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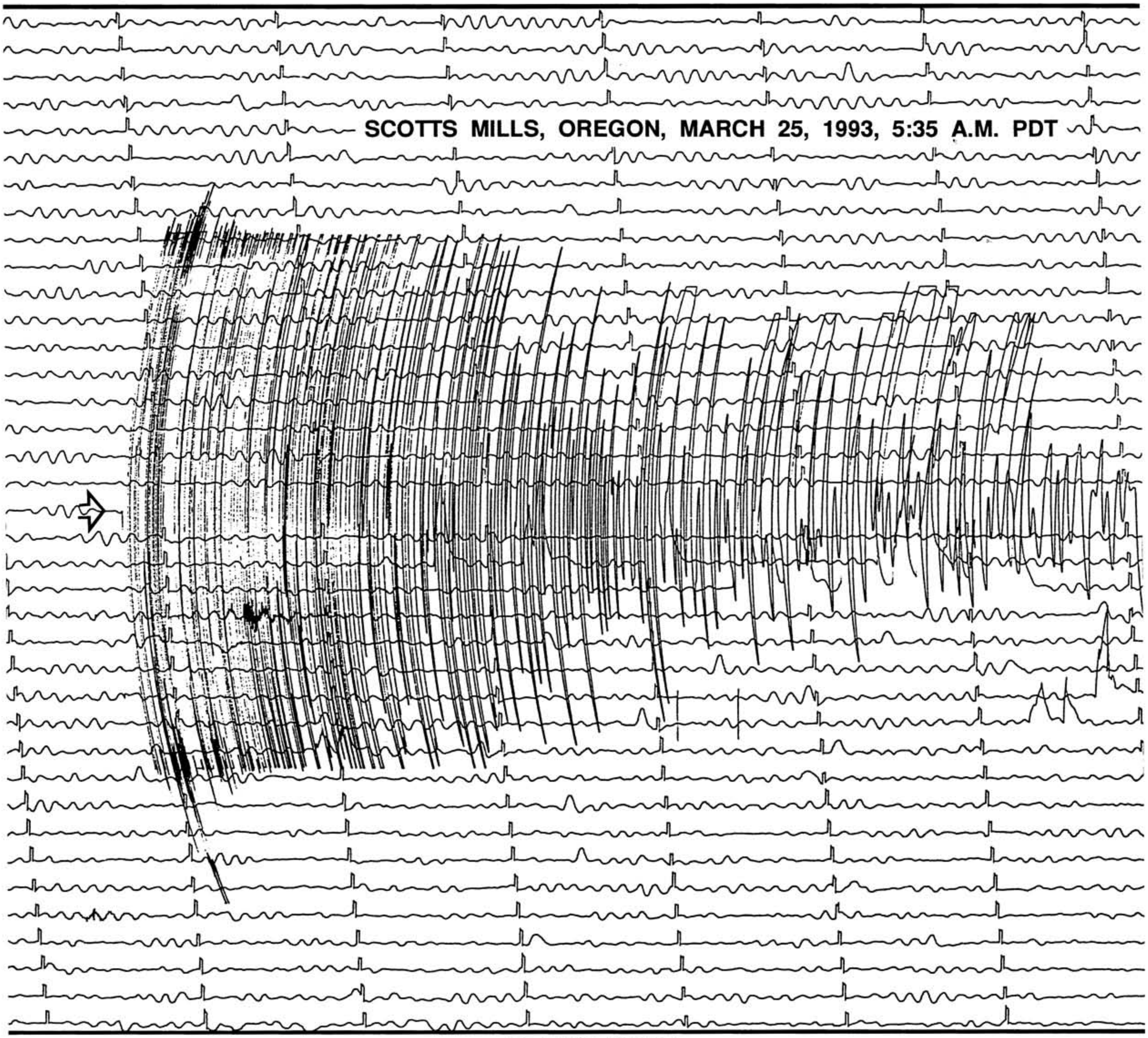

IN THIS ISSUE:

The Earthquake of March 25 at Scotts Mills,
Geology near Blue Lake County Park in Portland, and
Report on New Caldera Complex in Jackson County

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Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. If manuscript was prepared on common word-processing equipment (IBM compatible or Macintosh), a file copy on diskette should be submitted in place of one paper copy (from Macintosh systems, 3.5-inch high-density diskette only). Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications. (See the USGS manual *Suggestions to Authors*, 7th ed., 1991 or recent issues of *Oregon Geology*.) The bibliography should be limited to references cited. Authors are responsible for the accuracy of the bibliographic references. Names of reviewers should be included in the acknowledgments.

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

Cover photo

Seismogram of the Scotts Mills earthquake on March 25, 1993, at 5:35 a.m., as recorded on the seismograph of the Portland State University (PSU) Department of Geology. The trace marked by an arrow shows the response of approximately the first six minutes after the main shock. Each subsequent horizontal trace represents a time interval of half an hour; the tick marks on each trace represent intervals of one minute. Courtesy of the Department of Geology, PSU.

OIL AND GAS NEWS

Reclamation of drill sites at the Mist Gas Field

During March, Nahama and Weagant Energy Co. of Bakersfield, California, reclaimed three drill sites at the Mist Gas Field. The company reclaimed the drill sites CC 31-15-65, CC 43-33-75, and Wilson 11A-5-65, using the patented Soli-bond process, in which drilling material is solidified on site, in the sump, into a stable soil material. The sites were then graded for future beneficial use. This is the first time that this procedure has been used at the Mist Gas Field. The same procedure may be used for reclamation of drill sites in the future.

Recent applications:

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
477	Nahama and Weagant LF 43-32-65 36-009-00302	SE¼ sec. 32 T. 6 N., R. 5 W. Columbia County	Application; 4,700.
478	Nahama and Weagant LF 32-36-65 36-009-00303	NE¼ sec. 36 T. 6 N., R. 5 W. Columbia County	Application; 4,100.
479	Nahama and Weagant CC 42-32-74 36-009-00304	NE¼ sec. 32 T. 7 N., R. 4 W. Columbia County	Application; 1,700.
480	Nahama and Weagant CC 43-8-64 36-009-00305	SE¼ sec. 8 T. 6 N., R. 4 W. Columbia County	Application; 2,150.
481	Nahama and Weagant CC 22B-19-65 36-009-00306	NW¼ sec. 19 T. 6 N., R. 5 W. Columbia County	Application; 3,350.
482	Nahama and Weagant CC 41-36-75 36-009-00307	NE¼ sec. 36 T. 7 N., R. 5 W. Columbia County	Application; 1,650.
483	Nahama and Weagant CFW 41-35-75 36-009-00308	NE¼ sec. 35 T. 7 N., R. 5 W. Columbia County	Application; 2,500.
484	Nahama and Weagant CC 42-34-65 36-009-00309	NE¼ sec. 34 T. 6 N., R. 5 W. Columbia County	Application; 3,150.

□

ANNOUNCEMENT
from
The Oregon Department of Geology and Mineral Industries

Because of anticipated curtailment of funds, the Oregon Department of Geology and Mineral Industries expects to close its geologic-geochemical laboratory.

A sealed-bid sale will be held for the laboratory equipment and such infrastructure items as benches, fume hoods, and other built-in devices. Following is a partial list of items, most of which are in excellent condition.

Jaw crusher	X-ray diffractometer (XRD)
Cone crusher	Atomic absorption spectrometer
Ring and puck mill	Two centrifuges
Disk pulverizer	Two analytical balances
Hammer and screen mill	Microbalance
Sieve shakers, 8- and 8/12-in.	Toploader balance (4-kg cap.)
Drying ovens	Gold Screw autopanner
Two filter presses	Reflectance meter
Large ultrasonic cleaner	Compressor, 5 hp.
Fire-assay furnace and assay chemicals	

Interested persons may call Jean Pendergrass at (503) 731-4100 for further information.

March 25, 1993, Scotts Mills earthquake—western Oregon's wake-up call

by Ian P. Madin[1], George R. Priest[1], Matthew A. Mabey[1], Steve Malone[2], Tom S. Yelin[3], and Dan Meier[4]

INTRODUCTION

On March 25, 1993, at 5:35 a.m., much of northwestern Oregon and parts of southwestern Washington received an unmistakable wake-up call from Mother Nature. The message came as a magnitude 5.6 earthquake that woke up over a million people to the fact that Oregon is vulnerable to damaging earthquakes. This was probably the largest earthquake in the historical record of northwest Oregon but is surely not the largest that can occur. This event should give us notice that we need to prepare for earthquakes that will be many times larger and far more devastating.

The Oregon Department of Geology and Mineral Industries (DOGAMI) has been delivering this message continually during the last six years while working to map the hazards in heavily populated areas. This article summarizes what we know about the Scotts Mills earthquake, what the threat is from future earthquakes, and what can be done to mitigate loss of life and property from them.

NATURE OF THE EARTHQUAKE

The epicenter of the Scotts Mills earthquake was located at lat 45°02.00′N. and long 122°36.43′W. (sec. 19, T. 6 S., R. 2 E.), about 3 mi (4.8 km) due east of Scotts Mills, which is near Silverton and Mount Angel, Marion County, Oregon (Figure 1). As of April 8, 1993, numerous aftershocks had been located by the University of Washington (UW) seismic network (Figures 1 and 2). A vertical cross section of the aftershock activity is presented in Figure 3. Many more aftershocks were recorded on the closest UW station than were located by the network (Figure 2). Portable seismographs deployed by teams from the U.S. Geological Survey, the University of Oregon, and Oregon State University will allow for the location of many of these aftershocks.

[1] *Oregon Department of Geology and Mineral Industries*
[2] *University of Washington Seismology Lab*
[3] *U. S. Geological Survey, Seattle, WA*
[4] *Woodward Clyde Consultants, Portland, Oregon*

GEOLOGY

No ground rupture, cracking, landsliding, liquefaction, or other surface geologic effects that could reliably be attributed to the Scotts Mills earthquake have come to our attention.

