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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 the Oregon Department of Geology and Mineral Industries.

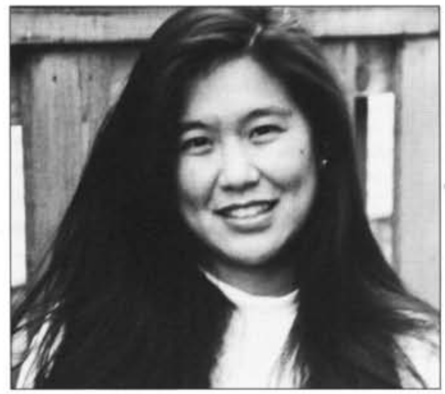
Cover photo

Yaquina Head near Newport, Lincoln County, on the central Oregon coast. This 1976 photo shows the area that in 1980 was established as an Outstanding Natural Area. Article beginning on next page presents an introduction to its geologic history.

Earthquake engineering specialist and minerals economist join DOGAMI staff

Mei Mei Wang, earthquake engineering specialist, and Robert Whelan, minerals economist, have joined the Oregon Department of Geology and Mineral Industries (DOGAMI). The two positions are supported by Oregon Lottery funds.

Wang has a master of science degree in civil engineering from the University of California at Berkeley and is continuing her studies toward a doctorate in engineering at Oregon State University. She has expertise in earthquake engineering, geological engineering, and slope and dam assessments. She comes to DOGAMI from Oakland, California, where she owned her own consulting firm, GeoLogic.



Mei Mei Wang

Most recently, she just returned from a month-long tour of Venezuela. At DOGAMI, she will be responsible for developing earthquake hazard maps for parts of the coast and of the Willamette Valley, starting with the Siletz Bay and Salem areas.

Whelan, who has a master of science degree in mineral economics from Pennsylvania State University, has experience in business and market research, economic forecasting, strategic planning, business development, and technology assessment. He has worked with

Robert Whelan

Chase Econometrics, Climax Molybdenum, and Nerco, Inc., as economist, market research analyst, and director of business analysis and development. Most recently he was a private consultant in Portland. His responsibilities at DOGAMI will be to do a regional analysis of demand for aggregate minerals, to develop mineral production statistics for the state of Oregon, and to find marketing opportunities for Oregon industrial minerals to be used in environmental protection applications. □

A geologic overview of Yaquina Head, Oregon

by Cheryl L. Mardock, Albany Research Center, U.S. Bureau of Mines, Albany, OR 97321-2198

ABSTRACT

Yaquina Head is a distinct promontory located approximately 3 mi north of Newport on the Oregon coast. The headland is a distal lobe of the Ginkgo basalt, a flow of Wanapum Basalt of the Columbia River Basalt Group. This unique setting was established as an Outstanding Natural Area in 1980 to preserve its natural, scenic, historic, scientific, educational, and recreational values. The U.S. Bureau of Mines, in a cooperative agreement with the U.S. Bureau of Land Management, provided a nontechnical interpretation of the area's geology for exhibits that are scheduled to be completed in August 1995.

The geologic features at the site are exceptional. Impressive exposures of columnar basalt and local faulting are evident even to the untrained eye. The explosive confrontation between the Columbia River basalts and the Pacific Ocean is recorded in the exposed rocks of the cliffs and beaches. Uplift and sea-level changes have carved multiple terraces into the headland, and superb examples of faults, folds, joints, dikes, and erosional features are exposed at the site.

INTRODUCTION

Yaquina Head is located on the extreme western edge of the Coast Range physiographic province in Lincoln County along the north-central portion of the Oregon coast (Figure 1). The boundaries of the landform lie within secs. 29 and 30, T. 10 S., R. 11 W., Willamette Meridian. Newport is approximately 3 mi to the south, Agate Beach is adjacent to the east, and Beverly Beach is 3 mi to the north. Access is by Lighthouse Drive, a mile-long paved road off U.S. Highway 101, the major north-south highway along the Pacific coast. Figure 2 shows an aerial view of Yaquina Head with geologic feature locations marked for reference.

From 1917 to the late 1970s, Yaquina Head provided a unique source of competent rock for road material. Rocks from other flows in the region proved to be fragile and unserviceable because they are rich in swelling clays. There are two major quarries on the headland: an upper quarry near the summit of the headland and a lower quarry on the south side near sea level. Their large size attests to the many years that this basalt supplied an invaluable resource for building the local infrastructure including Highway 101. Efforts to close the quarries to preserve the profile of the headland stimulated action to create the Yaquina Head Outstanding Natural Area. The quarries' walls now provide superb windows onto the geology of the headland.

Public Law 96-199 created the Yaquina Head Outstanding Natural Area on March 5, 1980, to serve as a basis for managing the natural, scenic, historic, scientific, educational, and recreational values of Yaquina Head. Managing agencies include the U.S. Bureau of Land Management (BLM), the U.S. Coast Guard, the Oregon Department of Parks and Recreation, and the U.S. Fish and Wildlife Service. When development is completed, the area will feature the unique combination of an interpretive center, tidal-zone marine gardens, geologic features and exhibits, archaeological exhibits, the Yaquina Head lighthouse, harbor-seal rocks, seabird rookeries, shoreline and freshwater-marsh ecosystems, a whale-watching observation area, and the Fishermen's Memorial.

U.S. Bureau of Mines geologists had the pleasure of interpreting the geologic story of the headland for BLM's proposed Interpretative Center Complex. The resulting general geologic overview is the most comprehensive work done to date on Yaquina Head. Perhaps this groundwork will encourage other geologists to do more in-depth studies of this exceptional site.

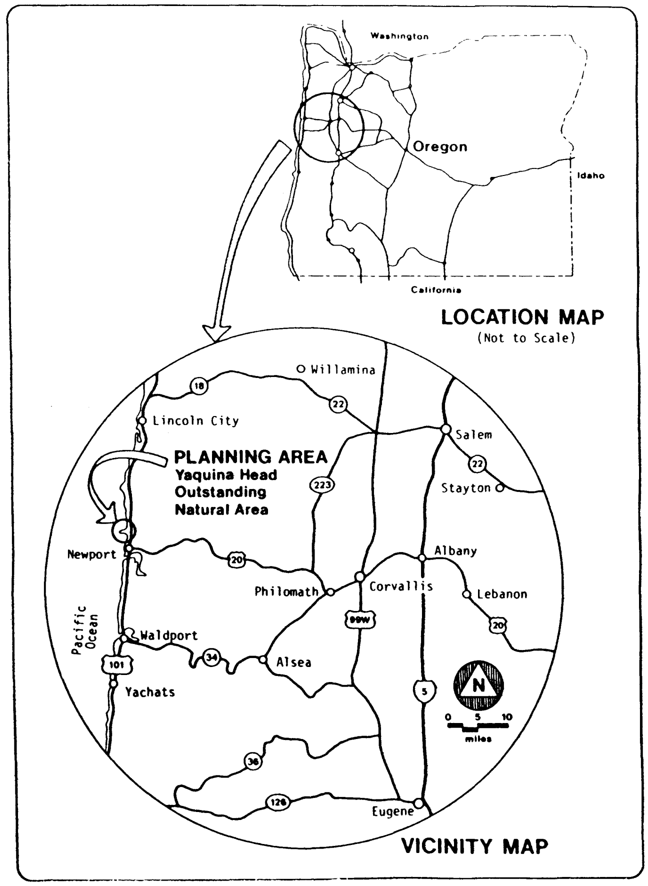


Figure 1. Location of Yaquina Head Outstanding Natural Area.

THE GEOLOGIC STORY

Fire fountains erupt in Oregon, Washington, and Idaho

Between 12 and 16 million years ago during middle Miocene time, huge floods of basalt lava flowed out of great fissures in eastern Oregon, southeastern Washington, and western Idaho. Like fountains of fire, flood basalts surged from chains of fissures up to 50 mi long, filling low-lying areas and eventually reaching the western coastline of Oregon (Beeson and others, 1985). The flows remained fluid over a journey stretching in excess of 300 mi because their immense volume allowed the flows to retain their heat and because the basalt was low in silica and consequently low in viscosity. The lava flowed over much of northeast Oregon and southeast Washington. The flow that traveled to Tillamook Head, Cape Falcon, Cape Meares, Cape Lookout, Cape Kiwanda, Depoe Bay, Yaquina Head, and Seal Rock (Figure 3) flowed westward, through the Columbia River Gorge, and down an ancient Columbia River channel to the northern and central Oregon coast (Tolan and others, 1984; Orr and others, 1992). The Columbia-Snake River basalt plateau covers an area of about 200,000 mi^2; it has an average thickness of 3,000 ft and a maximum thickness of 15,000 ft (Reidel and Hooper, 1989).

The Ginkgo basalt

The basalt at Yaquina Head was previously called the Cape Foulweather Basalt when it was believed that this basalt flowed

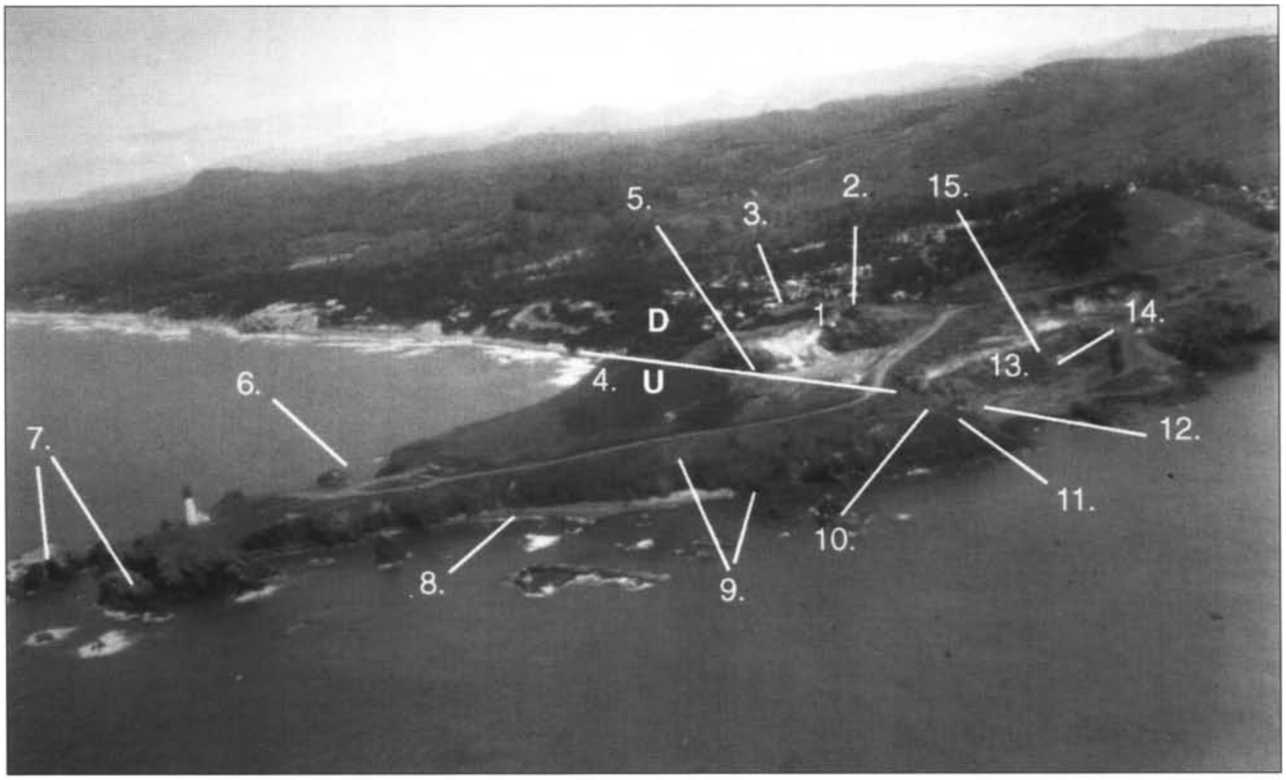


Figure 2. Aerial view of Yaquina Head shows geologic features: (1) upper quarry; (2) eolian sands; (3) colonnade; (4) large fault, U = upthrown side, D = downthrown side; (5) spheroidal weathering feature; (6) arch; (7) erosional features; (8) cobble beach; (9) dikes; (10) breccia; (11) uplifted beds; (12) colonnade; (13) lower quarry; (14) entablature; (15) small fault. Modified from photo courtesy U.S. Bureau of Land Management.

