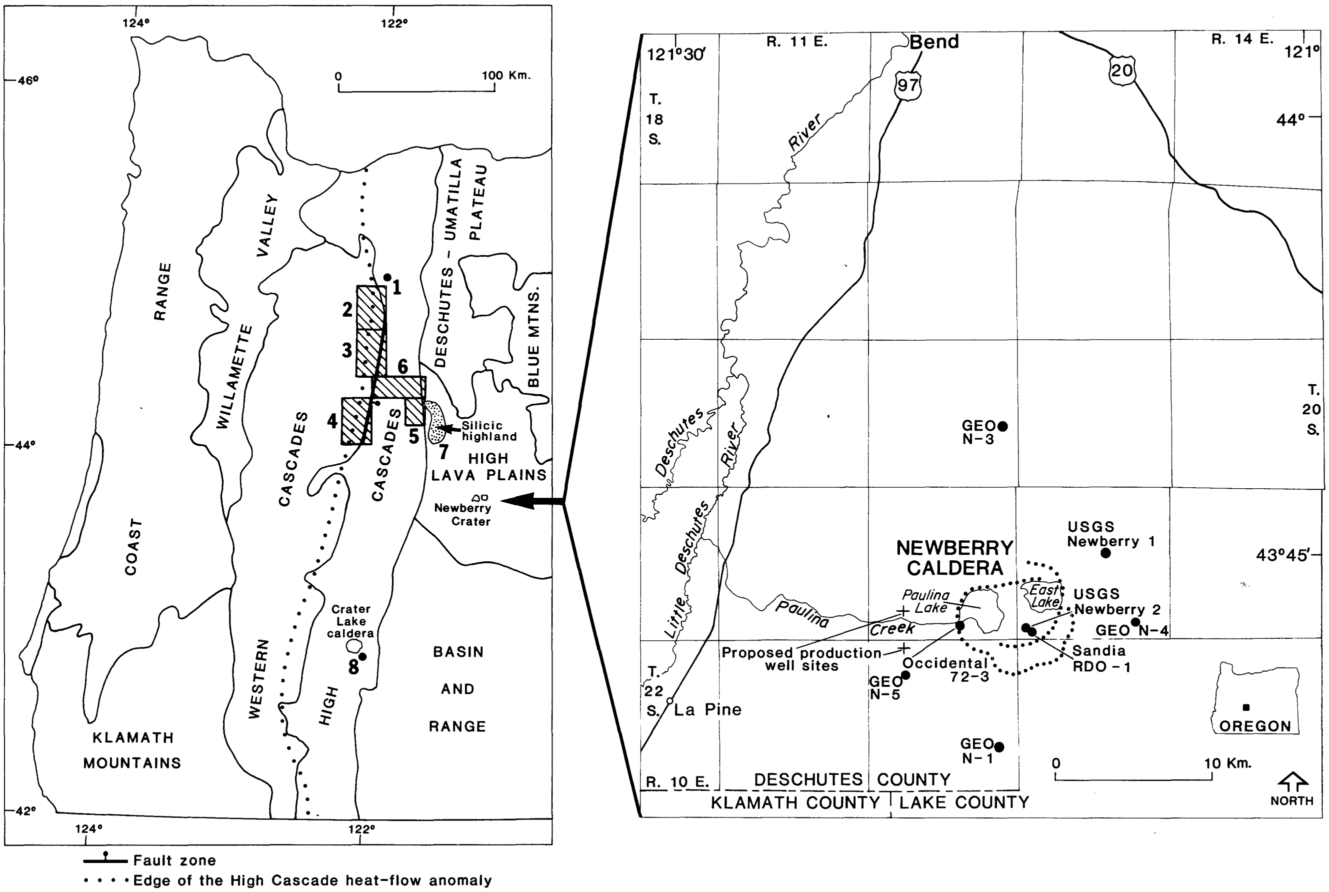


Figure 5. Physiographic provinces of western Oregon (after Dicken, 1950) showing major areas of geothermal activity discussed in text. 1. Location of Thermal Power drill hole CTGH-1. 2. Breitenbush River map area. 3. Crescent Mountain map area. 4. McKenzie Bridge quadrangle. 5. NW Broken Top quadrangle. 6. Santiam Pass study area. 7. Silicic highland. 8. Location of CECI drill hole MZI-11A. Edge of High Cascade heat-flow anomaly after Black and others (1983).

Inset map of Newberry caldera area shows locations of temperature-gradient holes discussed in text and GEO permitted production well sites. Dotted lines show ring-fractures of Newberry caldera.

that the OWRD continue to closely monitor conditions in the geothermal aquifer and track progress toward the elimination of wasteful discharge. If the decline continues after 1990, the OWRD will evaluate the situation in Klamath Falls and may consider administrative action to stabilize water levels.

Water levels fluctuate yearly in Klamath Falls, with lowest levels occurring during the peak heating season in February. Water levels in February 1988 did not show any decline relative to 1987, probably due to the mild weather and resultant decreased heating demand.

The responsibility for the OWRD low-temperature geothermal program has been recently transferred from Marshall W. Gannett, who took over the program in 1984, to Susan V. Hartford.

ACTIVITIES OF OREGON DEPARTMENT OF ENERGY

In 1987, geothermal activities of the Oregon Department of Energy (ODOE) focused on research and support for other agencies. ODOE, in cooperation with the Washington State Energy Office, continued to perform economic research into new geothermal power plants for the Bonneville Power Administration (BPA). Research into direct-use district heating systems was completed, and a paper titled "District Heating in Oregon" was published by ODOE in July 1987.

ODOE continues to respond to inquiries on geothermal energy development from the public. Over 130 such responses were provided in 1987. ODOE also certifies geothermal tax credits. Thirty-six residential and seven business tax credits were certified in 1987.

ODOE continues to provide leadership in the Pacific Northwest Section of the Geothermal Resources Council (GRC). Finally, ODOE reviewed and commented on the geothermal-energy aspects of the remaining National Forest Draft Management Plans. All of these plans have now been completed in draft form.

GEO-HEAT CENTER, OREGON INSTITUTE OF TECHNOLOGY

The Geo-Heat Center at OIT specializes in assisting in the development of low-temperature (<90 °C) and moderate-temperature (90-150 °C) geothermal applications for direct use. The Center is under contract with USDOE to provide geothermal services to State and Federal agencies who receive requests from engineering consultants, planners, and developers for development assistance on direct-use projects. The assistance can range from answering technical questions and simple consultations on methods, equipment, and applications to providing feasibility studies. The Geo-Heat Center has published over 70 such feasibility studies, which are available as examples. The project period is slated to run through the end of 1992.

In 1987, the Geo-Heat Center started to assemble information on the original design and subsequent performance of a selected group of geothermal district heating systems that have logged at least three years of operation. Specific areas of investigation are customer connect time, disposal, and equipment type and construction materials for production pumps and transmission piping. The operational performance of equipment in each of these areas will be described and will serve as a reference for designers of new systems and operators of existing systems. The report will be published in 1988.

The Geo-Heat Center continues to evaluate the performance of downhole heat exchangers. It is currently gathering information on design, applications, and research throughout the world. The information will be available in late 1988.

The Geo-Heat Center aided OIT in making plans to drill an injection well to eliminate surface discharge from its geothermal system. The OIT geothermal system has utilized surface discharge of spent geothermal fluids since its inception. The well will be drilled in the summer of 1988, and all surface discharge from the OIT campus is expected to cease in 1989.

The Geo-Heat Center continues to be involved in the evaluation of the Klamath Falls geothermal aquifer. Its staff plays an active role on the Klamath Falls Geothermal Advisory Committee. The Center continues to publish the Geo-Heat Center *Quarterly Bulletin*, which has been in circulation since 1975.

RELEVANT RESEARCH BY OREGON STATE UNIVERSITY

E.M. Taylor of Oregon State University (OSU) completed a report on the geology of the northwest quarter of the Broken Top quadrangle. The paper was published in 1987 as DOGAMI Special Paper 21 (Taylor, 1987). Taylor also aided in the compilation of the geology of the McKenzie Bridge quadrangle, which will be published in 1988 in DOGAMI's Geological Map Series as Map GMS-48 (Priest and others, 1988).

B.E. Hill, a doctoral candidate at OSU, is continuing his work on Quaternary ash flows in the Bend area (Hill, 1985) and the silicic highland west of Bend (Figure 5). As detailed in last year's geothermal summary (Priest and others, 1987b), new data indicate that the Bend Pumice/Tumalo Tuff air-fall/ash-flow sequence may be considerably younger than previously supposed (Sarna-Wojcicki and others, 1987). Hill has also acquired data that support a silicic highland source for the ash flows (Hill, 1985). In an abstract prepared for the Geological Society of America (GSA) annual meeting in 1988, Hill proposes that the silicic highland be formally named the Tumalo Volcanic Center (B.E. Hill, written communication, 1988).

J. Dymond and R.W. Collier of the OSU College of Oceanography started investigations at Crater Lake during the summer of 1987. They are trying to determine whether hot springs exist on the floor of the lake. In September 1987, they used an unmanned submersible in the lake in an attempt to directly observe the supposed springs. Results were equivocal. Further dives in a manned submersible were planned for 1988.

ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY

The USGS was involved in several geothermal-related projects in 1987. Compilations of the geologic map of the State of Oregon by G.W. Walker and N.S. MacLeod and the Salem 1° by 2° sheet by Walker and R.A. Duncan were completed.

D.R. Sherrod continued his work on a compilation of the geology of the Oregon Cascade Range. The final product of this project, which is headed by J.G. Smith, will be a geologic map of the entire Cascade Range in the United States. The map scale will be 1:500,000. Quaternary volcanic rocks are emphasized on the maps because of their importance to geothermal investigations. These rocks are split into five age divisions and four compositional divisions. Western Cascades rocks, which are not so well known as the younger rocks, are shown in less detail (Sherrod, 1987).

In addition to his compilation of the geology of the Oregon Cascades, Sherrod is coordinating a study on the Thermal Power Company CTGH-1 drill hole for DOGAMI. The study is funded by USDOE. Sherrod and R.M. Conrey (Washington State University) completed mapping of approximately 15 mi² around the drill hole in 1987. The report is scheduled for publication in the fall of 1988. In addition to his work on the Thermal Power hole for DOGAMI, Conrey continued his detailed geologic mapping at Mount Jefferson.

T.E.C. Keith and K.E. Bargar continued their hydrothermal-alteration studies of holes drilled under the USDOE cost-share program. They will be contributors to the Thermal Power report.

D.V. Fitterman is editing a special issue of the *Journal of Geophysical Research* on Newberry volcano. The issue will include articles on geology, hydrothermal alteration, transient electromagnetic soundings, magnetotelluric soundings, resistivity, high-resolution seismic imaging, gravity, and magnetics (Muffler, 1987).

A.M. Sarna-Wojcicki was main author of a summary of tephra-correlation studies that are relevant to the geothermal potential of the Cascades in the Three Sisters-Bend area (Sarna-Wojcicki and others, 1987). See Priest and others (1987b) for a detailed discussion of these data and the geothermal potential of the silicic highland (Figure 5).

The USGS Water Resources Division completed three years of intensive work in the Cascade Range. The program included NaCl surveys, stable-isotope studies, and water-chemistry and temperature-gradient work in the central Oregon Cascades between Mount Hood and the Three Sisters. The data will be summarized in an open-file report to be released in the fall of 1988. The Water Resources Division intends to drill a series of six shallow temperature-gradient holes in the Cascade Range in 1988 to fill in gaps in the existing heat-flow data base (S. Ingebritson, personal communication, 1988).

In May 1987, R.L. Christiansen replaced L.J.P. Muffler as Chief of the Branch of Igneous and Geothermal Processes and Coordinator of the Geothermal Research Program. Muffler will return to research activities in geothermal energy.

ACTIONS OF REGULATORY AGENCIES CONCERNING GEOTHERMAL EXPLORATION

The Oregon Board of Geologists Examiners ruled that individuals practicing in the fields of hydrogeology and geothermal geology do not have to be certified by the Board as engineering geologists. It was felt that these fields require a broad range of geologic expertise that is not limited to the domain of engineering geology. Persons practicing in these fields do, however, have to be registered geologists and must adhere to the Code of Professional Conduct (Chapter 809 of Oregon Administrative Rules).

Two wells of California Energy Company, Inc., (CECI) near Crater Lake have been placed in suspended status by DOGAMI and USBLM. CECI requested the suspension while the company responds to the Sierra Club appeal of the USBLM ruling to the Board of Land Appeals. USBLM had ruled to grant CECI permission to drill the two temperature-gradient holes to 5,500 ft with total loss of circulation. The situation at Crater Lake is discussed in detail in a later section.

In early 1987, BPA announced its objectives to implement the 1986 Power Plan developed by the Pacific Northwest Power Planning Council. In the 1983 Power Plan, the Council had recommended that BPA develop a 10-MWe-capacity demonstration program. It was hoped that the demonstration program would encourage confirmation of the geothermal resource in the Pacific Northwest. The new 1986 power plan focused on resource confirmation rather than a demonstration plant. BPA's objectives to implement the 1986 plan are threefold:

1. Design a confirmation program that will result in the confirmation of a single-site, environmentally acceptable geothermal resource capable of supporting 100 MWe for 30 years.

2. Provide assurance that the electrical power generated from the resource will be made available to the region at competitive prices when it is needed in the future.

3. Complete the design of the confirmation program by the end of fiscal year 1988 (Geothermal Resources Council, 1987a).

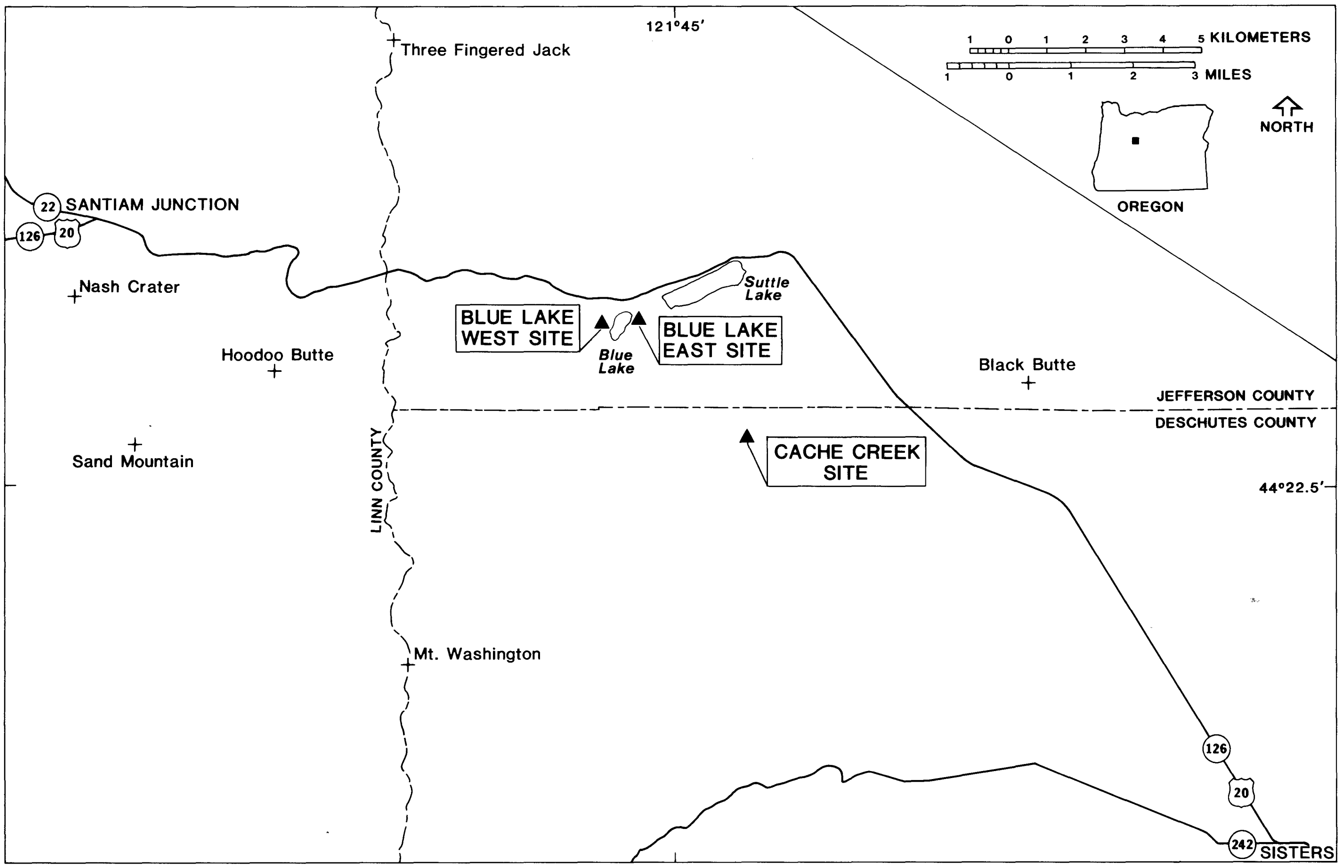


Figure 6. Location of potential PSDC drill sites near Santiam Pass, Oregon.

NEWBERRY VOLCANO

There was moderate activity at Newberry volcano during 1987. GEO-Newberry Crater, Inc., (GEO) drilled two holes: one on the southwest flank (Hole GEO N-5, Figure 5; Table 1) and the other on the east flank of the volcano (Hole GEO N-4, Figure 5; Table 1). Both holes were wireline-drilled temperature-gradient tests permitted to 5,000 ft.

GEO also announced plans to drill a small production well on one flank of the volcano in 1988. DOGAMI in early 1988 granted permits for two sites: SE¼ sec. 29, T. 21 S., R. 12 E., and NE¼ sec. 5, T. 22 S., R. 12 E. (Figure 5). As of mid-June 1988, the Environmental Assessment for the drilling had been approved by USBLM, and the thirty-day appeal period had passed with no appeals filed. It appears at this time, however, that drilling operations on Newberry will not begin until 1989.

The period of confidentiality on data from a hole drilled on the west flank of Newberry volcano ended in late 1987; the data are therefore now available to the public. The hole was spudded in September 1983 by Occidental Geothermal, Inc., in sec. 3, T. 22 S., R. 12 E. (Occidental 72-3, Figure 5). The hole was drilled to a total depth of 3,504 ft in the fall of 1983. The hole was reentered in the fall of 1984 and deepened to 4,501 ft. Information from only that portion of the hole above 3,504 ft is currently available. Data on the remainder of the hole will become public in the fall of 1988. The operator of record is now Santa Fe Geothermal, Inc., of Bakersfield, California.

The temperature-depth curve for hole 72-3 is reproduced in Figure 7, along with the other available temperature-depth curves from deep holes drilled at Newberry Crater. The hole was logged in October 1985, approximately one year after the completion of drilling operations in 1984. The temperature-depth curve can be divided into two parts. The upper part is essentially isothermal to a depth of approximately 470 m. This section of the curve represents the "rain curtain" typical of the young volcanic rocks of the High Cascade Range and Newberry Crater. The lower part of the curve is linear and represents conductive heat flow. The gradient for this portion of the hole is 138 °C/km. The bottom-hole temperature (at 1,060 m) is 114 °C.

In all, data from six deep holes at Newberry are now available. Temperature-depth profiles from two holes inside the caldera (USGS Newberry 2 and Sandia Laboratories RDO-1, Figures 5 and 7) have isothermal gradients to depths of approximately 275 m. On the flanks of the volcano, data from four holes (USGS Newberry 1, Occidental 72-3, and GEO N-1 and N-3, Figures 5 and 7) indicate that the "rain curtain" extends to depths of approximately 450-550 m.

CRATER LAKE

In November of 1986, California Energy Company, Inc., (CECI) suspended drilling on its MZI-11A hole on the southeast flank of Mount Mazama. Drilling was ordered suspended by USBLM because the loss of circulation encountered in the hole was a violation of the drilling permit. CECI requested that the Environmental Assessment for the Crater Lake drilling operations, which contained stipulations prohibiting drilling without circulation, be changed to allow drilling with total loss of circulation (a standard procedure in the porous volcanic rocks of the High Cascade Range). USBLM subsequently ruled to grant CECI permission to drill without circulation. The Sierra Club then filed an appeal of the USBLM ruling to the Board of Land Appeals in Arlington, Virginia. The appeal is currently under review. A ruling is expected to take one to two years. At company request, pending outcome of the appeal, CECI's two wells near Crater Lake have been placed in suspended status by DOGAMI, and the leases have been placed in suspended status by USBLM.