No faults that coincide directly with the epicenter of the Scotts Mills earthquake are known. The closest—and at this point the only—candidate for a causative structure is the Mount Angel fault (Figure 1). This northwest-trending structure was first mapped by Hampton (1972) near Mount Angel and later extended by Werner and others (1992) on the basis of evidence from water wells and seismic reflection lines. However, the mapped extent of the Mount Angel fault ends at least 5 mi (8 km) west of the Scotts Mills epicenter. A geologic map of the epicentral area (Miller and Orr, 1984) shows no significant

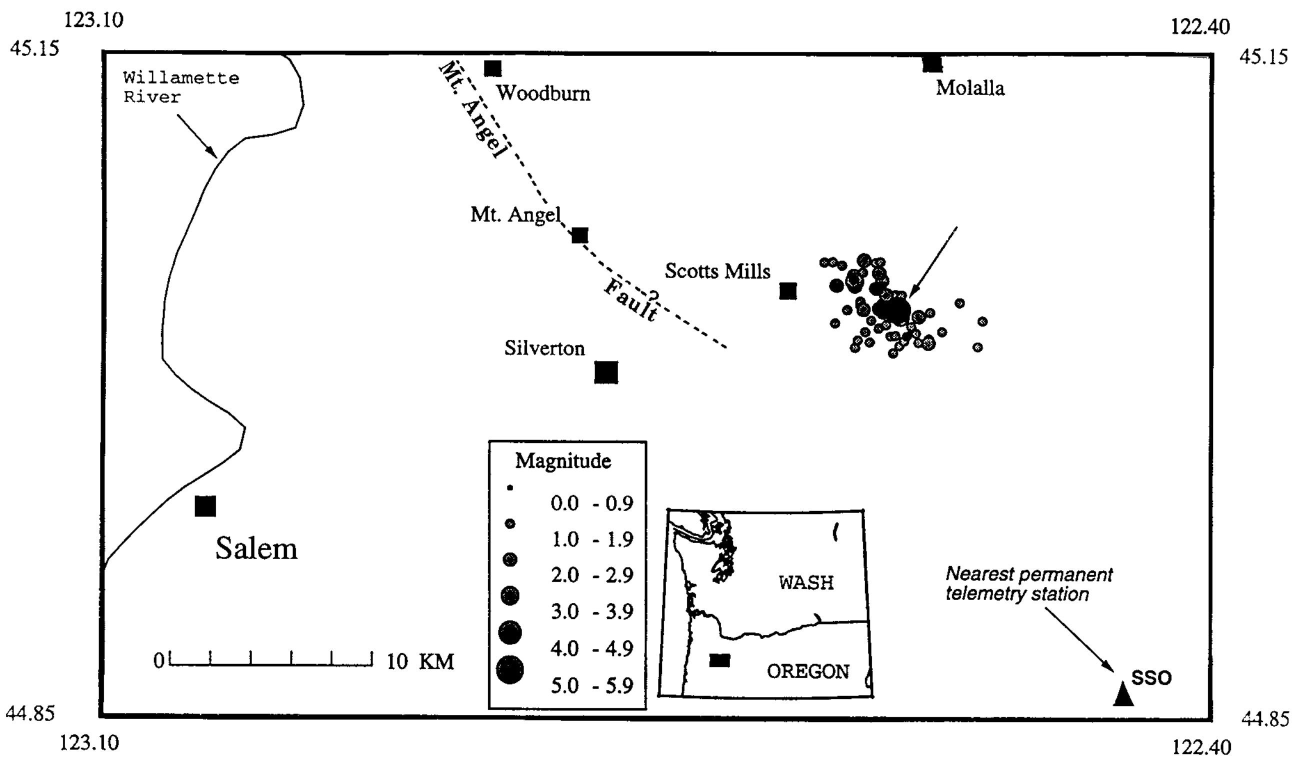

Figure 1. Map showing location of the epicentral area (arrow) of the March 25, 1993, Scotts Mills earthquake (large filled circle), aftershocks during the first two hours (smaller filled circles), and aftershocks through April 8, 1993 (gray circles). Trace of the Mount Angel fault shown by dotted line. Locations were determined with data from the University of Washington telemetry network stations, the closest of which is station SSO at 13.7 mi (22 km) distance (lower right corner of map). Locations are preliminary and subject to revision.

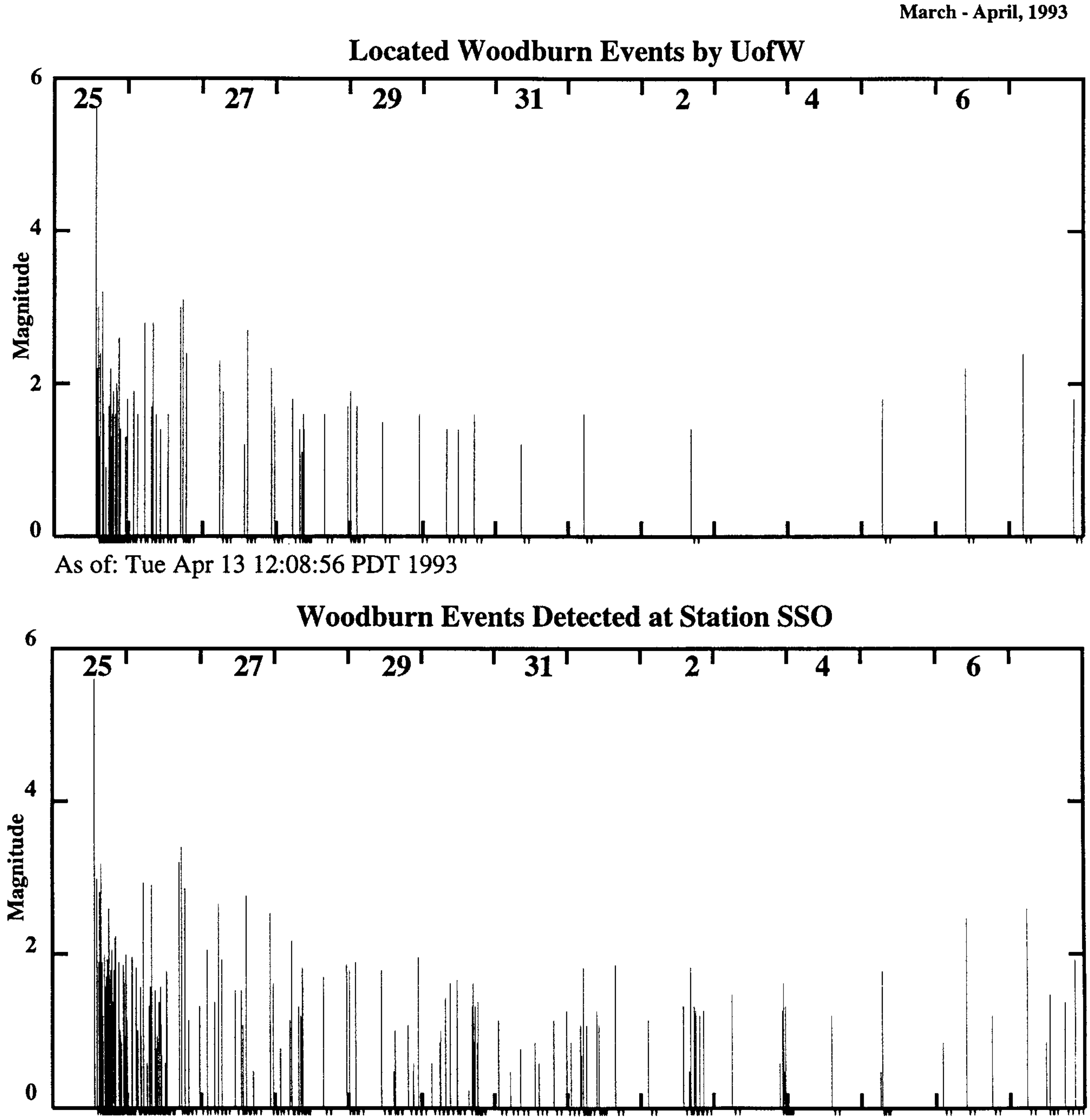

Figure 2. Earthquake magnitude versus time plots for March 25, 1993, Scotts Mills earthquake and first two weeks of aftershocks. Top plot is for earthquakes recorded by the triggered telemetry seismic network, and bottom plot is for events detected on the helicorder records from station SSO (distance 13.7 mi = 22 km).

faulting. Werner and others (1992) suggested that the Mount Angel fault showed right-lateral strike-slip offset with some north-dipping reverse motion and, on the basis of a 1990 earthquake swarm located beneath Woodburn at the north end of the fault, postulated that the Mount Angel fault might be active. So far, we do not know whether the Scotts Mills earthquake occurred on the Mount Angel fault or on another fault that may not even have a surface manifestation.

STRONG-MOTION RECORDING OF THE SCOTTS MILLS EARTHQUAKE OF MARCH 25, 1993

To date, strong-motion recordings of the Scotts Mills earthquake have been processed for four sites. The strongest motions were recorded by three instruments at the U.S. Army Corps of Engineers Detroit Dam located approximately 22 mi (36 km) southeast of the epicenter. The instrument located at the downstream toe of the dam recorded a peak acceleration of 0.06 *g*, while an instrument located in a gallery within the dam recorded a peak of 0.18 *g*.