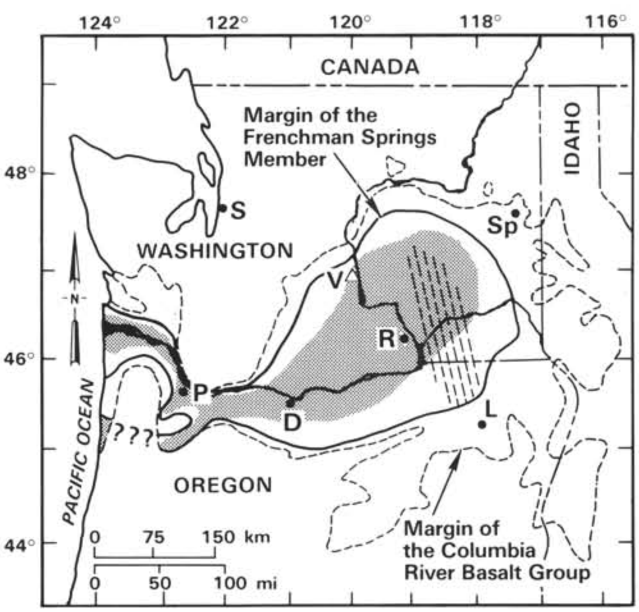


Figure 3. Inferred original extent (stippled area) of the basalt of Ginkgo, a flow of the Frenchman Springs Member of the Columbia River Basalt Group. Dike and vent area is shown schematically by parallel dashed lines. Open triangle designates location of type locality. Abbreviations for cities: D = The Dalles; L = LaGrande; P = Portland; R = Richland; S = Seattle; Sp = Spokane; V = Vantage. From Beeson and others (1985).

from a local coastal volcano (Snavely and MacLeod, 1971; Snavely and others, 1973). Studies now indicate that the basalt is the basalt of Ginkgo, a flow of the Frenchman Springs Member of the Wanapum Basalt in the Columbia River Basalt Group (Beeson and others, 1979; Beeson and others, 1985). The Ginkgo basalt at Yaquina Head is tholeiitic; it contains volcanic glass and little to no olivine and has orthopyroxene, clinopyroxene, and calcium plagioclase. The groundmass is a combination of glass and fine- to medium-grained crystals; it is sparsely microporphyritic and contains both tabular and acicular plagioclase microphenocrysts.

Although all of the basalt on Yaquina Head came from the same source and has the same chemistry and mineralogy, it has very different morphology resulting from a range of complex cooling environments. Geomorphic forms include columnar basalts, breccias, and smooth, unjointed basalt. Faulting, folding, weathering, and erosion have further changed the basalt across the headland.

Columns

Columnar basalt occurs in numerous areas on Yaquina Head, including the eastern halves of both the upper quarry and lower quarry walls. The columnar appearance is due to jointing caused by shrinkage cracks that formed perpendicular to the cooling surface. The joints separate the basalt into columns with four to eight sides, but usually six sides. Basalt from both near the air-cooled surface and near the ground-cooled surface of the lava flow forms sets of thick, vertical, and parallel columns called colonnades. There are no sizable colonnades exposed on Yaquina Head. Small exposures include a short (approximately 3-ft-high) colonnade at the top of the eastern side of the upper quarry back wall and a small rock-island colonnade that lies in the sea entrance at the northern end of the lower quarry (Figure 4).

The columns in the lower quarry wall and much of the eastern side of the upper quarry wall are thinner than the colonnade columns and are oriented at varying angles, often forming irregular shapes resembling fans, chevrons, and rosettes (Figure 5). This phenomenon, called entablature, is characteristic of the central part of thick basaltic lava flows. One of the theories of its formation is that, as the flow cooled from the bottom and top, irregular cracks penetrated into the middle part of the flow. This created disarrayed cooling surfaces and caused the basalt to joint in complex patterns.

Figure 4. A small colonnade (mid-picture) at the sea entrance to the lower quarry is isolated by a fault from tectonically uplifted layers of hyaloclastic pillow breccia (upper part of picture) on the north wall of the lower quarry.

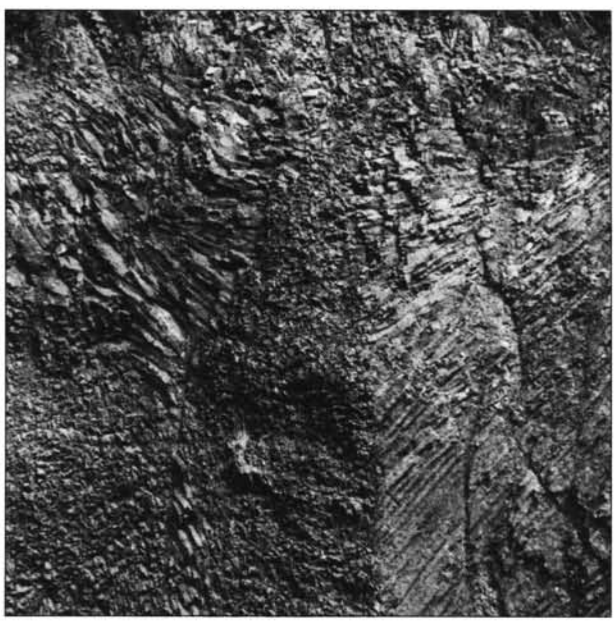


Figure 5. The lower quarry wall is an exceptional example of disarrayed columns forming complex chevrons, fans, and rosettes in the middle of a thick basaltic lava flow. View area is about 15 ft^2.

Breccia

The volcanic rock that is exposed along much of the southern beach area is a glassy basaltic breccia composed of both angular and well-rounded fragments of basalt and glass shards within both mineral and glass matrices. Most of the fragments in this breccia are less than an inch in diameter, but some large clasts are more than 6 ft wide. The breccia formed as the lava flowed into the ocean and either boiled and frothed or explosively fragmented as it quenched in the seawater.

Some of the breccia components are broken, blocky, angular fragments of finely crystalline, scoriacious, or glassy basalt. Some of the lava formed smooth, ellipsoidal, toelike, or pillow-shaped globs as it dropped into the sea—in much the same way as salad oil forms globs when poured into vinegar (Snavely and MacLeod, 1971). These pillows differ from undersea-extruded pillows in their distinctive small size and truncated forms.

The resulting composition of these unstratified, unsorted breccias (Figure 6) is one of variably sized and shaped lithic fragments of basalt, including broken and unbroken pillows, in a matrix of smaller fragments, spherules, glass, glass shards, and palagonite, a mineraloid created nearly instantaneously by hydration of the glass as soon as it enters the sea (MacDonald, 1972; Cas and Wright, 1987). The rock may be best described as a palagonitic pillow breccia (A.R. McBirney, University of Oregon, personal communication, 1994). Other scientists have called this type of rock "flow-foot breccias" (Jones and Nelson, 1970), "hyaloclastites" (Cas and Wright, 1987; Rittmann, 1962) "broken-pillow breccias" (Williams and McBirney, 1979), and "aquagene tuffs" (Carlisle, 1963).

The rind of the pillows is basaltic glass that formed by sudden quenching of the globs of lava. Most of these rinds have been altered to palagonite. The interior of the pillows, insulated by the chilled rinds, slowly solidified to felty-textured, finely crystalline basalt as the pillows settled amid the other fragmental material.

Mud, sand, and gravel also were incorporated into the breccia as the lava mixed with boiling, water-saturated sea-floor sediments.

Molten lava, glass, and palagonite cemented the solidified lava fragments, glass shards, pillows, and sediments together.

These palagonitic pillow breccias form a fringe around the seaward edge of the lava flows. They also lie below the dense,

Figure 6. Palagonitic pillow breccia along the shoreline is being eroded away, leaving resistant cobbles.

crystalline basalts that comprise much of Yaquina Head because they were laid down when the flows first encountered the sea, perhaps near where the headland begins. As the breccia filled the shore area, subsequent lava flowed over it as if on dry land, until the flows again reached seawater. This layered formation is known as a lava delta (Jones and Nelson, 1970).

Aa and pahoehoe

In addition to the palagonitic pillow breccia, there is some flow breccia (aa) formed by air cooling. As the surface of the moving flow cooled and solidified, the cooled skin of solid basalt continuously broke into fragments that tumbled along to intermix with the now-viscous lava beneath. The flow breccia may be identified because it has a relatively low glass and palagonite content and lacks pillows. Smooth, ropy, fluid pahoehoe also flowed over Yaquina Head. However, most of the sinuous surface features of this flow type have been eroded and are difficult to see.

Dikes, lobes, tongues, and sills

As the basalt flowed into the sea, it ponded in the bays and estuaries, and these ponds became so heavy that lava was forced downward into the underlying, water-saturated sediments. Layers of sediment were either gently lifted to the top of the lava or were fragmented and forced aside or intermixed with the basalt. The flows also created smooth, tabular dikes and sills as well as irregular dikes, lobes, and tongues of solid, unfragmented lava, mixtures of basalt and sedimentary material, or breccia within the sediments (Beeson and others, 1979). Similar bodies of dense basalt also intruded the basaltic debris (breccia) before it solidified.

Lava, sand, and mud

The basalt overlies sedimentary sandstone and siltstone of the lower Miocene Astoria Formation that form the buff-colored sea cliffs north and south of the headland. A contact between the Ginkgo basalt and the Astoria Formation is clearly exposed in the cliffs at the ends of the beaches on both sides of Yaquina Head. The Astoria Formation is famous for its fossil sharks' teeth and bones of turtles, whales, seals, and sea lions, as well as crabs, mollusks, corals, barnacles, and brachiopods (Orr and others, 1992). Accumulation of the Astoria Formation marine sands stopped when the land was uplifted, the sea retreated, and the basalt flows invaded the area (Snavely and others, 1973). Below the Astoria Formation lies the early lower Miocene Nye Mudstone (Snavely and others, 1964; Lund, 1974). These olive-gray mudstones and siltstones were deposited when the land was submerged, and mud and silt, rich in organic material, were deposited in the deep water. Modern eolian (wind-deposited) dune sands now cover parts of the basalt, sandstone, mudstone, and marine terraces (Figure 7).

Tectonics

Although the sedimentary rocks and breccia were deposited in water in nearly horizontal strata, most of them are now inclined 10° to 20° in a westward direction (Snavely and MacLeod, 1971) (Figure 4). The strata are folded and faulted (Snavely and others, 1980). A major episode of regional uplift occurred 14 million years ago, when the Juan de Fuca Plate pushed under the North America Plate, forcing the rocks of the continent to fold and fault. Immediately north and south of Yaquina Head, this inclination is clearly exposed in the tilted sandstones of the Astoria Formation. An exposure of similarly inclined layers of breccia may be seen at the north side of the entrance to the lower quarry.

Ice ages, continental uplift, and terraces of sand

The surf has cut platforms or terraces at different elevations as the level of the shoreline changed over the years. These changes resulted from continental uplift and changes in sea level that occurred during the Pleistocene ice ages between 8,000 and 3 million years ago. As the water level rose to cover the platforms, sediment was deposited. As the sea level again dropped or the coastline was uplifted, the terrace deposits were left behind. Sediments now rest on an ascending flight of platforms ranging in elevation from 40 to 500 ft above present sea level. These Pleistocene terrace deposits, mainly sand and pebble beds that include some organic materials, are well exposed on the basaltic sea cliffs between Yaquina Head and Otter Crest, a small cape 7 mi to the north.

Figure 7. Eolian sands cover much of the basalt of the upper quarry wall.

Figure 8. A fault divides the columnar basalt wall of the lower quarry from the uplifted beds on the lower quarry's north wall.