Table 3. *Mazama Geothermal Unit chronology*

1/84: California Energy Company, Inc. (CECI) enters into two geothermal unit agreements with the U.S. Bureau of Land Management (USBLM) on Federal geothermal leases it owns in the Winema National Forest. Mazama Unit I is east of Crater Lake National Park and contains 80,483.49 acres. Mazama Unit II is south of Crater Lake National Park and contains 18,682.66 acres.
2/84: CECI submits detailed plan of operation for drilling temperature-gradient holes at the Mazama Units I and II.
3/84: USBLM submits an Environmental Assessment of the proposed drilling operations for temperature-gradient holes in the two Mazama units. Comments are solicited.
12/84: USBLM and the USDA Forest Service (USFS) grant CECI permission to drill up to four temperature-gradient holes in the Mazama Units I and II.
5/85: CECI applies for drilling permits for four temperature-gradient holes in the Mazama Units I and II. USBLM and the Oregon Department of Geology and Mineral Industries (DOGAMI) approve the permit applications.
6/85: DOGAMI Governing Board grants a CECI request to allow the extension of the CECI drilling permits until 6/87.
9/86: CECI commences drilling operations on temperature-gradient hole MZI-11A, located in Mazama Unit I. The hole is cost-shared with the U.S. Department of Energy (USDOE).
11/86: CECI commences drilling operations on temperature-gradient hole MZII-1, located in Mazama Unit II. The hole is cost-shared with USDOE.
11/86: The two drilling operations are ordered to be suspended by USBLM due to loss of circulation while drilling, which is a violation of the drilling permit. Temporary suspension status is granted to CECI by USBLM. The MZI-11A hole is at a total depth of 1,354 ft with a bottom-hole temperature of 107 °C. The MZII-1 hole is at a total depth of 485 ft with surface casing set.
11/86: CECI requests that the USBLM grant approval of permit modification to complete the drilling of the MZI-11A and MZII-1 temperature-gradient holes to 5,500 ft without maintaining circulation of the drilling fluids to the surface.
2/87: *Federal Register* published regarding protection of significant thermal features within the National Park System. Crater Lake is included on the list of significant thermal features proposed for study on the basis of possible hot springs in the floor of the lake.
2/87: Crater Lake Technical Workshop held in Portland, Oregon, to discuss the *Federal Register*, hydrology, and potential impact of drilling temperature-gradient holes in Mazama Units I and II. Workshop is sponsored by the Pacific Northwest Section of the Geothermal Resources Council and is attended by representatives from DOGAMI, the U.S. Geological Survey (USGS), Portland State University (PSU), Oregon State University (OSU), CECI, USBLM, USFS, and numerous other State and Federal governmental, academic, industry, and environmental organizations.
5/87: USBLM submits Supplemental Environmental Assessment to the 3/84 Environmental Assessment regarding CECI's 11/86 request for permit modification.
6/87: DOGAMI cancels the two remaining CECI Mazama Unit drilling permits due to expiration of the permits. Permits for the MZI-11A and MZII-1 holes remain in suspended status.
7/87: USBLM rules to implement the Supplemental Environmental Assessment. That is to grant CECI permission to drill the temperature-gradient holes to a depth of 5,500 ft with fluid loss to the subsurface. USBLM finds that the proposed action of drilling temperature-gradient holes would not have a significant impact on the environment.
8/87: Final list of National Parks with significant thermal features is published in the *Federal Register*. It is decided that there are insufficient data to warrant the inclusion of Crater Lake National Park in the final list. A decision on Crater Lake National Park is deferred until more information is available.
Fall/87: USGS releases Open-File Report 87-587 on the chemical analysis of waters from Crater Lake and nearby springs. The authors find that the data are permissive of hot spring input into the floor of the lake, but are not conclusive. The data did not permit the assessment of amount, temperature, or composition of any fluids that might be entering the lake (Thompson and others, 1987).
9/87: The Sierra Club files an appeal of the USBLM decision of 7/87 to the Board of Land Appeals, Arlington, Virginia. The appeal is currently under review.
9/87: The National Park Service deploys an unmanned submersible in Crater Lake in an attempt to gather direct physical evidence of the existence of hot springs in the floor of the lake. The deployment is in support of research in progress by J. Dymond and R.W. Collier of OSU.
10/87: CECI must respond to the Sierra Club appeal of the USBLM ruling to the Board of Land Appeals. It normally takes one to two years for the Board to respond with a ruling. During this time, the two Mazama Unit wells may remain in suspended status.
10/87: E.A. Sammel (USGS, retired) and S. Benson (Lawrence Berkely Laboratory) publish their findings in the *Transactions* of the Geothermal Resources Council annual meeting. They interpret the data to indicate that geothermal drilling will neither pollute the lake nor affect the hydrologic regime in the vicinity of the caldera.
1/88: Senator Mark Hatfield of Oregon puts forth an amendment before the Senate Energy and Natural Resources Committee that would establish Crater Lake as a significant thermal feature. The amendment does not prohibit geothermal drilling, but allows the Secretary of the Interior to withdraw lands from geothermal leasing, if geothermal development appears likely to damage the lake. It also requires the Secretary to halt or restrict ongoing geothermal activity that appears likely to cause damage. The legislation was approved by the Committee.
2/88: In a letter to the Secretary of the Interior, Oregon Governor Neil Goldschmidt urges the Department of the Interior to halt further geothermal leasing on national forest lands around Crater Lake National Park. The Governor is concerned that geothermal development on the flanks of the Crater Lake caldera would adversely affect the beauty and serenity of the park.
2/88: The DOGAMI Governing Board grants suspended status to the MZI-11A and MZII-1 temperature-gradient wells through August 31, 1988. USBLM has previously granted suspended status to the leases through the same date. The suspension was granted at CECI request.
2/88: Draft report titled "Studies of Hydrothermal Processes in Crater Lake: A Report of Field Studies Conducted in 1987 for Crater Lake National Park," by J. Dymond and R.W. Collier of OSU is released to the National Park Service.
3/88: USBLM releases a review of the Collier and Dymond report, concluding that there is still a lack of definitive evidence regarding the presence or absence of hot springs in the floor of the lake.
5/88: Senator Hatfield's amendment to add Crater Lake to the list of significant thermal features passes the Senate.
5/88: Senator Hatfield's amendment to add Crater Lake to the list of significant thermal features clears the House Interior Committee on a voice vote. Tony Coehlo of California offers a provision that would allow sites to be removed from the list if conclusive evidence shows no thermal feature would be harmed by leasing. A compromise places Crater Lake on the protected list, but requires the Secretary of the Interior to report to Congress in six months as to whether or not significant thermal features actually exist in Crater Lake National Park.
6/88: The Pacific Division of the American Association for the Advancement of Science holds a special session on "The Clarity of Crater Lake, Oregon. An Ecosystem Study." The session includes talks by 16 speakers active in research at the lake. Subjects covered include geology, sedimentology, chemistry, clarity, color studies, climatology, and biology.

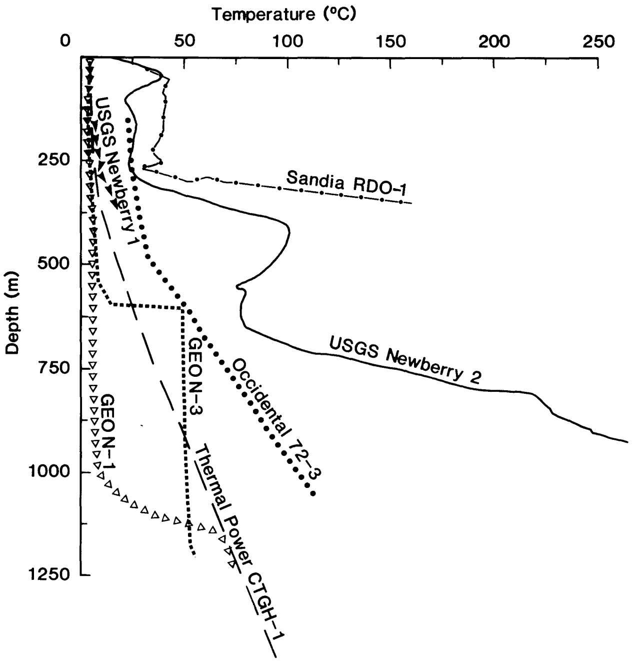


Figure 7. Temperature-depth curves for Newberry drill holes and Thermal Power CTGH-1.

In deciding to grant CECI permission to drill without circulation, USBLM hired as a consultant E.A. Sammel (USGS, retired). Sammel and S. Benson (Lawrence Berkeley Laboratory, funded by USDOE) collaborated on a study of the ground-water flow system in the vicinity of Crater Lake to examine the potential effects of introducing drilling mud into this flow system. In a paper published in 1987, Sammel and Benson stated that, "Based on our calculations that show the regional flow of ground water will oppose the flow of drilling mud toward the lake, and based on our volumetric estimate of drilling mud migration, our study concludes that drilling without returns will not pollute Crater Lake, nor will it affect the hydrologic regime in the immediate vicinity of the Crater Lake caldera" (Sammel and Benson, 1987).

The USBLM, in response to an October 15, 1986, Congressional order, suspended geothermal leasing on Federal lands (see Section 115(2)(a) of the October 15, 1986, *Congressional Record*). The order gave the Secretary of the Interior 120 days to publish a proposed list of significant thermal features in the National Park System. After publication of the proposed list, the Secretary was given 60 days to evaluate public comment and send a final list to the Committee on Energy and Natural Resources of the Senate and the Committee on Interior and Insular Affairs of the House of Representatives. The proposed list was published on February 13, 1987, in the *Federal Register* (Federal Register, 1987a). It contained references to the heat-flow anomalies found by the USGS on the floor of Crater Lake (Williams and von Herzen, 1983). The Department of the Interior was faced with the decision as to whether these heat-flow anomalies qualified as "significant thermal features" under the guidelines of the Congressional order. The final list was published in the *Federal Register* in August 1987. Crater Lake was not included on the final list. It was decided to defer a decision on Crater Lake pending further studies.

In February 1987, the Pacific Northwest Section of the Geothermal Resources Council held a special symposium on Crater Lake. Topics of discussion included geology, Crater Lake heat flow, the presence or absence of hot springs in the floor of the lake, the interpretation of lake geochemistry, possible causes of loss of lake clarity, and the effects of drilling outside the Park boundary on hydrothermal convection systems beneath the lake.

In the summer of 1987, J. Dymond and R.W. Collier of OSU commenced studies aimed at establishing the presence or absence of hot springs in the floor of Crater Lake. The studies culminated in September when the National Park Service deployed an unmanned submarine in Crater Lake. The results were equivocal.

Table 3 is a chronology of events at the Mazama geothermal unit since 1984, when CECI entered into unit agreements with USBLM.

ACKNOWLEDGMENTS

This paper could not have been written without the cooperation of numerous individuals in government and industry. Jacki Clark of USBLM provided the Federal leasing data. Jack Feuer, Dennis Simontacchi, and Dennis Davis of USBLM and Bob Fujimoto of USFS provided much useful information on regulatory issues. Dennis Olmstead and Dan Wermiel of DOGAMI provided the data on drilling permits. Alex Sifford of ODOE and Marshall Gannett of OWRD provided the information on their agencies' activities for the year. Paul Lienau of OIT provided much of the information on direct-use projects around the state. David Sherrod of the USGS and Steve Ingebritson of USGS Water Resources provided accounts of USGS activities in Oregon in 1987. Joe LaFleur of California Energy and Cliff Walke of GEO provided activity accounts of their respective companies in Oregon at Crater Lake and Newberry Crater.

REFERENCES CITED

Black, G.L., Blackwell, D.D., and Steele, J.L., 1983, Heat flow in the Oregon Cascades, *in* Priest, G.R., and Vogt, B.F., eds., Geology and geothermal resources of the central Oregon Cascade Range: Oregon Department of Geology and Mineral Industries Special Paper 15, p. 69-76.

Black, G.L., Woller, N.M., and Ferns, M.L., 1987, Geologic map of the Crescent Mountain area, Linn County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-47, scale 1:62,500.

Brown, D.E., McLean, G.D., Priest, G.R., Woller, N.M., and Black, G.L., 1980, Preliminary geology and geothermal-resource potential of the Belknap-Foley area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-80-2, 58 p.

Dicken, S.N., 1950, Oregon geography: Eugene, Oreg., University of Oregon Cooperative Bookstore, 104 p.

Federal Register, 1987a, Significant thermal features within units of the National Park System: Federal Register, v. 52, no. 30, p. 4700-4710.

———1987b, Significant thermal features within units of the National Park System: Federal Register, v. 52, no. 148, p. 28790-28800.

Geo-Heat Center, 1987, Geothermal pipeline: Geo-Heat Center Quarterly Bulletin, v. 10, no. 1, p. 17-19.

Geothermal Resources Council, 1987a, On location. Federal scene: Geothermal Resources Council Bulletin, v. 16, no. 3, p. 24.

———1987b, On location. State scene: Geothermal Resources Council Bulletin, v. 16, no. 3, p. 21-24.

Hill, B.E., 1985 [compl. 1984], Petrology of the Bend pumice and Tumalo tuff, a Pleistocene Cascade eruption involving magma mixing: Corvallis, Oreg., Oregon State University master's thesis, 101 p.

Muffler, L.J.P., 1987, Geothermal studies of the U.S. Geological Survey in the Cascade Range: Geothermal Resources Council Transactions, v. 11, p. 281-283.

Priest, G.R., Bargar, K.E., Black, G.L., Blackwell, D.D., Couch, R.W., Collier, R., Duncan, R.A., Dymond, J., Evans, J., Goldstein, N., Haimson, B.C., Hughes, S., Iyer, M., Keith, T.E.C., Korosec, M.A., Laul, J.C., Levy, S., Mariner, R.H., Mooney, W.D., Rowley, J., Sherrod, D.R., Smith, M., Waibel, A., Weaver, C.S., Woller, N.M., and Wright, P.M., 1987a, Investigation of the thermal regime and geologic history of the Cascade volcanic arc: First phase of a program for scientific drilling in the Cascade Range: Oregon Department of Geology and Mineral Industries Open-File Report O-86-3, 120 p.

Priest, G.R., Black, G.L., Woller, N.M., and Taylor, E.M., 1988, Geologic map of the McKenzie Bridge quadrangle, Lane County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-48, in press.

Priest, G.R., Woller, N.M., Blackwell, D.D., and Gannett, M.W., 1987, Geothermal exploration in Oregon, 1986: Oregon Geology, v. 49, no. 6, p. 67-73.

*(Continued on page 116, **Geothermal**)*

New guides for central Oregon published

ROADSIDE GUIDE TO THE GEOLOGY OF NEWBERRY VOLCANO, by R.A. Jensen, Bend, Oregon, 1988, 75 p., $7.95 (postage paid).

The area of Newberry volcano, the dominant geologic feature of the northwestern end of Oregon's High Lava Plains physiographic province, is an ideal laboratory for visitors who are interested in volcanic features. Located approximately 25 mi south of Bend, the Newberry area contains nearly every conceivable variety of volcanic rock produced by a volcano whose eruptive history spans more than half a million years. Jensen's guidebook brings together the available information on Newberry volcano in a form useful to any visitor interested in the geology or history of the area.

As a roadside guide, the book presents five major tours, one circling the entire area (a round-trip of almost 150 mi, departing from and returning to Bend) and four tours dissecting the area, mainly from Newberry Crater to the south. Most tours include some side trips that lead to points of particular interest. All tours and side trips are tied in with the "Circle Newberry Tour" by cross-references.

The description of observable features along the trip routes is presented in great detail and accompanied by many helpful illustrations, maps, and tables. Thus, for instance, the initial map of the entire area shows not only all tour roads but also their quality, from paved roads to unmaintained dirt roads. An index map shows all 7½-minute quadrangles that make up the Newberry area, so that visitors can equip themselves with the appropriate detailed USGS topographic quadrangle maps for their trips. Toward the end of the book, three "viewpoint tables" explain practically all visible features that can be seen from the tops of Pilot Butte, Lava Butte, and Paulina Peak.

It almost goes without saying that such a thorough guide includes a general discussion of the geology, a glossary of geologic terms, and reference lists for the geology of volcanic phenomena in general as well as the history and geology of the Newberry area in particular.

The book is available from CenOreGeoPub, 20180 Briggs Road, Bend, Oregon 97701, and at the Lava Lands Visitor Center near Bend as well as various bookstores in central Oregon.

CENTRAL OREGON CAVES, by Charlie and Jo Larson. ABC Printing and Publishing, Vancouver, Washington, 1987, 44 p., $3.85.

For accomplished cavers as well as for people who just want to learn something about caves, especially lava tubes, this book (size approximately 9x6 in.) provides an introduction to the cave-rich central Oregon area around Bend.

Following a general introduction about the formation and features of lava tubes and similar caves, twenty caves or groups of caves are described by the authors. Most of the caves are located in the area south of Bend, on the flanks of Newberry volcano; a few are farther away, near Redmond and in the High Cascades to the west. Most descriptions are accompanied by photographs, maps, and cross sections of the caves.

The descriptions touch lightly on all aspects of interest—access, geology, special warnings for explorers, historical features—without giving away too much, thus stimulating the reader's appetite for learning more (wouldn't you like to find out, for instance, what's in the "Grim Reminder Room" of the South Ice Cave?).

For the visitor who is new to, but interested in, caving as a recreational activity, the authors provide introductory information, such as debunking myths about caves, preparations for entering caves, and safe and considerate conduct in them.

The book concludes with a glossary explaining some technical terms, a short list of further reading on caves, and information about the National Speleological Society, to which most local caving clubs belong.

LAVA RIVER CAVE, by Charlie and Jo Larson. ABC Printing and Publishing, Vancouver, Washington, 1987, 24 p., $2.85.

Lava River Cave was a state park from 1926 to 1981, when it became part of the Deschutes National Forest, and is now managed as a day-use recreational site.

Similar in format and style to the booklet described above, this one deals in extensive detail with the longest, most accessible, and most popular cave of the Bend area—"a lava tube of world-class dimensions."

The guide divides the approximately 1 mi of lava tube into five sections, describing, mapping, and illustrating each in considerable detail. It includes occasional discourses on such features as the air movement, the accumulations of "sand," or the erosive action of "ice wedging" in the cave.

Both booklets are excellent introductions and guides for the visitor to central Oregon. They are available from the publisher, ABC Printing, 13318 NE 12th Avenue, Vancouver, WA 98685. For each title, the prices given above include $0.90 for postage. □

GPO offers books in Oregon

The U.S. Government Printing Office (GPO) has opened a bookstore for its publications in Portland, the latest of about two dozen stores throughout the Nation.

This new outlet for products of the GPO offers book publications (also some maps and posters) produced by various Federal agencies and released by them for sale through the GPO. On opening day, we found, for example, publications related to earth science and mineral industry from such agencies as the USDA Forest Service, NASA, the Office of Surface Mining Reclamation, the Office of Technology Assessment, and the U.S. Geological Survey (Survey maps are not offered here, but, e.g., a Professional Paper on Mount St. Helens and an open-file report on ice volumes of Cascade volcanoes). Most of the titles offered on the store's shelves are intended for nontechnical use and the general public. However, the bookstore's management is flexibly oriented toward the public's demand for publications and will update its stock periodically according to that demand.

In addition, the bookstore offers its services not only by presenting publications in the store but also by making available a current catalog of available publications and a subject-oriented bibliography and index of all GPO publications, so that customers may order these materials through the bookstore. Both the catalog and the subject indexes are available upon request. They may prove to be a convenient way for many Oregonians to gain access to publications that are not easily obtained from regular bookstores.

The new facility is located at 1305 SW First Avenue, Portland, OR 97201-5801, phone (503) 221-6217, and is open Monday through Friday from 9:00 a.m. to 5:00 p.m. □

(MLR, continued from page 98)

4. Permit boundary line. New rules require the identification of a permit boundary line that describes the area within which mining activities are permitted. Buffer strips, processing areas, spoil sites, and future mining areas are to be located within the permit boundary. For more specific information, operators should contact the Department MLR office.

5. Fee increases scheduled. The Department has scheduled to raise fees to the statutory maximum for all renewals and new applications, the change to be effective October 1, 1988. Renewal fees will be increased from $375 to $385 per year, fees on new applications from $500 to $535 per year. Comments and suggestions should be submitted to the MLR office. □

OIL AND GAS NEWS

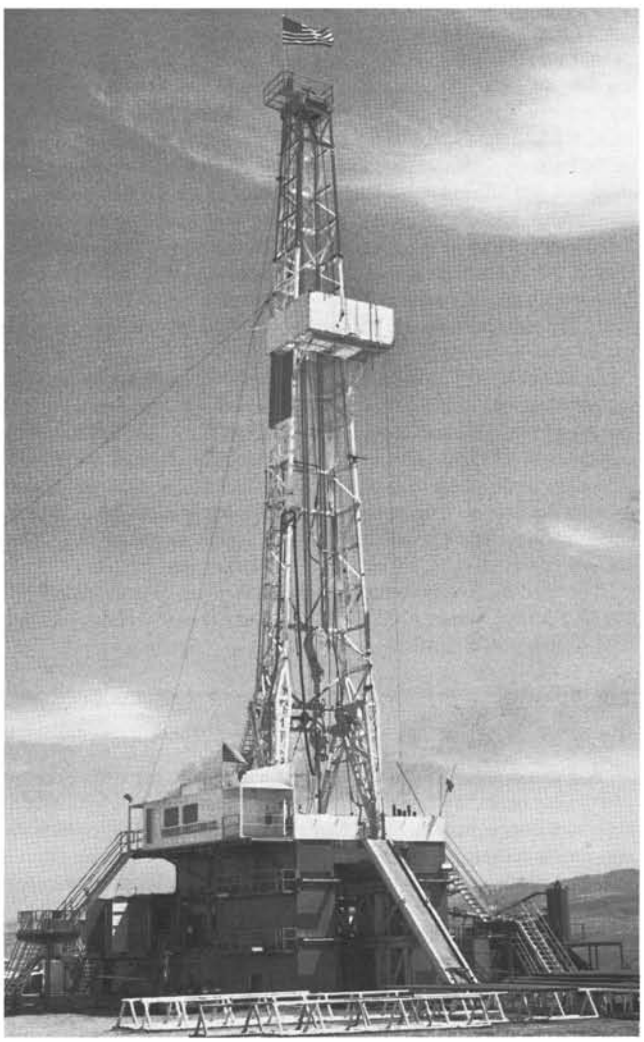
Mist Gas Field: Gas storage

Oregon Natural Development continues its program of four injection wells and one monitor well this season. These wells will complete the drilling portion of the storage project. Three injection wells have been drilled and completed: IW 330-3, IW 23B-3, and IW 42C-10. The remaining wells this year will be IW 22D-10 and OM 43B-10.