The other three instruments for which records have been processed are in the area of Portland, Oregon, and Vancouver, Washington. A recently installed digital instrument in Portland recorded a peak acceleration of 0.03 *g*, while older analog instruments at Portland State University in Portland and at the Vancouver Ex-

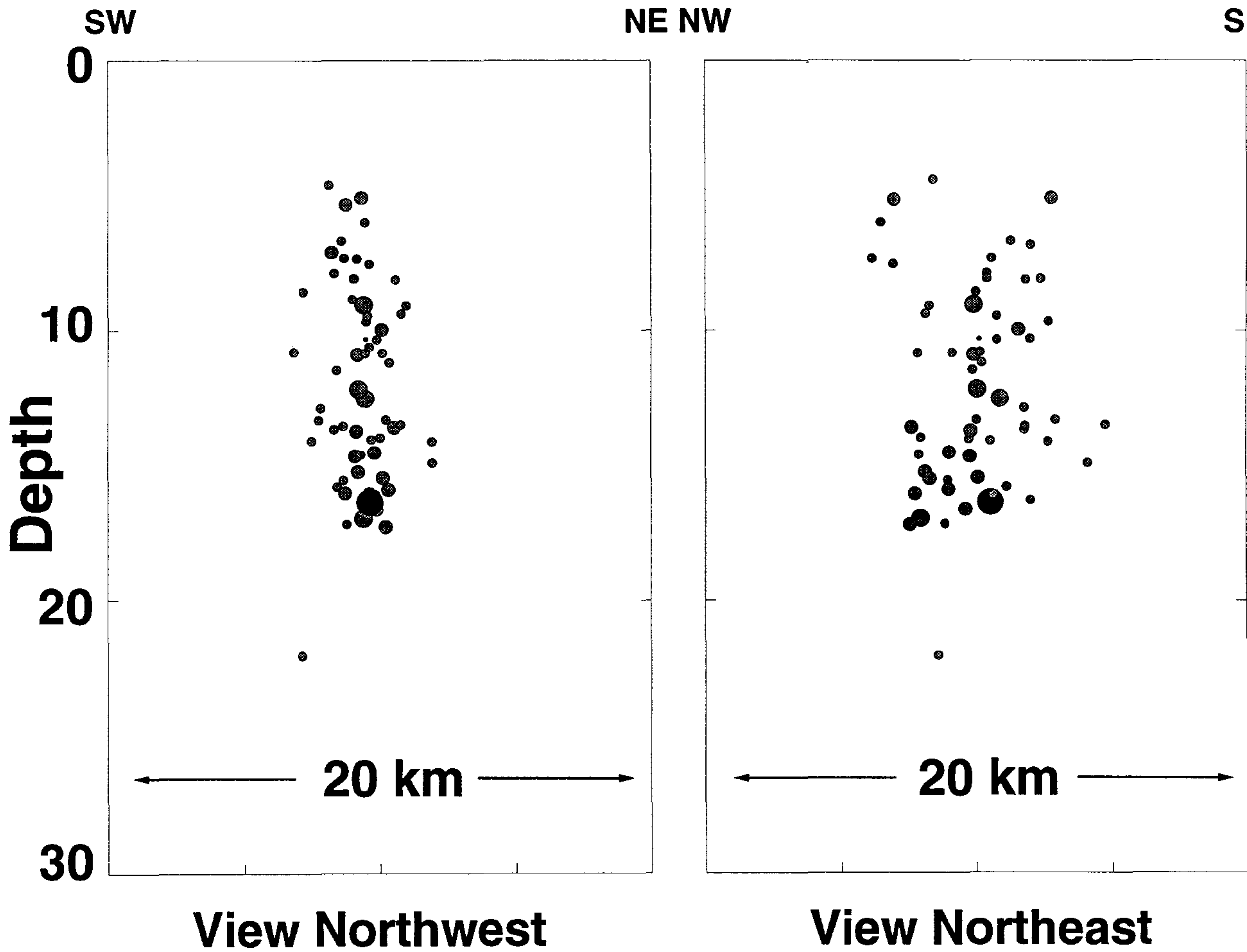

Figure 3. Perpendicular cross sections showing the vertical distribution of the main shock (solid circle) and aftershocks (gray circles) of the March 25, 1993, Scotts Mills earthquake. The depth determinations are preliminary and subject to revision.

tended-Care Division of the Portland VA Medical Center both recorded peak motions of 0.02 *g*. The stations in Portland are approximately 35 mi (56 km) north of the epicenter, and the Vancouver location is approximately 44 mi (70 km) north.

All of these measured motions are consistent with the intensities observed near the respective locations of the instruments. The Portland-Vancouver recordings were all from soil sites, but all the peak accelerations have been plotted in Figure 4, for comparison, with a bedrock attenuation relationship developed by Joyner and Boore (1982).

INTENSITY AND DAMAGE

The earthquake caused significant structural damage to a number of unreinforced masonry (URM) buildings in and around the epicentral area but left most wood-framed houses and buildings unscathed. In Molalla, the unreinforced masonry high school suffered significant damage and remains closed. In Mount Angel, unreinforced masonry buildings at the Benedictine convent and training center, the Benedictine Abbey, and St. Mary's Church and School were significantly damaged. Numerous URM commercial buildings in downtown Woodburn were significantly damaged and remain closed. The Oregon State Capitol in Salem suffered cracking of the inner walls of its rotunda and other minor damage to beams supporting the ceilings of the legislative chambers. A number of chimneys toppled in Scotts Mills, Woodburn, Mount Angel, and Molalla. The Highway 18 bridge across the Yamhill River near Dayton was put out of commission for several days by damage to the supports for the expansion rockers. A passing motorist had all four tires blown out when he hit the resulting ledge.

There were widespread reports of minor damage such as cracked plaster and foundations from as far away as the Portland metropolitan area. Surprisingly, at least 90 buildings located 28 mi (45 km) from the epicenter in the town of Newberg were damaged. Damage assessments by the Oregon Emergency Management Division and the Federal Emergency Management Agency (FEMA) are listed in Tables 1-3. The total damage estimate is about $28,4 million.

The distribution of damage and felt effects is being compiled at the Oregon Department of Geology and Mineral Industries (DOGAMI) to aid in production of an intensity map. This map will help identify areas like Newberg that may be more prone to severe damage in the event of another earthquake. These maps may also be used in the preparation of relative earthquake hazard maps for the Portland and Salem urban areas, currently in preparation by DOGAMI. An intensity questionnaire published in several Oregon newspapers has resulted in approximately 4,000 intensity reports from the public, which have yet to be compiled. A preliminary intensity map derived from this data set is presented as Figure 5.

If you have any personal observations from your own experience, or if you sustained damage to your house, please fill out and send in the form at the end of this article.

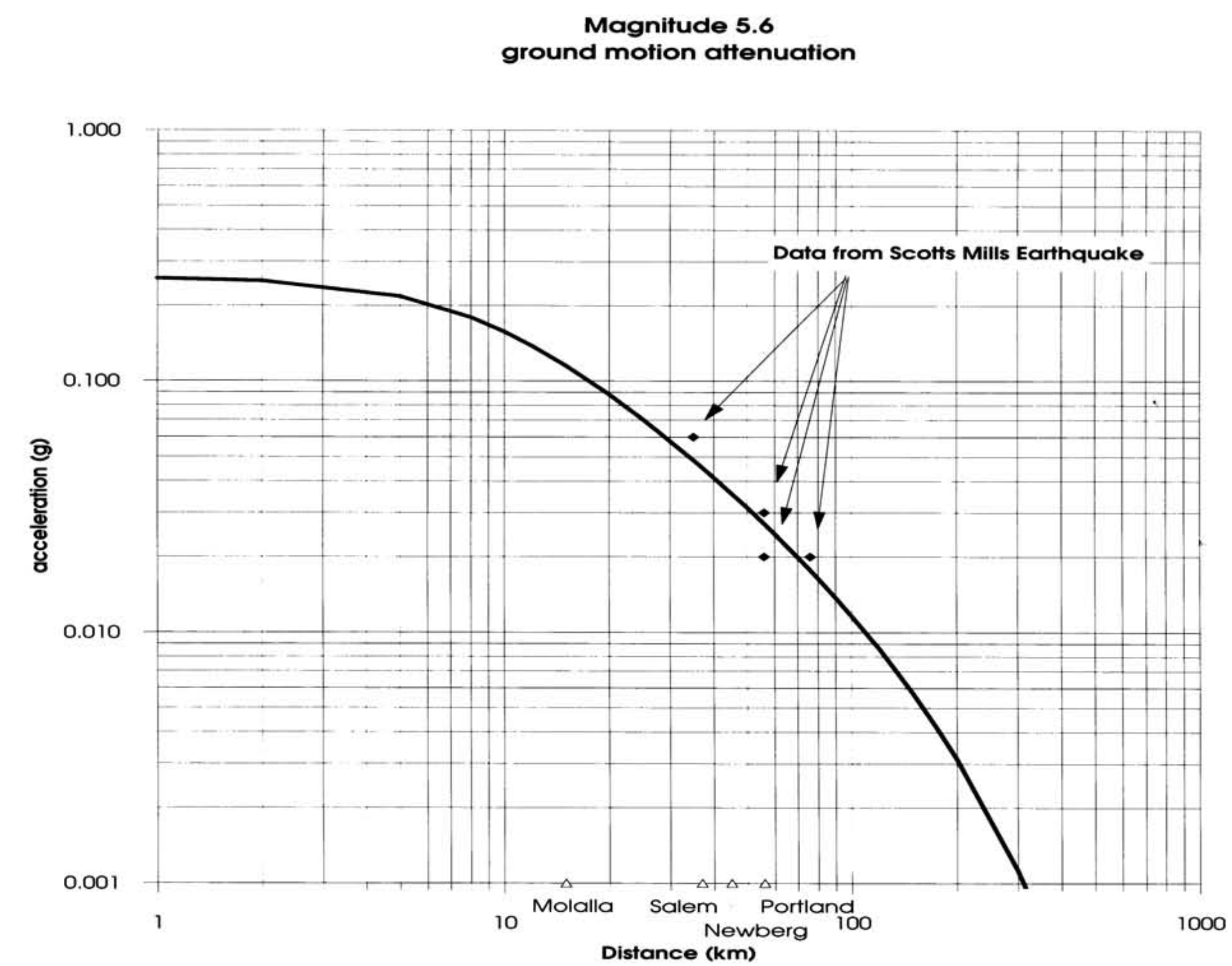

Figure 4. Recorded ground motions plotted with bedrock ground motion attenuation relationship as developed by Joyner and Boore (1982).