Faults

Between the western (seaward) uplifted beds and the eastern columnar basalt wall in the lower quarry is a soil-covered fault trace (Figure 8). The fault may also be traced through the central back wall of the upper quarry, where it divides the breccia on the western wall from the columnar basalt on the eastern wall. The seaward side of the fault is upthrown, and the inland side of the fault is downthrown. This fault strikes roughly north-south and is one of a series of regional north-trending, high-angle, eastward-dipping, normal en-echelon faults that resemble a flight of steps. These en-echelon faults parallel the coastline for at least 15 mi north of Newport. This zone of normal faulting is astride the "hinge line" between areas of post-late Miocene subsidence in the deep marginal basin and uplift in the Coast Range (Snavely and others, 1980).

Another normal fault that appears to displace the columnar basalt by approximately 20 ft may be seen in the lower quarry wall (Figure 9).

Figure 9. A small normal fault in the lower quarry wall appears to displace the columnar basalt about 20 ft.

Stacks, reefs, arches, and rock knobs

Yaquina Head was considerably larger in the past and has suffered intense erosion by the surf. Differential weathering, due to either rock cohesion or fracture patterns, has resulted in the present irregular outline of Yaquina Head. As erosion progressed, the resistant rocks were separated from the mainland and are now the stacks, reefs, and rock knobs seen offshore; an erosional arch is carved into the northern side of the headland.

The softer sedimentary rocks and breccia have been eroded to expose many of the dense, resistant basalt dikes and sills. The dikes are aligned perpendicularly with the coastline and may be recognized as the ridgelike rocks that jut out into the sea (Figure 10).

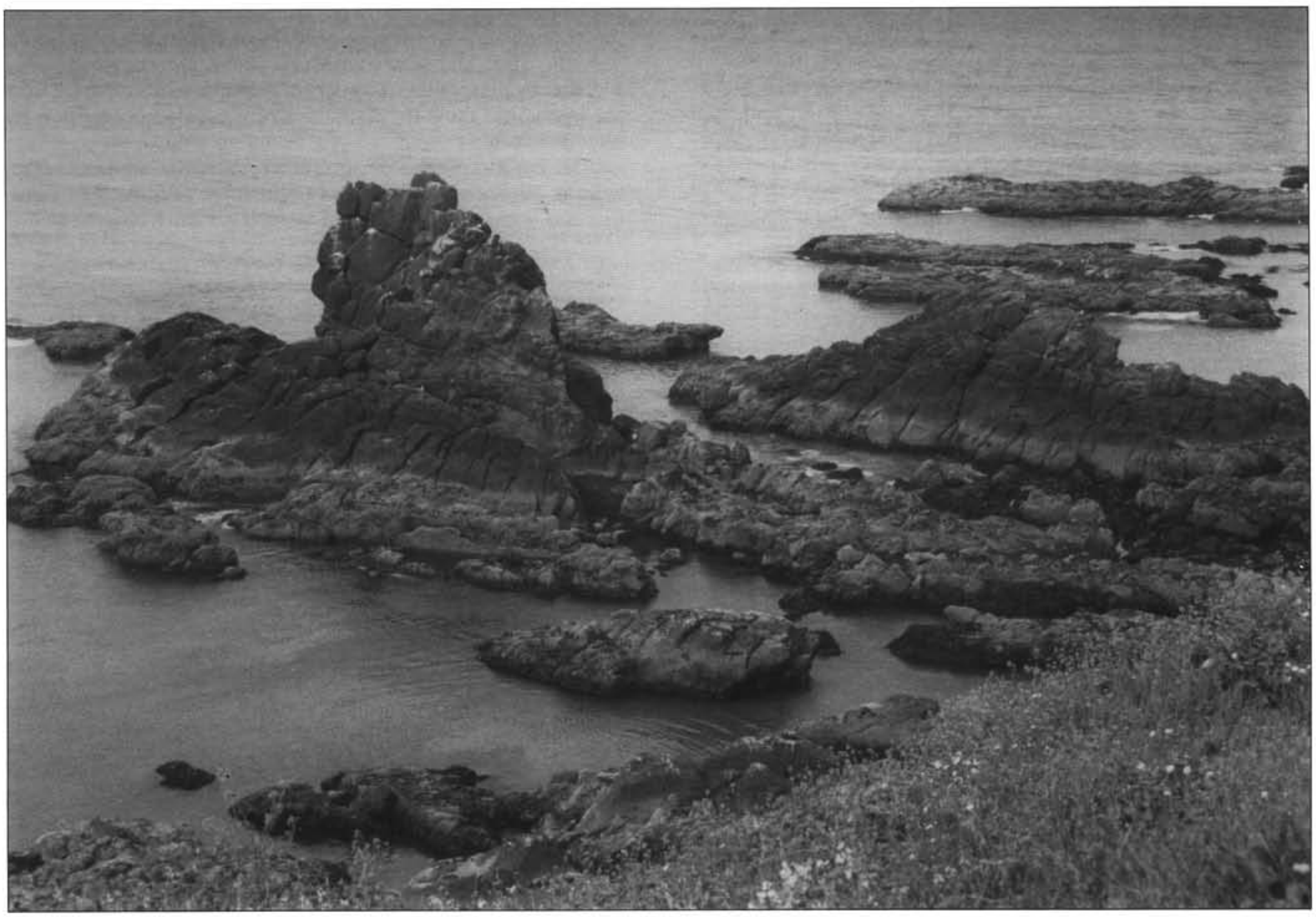


Figure 10. The ridgelike rocks that jut into the sea are resistant dikes of solid basalt. Photo courtesy U.S. Bureau of Land Management.

Spheroidal weathering phenomenon

As jointed basalt weathers, it sometimes spalls off in successive shells, like the skins of an onion, around a solid rock core. This spalling, or exfoliation, is caused by physical and chemical forces that produce differential stresses within the basalt. When spalling begins, the outermost shells are bounded by sets of nearly parallel joint planes present in the basalt. Water moves slowly along these intersecting joint sets, altering constituents such as feldspars and glass in the basalt to more voluminous secondary minerals. The innermost shells are more spherical as the rock becomes reduced in size and the corners more rounded (Skinner and Porter, 1989). This phenomenon may be seen at the top of the north cliff face of the upper quarry (Figure 11).

Figure 11. Biscuitlike erosional features are the product of spheroidal weathering of the basalt wall of the upper quarry.

Cobbles, pebbles, and sand

The beach at Yaquina Head Outstanding Natural Area is small and is often exposed to high-energy Pacific storm waves. As the abundant, less resistant, glassy breccia matrix was eroded, it disintegrated to sand and silt, and the dense, resistant crystalline-basalt fragments and pillows were released and concentrated by waves into beach cobbles and pebbles (Figure 12). The unique ellipsoidal to spherical shape of the cobbles is a result of the original blocky to pillow-shaped forms of the breccia fragments. Both fragmental types are surrounded by either palagonite or easily weathered glass. This offers the opportunity for water to channel around the blocks and pillows, further rounding them, in situ, through the spheroidal weathering process. The action of the surf further rounds and sorts these sturdy rocks. These cobbles, therefore, differ from the more common, flatter beach cobbles that are formed from erosion of more massive, homogeneous rock on many Oregon beaches. (The cobble beach is accessible on the south side of the promontory. The unusual roundness of the cobbles requires that visitors take special care to avoid falling when walking the beach at Yaquina Head Outstanding Natural Area. Note also that visitors are prohibited from taking samples so this unusual beach deposit may be preserved.)

Sand accumulates on the cobble beach during summer, but most of it is swept out to deeper water during winter storms. Some of the sand is pushed northward by longshore currents. In many places on the beach, the bedrock is swept clear, and in others the beach deposit is mostly cobbles and pebbles.

Secondary minerals

Much of the basalt shows evidence of chemical weathering. Palagonite, a pale-yellow to orange, fibrous to gel-like, hydrated mineraloid, is a weathering product of the highly susceptible volcanic glass and seawater. Much of the breccia is cemented together by palagonite, and many of the large rocks offshore from the lighthouse show the distinctive brown coloration of palagonite alteration.

The basalt contains several other alteration minerals. Iron-bearing minerals have oxidized to limonite, goethite, and hematite, and some of the aluminum-bearing minerals have altered to

Figure 12. Cobbles, pebbles, and sand are constantly shifted and sorted by wave action on the cobble beach.

Figure 13. Minute, delicate zeolite crystals line cracks and vesicles in the basalt.

small, delicate, gold, green, white, or colorless crystals of zeolites (Figure 13). Other alteration minerals include various clays and chlorite. Secondary calcite, recrystallized from primary calcite that was dissolved from the surrounding sedimentary rocks, forms white to colorless crystals on some of the basalt surfaces. Tiny crystals of all of these alteration minerals may be seen in vesicles in the basalt, and the zeolites and calcite may completely fill larger cavities.

CONCLUSION

The Yaquina Head Outstanding Natural Area offers a unique opportunity for the lay visitor to see the results of volcanic, sedimentary, geomorphic, and tectonic processes. The geologic history of Yaquina Head is a fascinating story that can be read in the exposed rocks. The story chronicles the fiery beginnings of the lava 300 mi to the northeast, the explosive confrontation of molten lava with the ocean, the processes of flowing and cooling lava, the movement of the earth's plates, and the continuing processes of weathering and erosion. The expected 600,000 visitors per year should come away from the area with an appreciation for the many geologic processes that have formed and continue to shape our world.

ACKNOWLEDGMENTS

I would like to thank U.S. Bureau of Mines geologists Cathy Summers and René LaBerge, photographer Steve Anderson, and University of Oregon volcanologist Dr. Alexander McBirney for their generous assistance in this endeavor. I am most grateful to Geologist Singh Ahuja, and Interpretative Specialist Jack Delaini, both of the U.S. Bureau of Land Management, Salem District, for giving us the opportunity to define this interesting geologic feature and for freely offering their transportation, support, and encouragement. Reviewers David Dahlin, Carl Almquist, and Carla Kertis of the Bureau of Mines provided many invaluable comments and suggestions.

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USGS offers new teacher's packets

The U.S. Geological Survey (USGS) has produced two teacher's packets that can help upper elementary and junior high school students understand and use maps and introduce them to the concept of global change.

The packet *What Do Maps Show?* contains a teaching poster, background information and four lesson plans for the teacher, and reproducible maps and activity sheets for student packets.

The poster shows one location, Salt Lake City, in several pictures and symbolic representations, including aerial photography; shaded-relief, topographic, and road maps; and a (three-dimensional) terrain model created from computerized data. It provides visual support for the major points of the lessons: that there are different types of maps; what information is needed to read maps (such as direction, latitude, longitude, scale, and map legend); and how two-dimensional maps can represent three-dimensional surfaces.

The packet *Global Change* contains a teaching poster, background information, and three lesson plans for grades 4–6, introducing this relatively new area of scientific study under the concepts of "time," "change," "cycles," and "Earth as home." The activities include learning how to read tree rings, how to understand concentration and measurement in parts per million, and how to consider "Earth as home" as an ecosystem in which changes in one part can cause changes to other parts. For each of the activities, illustrations on the poster provide large-scale visual support.

The packets are available through the Earth Science Information Centers (ESIC), including the Oregon Department of Geology and Mineral Industries Nature of Oregon Information Center (see back cover of this issue) and the USGS ESIC at W. 904 Riverside Avenue, Spokane, Washington 99201, phone (509) 353-2524. □

AGI offers services for educators

The American Geological Institute (AGI) announces that it has received a grant from ARCO to help support the ongoing program of the Earth-Science Education Clearinghouse. AGI established the clearinghouse in 1993 to provide an effective system for disseminating information about earth-science educational materials and activities.

With such industry support, AGI has just produced its first Clearinghouse product for the public, the *Earth-Science Education Resource Directory*. The first edition of this directory contains information on more than 125 organizations with more than 350 products that run programs, produce classroom resource materials, and supply related earth-science activities in the content areas of atmosphere, biosphere, hydrosphere, lithosphere, and space science. That information comes from the Clearinghouse database on earth-science organizations and educational resources. The database is one of the resources that Clearinghouse staff members use in responding to some 10,000 information requests annually.