The company is concurrently making extensive modifications and additions to the gas treatment and compressor plant at the storage site. In addition, a new 50-mi pipeline is planned to carry gas from Mist to the Portland area. This project is scheduled for 1989.

ARCO continues exploration at Mist

ARCO has pursued a busy exploration schedule in the field, mainly south of State Highways 202 and 47. So far, the following wells have been drilled: CC 42-8-54, CC 44-27-65, LF 32-20-65, LF 32-20-65R, CFI 34-1-55, and Johnson 44-19-65. Of these, three have been completed as producers: CC 42-8-54, CC 44-27-65, and CFI 34-1-55. Flow rates will be released by ARCO at the end of the season. Wells LF 32-20-65 and Johnson 44-19-65 were plugged and abandoned, and LF 32-20-65R is now being drilled as a replacement for LF 32-20-65, which did not reach its proposed total depth.



ARCO well Hanna 1 in Morrow County

Morrow County wildcat drilling

ARCO continues to drill its Morrow County well, Hanna 1. The well, 6 mi from Heppner, was spudded June 7, and has a proposed total depth of 9,000 ft. No information has been released from the well. The well should be at total depth by November of this year.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
411	ARCO Hamlin 33-17-65 36-009-00245	SE¼ sec. 17 T. 6 N., R. 5 W. Columbia County	Location, 2,835.
412	ARCO Longview Fibre 32-20-65R 36-009-00246	NE¼ sec. 20 T. 6 N., R. 5 W. Columbia County	Location, 3,100.

□

(Geothermal, continued from page 114)

Priest, G.R., Woller, N.M., Black, G.L., and Evans, S.H., 1982, Overview of the geology and geothermal resources of the central Oregon Cascades, *in* Priest, G.R., and Vogt, B.F., eds., Geology and geothermal resources of the Cascades, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-82-7, p. 5-70.

———1983, Overview of the geology of the central Oregon Cascade Range, *in* Priest, G.R., and Vogt, B.F., eds., Geology and geothermal resources of the central Oregon Cascade Range: Oregon Department of Geology and Mineral Industries Special Paper 15, p. 3-28.

Priest, G.R., Woller, N.M., and Ferns, M.L., 1987, Geologic map of the Breitenbush River area, Linn and Marion Counties, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-46, scale 1:62,500.

Sammel, E.A., and Benson, S., 1987, An analysis of the hydrologic effects of proposed test drilling in the Winema National Forest near Crater Lake, Oregon: Geothermal Resources Council Transactions, v. 11, p. 293-303.

Sarna-Wojcicki, A.M., Morrison, S.D., Meyer, C.E., and Hillhouse, J.W., 1987, Correlation of upper Cenozoic tephra layers between sediments of the western United States and eastern Pacific Ocean and comparison with biostratigraphic and magnetostratigraphic age data: Geological Society of America Bulletin, v. 98, no. 2, p. 207-223.

Sherrod, D.R., 1987, New compilation map of the Cascade Range in Oregon: Geothermal Resources Council Transactions, v. 11, p. 305-307.

Smith, G.A., 1987a, Geologic map of the Eagle Butte and Gateway quadrangles, Jefferson and Wasco Counties, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-43, scale 1:24,000.

———1987b, Geologic map of the Seekseequa Junction and a portion of the Metolius Bench quadrangles, Jefferson County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-44, scale 1:24,000.

———1987c, Geologic map of the Madras West and Madras East quadrangles, Jefferson County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-45, scale 1:24,000.

Taylor, E.M., 1980, Volcanic and volcaniclastic rocks on the east flank of the central Cascade Range to the Deschutes River, Oregon, *in* Oles, K.F., Johnson, J.G., Niem, A.R., and Niem, W.A., eds., Geologic field trips in western Oregon and southwestern Washington: Oregon Department of Geology and Mineral Industries Bulletin 101, p. 1-7.

———1987, Field geology of the northwest quarter of the Broken Top 15' quadrangle, Deschutes County, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 21, 20 p.

Thompson, J.M., White, L.D., and Nathenson, M., 1987, Chemical analyses of waters from Crater Lake, Oregon, and nearby springs: U.S. Geological Survey Open-File Report 87-587, 26 p.

Williams, D.L., and von Herzen, R.P., 1983, On the terrestrial heat flow and physical limnology of Crater Lake, Oregon: Journal of Geophysical Research, v. 88, no. B2, p. 1094-1104. □

USGS, USBM open joint minerals information office

A new mineral and earth science information center has been opened in Washington, D.C., as a cooperative venture of the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). The new Minerals Information Office will provide greatly expanded services from the Nation's largest pool of earth science information sources and public mineral scientists, both to the general public and to users from government, industry, and the scientific community.

The new Minerals Information Office is located next door to the expanded and renamed USGS Earth Science Information Center (formerly Public Inquiries Office) in the 2600 corridor at the E Street entrance of the main Interior Department Building, 18th and E Streets, NW.

Among the services the new offices offer to users are the following:

Availability of minerals experts from both USBM and USGS to provide access to all of the hundreds of thousands of reports on mineral-related subjects that have been published by the two Interior Department agencies over the last century.

Sale of and access to more than 70,000 topographic maps of the Nation and more than 17,000 different maps and reports on earth science subjects—earthquakes, volcanoes, floods, and fossils, to name a few—that have been published by the USGS.

Updated listings of current reports and maps prepared by the two agencies—about 10,000 new titles a year—plus computerized listings of 127,000 titles that are part of the USGS library, largest earth science library in the western world.

The largest statistics on worldwide mineral production and use, compiled by USBM, covering more than 100 commodities from every country in the world.

The new facilities are open to the public from 8:15 a.m. to 3:45 p.m. daily. Addresses and phone numbers are, for the USBM/USGS Minerals Information Office: Department of the Interior, Mail Stop 2647-MIB, Room 2647, 18th and C Streets, NW, Washington, D.C. 20240, phone (202) 343-5512; and for the USGS Earth Science Information Center: U.S. Geological Survey, Department of the Interior Building, Room 2650, 18th and C Streets, NW, Washington, D.C., 20240, phone (202) 343-8073.

—USGS/USBM news release

USGS names new public affairs officer in Menlo Park

Patricia A. Jorgenson has been named public affairs officer for the U.S. Geological Survey (USGS) in Menlo Park, California, the USGS Western Region headquarters.

She served as deputy chief (1980-1983) and chief (1983-1984) of the USGS Central Region Public Affairs Office in Denver, Colorado, before she resigned to enter private business. She now succeeds Edna G. King, who retired earlier in 1988 after serving in this position for more than eight years.

Jorgenson's special area of responsibility is the eight-state Western Region (Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, and Washington). For this region, she will provide special emphasis on earthquakes and other earth hazards.

The USGS Western Region Public Affairs Office can be reached under the following address and telephone number: Public Affairs Office, U.S. Geological Survey, Mail Stop 144, 345 Middlefield Road, Menlo Park, CA 94025, phone (415) 329-4000.

—USGS news release

DOGAMI Governing Board adds new member

Ronald K. Culbertson of Myrtle Creek has been appointed by Governor Neil Goldschmidt and confirmed by the Oregon Senate for a four-year term as member of the Governing Board of the Oregon Department of Geology and Mineral Industries. He succeeds Allen P. Stinchfield of North Bend, whose term ended on June 30.

Ronald K. Culbertson

Culbertson is President of the South Umpqua State Bank in Roseburg. A native of Baker, Oregon, he has worked for more than forty years in the banking business, all of it in Oregon.

Serving with Culbertson on the three-member board are Donald A. Haagensen, currently chairman, a Portland attorney and member of the law firm of Schwabe, Williamson, Wyatt, Moore, and Roberts, and Sidney R. Johnson, president of Johnson Homes in Baker. □

(Netarts Bay, continued from page 106)

Heaton, T.H., and Hartzell, S.H., 1986, Source characteristics of hypothetical subduction earthquakes in the northwestern United States: Seismological Society of America Bulletin, v. 76, no. 3, p. 675-708.

Heaton, T.H., and Kanamori, H., 1984, Seismic potential associated with subduction in the northwestern United States: Seismological Society of America Bulletin, v. 74, no. 3, p. 933-941.

Rogers, G.C., 1983, Seismotectonics of British Columbia: Vancouver, B.C., University of British Columbia doctoral dissertation, 227 p.

Stuiver, M., and Reimer, P.J., 1986, A computer program for radiocarbon age calibration, *in* Stuiver and others, eds., Calibration issue: Radiocarbon: v. 28(2B), p. 1022-1030.

Weaver, C.S., and Baker, G.E., 1988, Geometry of the Juan de Fuca Plate beneath Washington and northern Oregon from seismicity: Seismological Society of America Bulletin, v. 78, no. 1, p. 264-275.

Weaver, C.S., and Smith, S.W., 1983, Regional tectonic and earthquake hazard implications of a crustal fault zone in southwestern Washington: Journal of Geophysical Research, v. 88, no. B12, p. 10371-10383.

West, D.O., and McCrumb, D.R., 1988, Coastline uplift in Oregon and Washington and the nature of Cascadia subduction-zone tectonics: Geology, v. 16, no. 2, p. 169-172. □

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that, we feel, are of general interest to our readers.

CENOZOIC ACTIVE MARGIN AND SHALLOW CASCADES STRUCTURE: COCORP RESULTS FROM WESTERN OREGON, by R. William Keach II (M.S., Cornell University, 1986), 51 p.

COCORP recorded two profiles totaling 98 km in western Oregon in 1984, providing some of the first onshore deep seismic-reflection data from the forearc and arc of an active convergent margin. These data are of lower quality than most COCORP data, but when combined with other geological and geophysical data, they provide some useful insights into the subduction zone beneath Oregon and into extensional structures in the Cascades.

Line 1 crossed the Eocene sediments and underlying pillow basalts of the Coast Range and the western Willamette Valley. Reflections from the Willamette Valley clearly define the lower and western boundary of flat-lying, rhythmically bedded Eocene sediments. These sediments appear to be underlain by up to 8 km of seismically transparent Eocene pillow basalts. Layered reflections at depths of 8-16 km may indicate a remnant crust upon which the Eocene pillow basalts were erupted. East-dipping reflections at depths of 35-40 km may represent the decollement above the subducting Juan de Fuca Plate.

Oregon line 2 crosses the Cenozoic volcanic arc terranes of the Western and High Cascades. Interpretation of COCORP seismic data suggests modification of existing models for normal faulting which postulate a symmetric graben or grabens in the Cascades of Oregon. In the High Cascades along COCORP Oregon line 2, reflections suggest a large, gently west-dipping half-graben with major offset only on the west side of the range. The seismic data, when combined with other geological and geophysical data, suggest that, in general, the High Cascades were built on a series of blocks, rather than a single graben. The blocks were differentially faulted during the Pliocene. Seismic data from the Western Cascades indicate several normal faults with down-to-the-east offset, including a major, previously unidentified fault probably of Miocene age.

RELATIONS BETWEEN GEOLOGY AND MASS-MOVEMENT FEATURES IN A PART OF THE EAST FORK COQUILLE RIVER WATERSHED, SOUTHERN COAST RANGE, OREGON, by Jeffrey W. Lane (M.S., Oregon State University, 1988 [compl. 1987]), 107 p.

Various types of mass-movement features are found in the drainage basin of the East Fork Coquille River in the southern Oregon Coast Range. The distribution and forms of mass-movement features in the area are related to geologic factors and the resultant topography.

The Jurassic Otter Point Formation, a melange of low-grade metamorphic and marine sedimentary rocks, is present in scattered outcrops in the southwest portion of the study area but is not extensive. The Tertiary Roseburg Formation consists primarily of bedded siltstone and is compressed into a series of west- to northwest-striking folds. The overlying Lookingglass, Flournoy, and Tyee Formations consist of rhythmically bedded sandstone and siltstone units with an easterly to northeasterly dip of 5°-15°, decreasing upwards in the stratigraphic section. The units form cuesta ridges with up to 2,000 ft of relief.

The distribution of mass movements is demonstrably related to the bedrock geology and the study area topography. Debris avalanches are more common on the steep slopes underlain by Flournoy Formation and Tyee Formation sandstones, on the obsequent slope of cuesta ridges, and on north-facing slopes.

Soil creep occurs throughout the study area and may be the primary mass-movement form in siltstone terrane, though soil creep was not studied in detail. Slump-earthflows, rockfalls, and rock slumps also occur in the study area though less extensively than debris avalanches.

Stratigraphy and bedrock attitude contributed to the prehistoric occurrence of a major landslide involving Flournoy and Tyee Formation bed rock. The Sitkum landslide dammed the East Fork Coquille River, forming a substantial lake which is now filled with sediments. The form and size of the Sitkum landslide is similar to other landslides which have dammed drainages in the Coast Range, including Look Lake, Triangle Lake, and Drift Creek.

Comparisons with the Loon Lake landslide, which has a known radiocarbon date, provide estimated dates of 3,125 years B.P. for the Sitkum landslide and 10,300 years B.P. for the Triangle Lake landslide.

GEOCHEMICAL FEATURES OF THE BEAR CREEK LAVAS, DESCHUTES AND CROOK COUNTIES, OREGON, by Alan D. Brandon (M.S., University of Oregon, 1987), 122 p.

The Bear Creek lavas and other Neogene basaltic units crop out both along Oregon State Highway 27 between Prineville Reservoir and Millican and along the Bear Creek drainage to the east of Highway 27. Geochemical features of these rocks suggest that two series, Al_2O_3-rich and Al_2O_3-poor series, are similar in major-element contents to high-alumina basalt (HAB) and tholeiitic trends, respectively. Incompatible trace-element enrichments require contamination of the initial melt with a sedimentary component.

Phase equilibria and quantitative trace-element models are most consistent with derivation of the Bear Creek magmas from a depleted peridotite. The evolved Bear Creek magmas (basaltic andesites) are contaminated with a pre-Tertiary graywacke, probably from an accreted terrane that underlies the Bear Creek region and is similar to accreted terranes that crop out in eastern Oregon. The Al_2O_3-rich series underwent assimilation/fractional crystallization to pick up the graywacke signature, while the Al_2O_3-poor series initially acquired this sediment signature and subsequently underwent closed-system fractionation.

GEOLOGY OF THE SULTANA VEIN, BOHEMIA MINING DISTRICT, OREGON, by Stephen M. McChesney (M.A., University of Oregon, 1987), 160 p.

The Sultana Vein, Bohemia mining district, Oregon, is a gold-bearing base-metal sulfide/quartz/adularia vein cutting Tertiary basaltic-andesitic to rhyodacitic tuffs and lavas. Sericitic-argillic alteration parallels the vein, cutting propylitically altered rock.

The vein is in a right-lateral strike-slip fault, striking west-northwest, and dipping vertically. It cuts older northwest- and northeast-trending veins and dilates the northwest-trending veins into ore shoots. A wrench-faulting model suggests right-lateral shear at depth driving the deformation, kinematically consistent with differential extension in the Basin and Range starting 25 m.y. ago.

Base-metal sulfides, arsenic-free pyrite, and gold precipitate early. Paragenetically later tetrahedrite and arsenic-bearing botryoidal pyrite suggest arsenic enrichment of the fluids with time, possibly from a late magmatic source. These late fluids alter early base-metal sulfides to an assemblage of digenite, covellite, and pyrite. Supergene fluids enrich electrum at higher elevations in gold; deeper electrum wires have silver-enriched rims. □

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IN THIS ISSUE:
Middle Jurassic ammonite biochronology, Snowshoe Formation

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Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Example of ammonite species *Euhoploceras crescenticostatum* n. sp., one of the new species from the Showshoe Formation in east-central Oregon described in article beginning on next page. Maximum diameter of specimen shown is 218 mm (approximately 8½ in.).

OIL AND GAS NEWS

ARCO continues operations at Mist

ARCO has continued drilling at Mist Gas Field, Columbia County. The LF 32-20-65R-RD1 was drilled and completed as a gas producer, as was the CFW 12-15-64. This well is now the easternmost producer in the field. The wells CC-24-9-64 and CC 12-19-65 were drilled and have been suspended. ARCO plans to begin operations next on the CFI 23-16-64 well.

Mist Gas Field: Gas storage summary

The following service wells were drilled by Oregon Natural Gas Development Corporation during 1988 as part of the gas storage project at Mist Gas Field. Four injection-withdrawal wells were drilled, two each in the Flora and Bruer Pools. These are the IW 22D-10, IW 23B-3, IW 33D-3, and the IW 42C-10. The final well was an observation-monitor well, OM 43B-10. The company continues to make modifications and additions to the gas treatment and compressor plant at the gas storage site.

ARCO abandons Morrow County well

ARCO plugged and abandoned its wildcat well in the Columbia River Basin of eastern Oregon. The Hanna 1 well was the first well drilled in Morrow County and was located about 6 mi northeast of Heppner. Information has not been released from the well.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
413	ARCO Columbia Co. 22-17-75 36-009-00247	NW¼ sec. 17 T. 7 N., R. 5 W. Columbia County	Location; 2,760.
414	ARCO Sterling 12-24-66 36-007-00019	NW¼ sec. 24 T. 6 N., R. 6 W. Columbia County	Location; 3,150.
415	ARCO Greenup 1 36-049-0003	NE¼ sec. 9 T. 2 S., R. 28 E. Morrow County	Denied (application withdrawn).
416	ARCO Greenup 2 36-049-0004	NW¼ sec. 24 T. 2 S., R. 28 E. Morrow County	Denied (application withdrawn).
417	ARCO Longview Fibre 24-8-75 36-009-00248	SW¼ sec. 8 T. 7 S., R. 5 W. Columbia County	Location; 3,100.

□

CONTENTS

Middle Jurassic (late Aalenian and early Bajocian) ammonite biochronology of the Snowshoe Formation, Oregon

by David G. Taylor, Department of Geology, Portland State University, Portland, Oregon 97207

The John Day inlier of east-central Oregon is known for having a relatively undisturbed Jurassic sequence. Ammonite-rich molluscan faunas from it have proved to be important for dating these rocks. A relative time scale based on such fossil organisms is called a zonation. Historically, in using the ammonites for dating, paleontologists have turned to the European standard ammonite zonation for calibration, since there was no independent zonation for North America.

In recent years, however, it has become evident that an independent zonation is necessary. In the current effort to zone the Jurassic in our continent, attention is being turned to Oregon. This paper, which establishes an ammonite zonation for part of the lower Middle Jurassic, is a contribution to that effort. It is based on the Snowshoe Formation, which yields the finest sequence in North America for that part of the lower Middle Jurassic discussed in this paper. Such zonations as the one provided herein are indispensable not only for refining our picture of the Jurassic history of Oregon but also for interpreting the Mesozoic history of western North America.

ABSTRACT

This paper provides the description of one new ammonite genus (*Freboldites*) and 26 new species from the Snowshoe Formation. The ammonite biochronology established herein encompasses the latest Aalenian and much of the early Bajocian and furnishes five new zones and three new subzones.

INTRODUCTION

The Snowshoe Formation is part of a thick, lower Mesozoic volcaniclastic sequence in the John Day inlier in east-central Oregon (Dickinson and Vigrass, 1965; Dickinson and Thayer, 1978; Smith, 1980). The western exposures of the Snowshoe Formation in the Suplee area (Figure 1) yield a diverse and well-preserved ammonite fauna treated by Imlay (1973), when he described Bajocian ammonites from eastern Oregon. Detailed work by the author in the Suplee area (Taylor, 1981, 1982) resulted in the ammonoid succession established herein. Because the fauna has Tethyan affinities, the new biochronologic units described herein will assist in providing a zonal standard of reference for coeval faunas elsewhere in North America referable to the Tethyan Realm. Moreover, the Oregon fauna furnishes a critical key for close correlation between the East Pacific and Europe. The zonation, in fact, permits the first definitive correlation of the Aalenian-Bajocian stage boundary between the two regions. Preliminary description of new ammonite taxa is provided in advance of their monographic treatment to facilitate the description of the zonation.