Table 1. *Individual assistance damage estimates by FEMA for Clackamas, Marion, and Yamhill Counties. Major damage = building or part of building unsafe; minor damage = some aspect of building function impaired; other damage = cosmetic damage*

	Clackamas	Marion	Yamhill	Totals
Number of residences				
Destroyed	0	0[1]	0[1]	0
With major damage	7[1]	0[1]	9[1]	16
With minor damage	150[1]	0[2]	36[1]	186
With "other damage"	485[2]	428[2]	8[2]	921
Estimated total dollar loss	$1,180,000	$0	$408,500	$1,588,500
Number of businesses				
Destroyed	0	0	0	0
With major damage	6	28	20	54
With minor damage	19	58	17	94
Estimated total dollar loss	$915,000	$4,054,300	$1,270,000	$6,239,300

[1] Based on field inspections guided by county emergency management officials.
[2] Based on data submitted by county emergency management officials and drive-by observations.

Table 2. *Public assistance damage estimates by FEMA, based on field inspections guided by county emergency management officials*

Clackamas County	$4,149,810
Marion County	$1,904,750
Washington County	$0
Yamhill County	$249,400
Total dollar damage	$6,303,960

Note: The above figures do not include estimated damages to state government buildings or to bridges, such as the one damaged on Highway 18, which are part of the Federal Aid Highway System. Damages to state government buildings are covered either by self-insurance or by the state's $300 million re-insurance program and were therefore not inspected by the joint federal-state-local government damage assessment teams. Repairs to the State Capitol rotunda, the largest single earthquake-damaged state building, are estimated at $850,000. These estimates do not include damages to insured properties, such as the Abbey College, the Benedictine Nursing Home, and St. Mary's Church. Dollar damages to these three facilities are estimated to be $15 million.

Table 3. *Damage costs for public facilities estimated by FEMA*

Marion County		
Monitor Cooperative Telephone Co.		$167,750
Monitor Rural Fire Department		$176,000
Monitor Elementary School		$1,000
St. Mary's Public School		$500,000
JFK High School		$100,000
Howard Hall and facilities		$50,000
City Hall, Mount Angel		$30,000
Salud Medical Center		$880,000
	Total	$1,904,750
Clackamas County		
Lake Oswego Fire Station		$11,360
Molalla City Hall/Police Station		$1,450
Molalla High School		$4,000,000
Oregon City Correction Office		$1,000
Canby Philander School		$50,000
Oregon City, City Hall		$4,000
Oregon City, Gardner Elementary School		$15,000
Ogden Junior High School		$10,000
Carus Elementary School		$5,000
Mulino School		$1,000
Molalla Fire Station #1		$50,000
Canby, Wm. Knight Elementary School		$1,000
	Total	$4,149,810
Yamhill County		
McMinnville High School		$3,000
Adams School		$2,500
Columbus Grade School		$200,000
Newby School		$300
Dundee Grade School		$5,000
City of Newburg, City Hall		
Newburg Public Library		$300
Wascher Elementary School		$300
City of Lafayette, Lafayette City Hall		$300
County Fairground, McMinnville		$20,000
Debris removal		$1,000
Protective measures		$16,000
	Total	$249,400
Washington County		
Forest Grove Fire Station		$0
	Grand total	$6,303,960

EXPECTED FUTURE EARTHQUAKES

Northwestern Oregon is vulnerable to earthquake damage from three sources (Figure 6):

Crustal earthquakes occur on faults located within the North American Plate. The Scotts Mills earthquake was a crustal event, as were most of the earthquakes in Oregon's historical record. Scientists are only now beginning to learn about the location and earthquake potential of crustal faults in western Oregon. The historical record suggests that much of western Oregon should anticipate events like the Scotts Mills earthquake, possibly up to magnitude 6.5, at any time.

Intraplate or **Benioff zone earthquakes** are the type that severely rocked the Puget Sound region in 1949 and again in 1965. Those who lived in Portland in 1949 may recall that the Portland area suffered some damaging and frightening effects from that earthquake. Intraplate earthquakes occur within the remains of the ocean floor, which has been shoved (subducted) beneath North America. It is now believed that this type of earthquake could occur closer to Portland or the Willamette Valley, perhaps 25-35 mi (40-60 km) deep directly beneath western Oregon.

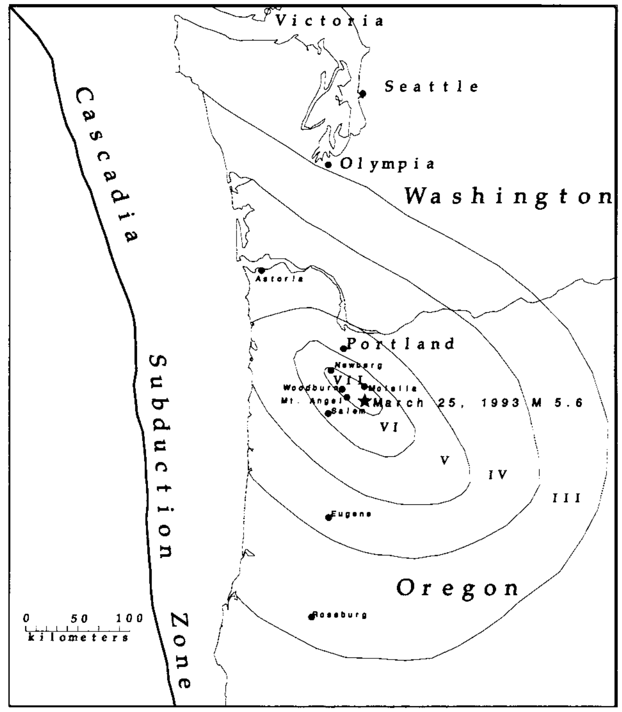

Figure 5. Preliminary Modified Mercalli intensity map for the March 25, 1993, Scotts Mills earthquake.

Great subduction earthquakes occur around the world in subduction zones, where continent-sized pieces of the earth's oceanic crust are shoved deep into the body of the earth. These earthquakes consistently are among the most powerful recorded, often having magnitudes of 8 to 9 on the moment magnitude scale. The Cascadia Subduction Zone, which has long been recognized off the coast of Oregon and Washington, has not had any great subduction earthquakes during our short 200-year historical record. However, in the past five years, a variety of studies have found widespread evidence that these great events have occurred repeatedly in the past, most recently about 300 years ago, in the latter part of the 17th century. The best evidence available suggests that these great earthquakes have occurred, on average, every 350 to 700 years, and there is reason to believe that they will continue to occur in the future.

Northwestern Oregon is clearly threatened by all three types of earthquakes, but there is currently significant uncertainty about exactly where, how frequent, and how big future earthquakes will be. This makes it difficult to rely on a probability-based (probabilistic) approach to hazard mapping, which would provide information about absolute levels of ground shaking to be expected and how often such levels might be reached. Once reliable probabilistic ground motion maps become available, they will be integrated with the relative hazard mapping. This is the approach taken by DOGAMI in its earthquake hazard assessment work in recent years.

MITIGATION MEASURES

Since it is impossible, at present, to predict exactly when or how often earthquakes may occur, DOGAMI has concentrated on mapping those areas that are the most vulnerable to damage regardless of the earthquake source. Maps of these vulnerable areas can then be used by planners to guide development and emergency response measures.

Hazard mapping

DOGAMI earthquake hazard maps show areas most vulnerable to (1) amplification of shaking, (2) liquefaction (formation of quick

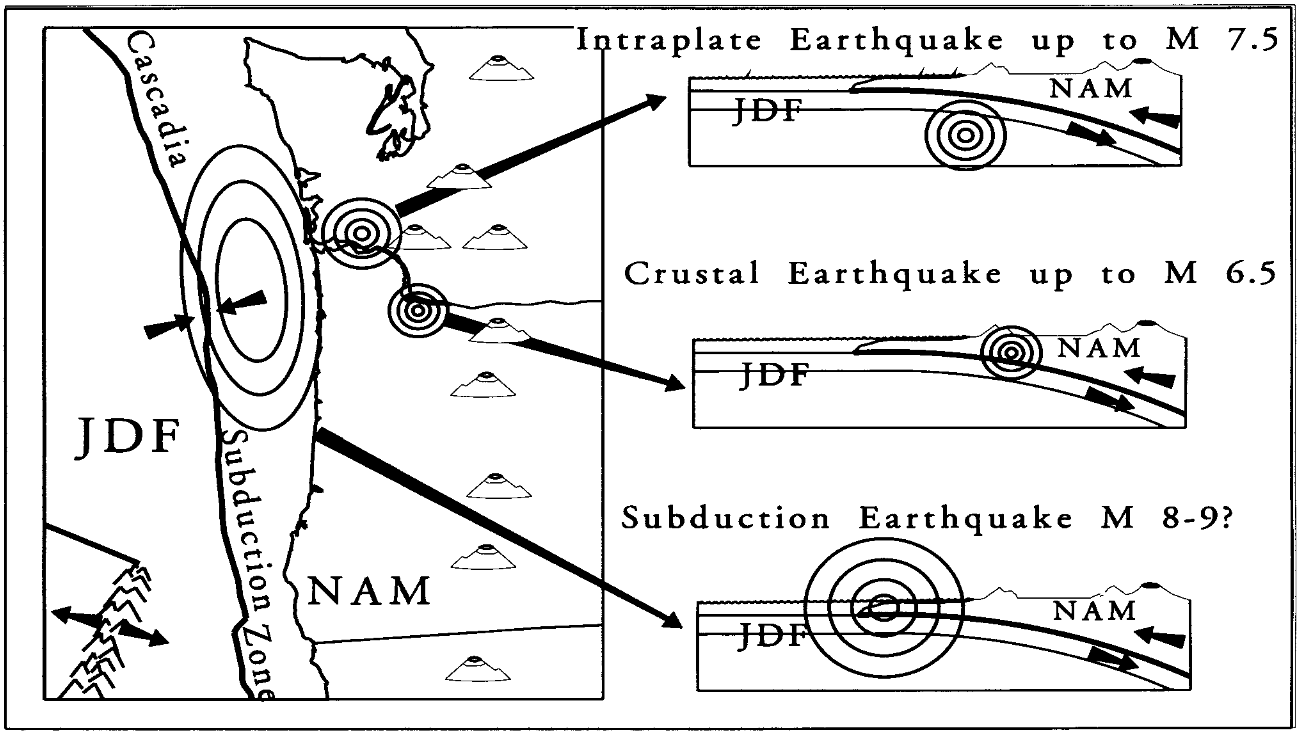

Figure 6. Earthquake source zones in the Pacific Northwest. JDF = Juan de Fuca Plate (subducting); NAM = North American Plate (overriding). Major Cascade volcanoes are shown. Northernmost section of Gorda spreading ridge is shown in southwest (lower left) corner of map. Short arrows indicate direction of plate motion, and centers of concentric circles show example locations of earthquakes, both in the map view and in the cross sections. Concentric ovals west of the coast line schematically represent the rupture zone for a great subduction earthquake (magnitude of approximately 8).