A leader in earth-science education since the 1950s, AGI is heading a major effort in developing modern curriculum materials and associated teacher-enhancement programs. In this effort, AGI is working with its member societies and other earth-science organizations. Requests for information from the Earth-Science Education Clearinghouse or about the AGI education and human-resources programs should be addressed to Education and Human Resources Department, American Geological Institute, 4220 King St., Alexandria, VA 22302-1507, or by phone to (703) 379-2480. The Internet number is ncese@aip.org.

AGI also offers *Careers in the Geosciences*, a full-color flyer describing what geoscientists do and where they work, future job prospects, salary figures, and sources for more information. The flyer, suitable for students 12 and older, is available from the National Center for Earth-Science Education, and up to 10 copies are free from AGI (address above). For more than 10 copies, phone the AGI Publications Center at (703) 953-1744.

From AGI releases

GSA 1994 Annual Meeting to be held in Seattle

The Geological Society of America (GSA) will hold its Annual Meeting October 24–27, 1994, in Seattle, Washington. More than a dozen associated societies will also participate in the meeting.

For papers to be presented, abstracts are due July 6. Copies of the required current abstract forms are available from most university geology departments and GSA Campus Representatives, offices of the U.S. Geological Survey and many corporations, symposium conveners, GSA section officers, or the GSA Abstracts Coordinator. The address of the GSA Abstracts Coordinator is, for U.S. Mail, P.O. Box 9140, Boulder, CO 80301-9140 or, for Express Service, 3300 Penrose Place, Boulder, CO 80301.

For further information, contact the GSA Meetings Department, P.O. Box 9140, Boulder, CO 80301, phone (303) 447-2020 or (800) 472-1988. □

Cordillera meeting set for April 1995

An invitation and call for papers has been sent out by the Geological Society of Nevada for the symposium "Geology and Ore Deposits of the American Cordillera," to be held April 10–13, 1995, at John Ascuaga's Nugget in Reno/Sparks, Nevada. The symposium is cosponsored by the Geological Society of Nevada and the U.S. Geological Survey.

The symposium will focus on the metallogeny of the American Cordillera from the Precambrian to the present and the role that depositional, tectonic, and magmatic events have played in the formation of ore deposits of the region. Sessions are being planned to cover a broad range of geologic environments and deposit types and will include oral and poster sessions, workshops, core displays, and field trips.

Papers may be submitted concerning all aspects of ore deposits of the Cordillera and related geological topics. Abstracts are requested by April 1, 1994; deadline for accepted papers will be October 1, 1994.

For further information, contact the Geological Society of Nevada at P.O. Box 12021, Reno, Nevada 89510, phone (702) 323-3500. □

SEPM renames journal

After renaming its organization some time ago, the Society for Sedimentary Geology (still carrying the acronym SEPM—for the original name "Society of Exploration Paleontologists and Mineralogists") has renamed its journal: The *Journal of Sedimentary Petrology* is now the *Journal of Sedimentary Research*. The new journal will have eight issues published in two sections: Section A, "Sedimentary Petrology and Processes," focuses on sedimentology, petrology, geochemistry, and processes; Section B, "Stratigraphy and Global Studies," focuses on broader aspects of sedimentary geology, such as stratigraphy and sedimentary basins. For more information, call (800) 865-9765. □

Formosa Exploration begins closure of Silver Butte Mine

Formosa Exploration of Vancouver, British Columbia, Canada, has begun reclamation of its Silver Butte Mine and cleanup of damage to Middle Creek in Douglas County. The work is being monitored by the Oregon Department of Geology and Mineral Industries (DOGAMI) and the Oregon Department of Environmental Quality (DEQ). The Oregon Department of Fish and Wildlife is also involved with the cleanup.

During routine inspections of the site by the agencies, numerous permit violations were discovered. Included in the violations were illegal disposal of zinc concentrates, illegal disposal of sulfide-bearing waste rock, diesel fuel spills, overfilling of water-storage ponds with water and mill tailings, and uncontrolled discharges of sulfides into Middle Creek. After a review of the work needed to put the site into compliance with the state permits, Formosa decided to cease mining operation and reclaim the site. Reclamation of the mine site and remediation work in Middle Creek are now in progress.

The Silver Butte Mine is located southwest of Riddle in Douglas County. After extensive exploration and permitting activities, the site was permitted by DOGAMI and DEQ in 1990. Operations of the mine and mill were designed to recover copper and zinc from the ore to be mined at a rate of approximately 200 tons per day. Mining continued from 1990 until August 1993, when mining ceased and reclamation began.

The reclamation security prior to the violations was $500,000, the statutory maximum. That amount was raised to $980,000 after DOGAMI and DEQ discovered the violations and evaluated the amount of reclamation required under the permits. Bond reductions are anticipated as work is completed. Some of the bond money will be held for at least three years to guarantee that the reclamation work has been accomplished successfully. □

Letter to the editor

[Regarding report on reader survey in the November 1993 issue. By William E. Eaton, Eugene]

I am calling to object.

What I still like to call the "Ore Bin" is a great publication for Oregonians. I read the results about ads, widening to the PNW, etc.

You say many readers made helpful comments. I saw no reference to its [the magazine's] former colorful name, nor ever a decent explanation/need for a name change. Is it more "PC"? Is a down-to-earth name bad appearance?

Let's make this a "Letter to the Editor" and see what replies you receive.

Sincerely,
Bill
"The Old Camper"

In explanation: The Oregon Department of Geology and Mineral Industries began to inform the public in the beginning (1937–1939) through "Press Bulletins." Volumes 1 through 40 (1939–1978) of Oregon Geology *were published under the title* Ore Bin. —*ed.*

Oil and gas exploration and development in Oregon, 1993

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

ABSTRACT

Oil and gas leasing activity declined during 1993. Four U.S. Bureau of Land Management (BLM) lease sales were held, but no leases were purchased. There were no over-the-counter filings for BLM leases during the year. The total number of federal acres under lease at year's end was 5,491 acres. The State of Oregon conducted no lease auctions during the year. The total number of State of Oregon acres under lease at year's end was 25,520. Coos County leased 8,212 acres at a lease sale held during the year. Columbia County granted natural gas storage rights on 960 acres.

Thirteen exploratory wells and three redrills were drilled during the year. Two of the exploratory wells were operated by Carbon Energy in the Coos Basin and are suspended pending further evaluation. The remaining wells were drilled at the Mist Gas Field by Nahama and Weagant Energy; five of the wells were successful gas wells, and the others were plugged and abandoned.

Twenty-one wells were productive at Mist Gas Field during the year, and six suspended wells awaited pipeline connection at year's end. A total of 3.5 billion cubic feet (Bcf) of gas was produced during 1993 with a value of $7.1 million.

The Oregon Department of Geology and Mineral Industries (DOGAMI) completed a study of the Tyee Basin located in Douglas and Coos Counties. Several maps and reports have been published on the oil, gas, and coal resources of the area, and the final study summary and geologic map will be released in the near future.

DOGAMI and the Northwest Petroleum Association (NWPA) sponsored a series of meetings at which the U.S. Geological Survey (USGS) and Minerals Management Service (MMS) discussed the ongoing national assessment of undiscovered oil and gas reserves. A celebration was held at Mist Gas Field to recognize that over $100 million from natural gas production was reached during the summer of 1993.

LEASING ACTIVITY

Leasing activity declined during 1993, which is a continuation of a trend that began during the late 1980s. Activity included four public sales by the BLM, and no bids were received at these sales. BLM received no over-the-counter lease filing applications during the year. Federal acres that expired, were terminated, or had pending offers withdrawn during the year totaled 29,819 acres in Oregon. The total number of federal acres under lease in Oregon at the end of 1993 amounted to approximately 5,491 acres located primarily in Jefferson and Crook Counties. Total rental income for the year was about $6,000. At year's end, applications on 28,231 federal acres located in Jefferson County were pending.

The State of Oregon held no lease sales during the year. The total number of State of Oregon acres under lease at year's end was 25,520 acres, about the same as at the end of 1992. Total rental income was about $25,520.

Coos County held an oil and gas lease sale in March, at which leases covering 8,212 acres were acquired by Carbon Energy of Kent, WA. The leases are in the Coos Basin, Coos County. Total income was $8,212.

Columbia County granted natural gas storage rights to Nahama and Weagant Energy on 960 acres for the minimum required bonus of $20 per acre for a total of $19,200. Columbia County held no other lease sales during the year.

Drilling operation at the Nahama and Weagant well LF 43-32-65, which was drilled by Taylor Drilling Company Rig 7 and was completed as a gas producer during 1993 at the Mist Gas Field. The well produced gas at a rate of over 2 million cubic feet per day during its first month of production.

DRILLING

Thirteen exploratory gas wells and three redrills were drilled in Oregon during 1993. This is an increase from the five exploratory wells and two redrills drilled during 1992. All but two of the wells were drilled at the Mist Gas Field, Columbia County, where most of the state's oil and gas drilling activity has occurred since the field was discovered in 1979. The other two exploratory wells were drilled by Carbon Energy Company in the Coos Basin about 10 mi south of Coos Bay. These two wells were drilled for coal-bed methane, which may be generated and trapped in coal beds. Both wells, the Coos County Forest 7-1, located in SE¼ sec. 7, T. 26 S., R. 13 W., and drilled to a total depth of 3,993 ft; and the WNS-Menasha 32-1, located in SW¼ sec. 32, T. 26 S., R. 13 W., and drilled to a total depth of 1,594 ft, were suspended pending further evaluation.

At Mist Gas Field, Nahama and Weagant Energy Corporation of Bakersfield, California, in partnership with Oregon Natural

Table 1. *Oil and gas permits and drilling activity in Oregon, 1993*

Permit no.	Operator, well, API number	Location	Status, depth(ft) TD=total depth PTD=proposed TD
456-R	Nahama and Weagant Adams 31-34-75 RD 36-009-00282-01	NE¼ sec. 34 T. 7 N., R. 5 W. Columbia County	Abandoned, dry hole; TD 3,419.
472	Nahama and Weagant CC 41-33-75 36-009-00297	NE¼ sec. 33 T. 7 N., R. 5 W. Columbia County	Extended; PTD 2,850.
474	Nahama and Weagant LF 12A-33-75 36-009-00299	NW¼ sec. 33 T. 7 N., R. 5 W. Columbia County	Completed, gas; TD 2,475.
476	Nahama and Weagant LF 12B-35-75 36-009-00301	NW¼ sec. 35 T. 7 N., R. 5 W. Columbia County	Completed, gas; TD 3,727.
477	Nahama and Weagant LF 43-32-65 36-009-00302	SE¼ sec. 32 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD 1,909.
478	Nahama and Weagant LF 31-36-65 36-009-00303	NE¼ sec. 36 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD 3,987.
479	Nahama and Weagant CC 42-32-74 36-009-00304	NE¼ sec. 32 T. 7 N., R. 5 W. Columbia County	Permit issued; PTD 1,700.
480	Nahama and Weagant CC 43-8-64 36-009-00305	SE¼ sec. 8 T. 6 N., R. 4 W. Columbia County	Permit issued; PTD 2,150.
481	Nahama and Weagant CC 22B-19-65 36-009-00306	NW¼ sec. 19 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD 2,940.
482	Nahama and Weagant CC 41-36-75 36-009-00307	NE¼ sec. 36 T. 7 N., R. 5 W. Columbia County	Abandoned, dry hole; TD 1,792.
483	Nahama and Weagant CFW 41-35-75 36-009-00308	NE¼ sec. 35 T. 7 N., R. 5 W. Columbia County	Abandoned, dry hole; TD 3,331.
484	Nahama and Weagant CC 42-34-65 36-009-00309	NE¼ sec. 34 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD 3,150.
485	Carbon Energy Intl. JCLC Menasha 28-1 36-011-00025	SW¼ sec. 28 T. 26 S., R. 13 W. Coos County	Application; PTD 1,650.
486	Carbon Energy Intl. WNS Menasha 32-1 36-011-00026	SW¼ sec. 32 T. 26 S., R. 13 W. Coos County	Suspended; TD 1,594.
487	Carbon Energy Intl. Coos County Forest 7-1 36-011-00027	SE¼ sec. 7 T. 27 S., R. 13 W. Coos County	Suspended; TD 3,993.
488	Nahama and Weagant Adams 14-31-74 36-009-00310	SE¼ sec. 31 T. 7 N., R. 4 W. Columbia County	Permit issued; PTD 2,700.
489	Nahama and Weagant HNR 42-27-64 36-009-00311	NE¼ sec. 27 T. 6 N., R. 4 W. Columbia County	Permit issued; PTD 2,500.
490	Nahama and Weagant HNR 24-22-64 36-009-00312	SW¼ sec. 22 T. 6 N., R. 4 W. Columbia County	Abandoned, dry hole; TD 2,553.
491	Nahama and Weagant HNR 31-21-64 36-009-00313	NE¼ sec. 21 T. 6 N., R. 4 W. Columbia County	Permit issued; PTD 2,100.
492	Nahama and Weagant CFW 23-33-74 36-009-00314	NW¼ sec. 33 T. 7 N., R. 4 W. Columbia County	Permit issued; PTD 1,700.
493	Nahama and Weagant CC 24-19-65 and RD 36-009-00315/-315-01	SW¼ sec. 19 T. 6 N., R. 5 W. Columbia County	Abandoned, dry hole; TD 3,044, RD 2,882.
494	Nahama and Weagant Hemeon 13-14-65 36-009-00316	SW¼ sec. 14 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD 2,800.
495	Nahama and Weagant Johnston 11-30-65 and RD 36-009-00317/-317-01	NW¼ sec. 30 T. 6 N., R. 5 W. Columbia County	Abandoned, dry hole; TD 2,794, RD 2,811.
496	Nahama and Weagant Libel 32-15-65 36-009-00318	NE¼ sec. 15 T. 6 N., R. 5 W. Columbia County	Abandoned, dry hole; TD 2,835.
497	Nahama and Weagant LF 21-32-75 36-009-00319	NW¼ sec. 32 T. 7 N., R. 5 W. Columbia County	Permit issued; PTD 2,500.
498	Carbon Energy Intl. Menasha Timber 16-1 36-011-00028	SW¼ sec. 16 T. 26 S., R. 13 W. Coos County	Application; PTD 2,650.
499	Carbon Energy Intl. Davis Cr. Menasha 32-2 36-011-00029	SE¼ sec. 32 T. 26 S., R. 13 W. Coos County	Application; PTD 1,800.