STRATIGRAPHY

This study is based on the Weberg and Warm Springs Members (Lupher, 1941; Dickinson and Vigrass, 1965), which are the lower two members of the Snowshoe Formation in the Suplee area. The Snowshoe Formation was deposited in an intra-arc setting (Dickinson and Thayer, 1978), and the facies in the Suplee area reflect deposition on a local "platform" relative to the basin to the east in the Izee area (Dickinson and Vigrass, 1965; Smith, 1980). The Weberg Member, which is restricted to the Suplee area, is a transgressive calcareous sandstone and siltstone unit up to 65 m thick (Dickinson and Vigrass, 1965; Taylor, 1981), while the superjacent Warm Springs Member is a siltstone and laminated mudstone unit that in the Suplee area attains a stratigraphic thickness of up to 275 m. That member occurs, as well, farther east in the Izee area (Smith, 1980).

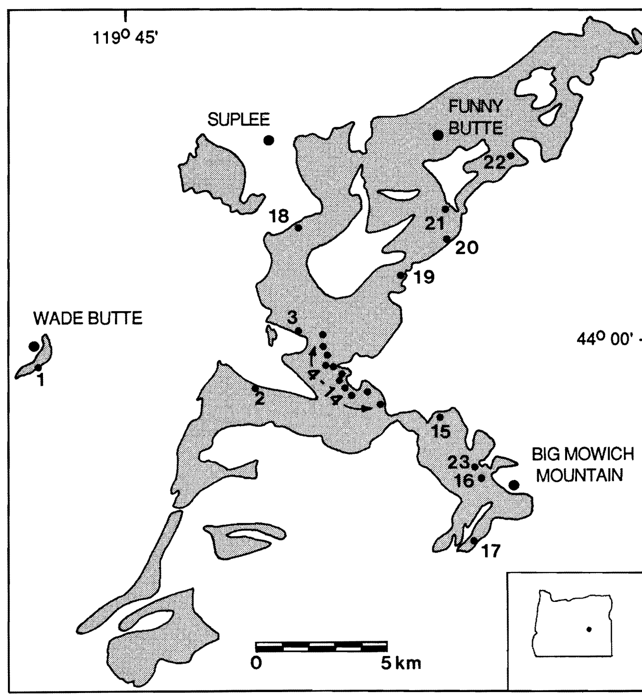


Figure 1. Map giving distribution of the Snowshoe Formation (shaded) in the Suplee area and localities of measured stratigraphic sections. Localities 1-17 are equivalent to those provided in Taylor (1982, Figures 1, 2).

BIOCHRONOLOGY

The data for the ammonite zonation are provided through closely spaced ammonite collections from 23 measured stratigraphic sections (Taylor, 1981, 1982). Figure 1 shows the locations of the stratigraphic sections, while Figure 2 is a composite range chart for the ammonites in the Suplee area. The zones recognized herein are discrete biochronologic units sensu Guex (1987a).

The earliest zones given below (Sparsicostatus through Tuberculatum Zones) are Tethyan Realm counterparts to the Howelli and Widebayense Zones in Alaska, belonging to the Boreal Realm. The latest zones (Crassicostatus and Kirschneri), on the other hand,

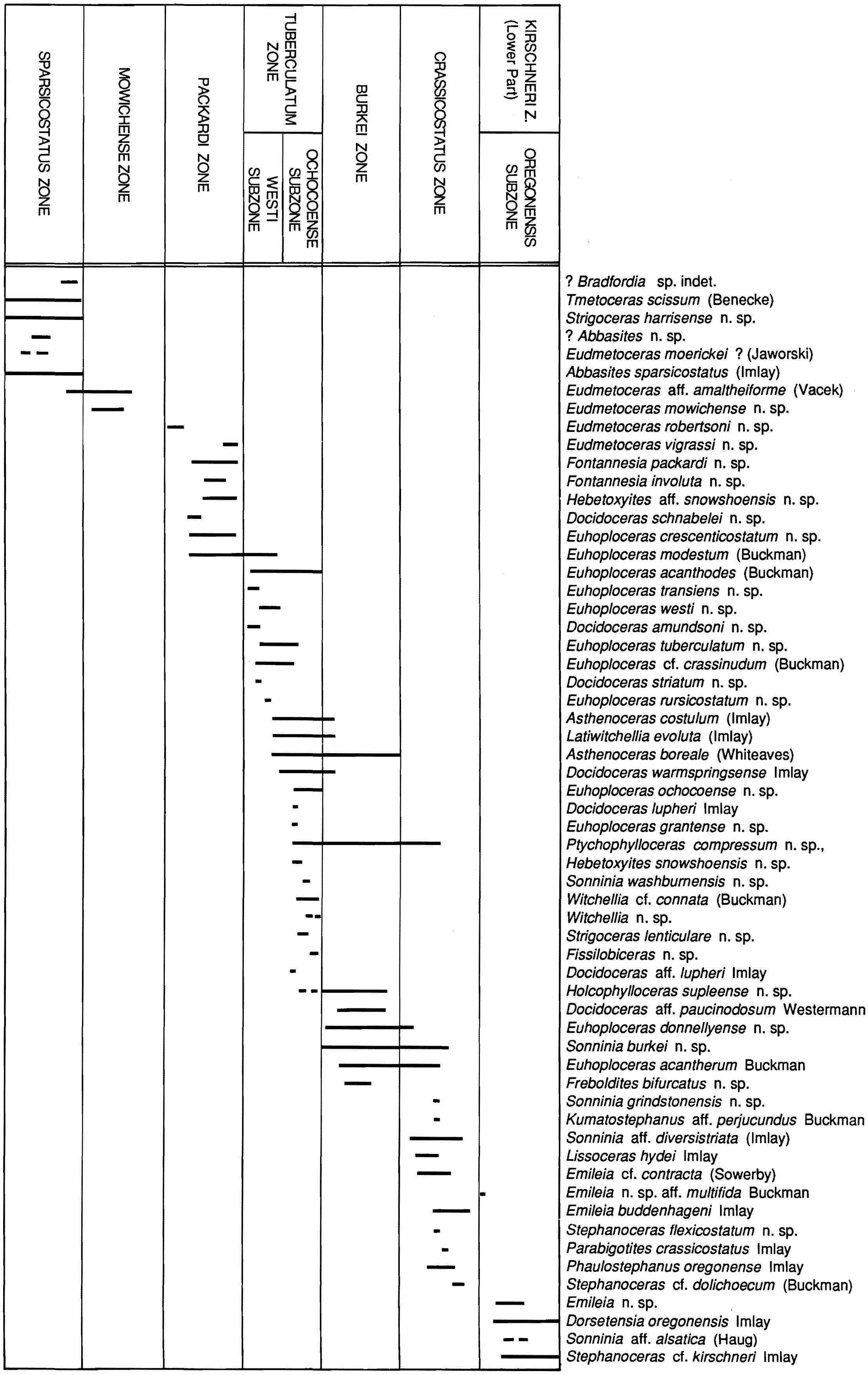


Figure 2. Ranges and zonal allocations of ammonites from the Snowshoe Formation near Suplee, Oregon.

represent an interval of time when the Boreal Realm was quite weakly differentiated from the Tethyan Realm. As a result, these zones are recognizable in the conterminous United States as well as in Alaska and Canada.

The chronologically diagnostic association for each zone in Figure 2 consists of those species that range no higher than, no lower than, or are restricted entirely to a given zone. Correlation of the zonation with Alaska, South America, and Europe is provided in Figure 3 (South American zonal terminology is based on Westermann and Riccardi, 1979, and Hillebrandt and Westermann, 1985).

Sparsicostatus Zone (nov.)

The name bearer for this zone is *Abbasites sparsicostatus* (Imlay). No type section is selected, since no section demonstrates superpositional control with both subjacent and superjacent zones. The type area is the Suplee area, and the fauna is best developed at Locality 22 (Figure 1), where it occurs in the lower part of the Weberg Member.

Mowichense Zone (nov.)

This zone is named after *Eudmetoceras* (*Planammatoceras*) *mowichense* n. sp. The type section for this zone is at Locality 4 (Figure 1), where ammonites characterizing it occur from 1 m to 5 m above the base of the Warm Springs Member. At that locality, the zone is sandwiched between the subjacent Sparsicostatus Zone and the superjacent Packardi Zone.

Packardi Zone (nov.)

The type section for the Packardi Zone (name bearer *Fontannesia packardi* n. sp.) is at Locality 14 (Figure 1), where it is represented 18.7 m to 20.1 m above the base of the Weberg Member and occurs in sequence with the superjacent Tuberculatum Zone. Crudely preserved material indicates that *Fontannesia* ranges into the base of the Tuberculatum Zone.

Tuberculatum Zone (nov.)

The name bearer *Euhoploceras tuberculatum* n. sp. is restricted

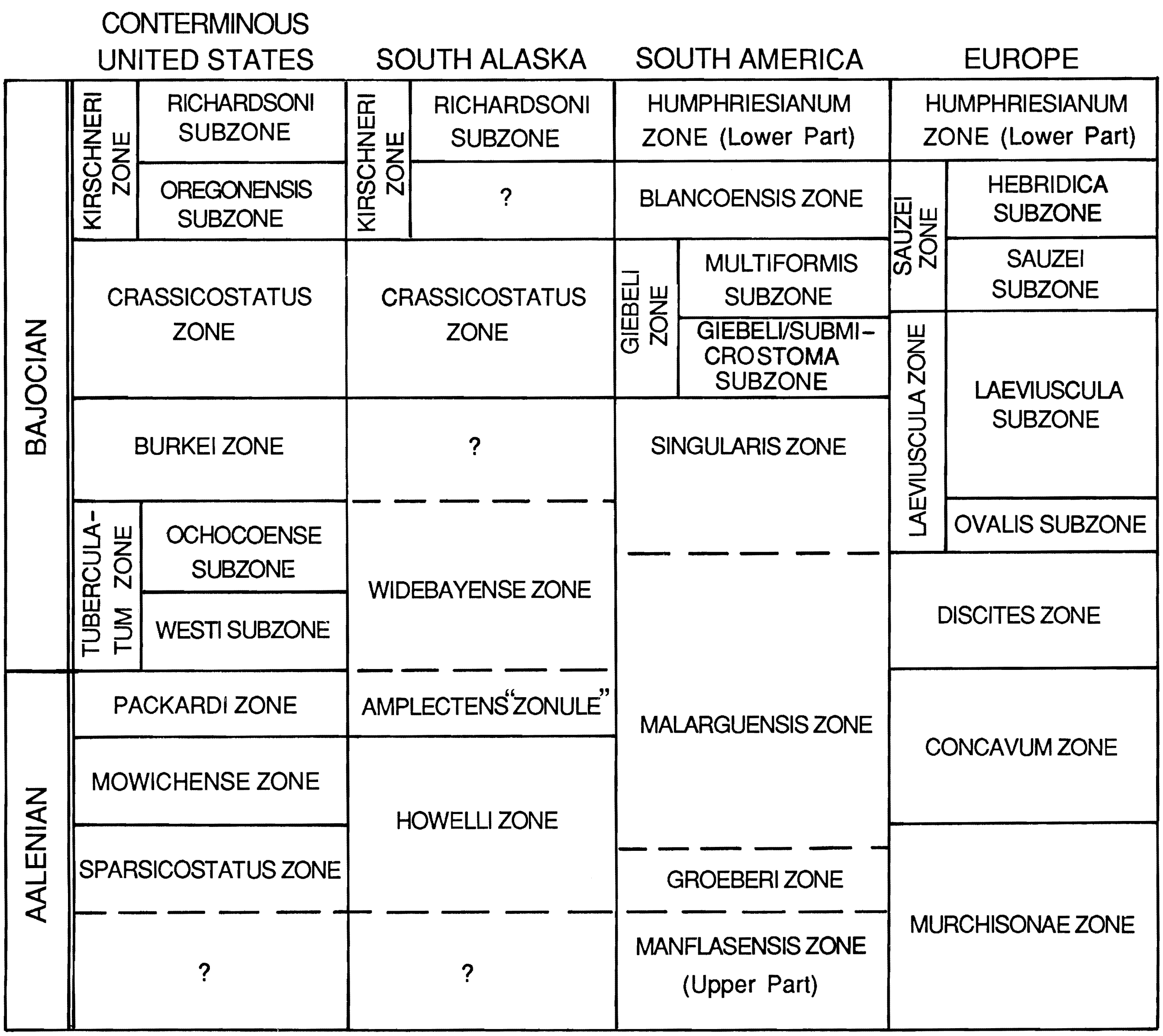


Figure 3. Correlation of late Aalenian-early Bajocian zonations from the conterminous United States, South Alaska, South America, and Europe.

to the lower two-thirds of the zone. The type section for the zone is at Locality 14 (Figure 1), where it occurs in succession with contiguous zones and is represented from 26.3 m to 34 m above the base of the Weberg Member.

Two subzones are assigned to the Tuberculatum Zone: (1) the Westi Subzone (nov.), name bearer *Euhoploceras westi* n. sp., type section at Locality 14 (Figure 1), from 26.3 m to 31.5 m above the base of the Weberg Member; and (2) the superjacent Ochocoense Subzone (nov.), name bearer *Euhoploceras ochocoense* n. sp., type section at Locality 14 (Figure 1), from 32 m to 34 m above the base of the Weberg Member.

The joint occurrence of early *Euhoploceras*, *Docidoceras*, and *Fontannesia* in the Packardi Zone and basal Tuberculatum Zone provides close correlation with the Aalenian-Bajocian boundary in Europe (Figure 3). Biostratigraphic studies in Scotland (Morton, 1976), southern England (Parsons, 1974), France (Pavia, 1983; Mouterde and others, 1972), and Portugal (Mouterde and others, 1972) provide detailed documentation for correlation.

The species of *Euhoploceras* that Morton (1975, 1976) tentatively allocated to the Concavum Zone are remarkably similar in morphology to some examples of *Euhoploceras crescenticostatum* n. sp. from the Packardi Zone.

Correlation is uncertain with the condensed Bradford Abbas section in southern England (Parsons, 1974), from which *Fontannesia* was not reported. The unfigured records of *Euhoploceras acanthodes* (Buckman) and *E.* cf. *crassiformis* (Buckman) that Parsons (1974) reported from the Concavum Zone apparently would be more like material in Oregon from the superjacent Tuberculatum Zone.

The sections that Mouterde and others (1972) reported from Marcous, France, and Murtinheira, Portugal, are expanded and provide a diverse fauna. Although the ammonites are not figured, both sections reveal the transitional nature of the ammonite sequence near the Aalenian-Bajocian stage boundary (=Concavum-Discites zonal boundary), and both yield *Fontannesia* together with *Euhoploceras*. The occurrences of *Fontannesia* at Marcous are allocated to the Concavum Zone, while the genus at Murtinheira is placed within the transitional interval between the Concavum and Discites Zones. Of the species of *Euhoploceras* described from the transitional interval from Murtinheira, *E. substriatum* (Buckman) is clearly comparable to *E. modestum* (which occurs in Packardi Zone), while figures of the other two species are required for certain assessment.

Another excellent work is that of Pavia (1983), based on sections in southeastern France. There, he drew the Concavum-Discites boundary at the first appearance of *Hyperlioceras* (thus allocating all *Euhoploceras* and *Fontannesia* from his study area to the Discites Zone). This boundary appears to be drawn at a lower biochronologic level than that of Mouterde and others (1972), notably from the section at Marcous. The most common practice has been to place all occurrences of *Hyperlioceras* in the Discites Zone, but the evidence provided by Mouterde and others (1972) demonstrates that this would make the *Graphoceras limitatum* horizon (upper part of Concavum Zone) difficult to recognize.

Burkei Zone (nov.)

Sonninia burkei n. sp. is the name bearer for this zone. The type section is at Wade Butte (Figure 1, Locality 1), where it occurs 14.5 m to 18.7 m above the base of the Weberg Member. Wade Butte is the only locality where the zone has been observed in sequence with both subjacent and superjacent zones.

Crassicostatus Zone

This zone was described by Hall and Westermann (1980), who selected its type locality in southern Alaska.

Kirschneri Zone

This zone was established by Hall and Westermann (1980), who selected its type area in southern Alaska. They named an upper Richardsoni Subzone but did not formally define the lower part of the Kirschneri Zone.

The Oregonensis Subzone (nov.), name bearer *Dorsetensia oregonensis* Imlay, type section at Locality 4 (Figure 1), from 207 m to 286 m above the base of the Warm Springs Member, serves to provide definition for the lower part of the Kirschneri Zone. The Richardsoni Subzone occurs in the superjacent Basey Member in the Suplee area.

SYSTEMATICS

Repositories for material referred to below include the Northwest Museum of Natural History (NWMNH), California Academy of Sciences (CAS), and the United States National Museum (USNM). Abbreviations for measurements (Smith, 1986) include maximum measurable shell diameter (DMAX), shell diameter at the end of the phragmocone (DPHRAG), shell diameter at which measurements were made (D), umbilical diameter (UD), whorl width (WW), and whorl height (WH). The term Psiloceratina (=Lytoceratina plus Ammonitina) sensu Guex (1987b) is used.

Order AMMONOIDEA Zittel, 1884
Suborder PHYLLOCERATINA Arkell, 1950
Superfamily PHYLLOCERATACEAE Zittel, 1884
Family PHYLLOCERATIDAE Zittel, 1884
Subfamily CALLIPHYLLOCERATINAE Spath, 1927
Genus *Holcophylloceras* Spath, 1927

Holcophylloceras supleense n. sp.
Plate 1, Figures 1, 2

Holcophylloceras sp., Imlay, 1973, p. 54, Plate 1, Figures 18-21 (not Plate 2, Figures 7, 8).

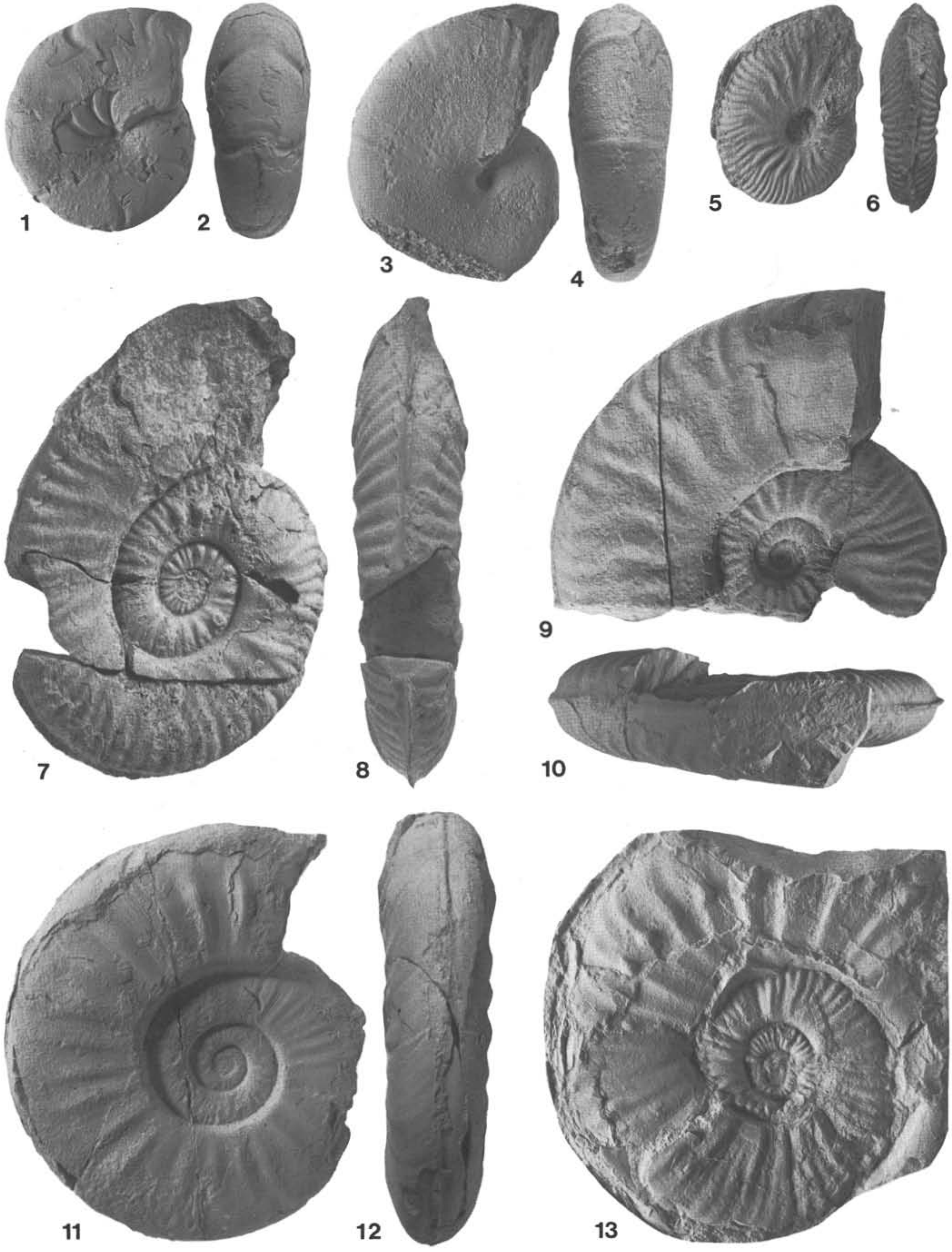
Holotype: NWMNH 25001. Provenance: Locality 18 (Figure 1); 17 m above base of Weberg Member; Burkei Zone. Dimensions: DMAX 44 mm, UD 1.5 mm, WW 20 mm, WH 25 mm.