sand or "quick silt"), and (3) landsliding. A relative hazard map of the Portland quadrangle has recently been published in cooperation with Metro (see announcement in this issue). It is a composite map depicting the relative hazard at any site, due to the combination of all three effects. It delineates areas that likely will experience the greatest effects from any earthquake. Those effects could range from people waking from their sleep to buildings collapsing or gas lines rupturing. These simple composite hazard maps can be used by planners, lenders, insurers, and emergency responders for first-order hazard mitigation and response planning. Similar maps are in preparation for the remainder of the Portland urban area and are planned for Salem and the other major Willamette Valley urban areas.

Emergency response and preparedness

Emergency preparedness is generally at a low level in Oregon, because we have experienced few historic earthquakes. Emergency response planning is still in the early stages for the same reason. The region would indeed have great difficulty in responding to a severe earthquake at this time. The Scotts Mills earthquake, by heightening awareness, offers an unprecedented opportunity to change this situation.

The general public would be well advised to take immediate measures to mitigate damage and injury from earthquakes that surely lie in our future. Detailed information on these actions can be found in recent issues of major newspapers and in pamphlets from the American Red Cross and emergency management agencies at the state and local level. Some contacts and references for this information are listed at the end of this article, but, as a minimum, the following steps can be taken immediately:

1. Make sure your family is prepared to spend 72 hours after an earthquake without outside help. This means keeping a supply of drinking water and food, cash, first aid supplies, emergency cooking and lighting equipment, and battery powered radios.

2. Make sure your house is bolted to its foundation. Houses built before 1974 are possibly not bolted down.

3. Strap down your hot water tank using metal straps bolted to the wall studs.

4. Make sure that tall book cases or other heavy objects are secured, so they cannot topple onto someone. The same goes for containers of hazardous liquids.

5. Establish a family emergency plan that specifies what actions to take during and after an earthquake. The plan should establish where and under what circumstances the family will rendezvous from work and school. It will be much easier to make phone calls out of the area than to receive incoming calls, so the plan should specify what out-of-state person to call to coordinate information.

6. Learn how to shut off the gas, power, and water connections to your home in the event that there are breaks or leaks in your home.

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Werner, K., Nábelek, J., Yeats, R., and Malone, S., 1992, The Mount Angel fault: Implications of seismic-reflection data and the Woodburn, Oregon, earthquake sequence of August 1990: Oregon Geology, v. 54, no. 5, p. 112-117.

FOR FURTHER READING

Bolt, B.A., 1993, Earthquakes: New York, W.H. Freeman and Company, 331 p.

ADDRESSES FOR FURTHER INFORMATION AND MATERIALS

American Red Cross
P.O. Box 3200
3131 N. Vancouver Avenue
Portland, Oregon 97208
(503) 284-1234.

Oregon Emergency Management Division
595 Cottage Street NE
Salem, Oregon 97310
(503) 378-4124.

EARTHQUAKE QUESTIONNAIRE

The Oregon Department of Geology and Mineral Industries (DOGAMI) needs the help of the public to accurately determine the effects of the March 25, 1993, Scotts Mills earthquake. Please take the time to read this questionnaire and answer the questions as fully as possible. **We need your information even if you did not feel or observe any effects.** This information may allow us to predict which areas might experience the greatest damage in future large earthquakes. Send to **Earthquake Survey, DOGAMI, 800 NE Oregon St., # 28, Portland, OR 97232**

Where were you during the earthquake? Please describe your location, either by a street address or nearest cross streets.

Were you in the open, in a car, in a building? (If you were in a building, list which floor you were on and how many floors the building has.)

What effects did you feel? Describe the sensation, was it barely felt, strongly felt, hard to stand?

What effects did you observe to surrounding objects? (Rocking cars, dishes ratttling on shelves, furniture or machinery shifting).

□

When is a Richter not a Richter?

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

INTRODUCTION

Newspaper stories about earthquakes today nearly always refer to earthquake strength in terms of "Richter magnitudes." It appears to be the quickest measure of what an earthquake means. But it is not by any means the only measure, and until recently I did not realize how many other ways to measure are being used just to indicate an earthquake's magnitude.

SCALES

Magnitude and intensity scales are the two best known systems now in general use for recording the strength of earthquakes.

Intensity scales, based on the degree of violence and resulting destruction, were first developed in 1878 and later refined several times. Since 1931, the version used is the Modified Mercalli (MM) intensity scale, which reports the results of the quake on a scale of intensity by Roman numerals ranging from I (not felt) to XII (catastrophic). Intensity VI can be damaging; intensity VII can destroy structures.

Magnitude has for many years been rated by the Richter magnitude scale (M_L) proposed first in 1935. It uses Arabic numbers on an open-ended logarithmic scale. The number is derived from measuring the wave amplitude recorded by the swing of the needle on a seismograph that has been calibrated to match a theoretical seismograph located 100 km from a quake.

Since the Richter scale is logarithmic, an increase of one unit on the scale corresponds to a tenfold increase in the amplitude of the shaking caused by the quake. Thus a Richter magnitude 7 earthquake is 100 times as large in amplitude as a 5, and an 8 is 1,000 times as large. Moreover, the amount of energy given off by the quake increases about 35 times with each increase by one unit, so that a Richter 7 is more than 1,000 times as energetic as a 5.

WAVES

Earthquakes generate a variety of waves, generally divided into body waves and surface waves. Body waves pass through many of the concentric spheres that make up the Earth: lithosphere (continental and oceanic crust), asthenosphere (a zone of very weak rock below the crust), upper and lower mantle, and outer and inner core. The waves can be reflected and refracted within these zones and at the boundaries between them several times and thus reach the seismograph by several different paths, which has led to the differentiation of a large number of "phases" of body waves.

Scientists distinguish two types of body waves. Those arriving first are called "Primary" or P-waves and are dilatation/compression or "push-pull" waves. Those arriving second are called "Secondary" or S-waves or shear waves.

By contrast, surface waves travel around the Earth's surface and are found only in the vicinity of the surface. They provide important additional information about earthquake waves. They have also been differentiated into several types. Three of them are Love, Rayleigh, and Stonely waves.

MAGNITUDE SYMBOLS

I first discovered other ways of measuring earthquake strength in a report by Waverly Person (1990) in an issue of *Earthquakes and Volcanoes*, published bimonthly by the U.S. Geological Survey. Person lists and describes many of 184 quakes that occurred worldwide between March 1 and December 31, 1990. More than two thirds of the magnitudes were identified by symbols I had never seen before!

In Person's list, six symbols indicate ways in which the magnitude number was derived. The seventh symbol is one that has recently come into use for large earthquakes whose fractures dislocate the surface. The numbers in the third column of Table 1 on the left indicate how often each symbol occurred in the total of 184 reported earthquakes.

Table 1. *Types of measuring earthquake magnitudes in Person (1990)*

No.	Symbol	Times used	Description
1.	M_L	58	Richter magnitude. L (local) reflects the original limitation to California earthquakes occurring within 600 km of a seismograph.
2.	M_S	45	Magnitude derived from surface waves.
3.	m_b	41	Magnitude derived from body waves.
4.	m_{bLg}	17	Magnitude derived from Love (surface) waves
5.	M_D	12	Magnitude derived from duration of earthquake.
6.	C_L	11	Magnitude derived from coda length. The coda ("tail") is the end part of a seismogram that registers continuing waves
7.	M_w	—	Moment magnitude. Derived from the length of the rupture

Two thirds of the listed earthquakes occurred within the United States, only one third outside. During the same time period, a total of 280 quakes occurred in the United States. Of these, 116 occurred in California, 54 in Alaska, 10 in Washington, and 2 in Oregon.

ACKNOWLEDGMENTS

I appreciate the careful review of this note by Ansel Johnson and Paul Hammond, both on the faculty at Portland State University, who helped me get up to speed on a subject that is not my specialty.

REFERENCE CITED

Person, W.J., 1990, Earthquakes, March-December 1990: Earthquakes and Volcanoes, v. 22, no. 6, p. 268-291. □

Earthquake scenario pilot project placed on open file

The Oregon Department of Geology and Mineral Industries (DOGAMI) has placed on open file a report that assesses, in a pilot scenario, the potential damage caused by a moderate earthquake in the Portland metropolitan area.

The report is entitled *Earthquake Scenario Pilot Project: Assessment of Damage and Losses* and has been released as DOGAMI Open-File Report O-93-06.

The pilot earthquake scenario project was undertaken by Metro (Regional Government) and DOGAMI and includes contributions from more than twenty researchers. Its purpose was to develop and provide an information system to support earthquake-preparedness planning in the Portland metropolitan region. The results are presented on 19 pages accompanied by a 16-page appendix.