Table 2. *Canceled permits, 1993*

Permit no.	Operator, well, API number	Location	Date issued, canceled	Reason
455	Nahama and Weagant CC 14-32-75 36-009-00281	SW¼ sec. 32 T. 7 N., R. 5 W. Columbia County	5-28-91, 5-29-93	Canceled; expired.
473	Nahama and Weagant CC 22B-35-75 36-009-00298	NW¼ sec. 35 T. 7 N., R. 5 W. Columbia County	12-21-92, 12-21-93	Canceled; expired.
475	Nahama and Weagant Adams 12-31-74 36-009-00300	NW¼ sec. 31 T. 7 N., R. 56 W. Columbia County	12-21-92, 12-21-93	Canceled; expired.

Gas Development of Portland, Oregon, operated all the wells during the year. This included eleven wells and three redrills. Of these, five were successful gas wells: CC 22B-19-65, located in NW¼ sec. 19, T. 6 N., R. 5 W., and drilled to a total depth of 2,940 ft; LF 12A-33-75, located in NW¼ sec. 33, T. 7 N., R. 5 W., and drilled to a total depth of 2,475 ft; LF 12B-35-75, located in NW¼ sec. 35, T. 7 N., R. 5 W., and drilled to a total depth of 3,727 ft; LF 31-36-65, located in NE¼ sec. 36, T. 6 N., R. 5 W., and drilled to a total depth of 3,987 ft; LF 43-32-65, located in SE¼ sec. 32, T. 6 N., R. 5 W., and drilled to a total depth of 1,909 ft. Six wells and three redrills were dry holes and were plugged and abandoned: CFW 41-35-75, located in NE¼ sec. 35, T. 7 N., R. 5 W., drilled to a total depth of 3,331 ft; CC 24-19-65 and RD, located in SW¼ sec. 19, T. 6 N., R. 5 W., drilled to a total depth of 3,044 ft and redrilled to a total depth of 2,882 ft; CC 41-36-75, located in NE¼ sec. 36, T. 7 N., R. 5 W., drilled to a total depth of 1,792 ft; HNR 24-22-64, located in SW¼ sec. 22, T. 6 N., R. 4 W., and drilled to a total depth of 2,553 ft; Johnston 11-30-65 and RD, located in NW¼ sec. 30, T. 6 N., R. 5 W., drilled to a total depth of 2,794 ft and redrilled to a total depth of 2,811 ft;

Wellhead at the LF 31-36-65 well, which was operated by Nahama and Weagant and completed as a gas producer during 1993 at the Mist Gas Field.

Libel 32-15-65, located in NE¼ sec. 15, T. 6 W., R. 5 W., drilled to a total depth of 2,835 ft; and Adams 31-34-75 RD, a redrill of a previously suspended well located in NE¼ sec. 34, T. 7 N., R. 5 W., which reached a total depth of 3,419 ft.

Total drilling footage for the year was 44,565 ft, which is a significant increase from the 18,102 ft drilled during 1992. Average depth per well was 2,785 ft, which is a greater depth than the 2,586 ft per well drilled during 1992.

During 1993, DOGAMI issued 21 permits to drill (Table 1), while three permits were canceled (Table 2).

DISCOVERIES AND GAS PRODUCTION

Mist Gas Field in Columbia County saw five new successful gas wells, an increase from the two gas wells drilled in 1992. Nahama and Weagant Energy is the operator of the new producers that include CC 22B-19-65, the westernmost producer in the field; LF 12A-33-75, the northernmost producer in the field; and the LF 12B-35-75, LF 31-36-75 and LF 43-32-65 wells, all of which are more centrally located in the field. Nahama and Weagant operated 21 gas wells during 1993. At the end of the year, the field contained 18 gas producers; in addition, six wells were awaiting pipeline connection.

Gas production for the year totaled 3.5 Bcf, an increase from the 2.5 Bcf produced during 1992. The cumulative field production as of the end of 1993 was 49.8 Bcf. The total value of the gas produced for the year was about $7.1 million, a significant increase from the $3.4 million during 1992. Gas prices ranged from about 16¢ to 25¢ per therm, which is an increase from the 13¢ to 16¢ per therm last year. Cumulatively, the total value of gas produced since the Mist Gas Field was discovered in 1979 is about $104 million.

GAS STORAGE

The Mist Natural Gas Storage Project remained fully operational during 1993. The gas storage project has nine injection-withdrawal service wells, five in the Bruer Pool and four in the Flora Pool, and thirteen observation-monitor wells. The pools have a combined storage capacity of 10 Bcf of gas. This allows for the cycling of about 6 Bcf of gas in the reservoirs at pressures between approximately 400 and 1,000 psi and will provide for an annual delivery of 1 million therms per day for 100 days. During 1993, about 6,264,736,000 cubic feet of gas was injected, and 6,302,467,000 cubic feet was withdrawn at the Mist gas storage project.

OTHER ACTIVITIES

DOGAMI completed a five-year study of the oil and gas potential of the Tyee Basin during 1993. The Tyee Basin is located in Douglas and Coos Counties in the southern Coast Range. The study, which was funded by landowners in the study area and by county, state, and federal agencies, is an investigation of source rock, stratigraphy, and structural framework for those characteristics that are needed to generate and trap oil and gas. As results of this investigation, DOGAMI has published a number of maps and reports that present a revised understanding of the geologic framework of the Tyee Basin (see references below). A final oil and gas study summary and revised geologic map of the Tyee Basin will be published in the near future.

DOGAMI and the Northwest Petroleum Association (NWPA) sponsored a series of meetings at which the U.S. Geological Survey and Minerals Management Service discussed the ongoing national assessment of undiscovered oil and gas reserves. The assessment is using a methodology in which oil and gas plays are

This former drill site, where ARCO Oil and Gas Company had drilled the Hamlin 33-17-65 well and abandoned the operation during 1990, was reclaimed for use as a cattle stockyard.

evaluated for their future potential reserves. A draft report is expected to be released during 1994. Individuals who are interested in oil and gas resources in the Pacific Northwest should contact DOGAMI for details.

The NWPA remained active during the year. At its regular monthly meetings, speakers gave talks related to energy matters in the Pacific Northwest. The 1993 symposium was held in Bend on "Earth Resources and the Pacific Northwest", and plans are now underway for the 1994 symposium. For information, contact the NWPA, P.O. Box 6679, Portland, OR 97228.

During the summer of 1993, the Mist Gas Field, which was discovered in 1979 and has 18 productive wells and an underground natural gas storage facility, reached $100 million in revenues from natural gas production. In recognition of this milestone, DOGAMI, Northwest Natural Gas, Oregon Natural Gas Development Corp., and Nahama and Weagant Energy held a celebration at the field. Mist Gas Field is a successful endeavor between private industry, government, and public organizations in which landowner rights and the environment are protected, while the natural gas generates tax and royalty revenues and provides other direct benefits for the residents of Columbia County.

Nahama and Weagant Energy and Oregon Natural Gas Development began work on the installation of a nitrogen rejection unit at the Mist Gas Field during 1993. The unit will remove nitrogen from the methane gas produced at the field, and the process will result in increased production from those wells that have high nitrogen levels.

Pacific Gas Transmission Company will soon complete construction of a 42-in. natural gas pipeline that stretches over 805 mi from Canada to California, crossing Oregon approximately parallel to State Highway 97, through Biggs, Bend, and Klamath Falls. The $1.7-billion project will increase supply capacity by approximately 900 million cubic feet per day, about 16 percent of it for the Oregon market. Statistics show that, during the last ten years, Oregon's consumption of natural gas has more than doubled. Much of the pipeline crosses lands managed by the U.S. Bureau of Land Management (BLM), so the BLM Prineville District has taken the lead in ensuring minimal environmental impact and proper restoration of the land disturbed by the pipeline and its construction.

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Tri-State Agreement on Mining begins implementation

by David K. Norman, Washington Division of Geology and Earth Resources, P.O. Box 47007, Olympia, Washington 98504-7007, and Allen H. Throop, Oregon Department of Geology and Mineral Industries, Mined Land Reclamation Program, 1536 Queen Avenue SE, Albany, Oregon 97321

This article was originally written by David K. Norman and appeared in *Washington Geology*, volume 21, number 3 (November 1993), page 19-21. It has been modified by Allen H. Throop and is reprinted here with permission. *—ed.*

INTRODUCTION

Officials of Idaho, Oregon, and Washington signed an agreement in 1993 to share technical information about mine regulation and training opportunities, the Tri-State Agreement on Mining. In a cooperative effort to learn from each other and avoid reinventing the wheel, the three states have obtained $225,000 from the U.S. Environmental Protection Agency to encourage the sharing of information, resources, and experience. Ultimately this agreement will lead to wiser resource development and protection.

Mine regulators in the three states now face more complex issues than in the past, and in order to be effective, they must keep abreast of the latest technology. Each state has a small staff working with mine permitting. By working together, the states are learning from each other. This article summarizes some of the completed and anticipated projects under the grant.

A team of regulators, represented mainly by Allen Throop (Oregon), Bruce Schuld (Idaho), and David K. Norman (Washington), visited several mines and proposed mine sites in Washington, British Columbia, Oregon, and Idaho. The emphasis of the team's investigation was on water quality, chemical processing and control, and reclamation techniques. A summary of some of the site visits is presented below.

Figure 1. Road reclamation in progress at the Cannon Mine, Washington. These slopes have been reshaped to match the local natural slopes. Seeding is done at first planting season after reshaping to minimize erosion.

Cannon Mine, Washington, Asamera Minerals, Inc.