Diagnosis: Shell weakly compressed; constrictions strongly sigmoidal, moderately strongly convex over venter, six to eight per whorl.

Description: The whorl section on the phragmocone is subovate and weakly compressed, and on the body chamber there is a slight accentuation of the ventro-lateral area. The body chamber comprises one-half volution. The apertural margin is strongly sigmoidal, with short ventral and broad lateral projections. The phragmocone has six strongly sigmoidal constrictions per whorl. The adoral half of the body chamber has three somewhat approximated constrictions, accounting for the counts of seven or eight constrictions on some specimens. The constrictions are moderately strongly convex over the venter. Faint ribbing subparallel to the trend of the constrictions is most noticeable on the upper flank at the largest shell dimensions.

Discussion: *Holcophylloceras supleense* n. sp. differs from the Alaskan and Oregonian *H. costisparsum* Imlay in having a more

***Facing page:** Plate 1. (All localities refer to Figure 1) — 1, 2.* Holcophylloceras supleense *n. sp.; holotype, NWMNH 25001 from Locality 18 (× 1). — 3, 4.* Ptychophylloceras compressum *n. sp.; holotype, NWMNH 25002 from Locality 11 (× 1). — 5, 6.* Eudmetoceras (Planammatoceras) mowichense *n. sp.; holotype, NWMNH 25003 from Locality 16 (× 1). — 7, 8.* Eudmetoceras (Planammatoceras) vigrassi *n. sp.; holotype NWMNH 25004 from Locality 16 (× 1). — 9, 10.* Eudmetoceras (Planammatoceras?) robertsoni *n. sp.; holotype NWMNH 25005 from Locality 16 (× 0.67). — 11, 12.* Sonninia burkei *n. sp.; holotype, NWMNH 25006 from Locality 18 (× 0.67). — 13.* Sonninia grindstonensis *n. sp.; holotype, NWMNH 25007 from Locality 2 (× 1).*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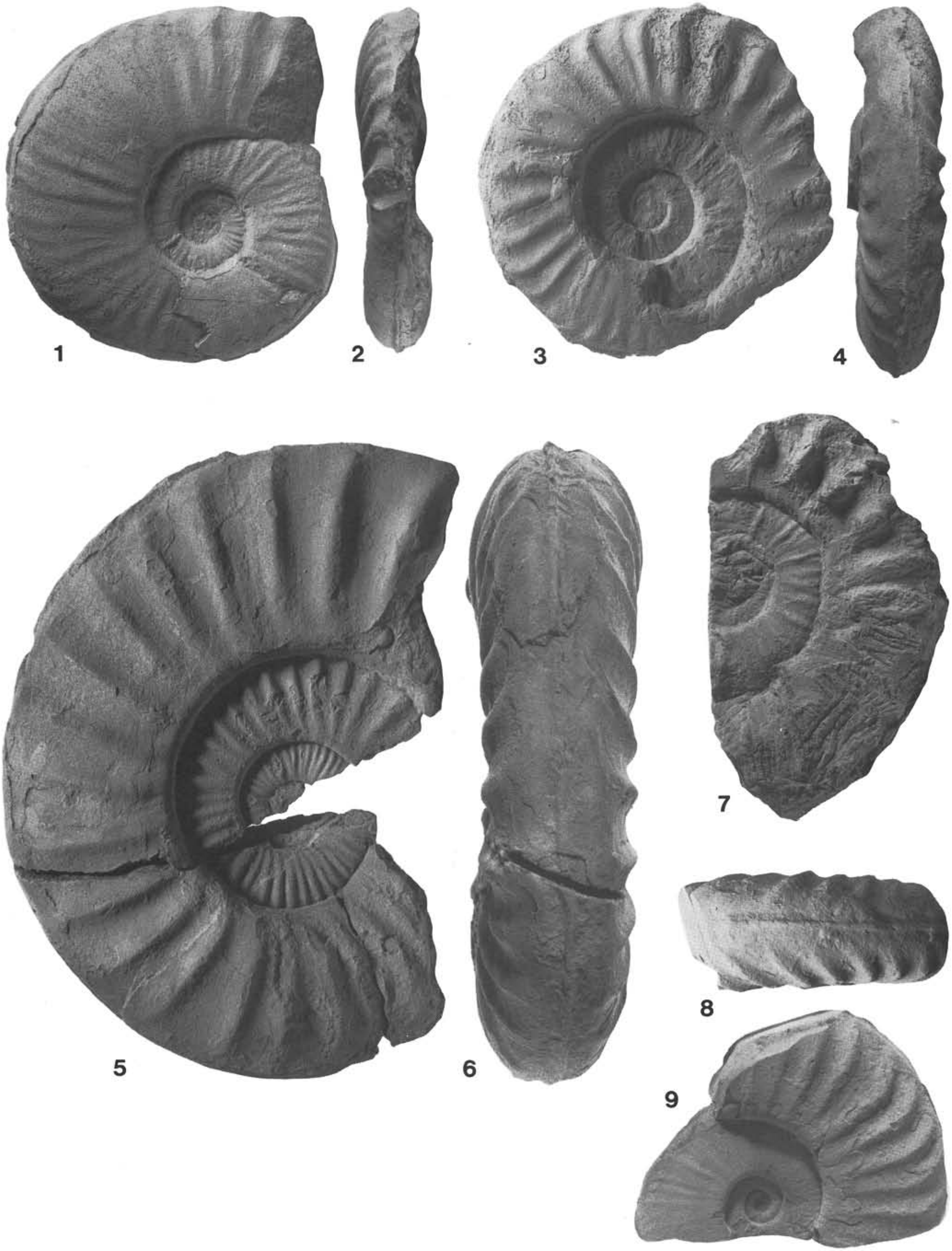
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inflated whorl section and constrictions that are more strongly flexed and distinctly approximated on the body chamber. The new species is similar to Alaskan material that Westermann (1964) identified as *H.* cf. *ultramontanum* (Zittel). *Holcophylloceras supleense* differs from that species in having constrictions that are less strongly flexed over the venter. The quite similar Californian *H. falciferum* (Crickmay, 1933) is considered to be nomen dubium, because it is based on a single crudely preserved mold consisting only of the body chamber. That species has more closely spaced constrictions than any specimen referred to the new species. *Holcophylloceras ultramontanum* is perhaps the European species closest to *H. supleense*. The new species has a stouter whorl section, closer spaced and more strongly flexed constrictions, and a narrower umbilicus.

Genus *Ptychophylloceras* Spath, 1927

Ptychophylloceras compressum n. sp.
Plate 1, Figures 3, 4

Holotype: NWMNH 25002. Provenance: Locality 11 (Figure 1); Weberg Member; Tuberculatum Zone. Dimensions: D 44 mm, UD 2.5 mm, WW 15.5 mm, WH 27.5 mm.

Diagnosis: Whorl section strongly compressed; constrictions feeble, not adorally flexed over venter; vague ventral folds present.

Description: The strongly compressed shell has flattened to gently convex flanks and an evenly rounded umbilical wall and venter. The shell is smooth except for feeble prorsiradiate, weakly flexed constrictions and folds (some specimens have no constrictions or folds preserved). The folds, which occur on the outer flank and venter, are weak but conspicuous (only on holotype), beginning at about 40-mm shell diameter, and are not noticeably arched adorally over the venter.

Discussion: This species has a much more compressed whorl section than others of this genus, except *Ptychophylloceras longarae* Sturani from the Venetian Alps. That species differs in having a wider umbilicus, a shallow groove on the lower flank, and constrictions that are conspicuously arched adorally over the venter.

Suborder PSILOCERATINA Houša, 1965
Superfamily HILDOCERATACEAE Hyatt, 1867
Family PHYMATOCERATIDAE Hyatt, 1867
Subfamily HAMMATOCERATINAE Buckman, 1887
Genus *Eudmetoceras* Buckman, 1920

Remarks: Because of the apparently close relationship between *Eudmetoceras* and *Planammatoceras* and the transitional nature of the morphology between these taxa (some species are not readily allocated to one or the other), *Planammatoceras* is assigned as a subgenus of *Eudmetoceras*.

Subgenus *Planammatoceras* Buckman, 1922

Eudmetoceras (*Planammatoceras*) *mowichense* n. sp.
Plate 1, Figures 5, 6

Eudmetoceras (*Euaptetoceras*) cf. *E.* (*E.*) *hauthali* (Burckhardt). Imlay, 1973, p. 60, Plate 6, Figures 6-9.

Holotype: NWMNH 25003. Provenance: Locality 16 (Figure 1); from 2 to 3.5 m above base of Warm Springs Member; Mowichense Zone. Dimensions: DMAX 38 mm, UD 6.5 mm, WW 11 mm, WH 20 mm.

Diagnosis: Involute, falcoid to falcate ribbing; keel small.

Description: The nucleus has a subcircular and slightly depressed whorl section. The adult section is compressed; the umbilical wall is subvertical and rounds sharply onto the flank, which is widest near mid-height of the whorl. The venter bears a low but distinct and thin keel. Ribbing on the intermediate whorls is falcoid to falcate and not strongly projected on the venter. The primaries are swollen just below mid-flank. Outer flank ribbing is characteristically bifurcate, although costae commonly arise through trifurcation and intercalation, as well. On the outer whorl, the ribbing becomes more gently flexed and weakens, particularly on the lower flank. The suture on the outer septate whorl is fairly complexly incised. The umbilical lobes are weakly retracted, and the associated saddle boundary is straight.

Discussion: This species is very similar in appearance to the Japanese *Eudmetoceras* (*Planammatoceras*) *ikianum* (Yokoyama) but differs by having a lower keel and perhaps ribbing that is more falcate on some specimens.

Eudmetoceras (*Planammatoceras*) *vigrassi* n. sp.
Plate 1, Figures 7, 8

Holotype: NWMNH 25004. Provenance: Locality 16 (Figure 1); 17.5 m above base of Warm Springs Member; Packardi Zone. Dimensions: DMAX 90 mm, UD 36 mm, WH 31 mm.

Name derivation: In reference to Lawrence W. Vigrass, who contributed to the knowledge of the geology of the Suplee area (Dickinson and Vigrass, 1965).

Diagnosis: Shell evolute; nodes on intermediate whorls only; suture essentially nonretracted.

Description: The evolute shell preserves an incomplete body chamber of one-half volution and has a compressed subovate section and high keel. Primary ribbing most commonly is weak, low on the flank, while secondary ribbing is stronger, concave, and only slightly projected where it abuts the keel. Nodes are restricted to the intermediate whorls, where they are widely spaced. On the body chamber, bullate swellings occur in their place. The tubercles and bullate swellings are set just below mid-flank. The suspensive lobe is only slightly retracted dorsal to U_2.

Discussion: The high keel on the new species reveals its affinities with *Eudmetoceras* rather than *Puchenquia*. This species is affiliated with a cluster of species that have evolute coiling, nodose ornamentation, and a comparatively compressed whorl section, such as *E.* (*Planammatoceras*) *lorteti* (Dumortier), *E.* (*P.*) *allobrogense* (Dumortier), and *E.* (*P.*) *spinosum* (Hantken in Prinz). The coiling is most like that of *E.* (*P.*) *lorteti*. *Eudmetoceras* (*P.*) *spinosum* shows some resemblance in the wide spacing of its nodes. Nodose ornamentation restricted to intermediate whorls sets *E.* (*P.*) *vigrassi* n. sp. apart from any of its congeners.

Eudmetoceras (*Planammatoceras*?) *robertsoni* n. sp.
Plate 1, Figures 9, 10

Holotype: NWMNH 25005. Provenance: Locality 16 (Figure 1); 15.5 m above base of Warm Springs Member; Packardi Zone. Dimensions: D 107 mm, UD 32 mm, WW 27 mm, WH 45 mm.

Name derivation: In honor of Les Robertson, a rancher from the Suplee area.

Diagnosis: Not nodose; inner whorls finely costate; keel low at largest shell dimensions.

Description: The whorl section is subcircular on the inner whorls and subogival on the adult whorls. The venter is somewhat narrow,

Facing page: *Plate 2. (All localities refer to Figure 1) — 1, 2.* Sonninia washburnensis *n. sp.; holotype, NWMNH 25008 from Locality 11 (× 0.5). — 3, 4.* Euhoploceras grantense *n. sp.; holotype, NWMNH 25010 from Locality 8 (× 0.5). — 5, 6.* Euhoploceras crescenticostatum *n. sp.; holotype, NWMNH 25009 from Locality 19 (× 0.55). — 7.* Euhoploceras rursicostatum *n. sp; holotype, NWWMNH 25014 from Locality 9 (× 0.5). — 8, 9.* Euhoploceras ochocoense *n. sp.; holotype, NWMNH 25011 from Locality 11 (× 0.5).*

and the keel is high on the penultimate whorl; on the last whorl, the venter broadens somewhat, and the keel becomes low and blunt. The primaries are concave and on the inner whorls comparatively weak at the base of the flank. The secondaries are gently projected on the venter of the outer whorl. Overall, costation is biconcave, with greatest flexure on the outer flank. Ribbing weakens on the adoralmost part of the phragmocone and on the body chamber.

Discussion: This species is readily distinguishable from its congeners in having such finely ornate inner whorls for a comparatively evolute species. Ribbing style of *Eudmetoceras* (*Planammatoceras*) *planinsigne* (Vacek) is quite similar on the intermediate whorls; otherwise, it is quite dissimilar in having nodes and an outer whorl that retains strong ribbing and a high keel. Ribbing is also quite dissimilar on the inner whorls. The new species is more similar to *E.* (*P.*) *planiforme* (Buckman), which is also nontuberculate. That species differs in having significantly stronger prorsiradiate ribbing and, apparently, a keel that remains high on the last whorl.

Family SONNINIIDAE Buckman, 1892
Genus *Sonninia* Bayle in Douvillé, 1879

Sonninia burkei n. sp.
Plate 1, Figures 11, 12

Sonninia (*Papilliceras*) *stantoni* (Crickmay). Imlay, 1973, p. 68 (part), Plate 26, Figure 10.
Sonninia (*Papilliceras*) cf. *S.* (*P.*) *espinazitensis* Tornquist. Imlay, 1973, p. 69, Plate 27, Figures 5, 6.

Holotype: NWMNH 25006. Provenance: Locality 18 (Figure 1); 17 m above base of Weberg Member; Burkei Zone. Dimensions: DMAX 120 mm; D 115 mm, UD 42 mm, WW 29 mm, WH 40.5 mm.

Name derivation: In memory of Bernard V. Burke, son of Mrs. Bernard V. Burke, who assisted in this project.

Diagnosis: Nucleus nonspinose; outer whorls with subogival section; on outer whorl, ribbing upright, with 10-12 papillate costae per half whorl.

Description: The inner whorls (beyond nucleus) are compressed and have a subovate section, while the outer whorls are subogival. The venter may be narrowly tabulated where shell is present and weakly sulcate on the internal mold. Ribbing on the inner whorls is rectiradiate or gently prorsiradiate, gently falcoid, and subfasciculate to bifurcate. Beginning on the outer whorl of the phragmocone or on the body chamber, ribbing becomes papillate, widely and evenly spaced, nearly straight, approximately radial, strongest on the inner flank, and weak high on the whorl side.

Discussion: *Sonninia blackwelderi* (Crickmay, 1933) has an ornamentation style like that of some finely ornate specimens of *S. burkei* n. sp. The former apparently is represented by one specimen, the holotype, which consists only of portions of the outer whorls. As such, the specimen is inadequate for certain identification and is considered to be a nomen dubium. The nonspinose nucleus sets the new species apart from most belonging to papillate *Sonninia*. *Sonninia pseudoarenata* (Maubeuge) has an outer whorl similar in appearance but has markedly coarser ribbing on the phragmocone. Imlay (1973) compared material pertaining to this species with the South American *S. espinazitensis* (Tornquist), redescribed in Westermann and Riccardi (1972). That species differs by having a robust keel, spinose inner whorls (on some specimens), rounded umbilical shoulder, more prorsiradiate ornamentation, and papillate and nodose ornamentation set well above mid-flank.

Sonninia grindstonensis n. sp.
Plate 1, Figure 13

Sonninia (*Papilliceras*) cf. *S.* (*P.*) *juramontana* (Crickmay). Imlay, 1973, p. 69, Plate 27, Figure 1.

Holotype: NWMNH 25007. Provenance: Locality 2 (Figure 1); 38 m above base of Warm Springs Member; Crassicostatus Zone. Dimensions: D 76 mm, UD 27 mm, WH 31 mm.

Name derivation: Referring to Grindstone Creek, located in the vicinity in which the holotype for the species was collected.

Diagnosis: Coiling moderately involute; inner whorls nonspinose, outer whorls of nucleus bearing small nodes; phragmocone with dense but well-defined, gently sigmoidal ribbing; papillae on outer whorl closely spaced.

Description: The first couple of whorls are nonspinose, while the nucleus adorally has widely spaced and very weak nodes. Nodose ornamentation does not persist onto the outer whorl of the phragmocone. Phragmocone ribbing is variably simple, subfasciculate, and bifurcate; it is gently falcoid and gently prorsiradiate to rectiradiate. Costation on the outer whorl is nearly upright and slightly falcoid to slightly concave and is stronger on the lower flank than on the upper flank. The papillate ornamentation on the outer whorl is fairly fine and closely spaced and coarsens with shell size.

Discussion: Imlay (1973) compared this species with *Sonninia juramontana* (Crickmay, 1933), which is represented only by the holotype consisting of outer whorls inadequate for identification. *Sonninia grindstonensis* n. sp. differs from *S. burkei* n. sp. in having finer and more closely spaced papillae and nodes on the inner whorls. Also, costate ornamentation is less strongly prorsiradiate on the inner whorls and better defined on the nucleus, extending down to a smaller shell diameter.

Sonninia washburnensis n. sp.
Plate 2, Figures 1, 2

Holotype: NWMNH 25008. Provenance: Locality 11 (Figure 1); 32 m above base of Weberg Member; Ochocoense Subzone. Dimensions: DPHRAG 82 mm, UD 27 mm, WW 25 mm, WH 34.5 mm.

Name derivation: In reference to the "Washburn Homestead," located in the vicinity where the holotype of the species was collected.

Diagnosis: Whorl section of phragmocone subovate; outer whorl compressed subogival; phragmocone with dense, slightly biconcave, prorsiradiate ribbing.

Description: The whorl section of most of the phragmocone beyond the nucleus is subovate, while the outer one to one-and-one-half whorls have a fairly strongly compressed subogival section. The venter (with shell) is slightly tabulated, and the keel is pronounced although not conspicuously high. The nucleus on two of the three specimens bears small spines. The shell is ornamented with closely spaced, slightly biconcave, fasciculate to subfasciculate, commonly striate (on phragmocone) ribbing that is moderately to strongly prorsiradiate. Ribbing is strongest at mid-flank.

Discussion: This species does not compare well with any of those from Europe. Its morphology, however, is most like that of certain specimens of *Euhoploceras acanthodes* (Buckman). The new species differs from finely ornate *E. acanthodes* in that the whorl section is more compressed, the nucleus is more finely spinose, and the closely spaced, biconcave, striate ribbing is more strongly prorsiradiate.

Genus *Euhoploceras* Buckman, 1913

Euhoploceras crescenticostatum n. sp.
Plate 2, Figures 5, 6

Holotype: NWMNH 25009. Provenance: Locality 19 (Figure 1); 38 m above base of Weberg Member; Packardi Zone. Dimensions; DMAX 218 mm, UD 87.5 mm, WW ~51 mm, WH 73 mm.

Diagnosis: Like *Euhoploceras acanthodes* (Buckman) but with nodes consistently restricted to 45-mm shell diameter and body chamber costation gently concave and widely spaced.

Description: The outer whorls have a compressed subrectangular whorl section, with rounded but well-defined umbilical shoulder and gently inflated flanks. The venter commonly has wide shallow sulci. The tuberculate stage is restricted to 40- to 45-mm shell diameter. Phragmocone ribbing is irregular in strength, is gently flexed, and incipiently biconcave and has a density of 15-19 costae per half whorl. Costation on the outer whorl rapidly decreases in density to 11-13 costae per one-half volution. The body chamber costae are highest and sharpest at mid-flank and nearly straight to characteristically gently concave.

Discussion: *Euhoploceras acanthodes* (Buckman), as represented in Europe and Oregon, is a highly variable species in whorl inflation and development of nodose ornamentation. The new species from Oregon is differentiated by having the nodose ornamentation restricted to 45-mm shell diameter and by having slightly crescentic, widely spaced body chamber costation.

Euhoploceras donnellyense n. sp.