The scenario is based on an assumed moderate (magnitude 6.5) earthquake, triggered by rupture of a section of the Portland Hills fault zone. It studies the effects on a portion of downtown Portland on either side of the Willamette River, an area that includes 185 buildings, two freeways, two bridges across the Willamette, railroad tracks, lifelines such as electrical power and communication lines, gas and water pipe systems, sanitary and storm sewers, and roadways and overpasses.

The study provides (1) an indication of the dollar amount of damage; (2) an approach for identifying potential liability issues; (3) an indication of areas requiring greater emergency response priority; (4) an indication of the variations in expected loss by structural types of buildings and critical facilities; (5) a data collection system that may assist development of a regional earthquake hazards mitigation program; (6)analytical tools that may be useful in identifying policy issues relating to earthquake planning; and (7) an indication of the nature of recovery and reconstruction processes that may be needed after a moderate earthquake.

Open-File Report O-93-06 is available for inspection at all DOGAMI offices and for purchase in a packet that includes the relative earthquake hazard map of the Portland quadrangle published jointly by Metro and DOGAMI (see discussion below). □

First relative earthquake hazard map released

Metro, Portland's regional service agency, and the Oregon Department of Geology and Mineral Industries (DOGAMI) have jointly published *Relative Earthquake Hazard Map of the Portland, Oregon, 7½-Minute Quadrangle.*

This is the first publication in a program that is planned to provide such maps for the Portland-Vancouver, Salem, Corvallis-Albany, Eugene, and coastal urban areas.

The Portland quadrangle covers an area that extends from Marquam Hill and downtown Portland north to the Columbia River and from 36th Avenue on Portland's east side as far west as Bybee Lake, Forest Park, and Elk Point. The map is at a scale of 1:24,000, where one inch represents approximately 2,000 ft. Its color pattern divides the area into four zones of relative hazard, from greatest (Zone A) to least (Zone D).

Current scientific understanding of the earthquake sources that might affect the Portland area is too limited to allow an accurate assessment of the likely size and location of future earthquakes—the absolute degree of earthquake hazard, so to speak. It is possible, however, to measure and predict the behavior of rock and soil at a given site and predict how that affects what damage is caused during an earthquake.

The damage is caused or aggravated by one or more of three effects: (1) amplification of ground shaking, (2) liquefaction of water-saturated sand, and (3) landsliding triggered by ground shaking. The degree to which the geology of a given site can make the combination of these effects greater or lesser, relatively speaking, is shown by the zones on the map. This information is especially valuable for planners, lenders, insurers, and those involved in emergency planning for earthquakes.

The relative earthquake hazard map, in a way, is a combination of three maps, each of which depicts the geology of the Portland quadrangle with regard to one of the three effects described above. These individual hazard maps will also be published soon. The data sets that produced the maps and allowed the combination of all three are created and stored in computers, so they can be incorporated by various agencies into their own information systems for sophisticated planning of land use, engineering, or emergency management.

The relative earthquake hazard map, together with explanatory text and DOGAMI Open-File Report O-93-06 (see previous article), can be purchased for $10 plus $3 for postage and handling from Metro Data Resource Center, 600 NE Grand Avenue, Portland, OR 97232, phone (503) 797-1720; or from DOGAMI's The Nature of Oregon Information Center, 800 NE Oregon Street, Suite 177, Portland, OR 97232, phone (503) 731-4444. □

Correction

Please note that the street address of the Oregon Emergency Management Division in Salem given on page 45 of the last issue of *Oregon Geology* was incorrect. The correct full address is 595 Cottage Street NE, Salem, OR 97310, phone (503) 378-4124.—*ed*

Geology near Blue Lake County Park, eastern Multnomah County, Oregon

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ABSTRACT

Information from well logs, geophysical logs, excavations, and outcrops near Blue Lake County Park in eastern Multnomah County, Oregon, indicates that the stratigraphy and geologic structure are more complex than previously described. These data suggest that the gravel deposits that form the Troutdale gravel aquifer are post-Troutdale Formation in age and that the contact separating the two rock units is an angular unconformity.

Structure contours on the Troutdale Formation show a large dome centered just south of Blue Lake. The Troutdale Formation was severely eroded along the northeast flank of the dome, presumably during Pleistocene catastrophic flooding events. Gravels of the Troutdale gravel aquifer overlie a portion of this eroded surface and thicken significantly toward the south and west.

Well logs and natural gamma logs from the Blue Lake area suggest that the northeast portion of the dome was cut by a northwest-trending fault with vertical displacement of up to 500 ft. Erosion has removed much of the upper portion of the Troutdale Formation north of the fault trace.

The absence of mappable siltstone units in the Troutdale Formation indicates lateral discontinuities that may have been caused by channel incision. These incisions, together with changes in sediment size and source areas, attest to the dynamic depositional environment of the east Portland Basin.

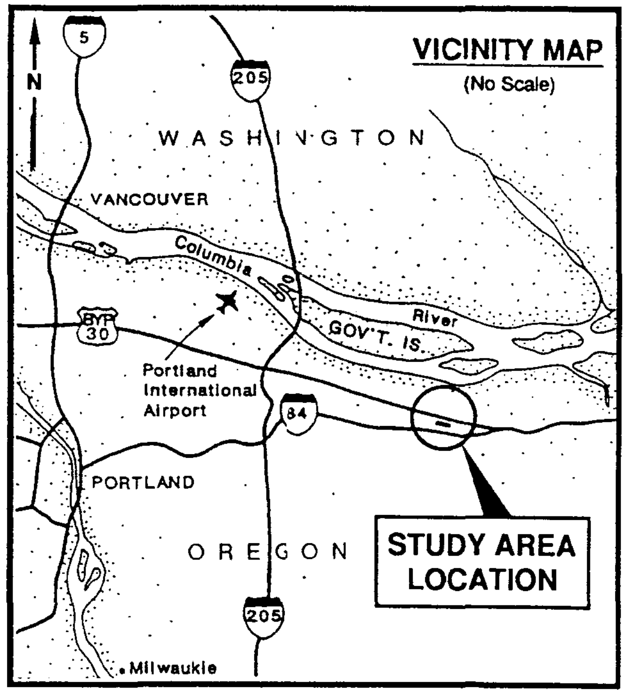


Figure 1. Sketch map showing location of study area.

INTRODUCTION

Several investigations have been completed in the east Portland Basin since Trimble (1963) mapped the geology of east Multnomah County and the City of Portland studied the area in 1977 and 1978 for a potential well field. These investigations focused on the hydrogeology of the east Portland area, with most work concentrated southeast of Blue Lake County Park.

This paper assimilates new geologic data into a model, accounting for the relatively complex stratigraphic and structural relationships displayed in the Troutdale Formation within the study area (Figure 1). Geologic cross sections, structure-contour maps, and isopach maps were constructed on the basis of the interpretation of geologic logs, driller reports, and natural gamma logs when available. Well locations used in this paper are shown in Figure 2. In addition to well logs, outcrops of the Troutdale Formation were examined in the field, and a review of pertinent literature was incorporated into the development of the model. Well logs provided data for geologic interpretations, because outcrops of the Troutdale Formation are rare in the study area.

REVIEW OF PREVIOUS INVESTIGATIONS

Previous work can be divided into geologic and hydrogeologic investigations.

Geologic investigations

Trimble (1963) mapped the geology of east Multnomah County and incorporated most of the previous work into a comprehensive investigation of the area. He described the Troutdale Formation as consisting primarily of vitric sandstone and conglomerate with a deeply weathered surface. Trimble separated and renamed the lower Troutdale Formation the Sandy River Mudstone, basing this separation on differences in lithology and genesis between the Sandy River Mudstone and the Troutdale Formation. Mundorff (1964) complemented Trimble's work by mapping the geology and hydrogeology to the north, across the Columbia River in Clark County, Washington. Mundorff used the designation "lower Troutdale" instead of Sandy River Mudstone.

Tolan and Beeson (1984) refined the range of the Troutdale Formation, using the stratigraphic relationship of Boring Lavas and Columbia River basalts at Bridal Veil, Oregon. On the basis of clast composition and source area they defined two separate and distinct facies within the Troutdale Formation: the "ancestral Columbia River" and "Cascadian stream" facies. The ancestral Columbia River facies, which contains nonlocally derived clasts of quartzite, schist, granite, and rhyolite, is found in the study area. The Cascadian stream facies, which contains predominantly volcanic clasts that were locally derived, is not found in the study area. Tolan and Beeson then subdivided the ancestral Columbia River facies informally into an upper and a lower member. The lower member consists primarily of conglomerates containing numerous exotic clasts and interbedded arkosic sandstones. The upper member consists of interbedded vitric-lithic sandstones and basaltic conglomerates with exotic clasts.

Swanson (1986) examined the geochemistry of the vitric sandstones occurring in the Troutdale Formation. He found that vitric sandstones from Tolan and Beeson's (1984) upper member have distinctive geochemical signatures. Swanson's geochemical work links sandstone outcrops at Blue Lake and Taggart Bluff and vitric sandstone samples from the City of Portland's well field west of Blue Lake (Figure 3) to the upper member of the Troutdale Formation established by Tolan and Beeson (1984) along the east side of the Portland Basin.