During their visits in Washington, the team members observed the underground operations, tailings impoundments, and surface reclamation at the Cannon gold mine in Wenatchee. The mine, operated by Asamera Minerals, Inc., uses a flotation method to concentrate gold. Concentrated ore is shipped to Japan for smelting. Asamera is nearing completion of mining and has finished earth work on some of the upper roads, drainages, and pits (Figure 1).

Stopes are backfilled with concrete made with locally mined sand and gravel, and ore is then removed from the adjacent stope. This method allows for more recovery of ore and eliminates subsidence.

Since they are too finely ground to be used as backfill, the tailings must be handled in an impoundment that was constructed across a valley immediately upstream from the mine and mill. Natural clays with a very low permeability act as a liner beneath the impoundment; no synthetic liner was used. Four wells in the valley below the impoundment were installed to detect any leakage. An additional well used to determine the background quality of water entering the tailings impoundment is upstream of the facility. The elevation of the well bottom is higher than the final maximum elevation of tailings.

Crown Jewel Project, Washington, Battle Mountain Gold

Battle Mountain Gold (BMG) proposes to develop an open-pit gold mine on Buckhorn Mountain near Chesaw in north-central Washington to recover gold from a skarn deposit. BMG plans to treat the ore with a vat cyanide leach process that uses a carbon recovery system and a sulfur dioxide (SO_2) cyanide destruction process patented by International Nickel Company. The proposal also calls for a tailings impoundment lined with clays compacted to very low permeability (10^{-6} cm/s or less) below synthetic geomembrane liners. Nine ground-water monitoring wells and 17 surface-water monitoring sites and water from four existing adits are being used to gather baseline data for the environmental impact statement that is being prepared.

Nickel Plate Mine, British Columbia, Homestake Mining Co.

The tri-state group visited the Nickel Plate Mine in southern British Columbia because it is geologically similar to the proposed Crown Jewel Project. The ore processing techniques are similar to those proposed for the Crown Jewel, as is the INCO SO_2 cyanide destruction method. However, due to the nature of the ore deposit at Nickel Plate, several open pits have been mined rather than one large pit as proposed for Crown Jewel. Homestake backfills mined-out pits with waste rock, leaving only the last pit as a series of benches and highwalls.

Final waste-rock dump slopes at the Nickel Plate Mine are generally 3 ft horizontal for each 1 ft vertical (3:1), with a maximum height of 80 ft between terraces or breaks in slope on the dumps (Figure 2). Topsoil is placed on the 3:1 slopes to support revegetation. Clays and silts are salvaged from nearby glacial till to supplement the thin soils. Crested wheat, rye, and clovers are the first ground-cover plantings used to stabilize the soils on dump slopes. Native plant species will be emphasized as revegetation proceeds.

The tailings impoundment is unlined. Leakage through the underlying glacial till has been a problem. Homestake installed collection piping and trenches about 3 ft below the level of the adjacent Canty Creek and between the creek and the tailings impoundment. The system appears to be effectively retrieving the low levels of escaped cyanide, which is then pumped back to the tailings impoundment.

NERCO DeLamar had also begun a program to improve water quality from the so-called "16 level adit," from which acidic water with high metal content has been draining for many years. The low pH and metals were degrading the water quality of Jordan Creek. As a short-term solution, discharge from the adit is now being pumped to the tailings pond, and the effect of the pumping on the water quality in the tailings impoundment is being studied. Possible long-term solutions include blocking the adit and flooding the old workings. This would prevent oxygen from reaching the system, which in turn would stop acid generation. Another approach would be to eliminate water from the underground workings.

To reduce handling costs and to improve reclamation, waste rock is being used to backfill some mined-out areas. Other reclamation completed at the site includes converting a clay borrow pit and numerous storm-water control ponds to wetlands.

Figure 2. Waste dumps at Homestake's Nickel Plate Mine in British Columbia is being reshaped to relatively flat (3:1) slopes, which are much more successful in revegetation efforts than steeper slopes.

Central Idaho

Because it is on patented claim land, the Coeur d'Alene Mining Co. Thunder Mountain gold mine, located at an elevation of about 8,000 ft, was excluded from the surrounding Frank Church River of No Return Wilderness Area. The site had been mined for gold in the mid-1980s (Figure 3). The company's earth-moving phase of reclamation, which was completed by 1991, was imaginative, and appropriately it received awards for innovative work. Coeur d'Alene reshaped most of the open pits, the cyanide heap leach processing area, and the waste dumps. Revegetation is slowly becoming established. Lodgepole pines are doing well despite two years of drought. Common yarrow is doing extremely well in one area in spite of heavy grazing by elk. Nonnative grasses are doing fairly well, although the disturbed areas are not yet fully covered. Ultimately, the area will return to a lodgepole pine forest.

DeLamar Mine, Idaho, Kinross Gold, Inc.

Representatives from all three states also visited the Kinross Gold, Inc., DeLamar gold and silver mine in southwest Idaho. This mine, which consists of several pits, uses an agitated cyanide leach process to recover gold and silver. The high cyanide content in the tailings impoundment represented hazards to waterfowl. In response to this, the former operator, NERCO DeLamar, constructed the first AVR (Acidification-Volatilization-Reneutralization) system in the U.S. at the DeLamar Mine. The plant is recovering 183 lb/hr of cyanide or over 90 percent of the cyanide in the tailings solutions, which is reused rather than destroyed.

Elsewhere on the site, acidic water draining from waste rock into Sullivan Gulch (a quarter of a mile southeast of the DeLamar Mine) is now being pumped to the tailings impoundment as a short-term measure to control acid-rock drainage problems. Proposed long-term solutions include capping the waste to prevent infiltration of water or processing the waste rock through the mill.

Figure 3. Sunnyside pit at Coeur d'Alene Thunder Mountain Mine at the end of the mining operation, before reclamation began. Completed reclamation is shown in Figure 4.

This site shows the contrast between the angle-of-repose waste dumps (with slopes approximately 1.5:1) and dumps whose slopes are at 3:1 or flatter. No vegetation was growing on the steep waste-rock dump slopes, which were failing, while gentler slopes were sustaining vegetation and appeared stable. An unsuccessful attempt was made to cover the steep dump with coarse rock to make it similar to a talus slope.

Detoxified spent ore was removed from the cyanide heap leach pad and used to backfill pits and reshape them to approximate the surrounding topography (Figure 4). Upon completion of the mining, all buildings were removed, and the processing area as well as most of the pits and dumps were covered with growth media. Some coarse rock and logs were spread for habitat diversity and microclimate enhancement.

Around the processing area, 13 monitoring wells were drilled, three updrainage and ten downdrainage. Numerous surface-water monitoring sites were established. No cyanide has been detected in the ground water. Only one apparently anomalous surface-water sample indicated that cyanide was present, but retesting failed to locate any cyanide in the surface or ground water.

Figure 4. Reclaimed Sunnyside pit at Coeur d'Alene Thunder Mountain Mine. Pit walls have been worked into sinuous contours and rolling topography. Newly planted vegetation has endured two years of drought. Lodgepole pines, which were severely stressed, show excellent recovery and growth after heavy winter snows and a wet summer. Grasses, although still sparse, continue to spread and provide seeds.

Successes at this site include the ponds created by shaping the topography to trap snow drifts and the notable lack of highwalls in reclaimed open pits. Elk and deer are already grazing on this site.

Not far from Thunder Mountain are two other gold mines: the MinVen Stibnite Mine and the Hecla Mining Co. Yellow Pine Mine. Hecla has completed mining and begun reclamation, sloping the waste rock dumps to about 3:1 to 4:1. Vegetation was doing well, and slopes appeared to be stable. The open pit has been mostly recontoured and revegetated. Because the neighboring MinVen mine is still operating, Hecla can do no further reclamation. The cyanide heap leach pad and ponds remain to be reclaimed.

Hecla is applying state-of-the-art bioneutralization techniques to destroy cyanide and nitrate in the heap leach pad. This process involves the cultivation and introduction of microorganisms that thrive on free cyanide and on most of the cyanide compounds found in the heap leach chemical environment and that break down the cyanide.

Coeur d'Alene, Hecla, and NERCO all won awards for their outstanding reclamation efforts at the mines just described, for efforts that went beyond the Idaho requirements. The awards were given last summer by the Idaho Mining Advisory Committee and presented by Idaho Governor Cecil Andrus at a luncheon held to honor the progressive mining companies.

Other interstate projects

The Washington Division of Geology and Earth Resources is preparing a bibliography of information about reclamation of metal mines. A rough draft has been sent to interested parties for review.

Oregon, Washington, and Idaho agency personnel reviewed the Newmont Mining Co. baseline data collection plan for the company's Grassy Mountain, Oregon, proposal. The team also reviewed the Formosa Exploration, Inc., Silver Butte Mine, also in Oregon, and the cleanup efforts of the operation's impact on Middle Creek.

Oregon and Washington representatives, including representatives from the Fish and Wildlife Departments and private industry, visited gravel pits in southwestern Washington to exchange ideas about using such areas as off-stream resting areas for anadromous fish.

Other anticipated activities within the framework of the Tri-State Agreement on Mining include:

- Conferences to discuss common issues in acid rock drainage characterization;
- Avoidance and rapid, inexpensive methods of stream characterization;
- Assessment and evaluation of blasting techniques for reclamation;
- Compilation of best management practices manuals for Washington and Oregon, based on a similar document used in Idaho;
- Publishing articles summarizing state-of-the-art reclamation practices in hard rock mining. □

Mineral information available in new directory

The U.S. Bureau of Mines has published a new *Directory of Mineral-Related Organizations* that provides information on minerals, mineral issues, and technical assistance. The directory includes federal and state government agencies and national, regional, and state associations concerned with the mineral, metal, and material sectors of the economy.

Price of the new directory is $8. It is available under GPO Stock No. 024-004-02271-0 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, phone (202) 783-3238. A little closer for Oregonians may be the GPO Book Store in Portland, which also has the book available. The address is 1305 SW First Avenue, Portland, OR 97201-5801, phone (503) 221-6217. □

Summary of 1994 activities, Oregon Department of Geology and Mineral Industries

The mission of the Oregon Department of Geology and Mineral Industries (DOGAMI) is to serve as the cost-effective centralized source of geologic information in Oregon for the public and for government. Its mission is also to serve as a cost-effective steward of mineral production with attention paid to environment, reclamation, conservation, and other engineering and technical issues.

With regard to geologic information, emphasis is placed on geologic mapping, cost-effective earthquake mitigation, geologic hazards, and mineral resources. With regard to mineral stewardship, authorities are in place for the exploration, production, and reclamation of oil, gas, geothermal, aggregate, and nonaggregate mineral resource activities. The emphasis in DOGAMI activities is placed on prevention of hazards and waste, benefits of long-range planning, and the efficiency of using land and mineral knowledge in policy decision making in government and the private sector.

Acronyms are explained at the bottom of this page.