Sonninia (*Papilliceras*) *stantoni* (Crickmay). Imlay, 1973, p. 68, Plate 26, Figures 1-9, 13 (not Figures 10, 12).

Holotype: CAS 13406. Imlay, 1973, Plate 26, Figure 13, Locality L57; Snowshoe Formation near Seneca.

Name derivation: In reference to Donnelly Creek (Figure 1, Locality 23), located in the drainage where material referred to this species was collected.

Diagnosis: Nucleus commonly not nodose; phragmocone strongly ribbed; costation radial to gently rursiradiate, nearly straight to weakly convex; "papillate" ornamenation coarse.

Description: The nucleus commonly is nontuberculate. The phragmocone has strong ribbing that is radial to slightly rursiradiate and nearly straight to weakly concave. "Papillate" ornamentation is strong.

Discussion: This new species was described fully by Imlay (1973) under *Sonninia* (*Papilliceras*) *stantoni* (Crickmay). *Euhoploceras donnellyense* n. sp. differs from *E. acantherum* (Buckman) (=*E. stantoni*) in having a more compressed whorl section with flatter flanks and a tightly rounded umbilical shoulder, denser and stronger ribbing on the phragmocone, and markedly straighter ribs.

Euhoploceras grantense n. sp.
Plate 2, Figures 3, 4

Holotype: NWMNH 25010. Provenance: Locality 8 (Figure 1); 12.5 m below top of Weberg Member; Westi Subzone. Dimensions: DMAX 135 mm, DPHRAG 96.5 mm, UD 38 mm, WW 28.5 mm, WH 35 mm.

Name derivation: In reference to Grant County, Oregon.

Diagnosis: Shell rather strongly evolute; inner and intermediate whorls densely costate; body chamber with strong, rursiradiate, falcoid ribbing, that is not nodose.

Description: The whorl section passes from subcircular to subogival by 10- to 15-mm shell diameter. On the outer whorls, the umbilical wall is vertical, the distinct umbilical shoulder is gently rounded, and the slightly convex subparallel flanks round evenly onto the venter. The nucleus is nonspinose. Phragmocone ribbing is gently falcoid or biconcave and may be slightly swollen near mid-flank. Costation is fasciculate to subfasciculate on the phragmocone and becomes more distantly spaced, stronger, and simple on the body chamber. These latter ribs are falcoid, are inflated at mid-flank, and remain strong high on the whorl side.

Discussion: This species bears no resemblance to any European species of *Euhoploceras*. *Euhoploceras grantense* n. sp. is most similar to *Euhoploceras rursicostatum* n. sp. but differs in being nontuberculate.

Euhoploceras ochocoense n. sp.
Plate 2, Figures 8, 9

Sonninia (*Euhoploceras*) *modesta* Buckman. Imlay, 1973, p. 62, Plate 7, Figures 1-4; Plate 8, Figures 3-5; Plate 9, Figures 5, 6; Plate 10.

Holotype: NWMNH 25011. Provenance: Locality 11 (Figure 1); float from 32 m above base of Weberg Member; Ochocoense Subzone. Dimensions: DMAX 116 mm, UD 36 mm, WW 37 mm, WH 46 mm.

Name derivation: Referring to the Ochoco Mountains in central Oregon.

Diagnosis: A comparatively involute compressed species of *Euhoploceras*; spinose stage restricted to 15-mm shell diameter; ribbing quite dense, gently prorsiradiate.

Description: The whorl section on the phragmocone is ogival with steeply inclined to overhanging umbilical wall. The outer whorl most commonly egresses near the end of the phragmocone. The body chamber comprises at least five-eighths of a whorl. The nucleus may be costate or nodose, in which case the spines do not persist beyond 15-mm shell diameter. On the intermediate whorls, ribbing is dense, fasciculate-bifurcate in style, and gently prorsiradiate. Commonly there are widely spaced low undulations on the lower flank. At largest shell dimensions, the ribbing becomes simple (or rarely bifurcate), more widely spaced, and stronger. Rib height is commonly greatest on the outer flank.

Discussion: This species is most similar to *E. modestum* (Buckman), from which it differs in that the ribbing tends to be less prorsiradiate and the height of the ribbing is conspicuously stronger in the ventro-lateral area, rather than at mid-flank.

Euhoploceras rursicostatum n. sp.
Plate 2, Figure 7

Sonninia (*Euhoploceras*) *crassispinata* Buckman. Imlay, 1973, p. 67 (part), Plate 23, Figure 2.

Holotype: NWMNH 25014. Provenance: Locality 9 (Figure 1); 39.5 m above base of Weberg Member; Westi Subzone. Dimensions: D (indet.), WH 41 mm, WW 28 mm.

Diagnosis: Shell evolute; moderately dense costae on phragmocone; outer whorl nodose, with falcoid rursiradiate ribbing.

Description: The evolute shell possesses outer whorls that are subrectangular in section. Shallow sulci are present on the internal mold of the body chamber. Ornamentation on the phragmocone consists of slightly biconcave and fairly dense costae that are irregular in strength. Ribbing is strongest at mid-flank, where the strongest costae may be slightly bullate or pointed. On the body chamber, costation becomes much stronger, more widely spaced, and simple. The ribs arise at the umbilical shoulder, trend rursiradiately, and have strong bullate nodes at mid-flank. The ribs remain strong on the ventro-lateral shoulder, where they bend forward sharply and expire against the sulci.

Discussion: This new species is readily distinguishable from *Euhoploceras polyacanthum* (Waagen). The new species differs in having a more finely costate phragmocone and an outer whorl with ribbing that is more falcoid and relatively stronger high on the flank. The new species is a derivative of *E. westi* n. sp. and differs from the latter in having an outer whorl with predominantly simple falcoid ribbing that is relatively stronger high on the flank. *Euhoploceras grantense* n. sp., on the other hand, is derived from *E. rursicostatum* and is distinguished by lack of nodose ornamentation and denser ribbing.

Euhoploceras transiens n. sp.
Plate 3, Figure 3

Holotype: NWMNH 25012. Provenance: Locality 13 (Figure 1); Weberg Member; Westi Subzone. Dimensions: DMAX 230 mm, UD 94 mm, WH 84 mm.

Diagnosis: Coarse, moderately to widely spaced tubercles on phragmocone; last whorl with strongly inflated but nonbullate, moderately dense body chamber ribbing that is strong on the upper flank.

Description: The inner whorls are subcircular in section, while the last whorl of the phragmocone has a gently rounded umbilical shoulder and may be weakly compressed. The body chamber comprises at least three-fourths of a whorl. The inner adult whorls bear widely spaced bullate tubercles, between which typically there are one or two low, thick ribs that are highest at mid-flank and straight to slightly sigmoidal or gently concave. The tubercle-bearing costae on the lower flank increase rapidly in strength as they ascend to the tubercle crests. These ribs decrease in strength much more quickly above the tubercles. The tuberculate stage drops out on the last whorl of the phragmocone. Adorally (within a quarter to three-quarters of a whorl) the variably strong costae become gently concave. Ribbing becomes nearly even in height on the last whorl. These costae are strongest at mid-flank and are as strong on the upper half of the whorl side as they are on the lower half, or stronger.

Discussion: *Euhoploceras transiens* n. sp. is most similar in appearance to *E. adicrum* (Waagen), from which it differs in that the tuberculate ornamentation on the phragmocone on some specimens is denser and that the body chamber ribbing is denser, more concave, not distinctly pointed or bullate at mid-flank, and strong high on the flank.

Euhoploceras tuberculatum n. sp.

Sonninia (*Euhoploceras*) *polyacantha* (Waagen). Imlay, 1973, p. 64, Plates 18, 19; Plate 20, Figures 1, 5-7; Plate 21, Figures 8, 9.

Holotype: CAS 13385. Imlay, 1973, Plates 18, 19, Locality 39 (L573); Weberg Member.

Diagnosis: Comparatively involute and compressed species of Euhoploceras; nodes (when present) on inner whorls restricted to 25-mm shell diameter; strongly prorsiradiate, dense ribbing; coarse tubercles on outer whorl.

Description: The whorl section is compressed and ogival to subrectangular, and the venter may have wide shallow sulci. The inner whorls of some specimens are nodose up to 25-mm shell diameter. The ribbing on the phragmocone is slightly falcoid; commonly it is slightly swollen near mid-flank, comparatively strong in the ventro-lateral area, and oriented prorsiradiately between 10° and 20°. The body chamber is strongly tuberculate, and costae there are highly variable in strength and pattern.

Discussion: The phragmocone of this distinctive species is more involute and has much finer ribbing than on *Euhoploceras polyacanthum* (Waagen), while the body chamber has much coarser tuberculate ornamentation. The phragmocone ribbing is most like that of *E. modestum* (Buckman), which differs by lacking tuberculate ornamentation on the body chamber.

Euhoploceras westi n. sp.
Plate 3, Figures 1, 2

Sonninia (*Euhoploceras*) *crassispinata* Buckman. Imlay, 1973, p. 67, Plate 22, Figures 1, 2, 4; Plate 23, Figures 3, 4 (not Figures 1, 2); Plate 24, Figures 1, 4; Plate 25, Figures 17-19.
Sonninia (*Euhoploceras*) cf. *S.* (*E.*) *crassispinata* Buckman. Imlay, 1973, p. 68, Plate 22, Figure 3; Plate 24, Figure 5.

Holotype: NWMNH 25013. Provenance: Locality 13 (Figure 1); Weberg Member; Westi Subzone. Dimensions: DMAX 127 mm; D 96 mm, UD 40 mm, WW ~24 mm, WH 32 mm.

Name derivation: In honor of the late Roy West, who conducted studies in the paleoecology of the Robertson Formation, Lower Jurassic.

Diagnosis: Phragmocone may be strongly tuberculate but has marked tendency for reduction of ornamentation on inner whorls; outer whorl has coarse, typically widely spaced tubercles.

Description: The whorl section is subcircular, subquadrate, or subogival on the phragmocone beyond the nucleus, and the outer whorl is weakly compressed. The innermost whorls usually are nontuberculate. Widely spaced tubercles appear at a variable stage beyond the nucleus. Costation fades adorally, and the lower flank between the tubercles on the last whorl is nearly smooth. Rib trajectory most commonly ranges from gently prorsiradiate to gently rursiradiate and usually is nearly straight. Coarser ribbing is straight to gently concave, while fine ribbing is gently sigmoidal. Secondary bifurcate and intercalatory ribbing is gently sigmoidal. The upper flank ribs may be strong but most commonly are weak.

Discussion: This species, in general, is most similar in appearance to *Euhoploceras adicrum* (Waagen) but differs from any European species of *Euhoploceras* in its strong tendency for paedomorphic development of finely costate ornamentation on the phragmocone, coupled with the development of coarse tuberculate ornamentation on the body chamber.

Genus *Fontannesia* Buckman, 1902

Fontannesia packardi n. sp.

Fontannesia cf. *F. evoluta* (Buckman). Imlay, 1973, p. 59, Plate 5, Figures 1-3.
Fontannesia cf. *F. carinata* Buckman. Imlay, 1973, p. 58, Plate 5, Figures 4-13.
Fontannesia cf. *F. luculenta* Buckman. Imlay, 1973, p. 58, Plate 5, Figures 14-19.

Holotype: CAS 13355. Imlay, 1973, Plate 5, Figures 18, 19, Locality L355; Weberg Member.

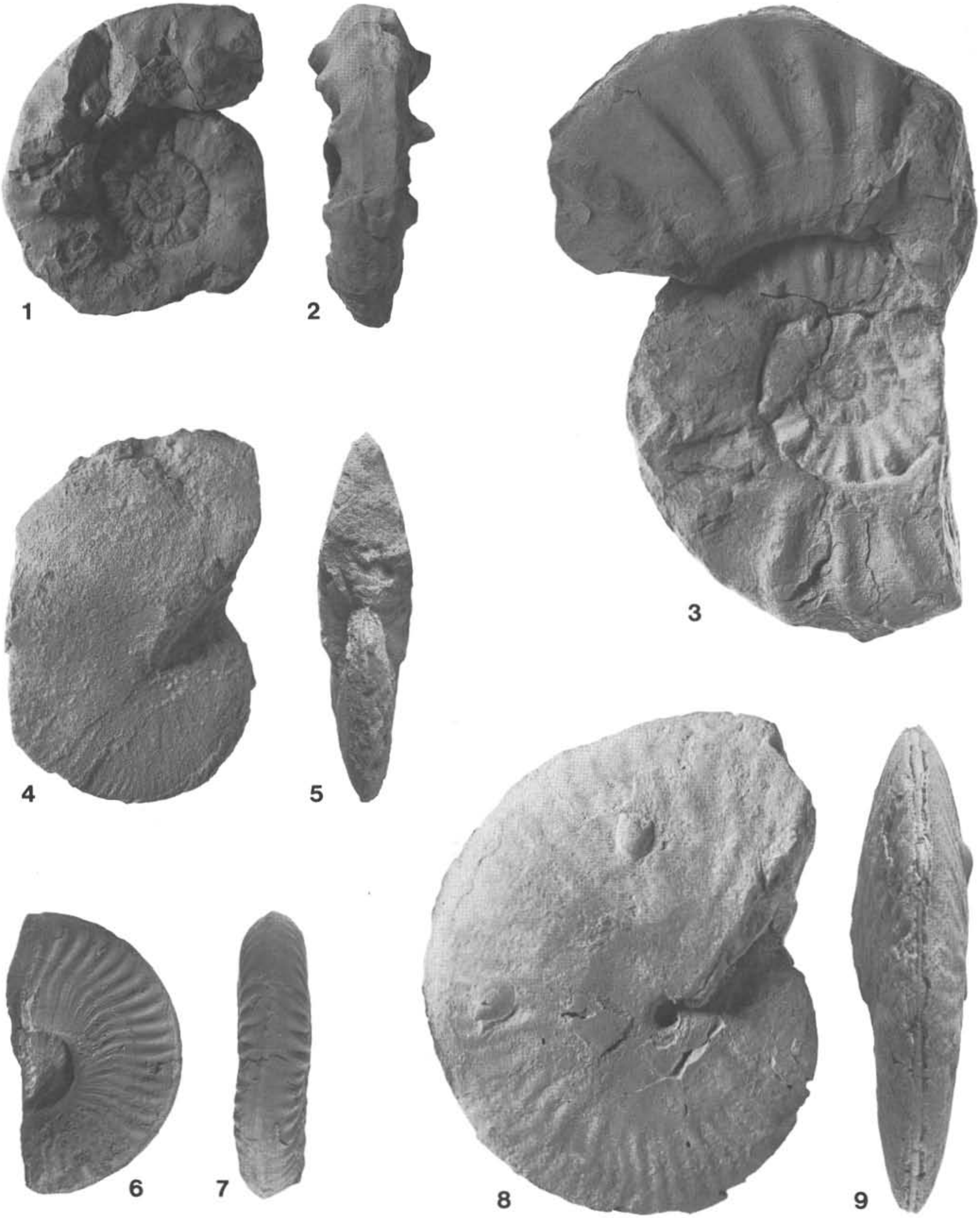
Name derivation: In honor of Earl L. Packard, who contributed to our knowledge of the pre-Tertiary geology of central Oregon.

Diagnosis: Nodose ornamentation present in ventro-lateral area.

Description: This species attains a shell diameter of at least 105 mm. The whorl section ranges from subrectangular to subcircular on the inner adult whorls and becomes more compressed through ontogeny. The venter is broadly rounded to fastigate and supports a low, prominent keel. The ribbing ranges from straight (uncommonly) to markedly falcoid. While a few examples have simple ribbing, ribs commonly arise by intercalation or in pairs on the lower half of the flank. Subnodose to tuberculate ornamentation often occurs in the ventro-lateral area and is strongest on the inner whorls. Tubercles do not persist to large shell dimensions.

Discussion: This species is most similar in coiling and ribbing style to *Fontannesia grammoceroides* (Haug), as recognized by Buckman (1892) prior to his subdivision of the species (Buckman, 1905). The most notable difference of the Oregon species from *F.*

***Facing page:** Plate 3. (All localities refer to Figure 1) — 1, 2.* Euhoploceras westi *n. sp.; holotype, NWMNH 25013 from Locality 13 (× 0.5). — 3.* Euhoploceras transiens *n. sp.; holotype, NWMNH 25012 from Locality 13 (× 0.5). — 4, 5.* Strigoceras harrisense *n. sp.; holotype, NWMNH 25015 from Locality 22 (× 1). — 6, 7.* Fontannesia involuta *n. sp.; holotype, UCMP 38158 from Locality 20 (× 1). — 8, 9.* Strigoceras lenticulare *n. sp.; holotype, NWMNH 25016 from Locality 11 (× 1).*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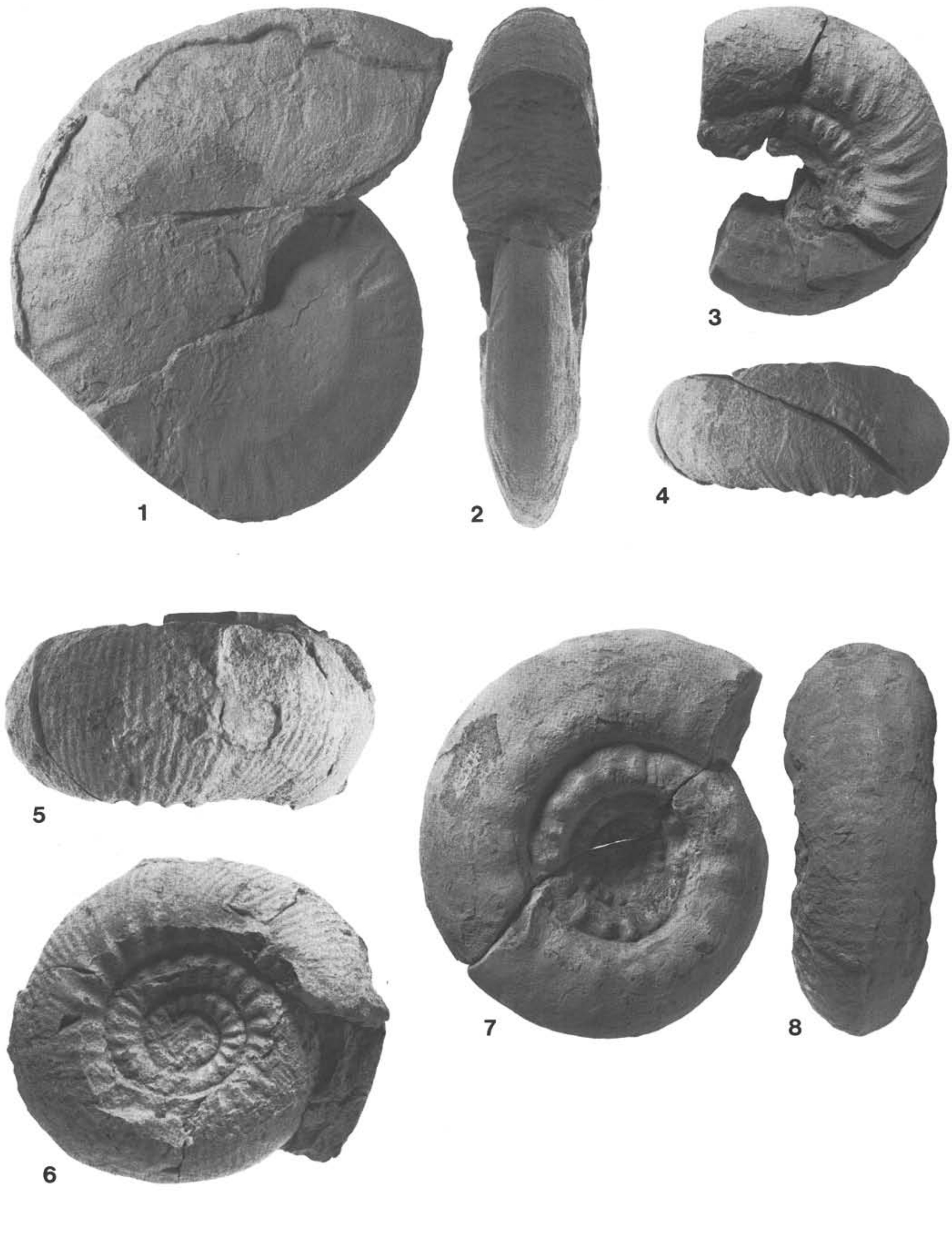
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grammoceroides or any other species of *Fontannesia* is the presence of nodose ornamentation.

Fontannesia involuta n. sp.
Plate 3, Figures 6, 7

Holotype: UCMP 38158. Provenance: Locality 20 (Figure 1); 23 m above base of Weberg Member; Packardi Zone. Dimensions: DMAX 52.5 mm, UD 15.2 mm, WW 13.5 mm, WH 22 mm.

Diagnosis: Involute; whorl section strongly compressed, umbilical shoulder well defined, flanks flattened.