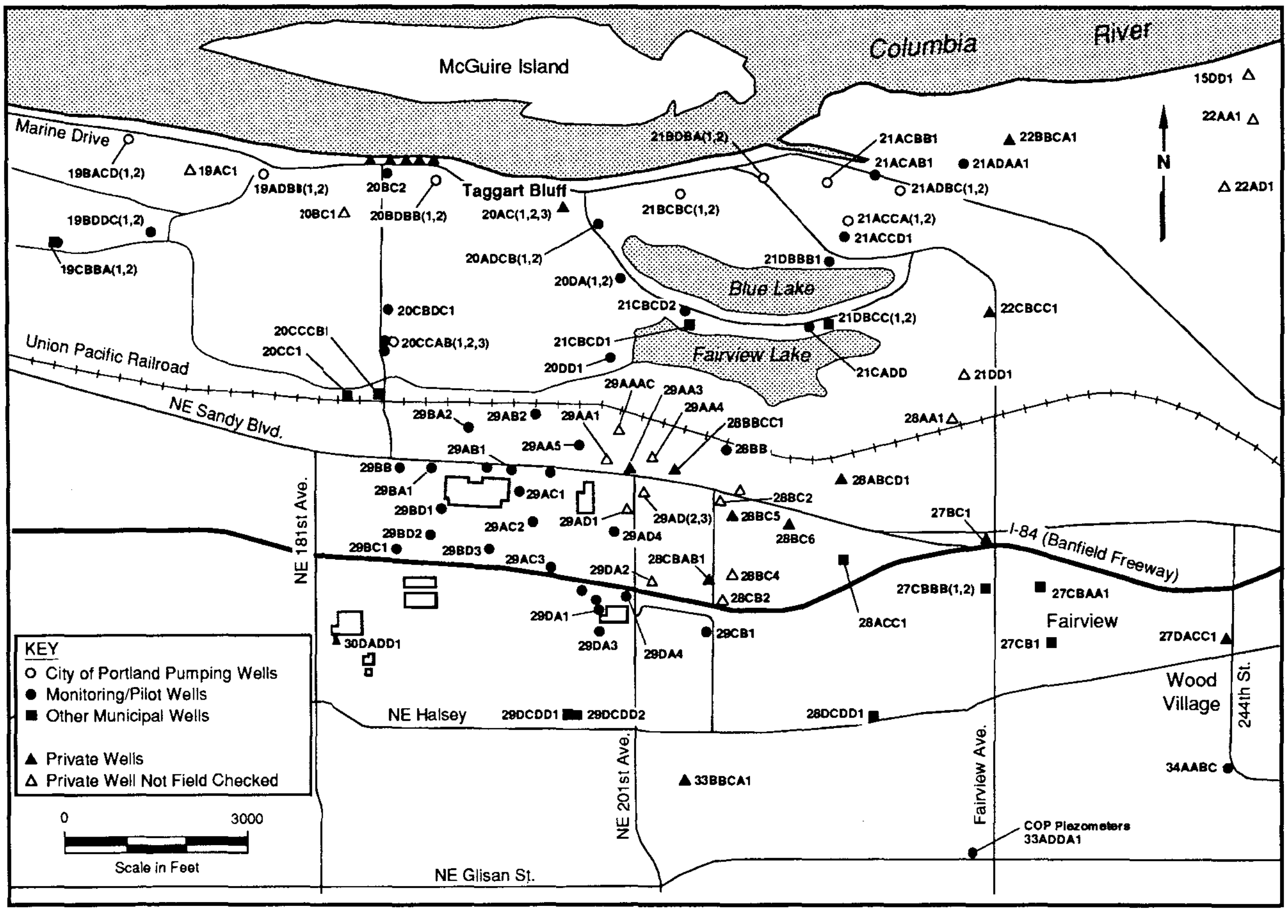


Figure 2. Map of study area with well locations. All well locations are within T. 1 N., R. 3 E.

Davis (1987) conducted gravity surveys along the Lacamas Creek and Sandy River lineaments. He showed that these lineaments are faults and characterized them as linear zones of normal and/or grabenlike failure with displacements approaching 300 m (984 ft). Davis suggested a "dextral stepover" between the Lacamas Creek and Sandy River lineaments, which would be characteristic of dextral step within a dextral strike-slip fault zone.

Hydrogeologic investigations

Hogenson and Foxworthy (1965) broadly defined rock units and their water-bearing characteristics in the east Portland area. Their general description of the Troutdale Formation follows Trimble's work. However, their interpretations of well logs near Fairview (Figure 2) include an overlying gravel deposit significantly younger than and not part of the Troutdale Formation. This gravel, which we identify as Pleistocene-age gravel, comprises an extensive geologic unit along the Columbia River and forms the major portion of the Troutdale gravel aquifer in east Multnomah County.

Willis (1977, 1978) further delineated and defined the hydrogeology of the study area during the development of the City of Portland's well field (Figure 3). He identified three aquifers and two aquitards within what he considered to be the Troutdale Formation and Sandy River Mudstone. Willis (1977) referenced Trimble's 1963 paper and described an "upper section" containing primarily conglomerates and a "lower section" containing primarily vitric sandstones, clays, and siltstone in the Troutdale Formation. He correlated the gravels that comprise the Troutdale gravel aquifer with the "upper section" of the Troutdale Formation. Willis correlated hydrogeologic units below the Troutdale gravel aquifer to the "lower section" of the Troutdale Formation and the Sandy River Mudstone. We find that Trimble (1963) did not divide the Troutdale Formation in this manner and that there is no real basis for this correlation. Willis (1977, 1978) also described a Pleistocene paleochannel cut by an ancestral Columbia River and filled by gravel forming the Blue Lake gravel aquifer.

Hoffstetter (1984) continued Willis' work on the subsurface geology in the Portland well field. He also assigned the gravel of the Troutdale gravel aquifer to the Troutdale Formation but extended the age of the Formation into the Pleistocene. Hartford and McFarland (1989) mapped the lithology, thickness, and extent of hydrogeologic units underlying the east Portland area.

STRATIGRAPHY AND GEOLOGIC UNITS

Continued evaluation of regional geologic events and development of fluvial facies models and a better understanding of the processes influencing the evolution of the ancestral Columbia River system have resulted in a revision of the depositional environments for the Troutdale formation and the Sandy River Mudstone. These sediments represent a complex fluvial depositional system resulting from a series of facies changes. Factors influencing deposition of the Troutdale Formation include (1) Cascadian basaltic volcanism producing a series of lava flows that repeatedly entered the ancestral Columbia River and were phreatically brecciated (source of vitric-lithic sands); (2) deposition of the vitric sands within the Portland Basin by a range of fluvial regimes (e.g., hyperconcentrated flood-flow to a normal river dominated by sandy bed load); (3) cyclic loss of the normal, coarse-clastic bed load of the ancestral Columbia due to ponding of the river further east, when the upper Ringold Forma-

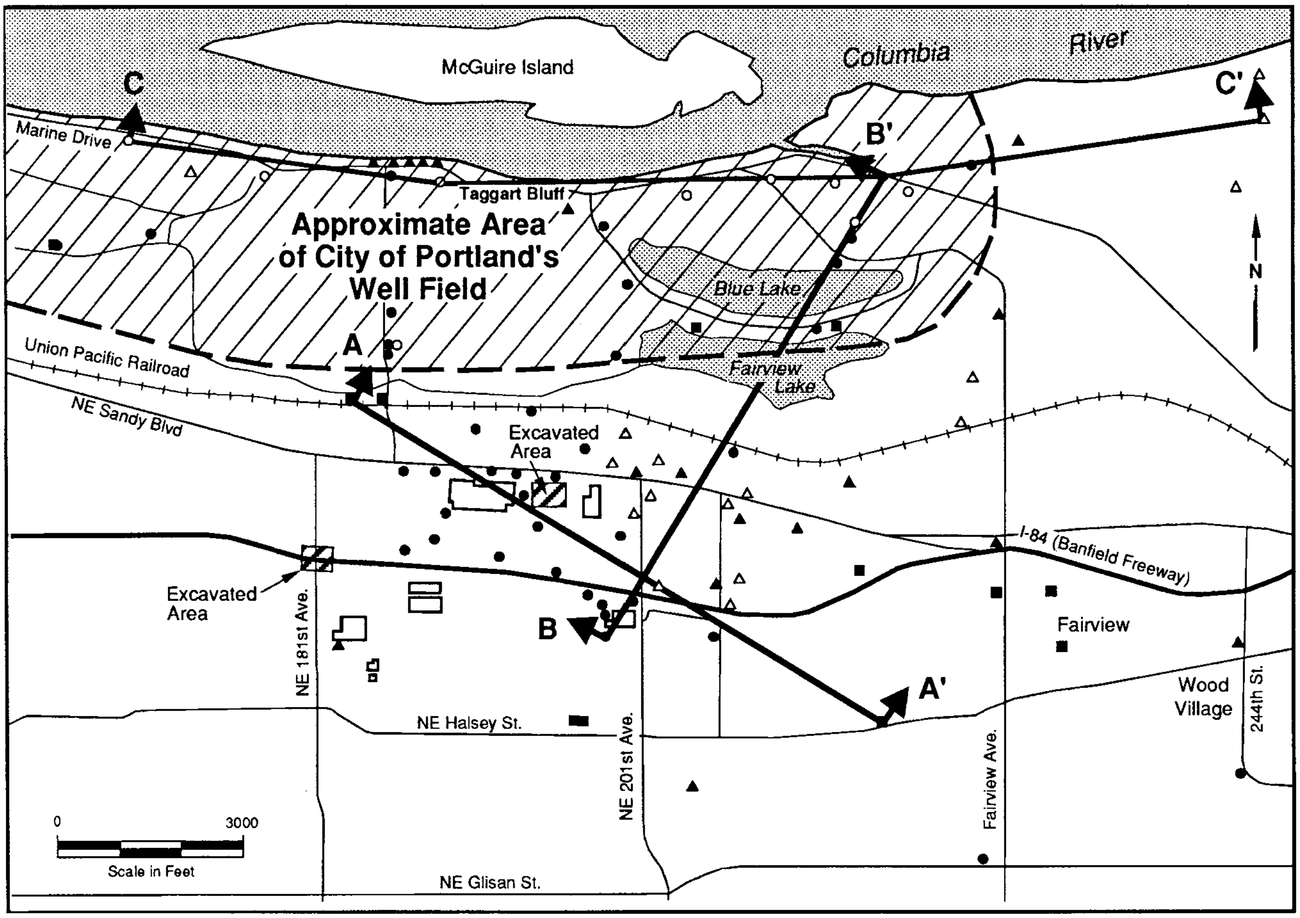


Figure 3. Cross section location map showing part of the City of Portland's well field and excavated areas along NE 181st Avenue and NE Sandy Boulevard. Excavation work occurred during the spring and summer of 1990.

tion in the Pasco Basin area was deposited (Smith and others, 1989); and (4) continued subsidence of the Portland Basin.