Focus	Activity/project	Contact persons	Description and partners
Geologic hazards (Delineation to facilitate cost-effective mitigation)	Earthquake hazard inventory	Ian Madin Matthew Mabey Mei Mei Wang (503) 731-4100	Provides ground-response maps and models for urban and coastal areas, seismic-velocity data from cooperative bore holes, leadership or technical assistance for earthquake scenarios, paleoseismology, active faults, workshops, earthquake response training and planning, and policy-centered mitigation. Partners and cooperators include USGS, METRO, PSU, ODOT, SSPAC, FEMA, OEM, and the Department of Higher Education.
	Coastal erosion	George Priest Dennis Olmstead (503) 731-4100	Continues analysis of coastal erosion and tsunami potential in a central-coast pilot project, using geologic analysis and historic shoreline data; evaluates results, integrates geologic considerations into a model, and cooperates in outreach efforts to develop mitigative strategies. Partners and cooperators include LCDC, OCZMA, OSU, and local government. Activity includes membership on Coastal Natural Hazard Policy Workshop Group and Technical Advisory Committee.
Regulation of extraction of geologic resources (Environmentally sound and safe exploration and production, followed by second beneficial land use)	Surface mined land reclamation	Gary Lynch Allen Throop Frank Schnitzer Peter Wampler (503) 967-2039	Provides for safe and environmentally sound surface mining, leading to beneficial second use, in cooperation with other agencies, including local government. Authority includes aggregate and metal mines, possible cyanide heap leach mines, and exploration. Cooperation with local government is provided in rules and State Agency Coordination Agreement. Partnerships with federal agencies are delineated in memoranda of understanding.
	Oil, gas, and geothermal resources	Dennis Olmstead Dan Wermiel (503) 731-4100	Provides for conservation of resource, protection of environment, safety, and second beneficial use of land plus equitable distribution of revenues where necessary. Authority includes exploration, drilling, production, and reclamation. Governing Board functions as Oil and Gas Commission. Partnerships with federal agencies are defined in memoranda of understanding.
Prioritized geologic mapping and data collection (Multidisciplinary geologic data for a broad variety of societal needs)	Northwest Oregon	George Priest (503) 731-4100	Guides in cooperation with Advisory Committee and prepares geologic mapping in northwestern Oregon with emphasis on quadrangles in the Portland area and East Vancouver sheet and on facilitating or attracting mapping efforts by cooperators in support of agency objectives.
	Southwest Oregon	Tom Wiley Frank Hladky Jerry Black (503) 476-2496	Conducts in cooperation with Advisory Committee mapping on a cooperative basis in the east-central Medford 1°x 2° sheet and the Roseburg 1°x 2° sheet. Partners and cooperators include UO and USGS.
	Eastern Oregon	Mark Ferns (503) 523-3133	Conducts in cooperation with Advisory Committee geologic quadrangle mapping of the Bend sheet and other areas for the purposes of enhancing local economy, facilitating cost-effective use of land resources, and delineating geologic hazards. Cooperators and partners include USGS, PSU, and the private sector. Current emphasis is on completion of 7½′ quadrangles leading to completion of 1:100,000-scale final map products.

Acronyms:

BLM	U.S. Bureau of Land Management	OCZMA	Oregon Coastal Zone Management Association
BPA	Bonneville Power Administration	ODOT	Oregon Department of Transportation
DSL	Division of State Lands	OEM	Oregon Emergency Management
FEMA	Federal Emergency Management Administration	OPAC	Ocean Policy Advisory Council
GIS	Geographic Information System	PSU	Portland State University
LCDC	Land Conservation and Development Commission	SWMG	Strategic Water Management Group
METRO	Metropolitan Service District	UO	University of Oregon
MILO	Mineral Information Layer for Oregon	USFS	USDA Forest Service
MLR	Mined Land Reclamation	USGS	U.S. Geological Survey

Summary of 1994 activities, Oregon Department of Geology and Mineral Industries (continued)

Focus	Activity/project	Contact persons	Description and partners
Public service and information (Getting the information out of government and to the public)	The Nature of Oregon Information Center	Don Haines (503) 731-4444	Serves as a multidisciplinary, multi-agency outlet for natural resource agency information. The center is located in the state office building in Portland. Emphasis is on distribution of information to the public in the Portland metropolitan area for the purposes of general public education, tourism enhancement, and public service. Cooperators include state natural-resource agencies, the Oregon Productivity Fund, and USGS.
	Oregon Geology, publications, library	Beverly Vogt Paul Staub Mark Neuhaus Klaus Neuendorf (503) 731-4100; Janet Durflinger Baker City Office (503) 523-3133; Kathleen Murphy Grants Pass Office (503) 476-2496	Serves to release a broad array of agency and cooperative geologic information to the broad public in a timely and cost-effective manner with publications, a subscription-based periodical, and a technical library coordinated with the State Library System.
Economic geology (Facilitating economic diversification, primarily in rural Oregon)	Mineral database for GIS, planning and policy guidance (MILO)	Frank Hladky (503) 476-2496	Provides a PC-oriented database of 8,500 mines, prospects, and occurrences based on all USGS, BLM, and MLR data and agency unpublished data bases and designed for dBase 3+ retrieval utilizing a variety of fields including location. Partners include USGS, BLM, and USFS. Applications include local planning, basin planning, and resource overviews. This database constitutes the state "mineral layer" for GIS applications.
	Industrial minerals and area inventories	Ron Geitgey Bob Whelan (503) 731-4100	Conducts statewide assessments and regional evaluations of industrial minerals for purposes of rural diversification. Current emphasis is on area studies for clients such as Warm Springs Indian Reservation, DSL, and other agencies with land holdings. The possible need for targeted aggregate studies is being monitored. Increasing emphasis is on minerals economics and cost-effective decision-making in the policy arena.
	Geologic energy	George Priest Jerry Black (503) 731-4100	Serves as source of geotechnical advice for geothermal energy and inventory resources in Cascades and southeastern Oregon. Continues natural-gas assessment of the southern Coast Range (Tyee Basin) with emphasis on resource targeting through reconnaissance mapping and transect development. Cooperators include BPA, landholders, DSL, Oregon Lottery, UO, USFS, and BLM.
Selected planning (Making sure geology, minerals, and hazards are realistically addressed by policy makers)	Water	Dan Wermiel (503) 731-4100	Links agency geologic mapping and data with state water-quality and water-quantity planning efforts through referrals, delivery of publications, and strategic technical advice, particularly to SWMG members.
	Facility siting	Dan Wermiel and selected hazards staff (503) 731-4100	Provides geotechnical site reviews for highest priority selected facilities such as power plants, dams, and essential or critical facilities with emphasis on geologic-hazard consideration.
	Local government	Dennis Olmstead Dan Wermiel (503) 731-4100; also, technical assistance by regional geologists at Baker City (503) 523-3133, Grants Pass (503) 476-2496, and Portland (503) 731-4100	Prioritizes and oversees agency planning involvement. Links planning efforts to necessary agency databases with emphasis on periodic review and plan amendments. Input is largely in areas of mineral potential and geologic hazards. Increasing emphasis is being placed on seismic information (ground response) and how it is to be utilized in relatively high risk areas in planning.
	Offshore coordination	Dennis Olmstead (503) 731-4100	Contributes to state offshore policy development through participation in OPAC and related policy and technical working groups. ☐

Tsunami — "Big wave in the harbor"

From an article by Klaus Jacob in Die Zeit, *overseas edition, no. 30 (July 30), 1993, p. 13, excerpted by Klaus K. Neuendorf. Additional information from Oregon Department of Geology and Mineral Industries.*

The most recent major tsunami event struck Japan not long ago. In late evening of July 12, 1993, a strong earthquake had just finished shaking the buildings on the small Japanese island of Okushiri, and many of them had collapsed. Seismologists later determined the earthquake magnitude to have been M_L 7.8 (Richter scale). As soon as the shaking subsided, fishermen ran to the harbor to look after their boats, the basis of their subsistence. It was only then that the real catastrophe hit them: A wave 8 m (26 ft) high crashed into the harbor and wiped out men and boats alike. A tsunami had been triggered by the earthquake and had rolled over Japan's coasts. A preliminary estimate counted at least 200 people killed by the combination of earthquake and wave.

The Japanese have always lived on a restless piece of the Earth's crust and are used to the hazards of volcanic eruptions, earthquakes—and tsunamis. However, these giant breakers, which can reach heights of up to 30 m (100 ft), threaten not only Japan but all countries that have sea coasts, even around the Mediterranean. Indeed, scientists suspect that it was a tsunami related to the explosion of the Santorini volcano that extinguished the Minoan civilization around 1500 B.C. And as recently as 1992, for example, towns in Nicaragua and Indonesia were devastated by 10- to 20-m (30- to 60-ft) tsunami waves.

We are not completely helpless against these forces of nature any more. As early as 1948, the first tsunami-alert service [the Pacific Tsunami Warning Center in Honolulu, Hawaii] began operations in the Pacific region, and others followed soon. When a strong earthquake is registered, the observers check to see whether their network's tidal gauges report any unusual water levels. If the sea level rises or falls more than normally, danger is imminent. Checking water levels is still an essential tool, because not every earthquake sets the sea in motion. A tsunami wave is generated only when the earthquake lifts the sea floor and pushes the water up as in a piston. If, on the other hand, two crustal blocks slide past each other in a horizontal motion, there is no danger. Thus, earthquakes along the infamous San Andreas fault in California leave the sea unruffled.

This fact was still unknown to pioneer seismologist T.A. Jagger more than half a century ago, when he—acting alone—warned the fishermen of Hawaii, after a strong earthquake in distant Kamchatka had set off a tsunami. In 1923, he was celebrated as a hero, because his alarm had saved lives and fishing vessels. After that early success, however, one false alarm followed another, when the seismometers in Jagger's observatory again and again registered strong motions.

In his day, Pioneer Jagger had to notify the fishermen himself whenever his indicators pointed toward high tides. Today, warning networks sound the alarm with all imaginable media involvement. Radio and television promptly go on the air with announcements. Thanks to modern electronics, everything clicks in a matter of just minutes: Data are delivered from the most remote seismograph and tidal gauging stations. Computers then calculate the epicenter and the magnitude of the earthquake. The path of the tsunami is determined, and the alert is passed on to the media.

During the tsunami of last July, everybody in Japan could watch on the screen at what time the tsunami would hit which coasts. Television programs displayed maps on which endangered coastal areas would be shown blinking red and yellow. Unfortunately, the warning came too late for the people on the island of Okushiri: They were too close to the epicenter of the tsunami-triggering earthquake, less than 100 km (60 mi) away. To cover that distance, the tsunami needed just a few minutes.

A tsunami can be as fast as a jet plane—and just as predictably on schedule. It is a curious phenomenon: Its speed depends entirely on the depth of the water. In a sea that is 4,000 m (13,000 ft) deep, it reaches a speed of 720 km (240 mi) per hour; if the sea floor drops to 6,000 m (20,000 ft), it speeds up to 870 km (260 mi) per hour. At the coast, it slows down abruptly. That is why it is easy for warning services to calculate the tsunami's path. In almost no time at all, a computer can deliver the time of arrival for all coastal areas if the sea-floor relief is stored in its memory and if it knows where the earthquake originated.

Another peculiarity of a tsunami is that it is hardly felt on the open sea. As wild as it may act on the coast, on the high seas it is rather tame. If one of its waves reaches a height of 2 m (7 ft) out on the ocean, it is already a big and dangerous tsunami. The wave does not approach as a big breaker: the sea level rises gradually, as if in slow motion, and falls again just as languidly. Ships' crews do not notice any of the spectacular action, because the crests of the waves are 100 km (60 mi) and more apart from each other. Such a wave resembles more the tidal heave caused by the moon rather than the choppiness caused by wind or storm.

Yet, in its inexorable advance, such an inconspicuous bulge of water, this sleeping giant, can cover thousands of miles and often crosses the entire Pacific Ocean. After the severe Alaska earthquake of 1964, a tsunami caused great damage as far away as California, at a distance of about 3,000 km (2,000 mi), where it arrived after 4 hours. One of the most devastating tsunamis arose in June of 1896, after an earthquake had shaken Japan. The tsunami ran toward the east, across the Pacific, overran Hawaii, crashed against the west coast of America, rebounded, and crossed the Pacific a second time, reaching coasts as far away as Australia and New Zealand. And it did all that in just one day.

It is only at the coast that a tsunami reveals its dramatic nature. Here, the wave rises to an impressive height and flings its entire force against the land. Few buildings can withstand the impact of such water masses. In April 1946, on an island in the Aleutians, even a lighthouse built of massive reinforced concrete and sitting 10 m (30 ft) above sea level collapsed. When the waters had dissipated, nothing was left of it but its foundation.

Bays are particularly endangered. Shores that converge at an acute angle focus the power of the entering water masses as a magnifying glass focuses light. The big breakers grow into massive, towering walls of water. All record flood levels have been measured in bays. That also means that a tsunami wreaks its worst havoc just where ports and cities are often located. That is why the Japanese have named the devastating flood "tsunami" — "big wave in the harbor."

In some bays, the giant waves may even reinforce each other. Hilo on Hawaii is known for this phenomenon: The first wave hits the coast, rebounds, and reinforces the second wave that arrives perhaps half an hour later. Each successive wave increases the water turbulence, so that often the maximum flood level is not reached until the third or fourth wave—at a time when in other places the all-clear signal has long been given.