Description: The shell is strongly involute, and the whorl section is markedly compressed. The inner whorls have a shallow umbilical slope; however, the outer whorl has a nearly vertical umbilical wall and a gently rounded but well-defined umbilical shoulder. The flanks are flattened and subparallel. Ribbing is gently flexuous on the lower flank, becomes well defined about a third of the distance up the flank, and is strongest in the ventro-lateral area.

Discussion: This species is readily differentiated from most others in the genus by being strongly involute and having a strongly compressed whorl section. *Fontannesia involuta* n. sp. differs from *F.* aff. *clarki* (Westermann and Getty) in that it has no distinct tabulae bordering the keel.

Superfamily HAPLOCERATACEAE Zittel, 1884
Family STRIGOCERATIDAE Buckman, 1924
Genus *Strigoceras* Quenstedt, 1886

Strigoceras harrisense n. sp.
Plate 3, Figures 4, 5

Praestrigites cf. *P. deltotus* (Buckman). Imlay, 1973, p. 75, Plate 35, Figures 4, 8, 9, 13 (not Figures 1-3, 5-7, 11, 12, 14).

Holotype: NWMNH 25015. Provenance: Locality 22 (Figure 1); Weberg Member; Sparsicostatus Zone. Dimensions: DMAX 68 mm, WW 16.5 mm, WH 42 mm.

Name derivation: Referring to the "Old Harris Place," an abandoned homestead near the locality where the holotype for this species was found.

Diagnosis: Spiral and radial ornamentation weak; flank costation fine, even in strength, prorsiradiate.

Description: The shell is oxyconic, and the minute umbilicus is bordered by a slightly raised shoulder. The thin keel is moderately high. The shell has weak spiral ornamention as well as radial ribs. The spiral ornamentation consists of slight ridges, a vague one about a quarter of the distance up the flank and an even weaker one at mid-flank. The radial ornamentation includes moderately to widely spaced, weak, prorsiradiate primary costae, that at mid-flank may be slightly swollen and convex. The outer flank ribs are more closely spaced, even in strength, and prorsiradiate and expire against the keel.

Discussion: The exceptionally weak radial and spiral ribbing and the prorsiradiate direction of the dense outer flank costae serve to distinguish this species from others belonging to *Strigoceras*. Most of the presumably weakly ornate strigoceratid ammonites Imlay compared with "*Praestrigites*" *deltotus* Buckman are referable to *S. lenticulare* n. sp. (Imlay, 1973, Plate 35, Figures 3, 5-7, 11, 12, 14), while one example (Imlay, 1973, Plate 35, Figures 1, 2) may be an involute and weakly ornate variant of *Eudmetoceras mowichense* n. sp.

Note that *Praestrigites* is a junior synonym of *Strigoceras*. The holotype of the type species from Great Britain, *Praestrigites praenuntius* Buckman, has longitudinal ridges.

Strigoceras lenticulare n. sp.
Plate 3, Figures 8, 9

Praestrigites cf. *P. deltotus* (Buckman). Imlay, 1973, p. 75 (part), Plate 35, Figures 3, 5-7, 11, 12, 14.
Strigoceras cf. *S. languidum* (Buckman). Imlay, 1973, p. 76, Plate 36, Figures 13, 17-21.
Strigoceras sp. undet., Imlay, 1973, p. 76, Plate 36, Figures 14-16.

Holotype: NWMHN 25016. Provenance: Locality 11 (Figure 1); 32-33 m above base of Weberg Member; Ochocoense Subzone. Dimensions: DMAX 92.5 mm, UD 4.5 mm, WW 22 mm, WH 54 mm.

Diagnosis: Umbilicus minute; ribbing feeble, weakly to strongly prorsiradiate on lower flank; on upper flank, ribbing rursiradiate, branching only on finely ornate specimens; three longitudinal ridges.

Description: The shell is septate to 92-mm shell diameter and has a minute umbilicus. Three spiral ridges are present and are spaced at intervals about a quarter of the distance up the whorl side. The mesial ridge is the strongest, while the one closest to the venter is the weakest. The umbilical shoulder is also raised slightly. Ribbing is falcoid, gently to strongly prorsiradiate on the lower flank, becomes rursiradiate a short distance above mid-flank, and is radial to gently projected on the venter. Ribs terminate against the keel. Ribbing most commonly is weak and comparatively sparse on the lower flank. Ribbing on the upper half of the whorl side is simple on coarsely ornate specimens and partly bifurcate and intercalatory on finely ornate material. A few ribs that are sporadically spaced and generally originating low on the flank are stronger than the others.

Discussion: *Strigoceras lenticulare* n. sp. resembles most closely the English species *S. languidum* (Buckman) and Alaskan material described under *S.* cf. *languidum* (Buckman) by Imlay (1964). *Strigoceras languidum* differs in having a markedly narrower L sutural element and a more gently rounded and wider umbilicus. The Alaskan *S.* cf. *languidum* is more umbilicate, has a more gently rounded umbilical shoulder, and is more weakly ornate on the lower flank.

Family OPPELIIDAE Douvillé, 1890
Subfamily OPPELIINAE Douvillé, 1890
Genus *Hebetoxyites* Buckman, 1924

Hebetoxyites snowshoensis n. sp.
Plate 4, Figures 1, 2

Holotype: NWMNH 25017. Provenance: Locality 11 (Figure 1); 33 m above base of Weberg Member; Ochocoense Subzone. Dimensions: D 145.5 mm, WW 34 mm, WH 87 mm.

Diagnosis: Minutely umbilicate; venter evenly rounded (not acutely rounded); outer flank ribbing weak, irregular in strength and spacing.

Description: The compressed shell has a minute umbilicus, the margin of which is not raised. The body chamber comprises half a volution. Spiral ornamentation consists of a pronounced ridge just above mid-flank (it becomes obsolete on the adoral end of the body chamber) and possibly another faint ridge just over three-fourths of the distance up the flank. The latter is perceptible only on the phragmocone.

Phragmocone growth striae are nearly radial on the lower flank, where they are gently concave; they are deflected rursiradiately at the mid-flank ridge, are concave on the upper flank, but have not been observed in the ventro-lateral area. The striae on the adoral

***Facing page:** Plate 4. (All localities refer to Figure 1) — 1, 2.* Hebetoxyites snowshoensis *n. sp.,; holotype, NWMNH 25017 from Locality 11 (× 0.67). — 3, 4.* Docidoceras striatum *n. sp.; holotype, NWMNH 25020 from Locality 9 (× 0.5). — 5, 6.* Docidoceras schnabelei *n. sp.; holotype, NWMNH 25019 from Locality 19 (× 1). — 7, 8.* Docidoceras amundsoni *n. sp.; holotype, NWMNH 25018 from Locality 13 (× 0.5).*

half of the body chamber are more gently falcoid. They are slightly rursiradiate or radial where they pass over the venter. The apertural outline is sigmoidal and parallel to the growth striae.

Ribbing is conspicuous only on the outer three-fourths of the flank and is irregular in strength. The costae are rursiradiate to slightly projected in the ventro-lateral area and are absent on the venter. Costation on the inner adult whorls is very irregular in strength. On the adoral part of the phragmocone and body chamber, the ribbing becomes simple, fairly uniform in strength, and moderately spaced; but adorally on the body chamber, the plicae rapidly become progressively distant, low, and broad, until they are to be seen no more on the last one-eighth volution. The septal suture is fairly complex but not deeply incised.

Discussion: This species is most like *Hebetoxyites hebes* Buckman, from which it differs in details of the septal suture, weaker outer flank ribbing, and more broadly rounded venter.

Superfamily STEPHANOCERATACEAE Neumayr, 1875
Family STEPHANOCERATIDAE Neumayr, 1875
Genus *Stephanoceras* Waagen, 1869
Subgenus *Skirroceras* Mascke, 1907

Stephanoceras (*Skirroceras*) *flexicostatum* n. sp.

Stephanoceras (*Skirroceras*) cf. *S.* (*S.*) *leptogyrale* (Buckman). Imlay, 1973, p. 88, Plate 46, Figure 15.

Holotype: USNM 168610. Imlay, 1973, Plate 46, Figure 15, U.S. Geological Survey Mesozoic Location 29241.

Diagnosis: Inner whorls with dense secondary ribbing, primaries strongly flexed.

Description: Primary ribbing is prorsiradiate and strongly flexed adorally, at least on the phragmocone. Tuberculate ornamentation on the inner whorls consists of small, rounded nodes and on the outer whorls is quite prominent. Secondary ribbing is densely spaced on the inner whorls and coarsens on the outer whorls.

Discussion: Material constituting this species was compared by Imlay (1973) with the English *Stephanoceras leptogyrale* (Buckman), which differs by having less flexed and prorsiradiate primaries and less densely spaced secondary ribbing on the inner whorls. *Stephanoceras flexicostatum* also resembles *S. macrum* (Quenstedt), from which it differs in its much smaller size, more oblique aperture, and the flexed primaries.

Genus *Freboldites* n. gen.

Type species: *Freboldites bifurcatus* n. sp.

Name derivation: In honor of the late Canadian paleontologist Hans Frebold.

Diagnosis: Shell small, exceptionally evolute, inner whorls with nearly smooth venter and nontuberculate, strongly prorsiradiate, bifurcate ribbing.

Discussion: *Freboldites* n. gen. appears to be an important transitional form, having outer whorls with an ornamentation style typical of *Stephanoceras* and ribbing on the inner whorls like that of perisphinctaceans. Also, the new genus just predates the first perisphinctid, *Parabigotites crassicostatus* Imlay. The inner whorls of *Freboldites bifurcatus* n. sp. are so similar to those of *P. crassicostatus* that it is very likely that the latter is a paedomorphic development of the former. Contrary to the assessment given by Pavia (1983), *P. crassicostatus* is probably a true perisphinctid; the species is reported to have a strongly retracted suspensive lobe (Imlay, 1964, p. B54) and does not appear to be a hammatoceratid descendant (as may be the case with *Praeleptosphinctes*; see Pavia, 1983). The stephanoceratid genus *Phaulostephanus*, which also first appears in the superjacent beds, was interpreted by Pavia (1983) to be the radical for the perisphinctids. *Phaulostephanus* is also a logical descendant of *Freboldites*. *Freboldites*, therefore, provides the first adequate demonstration of the transition between *Stephanoceras* (or immediate ancestor) and the Perisphinctaceae. *Phaulostephanus* may also be the radical of *Lupherites*.

Freboldites bifurcatus n. sp.

Stephanoceras (*Skirroceras*) cf. *S.* (*S.*) *dolichoecus* (Buckman). Imlay, 1973, p. 88, Plate 45, Figures 8, 11.
Parabigotites crassicostatus Imlay, 1973, p. 92 (part), Plate 47, Figures 31-32 (not Figures 33-36).

Holotype: CAS 61542. Imlay, 1973, Plate 45, Figure 8, Locality 38; Weberg Member.

Diagnosis: Inner whorls nontuberculate, with bifurcate ribbing; outer whorls finely tuberculate, with three to four secondaries per primary.

Description: The shell has about 10 whorls and is exceptionally evolute. The phragmocone ends at about 60-mm shell diameter, and the maximum preserved shell diameter is 77 mm. The whorl section is depressed in the nucleus, while on the outer whorls it is subcircular. Bullate primaries appear at about 1-mm shell diameter. The primaries are most strongly projected on the inner three whorls but are still moderately strongly projected on the next two to three volutions. The secondaries consistently arise in pairs on the inner whorls and are gently convex over the nearly smooth venter. The finely tuberculate ornamentation characteristic of the outer whorls may begin as late as the fifth or sixth whorl. On the outer whorls, the primaries are weak and rounded and nearly radial to markedly rursiradiate. There usually are three but sometimes as many as four secondaries to each of these primaries. There is no evidence of constrictions. The secondary costation on the outer whorls is at most gently projected over the venter and retains its strength across the venter.

Remarks: Imlay (1973) compared specimens belonging to this new species to *Stephanoceras dolichoecum* (Buckman), perhaps because of the supposed similar highly evolute coiling. He may have been misled by one of the two figures of the holotype of *S. dolichoecum* (Buckman, 1921, v. 3, Plate 265, Figure 1) that is highly reduced photographically, giving the appearance of an extremely evolute ammonite. The specimen figured by Imlay (1973, Plate 47, Figures 31, 32) under *Parabigotites crassicostatus* Imlay also belongs to this new species. The specimen is identical to the holotype of *Freboldites bifurcatus* n. sp. The inner whorls of *Freboldites bifurcatus* n. sp. differ from those of *P. crassicostatus* in that the coiling is more evolute, the whorl section is less depressed, and the primary ribbing is more closely spaced on the sixth whorl. The inner whorls are otherwise very similar between the two species and signify the probable paedomorphic development of *P. crassicostatus* from *Freboldites bifurcatus* n. sp.

Family OTOITIDAE Mascke, 1907
Genus *Docidoceras* Buckman, 1919

Docidoceras amundsoni n. sp.
Plate 4, Figures 7, 8

Holotype: NWMNH 25018. Provenance: Locality 13 (Figure 1); Weberg Member; Westi Subzone. Dimensions: DMAX 158.5 mm, UD 75 mm, WW 57 mm, WH 45 mm.

Name derivation: In honor of Clayton T. Amundson, who has worked extensively in the Suplee area and collected the holotype.

Diagnosis: Quite evolute; deeply umbilicate; coarsely ornate phragmocone.

Description: The evolute inner adult whorls are cadiconic. The whorls increase in height on the outer whorls, so that the body chamber has a depressed subelliptical section with conspicuously rounded flanks. The incomplete body chamber comprises just over one volution, and the last half whorl egresses noticeably. The widest part of the whorl section is near mid-flank on the inner adult whorls and migrates to a quarter or a third of the whorl height on the body chamber.

The inner preserved whorls have 10-11 rounded nodes per half whorl. On the outer whorls, the tubercles become progressively blunter and decrease in number to nine per half whorl. Primary costae are nearly radial to gently projected on the phragmocone, where they consist of low, broad undulations; they become even more diffuse on the body chamber. Equally diffuse prorsiradiate plicae above the nodes extend up the flank only a short distance before expiring. Barely perceptible secondary ribbing on the coarsely preserved penultimate half whorl appears to be fine and adorally arched. Lower broad costae cross the venter with little convexity on the adoral half of the body chamber.

Discussion: Closest correspondence of *Docidoceras amundsoni* n. sp. is with the similarly stout-whorled *Docidoceras zemistephanoides* Geczy from Hungary. The Oregon species is even more deeply umbilicate, has coarser and wider spaced nodose ornamentation, and has an outer whorl that is less depressed.

Docidoceras schnabelei n. sp.
Plate 4, Figures 5, 6

Docidoceras cf. *D. liebi* Maubeuge. Imlay, 1973, p. 79, Plate 37, Figures 13, 14.

Holotype: NWMNH 25019. Provenance: Locality 19 (Figure 1); 38 m above base of Weberg Member; Packardi Zone. Dimensions: DMAX 68 mm, D 57.2 mm, UD 25.7 mm, WW 31 mm, WH 15 mm.

Name derivation: In honor of rancher Les Schnabele.

Diagnosis: Coiling evolute; primaries densely spaced, short, and bullate on last whorl; secondary costation markedly convex adorally.

Description: One specimen with aperture preserved has a maximum shell diameter of 78.5 mm, but other less complete material indicates greater dimensions. The phragmocone whorl section is lenticular but has a rounded lateral edge. On the last half whorl, the body chamber egresses, and the whorl section becomes slightly less depressed. The aperture is strongly flared, markedly oblique, and apparently not collared. Primary ribs on the phragmocone are closely spaced, are radial to projected, and bear pointed bullae or nodes. The ribs are bullate and quite short on the last whorl. The dense secondary costation is conspicuously arched adorally and may be very weak at large shell dimensions. It tends to coarsen over the adoral part of the body chamber.

Discussion: *Docidoceras schnabelei* n. sp. is closely allied with the *D. widebayense* species group (=subgenus *Pseudocidoceras* Westermann, 1969) but differs from any of those Alaskan species in having shorter primaries and a more strongly flared aperture.

Docidoceras striatum n. sp.
Plate 4, Figures 3, 4

Holotype: NWMNH 25020. Provenance: Locality 9 (Figure 1); 38 m above base of Weberg Member; Westi Subzone. Dimensions: DMAX 118 mm, WH ~32 mm.

Diagnosis: Coiling not strongly evolute; phragmocone cadiconic; body chamber finely ornate on venter.

Description: The outer whorls of the phragmocone have a depressed lenticular section; the innermost preserved whorl has a comparatively sharp edge, and the penultimate whorl has a rounded edge. The body chamber is subovate and only moderately depressed. The body chamber comprises at least three-fourths of a volution.

Primary costation on the phragmocone is gently prorsiradiate and terminates in closely spaced, fine tubercles. Three to four secondaries arise from each primary and are projected over the venter. On the body chamber, the primaries are concave and give rise to bullate nodes. The strongly projected secondary ornamentation consists of fine fasciculate rib bundles, and the venter is heavily striate to exceptionally weakly ribbed.

Discussion: This species is readily distinguished by its striate body chamber. The phragmocone is identical in shell proportions and ornamentation to *Docidoceras schnabelei* n. sp., indicating derivation from that species. The latter also has a similar trend in weakening of ventral ornamentation on the body chamber.

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REFERENCES CITED

Buckman, S.S., 1887-1907, A monograph of the ammonites of the Inferior Oolite Series: London, Palaeontographical Society, 456 p., 103 pls.; Supplement, cclxii p., XXIV pls.

———1919-1930, Type ammonites: London, Wheldon and Wesley, v. 3-7.

Crickmay, C.H., 1933, Mount Jura investigation: Geological Society of America Bulletin, v. 44, no. 5, p. 895-926.

Dickinson, W.R., and Thayer, T.P., 1978, Paleogeographic and paleotectonic implications of Mesozoic stratigraphy and structure in the John Day inlier of central Oregon, *in* Howell, D.G., and McDougall, K.A., eds., Mesozoic paleogeography of the western United States: Pacific Coast Paleogeography Symposium 2, Sacramento, Calif., Society of Economic Paleontologists and Mineralogists, Pacific Section, p. 147-162.

Dickinson, W.R., and Vigrass, L.W., 1965, Geology of the Suplee-Izee area, Crook, Grant, and Harney Counties, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 58, 109 p.

Guex, J., 1987a, Corrélations biochronologiques et associations unitaires: Lausanne, Presses Polytechniques Romandes, 244 p.

———1987b, Sur la phylogenèse des ammonites du Lias inférieur: Bulletin de la Société Vaudoise des Sciences Naturelles, v. 78, no. 4, p. 455-469.

Hall, R.L., and Westermann, G.E.G., 1980, Lower Bajocian (Jurassic) cephalopod faunas from western Canada and proposed assemblage zones for the lower Bajocian of North America: Palaeontographica Americana, v. 9, no. 52, 93 p.

Hillebrandt, A. von, and Westermann, G.E.G., 1985, Aalenian (Jurassic) ammonite faunas and zones of the southern Andes: Zitteliana, v. 12, p. 3-55.

Imlay, R.W., 1964, Middle Bajocian ammonites from the Cook Inlet region, Alaska: U.S. Geological Survey Professional Paper 418-B, 61 p.

———1973, Middle Jurassic (Bajocian) ammonites from eastern Oregon: U.S. Geological Survey Professional Paper 756, 100 p.

Lupher, R.L, 1941, Jurassic stratigraphy of central Oregon: Geological Society of America Bulletin, v. 52, no. 2, p. 219-269.

Morton, N., 1975, Bajocian Sonniniidae and other ammonites from western Scotland: Palaeontology, v. 18, pt. 1, p. 41-91.

———1976, Bajocian (Jurassic) stratigraphy in Skye, western Scotland: Scottish Journal of Geology, v. 12, pt. 1, p. 23-33.

Mouterde, R., Ruget, C., and Caloo, B., 1972, Les limites d'étages. - Examen du problème de la limite Aalénien-Bajocien, *in* Colloque sur les méthodes et tendances de la stratigraphie: Paris, France, Bureau de Recherches Géologiques et Minières, Mémoire 77, p. 59-68.

Parsons, C.F., 1974, The *sauzei* and 'so-called' *sowerbyi* Zones of the lower Bajocian: Newsletters on Stratigraphy, v. 3, no. 3, p. 153-179.

Pavia, G., 1983, Ammoniti e biostratigrafia del Baiociano inferiore di Digne (Francia SE, Dip. Alpes-Haute-Provence): Museo Regionale di Scienze Naturali, Monografia II, 254 p.

Smith, P.L., 1980, Correlation of the members of the Jurassic Snowshoe Formation in the Izee basin of east-central Oregon: Canadian Journal of Earth Sciences, v. 17, no. 12, p. 1603-1608.