In times past, a tsunami always hit people unawares. Thus it was, for example, on June 15, 1896, when a Japanese fishing village was celebrating a happy feast on the beach. The reveling company would not let its fun be spoiled by an earthquake that shook the ground slightly. The celebration continued even when, shortly after, the sea withdrew with soft, smacking noises much farther than at normal low tide. A wide stretch of beach went dry; fish were flopping on the moist sand. One hour later, the festivities came to a sudden end. The sea returned with a roar. A wave front seven stories high rushed in and buried the entire village.

Nowadays, modern technology turns the catastrophe of nature into a media spectacle. But early warnings often tempt curiosity seekers to drive to the coast in order to experience the show close up. In 1964, on the California beaches, the spectators were joined even by police sent to organize a quick evacuation. To look catastrophe in the eye is a gamble with death: over 100 people died on that occasion.

ADVICE TO OREGONIANS

The Oregon coast is vulnerable to tsunamis generated in two different ways: (1) by undersea earthquakes occurring thousands of miles away from Oregon, and (2) by undersea earthquakes occurring just offshore. Tsunamis generated by earthquakes occurring far away will take hours to reach the Oregon coast, leaving adequate time for official warning.

But tsunamis generated by earthquakes occurring just offshore may strike the coast within minutes of the earthquake, before official warning is possible. The only warning that may occur is the earthquake itself. Therefore, anyone living along the Oregon coast or visiting it should remember the following rules:

1. If you feel an earthquake when you are on the coast, protect yourself from the effects of the earthquake by dropping, covering, and holding on if you are indoors or by staying away from objects that may fall if you are outside—until the earthquake is over.

2. Then, even though you have been frightened or hurt by the earthquake, if you are in a low-lying area that could be affected by tsunamis, you must **immediately** move inland or to high ground. Tsunamis can travel upstream in coastal estuaries, with damaging waves extending farther inland than the immediate coast. Evacuate on foot if possible because of traffic jams and probable earthquake damage to roads and bridges. If you are unable to reach safe ground, the third floor or higher of a reinforced concrete building **may** offer protection, but such a building should be used only as a last resort. Do not wait for official warning, because the tsunami may strike before authorities have time to issue a warning or all power may be out, leaving warning systems nonfunctional.

3. Do not return to shore after the first wave. Additional waves may arrive up to several hours later, be higher, and go farther inland. People have died because they survived the first wave and thought it was safe to return to the shore. Wait until officials tell you the tsunami danger has passed.

4. If you are camping on or near the beach, you may have to immediately abandon your recreational vehicle or campsite to move inland or to high ground to save your life.

5. Never go to the beach to watch for a tsunami. Tsunamis move faster than a person can run. Also, incoming traffic hampers safe and timely evacuation of coastal areas.

6. If you see a sudden or unexpected rise or fall in coastal water, a tsunami may be approaching. Move inland or to high ground as quickly as possible.

7. Stay tuned to your radio, marine radio, NOAA weather radio, or television station during a tsunami emergency for instructions from authorities.

8. Make disaster plans with your family **before** a disaster occurs. Family members should be trained so they will know what to do on their own to protect themselves from an earthquake, where to go to survive a tsunami, and whom outside the disaster area to contact in case they are separated from each other by a disaster.

EDITOR'S NOTE

The Oregon Department of Geology and Mineral Industries, is preparing a brochure about tsunami hazards along the coast and what to do in case of an offshore earthquake and accompanying tsunami. The brochure will be available in April. For copies, contact any of the Department offices listed on the first inside page (page 26) of this issue.

Also: The current (March) issue of the *Smithsonian* has an interesting article on tsunamis on p.28-39. □

April is Earthquake Preparedness Month in Oregon

In the context of Earthquake Preparedness Month, between April 13 and 24, over 200 government jusrisdictions and agencies across Oregon will be participating in "QuakeEx94," a large-scale (subduction zone type) earthquake response simulation drill.

The Oregon Department of Geology and Mineral Industries has a number of geologic publications available that are related to earthquakes and earthquake hazard mitigation, as well as other literature that provides help in protecting against the dangers of earthquakes. Contact the Department's Nature of Oregon Information Center or the Baker City and Grants Pass field offices (addresses listed on page 26 of this issue. □

Map of radon zones now available

The Oregon Department of Geology and Mineral Industries (DOGAMI) and the State Health Division announce the availability of the Environmental Protection Agency's (EPA) publication entitled *Map of Radon Zones for Oregon*. The radon zone map, which identifies areas in Oregon that have the potential to produce elevated levels of radon, is included in the book.

The *Map of Radon Zones for Oregon*, which is designed to help national, state, and local governments and other organizations target radon activities and resources, was prepared by the EPA Office of Radiation and Indoor Air in conjunction with the U.S. Geological Survey and the Association of American State Geologists. It identifies, on a county-by-county basis, three zones having different radon potentials, ranging from low (less than 2 pCi/L) in zone 3, through moderate (between 2 and 4 pCi/L) in zone 2, to high (greater than 4 pCi/L) in zone 1. (The average concentration of radon in U.S. homes is between 1 and 2 pCi/L).

The radon potential study was nationwide in scope. Included in the publication is a map of radon zones for the whole United States. The publication discusses the national program and describes how radon develops, how it enters homes, and what methods were used to collect data for this study.

The publication then focuses on the Pacific Northwest and finally on Oregon, describing the geologic provinces of Oregon and discussing which areas have greatest potential for radon problems. Added as an appendix are two 1993 information circulars produced by the Oregon Health Division: (1) "The Radon Measurement Guide Including a Listing of Northwest Radon Measurement Companies Servicing Oregon," and (2) "Radon Levels and Radon Abatement Projects in Oregon Homes Listed by Zip Code and by County."

The EPA publication is a generalized assessment of Oregon's geologic radon potential, and the data cannot be applied to individual homes. Rather, it presents a generalized description of causes of radon contamination in homes and identifies areas of highest potential. As EPA officials state, "All homes should be tested, regardless of zone designation."

Copies of the EPA *Map of Radon Zones for Oregon* are available for purchase for $6 from the Nature of Oregon Information Center, Ste. 177, 800 NE Oregon #28, Portland, OR 97232, phone 503-731-4444; and from DOGAMI's field offices in Baker City (1831 First Street, Baker City, OR 97814, phone 503-523-3133) and Grants Pass (5375 Monument Drive, Grants Pass, OR 97526, phone 503-476-2496). □

THESIS ABSTRACTS

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

Active faults and earthquake ground motions in Oregon, by Silvio K. Pezzopane (Ph.D., University of Oregon, 1993), 208 pages.

Aerial photo interpretations and geologic field investigations in southern and central Oregon, combined with previous fault and seismicity studies nearby, indicate that late Pleistocene and Holocene fault activity is concentrated along four zones stretching northward into the Cascade volcanic arc and across the northwestern Basin and Range Province. Placed in a regional context, these active fault zones serve to separate Western Oregon from "stable" North America. Regional geodetic measurements, historic earthquake moment tensors, and the orientations and slip rates of faults that cross Oregon are the basis for constructing a kinematic model which reveals that the active faults accommodate overall motion in a direction ~N. 60° W. ± 25° at a rate between ~2 and 12 mm yr^{-1}. The model indicates that this proposed shear zone through Oregon can account for as much as 10 percent to 20 percent of the total Pacific-North American transform motion and almost all of the lateral component of Juan de Fuca Plate motion relative to the North America Plate.

The kinematic model of faulting, together with data describing the locations, lengths, and slip rates of late Quaternary and Holocene faults, are the bases for constructing predictive maps of earthquake ground motions, that will help to understand better the seismic hazards in Oregon. Potential earthquakes are hypothesized to occur along eleven major source zones, which include the Cascadia subduction zone, the subducting Juan de Fuca Plate, and nine zones of onshore and offshore crustal faults. Empirical relationships and the active fault data are used to estimate the magnitudes and recurrence intervals of hypothetical earthquakes. This information is encoded as map elements in a Geographical Information System (GIS), which is used to apply earthquake attenuation relations and to establish contours of peak horizontal ground acceleration and velocity across Oregon. A regional map of surficial geology is used to improve predictions of site response by accounting for potential seismic amplification at sites underlain by soft young sediments. All data are stored as GIS database layers that are combined with population density and various algorithms to produce maps of seismic ground motion, duration of shaking, probability of exceeding a damaging level of shaking, and seismic risk. Results indicate that, by area, as much as one-half of Oregon can expect peak ground accelerations to exceed 0.2 g at the 5-percent probability level in a 100-yr interval. As much as 80 percent of the Oregon population resides in areas that can experience strong ground motions (>0.2 g) and long durations of shaking (>60 s).

Prediction of displacements due to liquefaction-induced lateral spreading, by Matthew A. Mabey (Ph.D., Brigham Young University, 1992), 133 p.

The magnitude of ground displacements due to liquefaction-induced lateral spreads can be realistically modeled. This model can be based on readily measured parameters using the Newmark technique and simulated or recorded ground motions. This estimation is simple enough to be economically applied to predictive maps of ground displacement and accurate enough to be applied to site-specific studies. □

DOGAMI PUBLICATIONS

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released two open-file reports that are not printed in multiple copies and are not for sale but limited to library access. These reports are available for inspection in the library of the Portland office of the DOGAMI (see address on page 26 of this issue). Photocopies may be obtained at cost. For copy services, contact Kinko's at 1605 NE 7th Avenue, Portland, OR 97232, phone (503) 284-2129.

Released January 28, 1994:
Preliminary geologic map of the Sourdough Spring quadrangle, Malheur County, Oregon, by M.L. Cummings. Released as Open-File Report O-93-11.

This map is part of the cooperative effort by DOGAMI, the U.S. Geological Survey, and Portland State University to map the west half of the Boise 1° x 2° sheet and has been released as supplementary map to the Vale 30′ x 60′ map published by DOGAMI as part of map GMS-79. The hand-colored map (scale 1:24,000) is accompanied by a 10-page explanatory text.

Released March 8, 1994:
Landslide and erosion hazards of the Depoe Bay area, Lincoln County, Oregon, by G.R. Priest. I. Saul, and J. Diebenow. This report was produced at the request of the City of Depoe Bay and has been released as Open-File Report O-94-3 for library access only. It includes a 23-page text and three hazard maps, with hazards plotted on aerial photos in which 1 in. equals 400 ft.

The report chiefly outlines chronic hazards of mass movement (unstable slopes) and sea-cliff erosion identified by investigations conducted during 1991-1993 and supported by the Federal Emergency Management Administration (FEMA) and the Oregon Department of Land Conservation and Development (DLCD) under the auspices of the National Oceanographic and Atmospheric Administration (NOAA). These investigations focused on the 31-mi stretch of coast from Cascade Head on the north to Seal Rock on the south.

An overview of catastrophic earthquake hazards is also included in the text, but these hazards are not mapped. The techniques for mapping earthquake hazard areas are being developed for an ongoing pilot study of the Siletz Bay area.

Open-File Report O-94-3 is preliminary and encompasses the city limits of Depoe Bay and adjacent lands. The final report will cover chronic hazards of the entire 31-mi study area and catastrophic hazards of the Siletz Bay area. □

MLR launches *Reclamation News*

The Mined Land Reclamation Program of the Oregon Department of Geology and Mineral Industries (DOGAMI-MLR) has published its first annual newsletter, *Reclamation News*.

The purpose of the newsletter is first of all to establish better communications between DOGAMI-MLR and those who hold mining permits. DOGAMI-MLR views *Reclamation News* as an informal way to convey information to operators, such as new reclamation strategies and techniques, advice on operating procedures that make reclamation easier and more cost effective, the names of the annual award recipients, and changes in Oregon's reclamation statutes.

As the *Reclamation News* states editorially: "DOGAMI-MLR's task is overseeing reclamation for the State of Oregon. The only way to make that job feasible is to provide technical assistance so that miners can accomplish effective reclamation themselves."

Questions, suggestions, and comments are invited. They sould be sent to Reclamation News, DOGAMI-MLR, 1536 Queen Ave. SE, Albany, OR 97321. □

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