———1986, The implications of data base management systems to paleontology: A discussion of Jurassic ammonoid data: Journal of Paleontology,

v. 60, no. 2, p. 327-340.
Taylor, D.G., 1981, Jurassic (Bajocian) ammonite biostratigraphy and macroinvertebrate paleoecology of the Snowshoe Formation, east-central Oregon: Berkeley, Calif., University of California doctoral dissertation, 317 p.
———1982, Jurassic shallow marine invertebrate depth zones, with exemplification from the Snowshoe Formation, Oregon: Oregon Geology, v. 44, no. 5, p. 51-56.
Westermann, G.E.G., 1964, The ammonite fauna of the Kialagvik Formation at Wide Bay, Alaska Peninsula, Part I, Lower Bajocian (Aalenian): Bulletins of American Paleontology, v. 47, no. 216, p. 327-503.
———1969, The ammonite fauna of the Kialagvik Formation at Wide Bay, Alaska Peninsula, Part 2, *Sonninia sowerbyi* Zone (Bajocian): Bulletins of American Paleontology, v. 57, no. 255, p. 5-226.
Westermann, G.E.G., and Riccardi, A.C., 1972, Middle Jurassic ammonoid fauna and biochronology of the Argentine-Chilean Andes Part I: Hildoceratacea: Palaeontographica, Abteilung A, Band 140, p. 1-116.
———1979, Middle Jurassic ammonoid fauna and biochronology of the Argentine-Chilean Andes Part II: Bajocian Stephanocerataceae: Palaeontographica, Abteilung A, Band 164, p. 85-188. □

USGS reports earthquakes

The world had 26 significant earthquakes during the first six months of 1988, three less than during the same period a year earlier, according to the U.S. Geological Survey (USGS). The USGS defines as significant those earthquakes that have a magnitude of 6.5 or greater. Shocks of lesser magnitude are also called significant, if they cause fatalities or injuries or substantial damage.

Waverly Person, chief of the USGS National Earthquake Information Service (NEIS) in Golden, Colorado, said that two of the significant 1988 earthquakes occurred in the United States or nearby waters.

The U.S. earthquakes included the strongest earthquake in the world during the first half of 1988, a magnitude 7.6 shock on March 6 in the Gulf of Alaska.

Person said that the frequency of significant earthquakes in the first half of 1988 is roughly in line with the long-term average of 60 significant earthquakes per year or 30 for six months.

The USGS scientist said that reports have been received of only 12 people being killed as a result of earthquakes in the first six months of this year. If this annual rate of 24 were continued through the end of the year, 1988 would have the lowest death toll on record since the NEIS began keeping detailed statistics more than 20 years ago. The previous low for a single year was 77 in 1984, and the high was more than 600,000 in 1976, most of them in a devastating earthquake in China.

One of the 1988 deaths was in the United States, from a heart attack after a magnitude 4.8 earthquake February 11 in the Whittier area of southern California.

Four of the 1988 earthquakes had magnitudes of at least 7.0:

- The magnitude 7.6 earthquake on March 6 in the Gulf of Alaska that was felt widely in parts of Alaska and Canada and caused minor damage to some ships. It also created a small tsunami (earthquake sea wave).
- The magnitude 7.1 earthquake on June 18 in Mexico's Gulf of California that was felt in parts of Mexico.
- The magnitude 7.0 earthquake on February 24 in the Philippine Islands that caused some slight damage at Virac on Luzon Island.
- The magnitude 7.0 earthquake on April 12 near the coast of Peru that was felt in various parts of Peru.

The world has now gone more than 20 months without a great earthquake (magnitude 8.0 or larger), Person said. The last one was a magnitude 8.1 shock on October 20, 1986, in the Kermadec Islands area of the South Pacific.

The largest death toll from a single earthquake during the first half of 1988 was eight people killed in a gold mine in a magnitude 5.2 earthquake in South Africa on January 5.

Two people were killed in a magnitude 5.8 earthquake on February 6 along the India-Bangladesh border. That earthquake also injured 100 people and caused extensive damage in some areas.

One person was killed, four were injured, and there was moderate local damage in a magnitude 6.3 earthquake on June 19 on Mindoro Island in the Philippines.

The northern Territory of Australia had three significant earthquakes in a single day, January 22, within less than 12 hours of each other. The magnitudes were 6.3, 6.4, and 6.7. The three earthquakes are believed to be the strongest on record in this area. The last and strongest of the three earthquakes caused damage in the Tennant Creek area and was felt over about two-thirds of Australia.

Three other 1988 earthquakes occurred near the coast of northern Chile: a magnitude 6.8 earthquake on January 19; a magnitude 6.7 earthquake on February 5 that caused minor damage in the Antofagasto-Taltal area; and a magnitude 6.1 earthquake later that same day.

Person said that the USGS, using data from seismograph stations throughout the world, normally locates from 10,000 to 12,000 earthquakes worldwide each year, ranging in magnitude from about 2.0 up to 8.0 or more. "Probably several million earthquakes occur each year," he added, "but most are so small in magnitude, or they occur in such remote areas, that they are not detected by even the the most sensitive instruments throughout the world."

Earthquake data gathered by the USGS are used not only to report on the occurrences of earthquakes worldwide but also to provide basic information used by federal, state, and local governments as well as private industry to study what causes earthquakes, when and where they may occur, and how the hazards of earthquakes might be reduced.

—USGS news release

Astoria Club displays rocks at Capitol

The Trail's End Gem and Mineral Club of Astoria has provided the current display at the State Capitol display case of the Oregon Council of Rock and Mineral Clubs (OCRMC). The collection will be on view until the middle of January of 1989.

More than 100 items from 13 Oregon counties are shown in the display, to which almost all members of the club contributed. Featured are three operating clocks, one of Clatsop County agate, one of Sherman County jasper, and one of red oak petrified wood from Crook County. The Friends Ranch yielded the material for a large frame of black and clear agate cabochons. Bookends on display were made from petrified wood and a large double thunder egg. A miniature set of rock hammer, pick, and shovel shows handles of petrified wood, and mahogany obsidian was used for salt and pepper shakers.

Among the other displays there are one very large slab of moss agate from Maury Mountain, Crook County, much of it a deep purple color; small, colorful zeolites from Quartz Creek, Clatsop County; a quantity of rough and tumbled Oregon sunstones, the State Gemstone; a large specimen of carnelian; agatized coral; tempskya (fern root); fossils from Humbug Mountain, Clatsop County; and five unusual agate geode core specimens, weathered from thunder eggs.

Following the Astoria club's display, from the middle of January 1989, the Oregon Department of Geology and Mineral Industries will present an exhibit.

—OCRMC news release

Baseline Road markers

by Howard F. Horner, Retired Superintendent of Schools, David Douglas School District, Portland, Oregon

On June 4, 1851, John R. Preston, first Surveyor General for the Territory of Oregon, established a point for the intersection of the Willamette Meridian and the Willamette Baseline. That spot, just off the 6500 block of NW Skyline Boulevard in Portland, marked by the Willamette Stone and, since 1945, surrounded by the Willamette Stone State Park, is the foundation for all Oregon and Washington surveys. Every lot, every farm, and every parcel of real estate in Oregon and Washington is referenced to that pin-point intersection of the Willamette Meridian and Baseline.

Benchmark in Willamette Stone State Park fixing the "Initial Point," the intersection of the Willamette Meridian and Willamette Baseline, for the Public Land Survey System for Oregon and Washington.

Preston was careful to set the baseline south of any part of the Columbia River. From the Willamette Stone, the baseline runs west to the Pacific Ocean near Bay City and goes east to the Idaho border near Imnaha. The Willamette Meridian hits California near Ashland and goes north to Canada.

In June 1851, Preston asked William Ives, Deputy Surveyor, to survey the baseline from the Willamette Meridian east for 36 mi, into the Cascades. Ives completed the survey in July 1851.

In April 1854, the Clackamas County Commission was petitioned for a road to run from the Willamette River to the Sandy River, along and as near as practicable to the baseline. The petition was signed by Perry Prettyman, Samuel Nelson, W.D. Gilham, B.F. Stark, William B. Jones, Gilsner Kelly, and 30 others. After some controversy, the petition was approved. The road followed the baseline survey and was opened to the public as Baseline Road (now NE Stark Street) on November 24, 1854. (A reminder of the baseline exists today as West Baseline Road that leads from the west side of Portland toward Hillsboro and generally follows the Willamette Baseline.)

Travelers leaving Portland to use the new Baseline Road crossed the Willamette River on the Stark Street ferry. A wooden trestle then took them to what is now the SE Grand Avenue area, where they could continue east on Baseline Road.

At some time after 1854, 15 basalt obelisk markers were set along Baseline Road to mark each mile from the Courthouse to the Sandy River. Each stone measures about 12 in. on a side and 6 ft in length, with 3 ft or more set into the ground. The top is rough-sculptured in obelisk form and engraved with the letter P, for Portland, and a number indicating the miles to downtown Portland. No one knows who put the stones in place and precisely when they were emplaced.

Markers P-1, -3, -8, -10, -12, and -15 have been lost, but, although the markers are well over 100 years old, nine have survived road excavations and can be seen along SE Stark Street:

P-2, at about 2350 SE Stark, is partially imbedded in the concrete wall of the Lone Fir Cemetery.

P-4 is at 61st and Stark, near Tabor Heights United Methodist Church. Stan Clarke, church historian and genealogist, rescued the stone from a road construction crew.

P-5 is at 78th and Stark. It has been painted yellow and is near the Portland Auto Upholstery shop. Cy Gengelbach, former owner of that company, moved the stone onto his property to save it. He put an iron hook in the stone and hung an air hose on it for use by early motorists.

Milestone P-7 at 117th and SE Stark in Portland, placed originally about 100 years ago along what was then Baseline Road.

(Continued on page 141, ***Markers****)*

An Oregon cure for Bikini Island? First results from the Zeolite Immobilization Experiment

by Dave E. Leppert, Geologist, Teague Mineral Products, Adrian, Oregon 97901

INTRODUCTION

Bikini Island, a part of Bikini Atoll in the Marshall Islands, was the home of the Bikinians prior to nuclear testing in the area from 1947 through 1958. In 1969, debris from the testing was removed, and plantations were established to prepare the island for resettlement. However, studies in 1978 showed that the settlers had accumulated unacceptable amounts of cesium-137 from food grown on Bikini. The Bikinians again had to leave their homeland until a solution could be found.

The Bikini Atoll Reclamation Committee (BARC) was established by Congress to study the cost and feasibility of rehabilitating Bikini, with decontamination of the island a primary goal. Studies have concentrated on reducing cesium uptake by plants, though excavation of the contaminated topsoil is a possible alternative. Other radionuclides are present on Bikini but do not pose a significant hazard.

I work primarily on development of environmental and agricultural applications for clinoptilolite zeolite. In 1986, I read in the *National Geographic Magazine* (Ellis, 1986) about the cesium-137 uptake by plants on Bikini Atoll and immediately realized that clinoptilolite zeolite might provide an attractive alternative to the possible remedies under discussion. Clinoptilolite occurs in large sedimentary deposits as an alteration product of volcanic tuff (Hay, 1977), and Teague Mineral Products mines three deposits of clinoptilolite in Oregon and Idaho.

Zeolites are hydrous aluminosilicate minerals with a porous framework structure. The pores within the structure contain exchangeable cations and account for the high cation-exchange capacity. The cation-exchange characteristics of clinoptilolite provide the basis for most environmental applications, and the mineral can selectively absorb (or adsorb—both terms hereafter subsumed under "sorb") many radionuclides, heavy metals, ammonium, and organic compounds, immobilizing them sufficiently to reduce uptake by plants.

I contacted Dr. W.L. Robison at Lawrence Livermore National Laboratories, and after he and BARC received background information from me on the ability of clinoptilolite to selectively sorb cesium and on its value as a soil amendment, they decided to test my hypothesis with the Zeolite Immobilization Experiment, which was soon started.

THE EXPERIMENT

In 1986, 15 plywood frames were built for the Zeolite Immobilization Experiment 1.5-m^2 test plots and installed on Bikini. Clinoptilolite (Feed Grade CH Zeolite), provided by Teague Mineral Products, was mixed by a concrete mixer with the surface foot of soil in three different amounts (9, 18, and 36 tons per acre). Corn and Chinese cabbage were initially planted, and sweet potato was planted later. Two control plots were established, one using excess potassium fertilizer, because previous tests had shown that extra potassium inhibits cesium uptake.

Results from the first crop grown in clinoptilolite-amended soil indicate that cesium-137 uptake was significantly less than in the untreated and potassium-treated controls (Figure 1). However, since a high-potassium clinoptilolite was used, it is unknown how much of the effect was due to cesium sorption by the clinoptilolite and how much was due to the effect of potassium released by the clinoptilolite's cation exchange. Successive cuttings and possibly other tests will be used to determine how much of the reduction was actually due to sorption by the clinoptilolite.

Problems will still have to be solved, no matter what approach is finally taken for the rehabilitation of Bikini. Though excavation

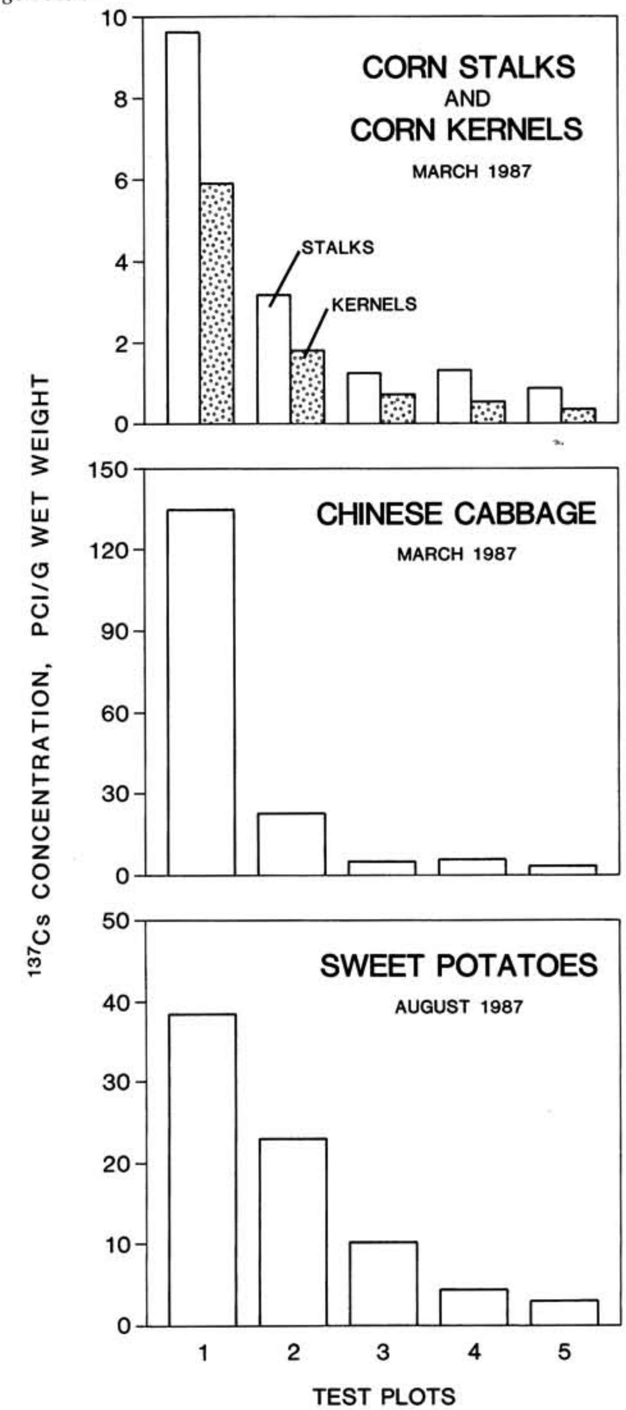

Figure 1. Zeolite Immobilization Experiment, November 1986-March 1987, showing cesium-137 concentrations in corn stalks and corn kernels, Chinese cabbage, and sweet potatoes grown in control plots and plots treated with clinoptilolite zeolite. Test plots were treated in the following ways: 1. Control plot, native potassium (K) only. 2. Control plot, plus 20 gm/m^2 K (178 lbs/acre). 3. Zeolite-treated plot (2 kg/m^2). 4. Zeolite-treated plot (4 kg/m^2). 5. Zeolite-treated plot (8 kg/m^2).

of the topsoil removes the contamination from the island, revegetation without topsoil may be difficult, and the problem of what to do with the contaminated soil remains. Application of large amounts of potassium may be effective, but repeated applications would be necessary every five years or so for the next 75 years.

Assuming that further testing will support the initial results, incorporation of clinoptilolite into the soil may provide an attractive alternative to and avoid some of the problems associated with the other approaches. Ultimately, a combination of treatments may be the most efficient and cost-effective way to decontaminate the island and finally allow the Bikinians to return home.

REFERENCES CITED

Ellis, W.S., 1986, A way of life lost, Bikini: National Geographic Magazine, v. 169, no. 6, p. 810-834.

Hay, R.L., 1977, Geology of zeolites in sedimentary rocks, *in* Mumpton, F.A., ed., 1977, Mineralogy and geology of natural zeolites: Washington, D.C., Mineralogical Society of America, p. 53-64.

Robison, W.L., and Stone, E.L., 1988, Bikini Atoll Reclamation Committee summary report: Washington, D.C., BARC Report No. 6, p. A5, A45-47. □

NWMA announces 94th annual convention

The Northwest Mining Association (NWMA) will hold its 94th annual convention in Spokane, Washington, from November 30 to December 3, 1988, under the title "Working Together—Exploring Mining's Future." Early registrations and a trade show that sold out by September 1 have raised hopes for an unusually well-attended and successful convention.

A new feature was added to this convention: The program was developed jointly by the NWMA and the Association of Exploration Geochemists. Exploration geochemistry is the topic of this year's short course, to be held November 28-30, and related topics are also part of the general program.

The NWMA's address is 414 Peyton Building, Spokane, WA 99201; phone (509) 624-1158; Fax (509) 623-1241.

—NWMA news release

Fellowship available for engineers

The Education Foundation of the National Society of Professional Engineers (NSPE) has announced its fellowship program for engineers pursuing graduate study on management. The program was endowed by the Society's division of Professional Engineers in Government (PEG) and is now in its fifth year. PEG is funding the $1,000 fellowship to encourage registered Professional Engineers (PE) and Engineers-in-Training (EIT) in any field of practice to pursue continuing professional development in the area of management.

Any PE or EIT employed in government, education, industry, construction, or private practice may apply. Qualifications include a minimum undergraduate grade-point average of 3.0; a desire to earn an MBA in management, engineering management, or public administration; and enrollment in, or acceptance to, a program accredited by the American Assembly of Collegiate Scholars of Business or by the Accreditation Board for Engineering Technology. Information and application materials may be obtained from the NSPE Education Foundation, 1420 King Street, Alexandria, Virginia 22314, phone (703) 684-2830, where applications must be received no later than February 1, 1989.

—NSPE news release

ABSTRACT

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that, we feel, are of general interest to our readers.

THE GEOLOGY AND EPITHERMAL VEIN MINERALIZATION AT THE CHAMPION MINE, BOHEMIA MINING DISTRICT, OREGON, by Kurt T. Katsura (M.S., University of Oregon, 1988), 254 p.

The Champion Mine exploits a gold/base-metal epithermal vein system that cuts a Miocene volcanic center in the Bohemia mining district, Oregon. The Champion vein system consists of four steeply-dipping, subparallel veins that are structurally simple at depth and become increasingly complex upward. The epithermal veins show crustification banding, multiple brecciations, vein sediments, and cross-cutting vein relations that cut an earlier porphyry-copper-style mineralization, associated with tourmaline breccia pipes.

Brecciation events are traced throughout the Champion system, providing time-equivalent markers that define four paragenetic vein stages. Gold occurs in two stages: in crustification bands with sphalerite, chalcopyrite, and galena, where it was deposited from boiling of sulfide-deficient fluids; and in kaolinite crustification bands, where it was deposited from mixing of boiled ascending fluids with a descending acid-sulfate water. Intense argillic alteration overprints the veins and is the product of descending acid-sulfate waters. □

*(**Markers**, continued from page 139)*

P-6 is at 98th and Stark, near Elmer's Pancake House. Craig Decker, former resident of that area, attached a notice to the stone reading, "Historic stone. If removal is necessary, notify Oregon Historical Society."

P-7 is at 117th and Stark. It was found in a landfill by Mount Hood Community College students and replaced at the southeast corner of Ventura Park. It is flanked by an Oregon Historical Society marker explaining the obelisk-stone mile markers.

P-9 is at 15802 SE Stark, in the front yard of a private residence.

P-11 can be seen near the Stark Street Market at 197th and Stark.

P-13 was rescued from rubble by the Gresham Historical Society. It was kept by that society until road work had been completed and then was reset at 236th and Stark, with a suitable dedication ceremony, on May 13, 1987.

P-14 is on the Mount Hood Community College property, just east of SE Stark and Kane Road.

History buffs of Multnomah County are ever on the lookout for the missing obelisk mile markers. Any persons who might find one of the stones or have any information on them are invited to call the Oregon Historical Society or the Gresham, Troutdale, or David Douglas Historical Societies, or the authors. □

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Some of you will find that the code number on your address label ends in "1288," which means your subscription expires with the December issue of 1988. If so, or if your expiration date is anywhere near this, please use the renewal form on the last page to make sure you will continue receiving *Oregon Geology*. And while you are at it—why not consider a gift subscription for a friend?

Index to OREGON GEOLOGY, volume 50, 1988

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