Previous investigations near the study area have generally divided the stratigraphic section into (from youngest to oldest) Quaternary systems, the Troutdale Formation, and the Sandy River Mudstone. In this paper, we separate the section into Holocene flood-plain deposits (alluvium), Blue Lake gravel, Pleistocene gravel (subdivided into Pleistocene gravel unit 1 and Pleistocene gravel unit 2), and Troutdale Formation (subdivided into siltstone unit 1, sandstone-conglomerate unit 1, siltstone unit 2, sandstone-conglomerate unit 2, and the Sandy River Mudstone). Recent mapping in the Portland area has challenged the validity of separating the Sandy River Mudstone from the Troutdale Formation (I.P. Madin, Oregon Department of Geology and Mineral Industries, personal communication, 1992). In this paper, we consider the Sandy River Mudstone a facies equivalent to the lower member of the ancestral Columbia River facies of the Troutdale Formation, as described by Tolan and Beeson (1984). The geologic units addressed in this paper and their relationship to hydrogeologic units are shown in Figure 4.

Flood-plain deposits

Recent flood-plain deposits from the Columbia River cover older units along the margins of the existing river. Flood-plain deposits consist of tan to gray, micaceous, sandy silt to silty, fine sand with some gravel. These sediments attain thicknesses as great as 95 ft near the Columbia River.

Blue Lake gravel

The Blue Lake gravels are coarse-clastic sediments filling a deep channel incised by an ancestral Columbia River. Hartford and McFarland (1989) indicate that this unit is comprised primarily of boulder-, cobble-, and pebble-sized clasts in a minor matrix of clayey to sandy silt, which is clast supported. They describe the gravel composition as primarily basalt with some quartzite, granite, and diorite. Thickness of the Blue Lake gravels ranges from 50 to over 200 ft. When saturated, these gravels form the Blue Lake gravel aquifer.

Pleistocene gravel

In the study area, Pleistocene gravels can be subdivided into at least two mappable units. We informally refer to these units as Pleistocene gravel unit 1 and Pleistocene gravel unit 2. Hydrogeologic investigations in the vicinity have used the names "unconsolidated gravel aquifer" and "Troutdale gravel aquifer" when discussing these units (Figure 4). Clast composition and size, massive bedding with matrix-supported clasts, and stratigraphic position suggest that these deposits are related to flooding events associated with Pleistocene outburst floods from glacial Lake Missoula.

Pleistocene gravel unit 1

Pleistocene gravel unit 1 correlates to Trimble's (1963) gravelly phase of the catastrophic flooding events. This unit is isolated in pockets along the present Columbia River flood plain and lower river terraces and may be present as silt deposits forming a veneer on the river terraces farther away from the river. The unit consists of fine to coarse and micaceous silty gravel, sandy gravel, gravelly sand, and silt and contains pebbles, cobbles, and occasional large boulders, which are matrix supported. Clast composition is primarily subrounded to well-rounded basalt with quartzite and granitic rocks (Trimble, 1963). In addition to basalt, large boulders of the Troutdale Formation were also observed in the study area. Cementation in the gravel varies from none to moderate. The thickness of Pleistocene gravel unit 1 ranges up to over 100 ft. The composition of this gravel is similar to that found in Pleistocene gravel unit 2, making it difficult to distinguish in well logs. In some logs, however, Pleistocene gravel unit 1 may be distinguished by the presence of large boulders within and of a clayey surface below the unit (at the top of Pleistocene gravel unit 2).

In the study area, Pleistocene gravel unit 1 was observed in outcrop unconformably overlying Pleistocene gravel unit 2 (Figure 5).

Pleistocene gravel unit 2

Pleistocene gravel unit 2 forms an extensive geologic unit that can be traced in well logs beyond the study area toward the east and west. When saturated, this unit forms the major portion of the Troutdale gravel aquifer (Figure 4).

Most of Pleistocene gravel unit 2 consists of subrounded to well-rounded, fine to coarse and micaceous sandy gravel and silty gravel, with occasional boulders and thin lenses of fine sand and silty sand. Clast composition is primarily basaltic with quartzite and other metamorphic, volcanic, and plutonic rocks, which are matrix supported (Figure 6). Clast composition is similar to conglomerates found in the Troutdale Formation. Clasts of vitric sandstone are also occasionally found, which suggests that some of the deposit is reworked Troutdale Formation. Cementation of the gravel varies from none to moderate. Well logs in the study area indicate that the thickness of Pleistocene gravel unit 2 ranges up to 250 ft.

Well logs from the southeast portion of the study area indicate a red or brown clayey silt, probably at the top of Pleistocene gravel unit 2. This clayey silt was observed in outcrop along NE 181st Avenue (Figure 3) during the recent expansion of the Banfield Expressway (Interstate I-84). The unit contained decomposed and highly weathered pebbles and cobbles. The unit can be traced southeast of the outcrop with certainty only in nearby wells but could extend farther east and west. The red clayey silt is not reported in well logs to the north along the lower terraces and the Columbia River and is assumed to have been removed by erosion.

Cross sections and field observations indicate that the contact between Pleistocene gravel unit 2 and the top of the Troutdale Formation is an angular unconformity. This contact was observed in outcrop during excavation activities along NE Sandy Boulevard in Gresham, Oregon (Figure 7). Pleistocene gravel unit 2 was found

SYSTEM	SERIES	GEOLOGIC SYMBOL (1)		GEOLOGIC UNIT (1)	HYDROGEOLOGIC UNIT (2)
Quaternary		Qa		Alluvium	
Quaternary	Pleistocene	Qbl		Blue Lake Gravels	Blue Lake Gravel Aquifer
Quaternary	Pleistocene	Qg1		Pleistocene Gravel Unit 1	Troutdale Gravel Aquifer
Quaternary	Pleistocene	Qg2		Pleistocene Gravel Unit 2	Troutdale Gravel Aquifer
Tertiary	Pliocene	Ttst1	Troutdale Formation (1)	Siltstone Unit 1	Confining Unit 1
Tertiary	Pliocene	Ttsc1 Ttss1 / Ttcg1	Troutdale Formation (1)	Sandstone-Conglomerate Unit 1 Sandstone Unit 1 Conglomerate Unit 1	Troutdale Sandstone Aquifer
Tertiary	Pliocene	Ttst2	Troutdale Formation (1)	Siltstone Unit 2	Confining Unit 2
Tertiary	Pliocene	Ttsc2 Ttst3	Troutdale Formation (1)	Sandstone-Conglomerate Unit 2 Siltstone Unit 3	Sand and Gravel Aquifer or Sandy River Mudstone Aquifer (3)
Tertiary	Pliocene	Ttsr	Troutdale Formation (1)	Sandy River Mudstone	
Tertiary	Miocene				

Figure 4. Generalized stratigraphy for the Blue Lake area with key to geologic symbols used in cross sections and maps and including equivalent hydrogeologic units. Modified from Trimble (1963), Willis (1977, 1978), and Hartford and McFarland (1989). Notes: (1) Geology used in this study. (2) Hydrogeology from Hartford and McFarland (1989). (3) Hydrogeology from Willis (1977, 1978).

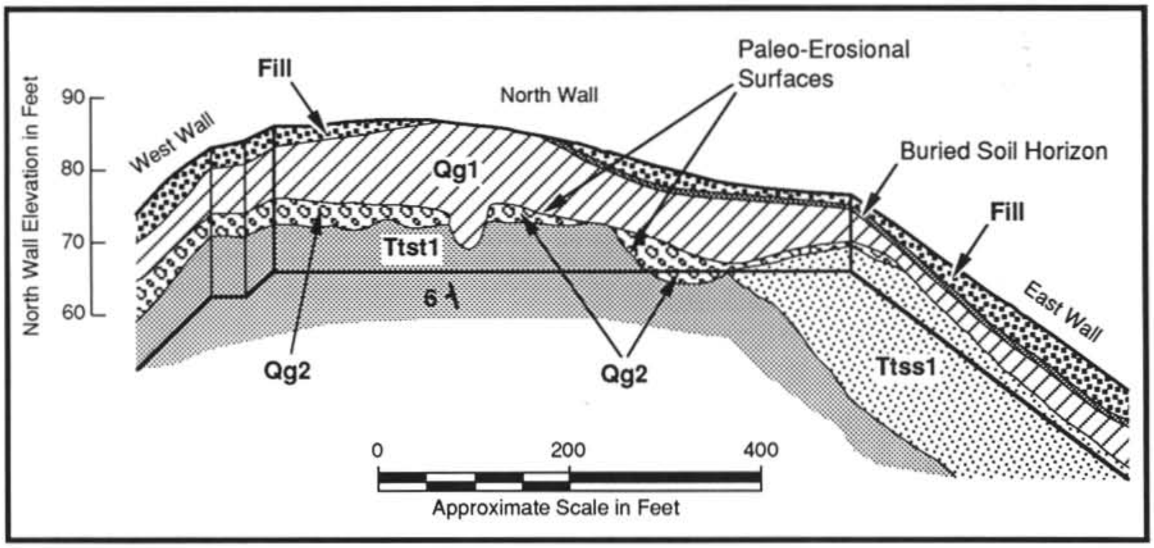


Figure 5. Fence diagram of excavated area along NE Sandy Boulevard (see Figure 3 for location). Qg1= Pleistocene gravel unit 1; Qg2= Pleistocene gravel unit 2; Ttst1= siltstone unit 1; Tss1= sandstone unit 1. In contrast to underlying units, Pleistocene gravel unit 2 is not deformed and unweathered and thickens significantly toward the west. Pleistocene gravel unit 2 was also found to be overlying portions of a major erosional surface located at the top of the Troutdale Formation. These relations indicate an angular unconformity between Pleistocene gravel unit 2 (Qg2) and siltstone unit 1 (Ttst1).

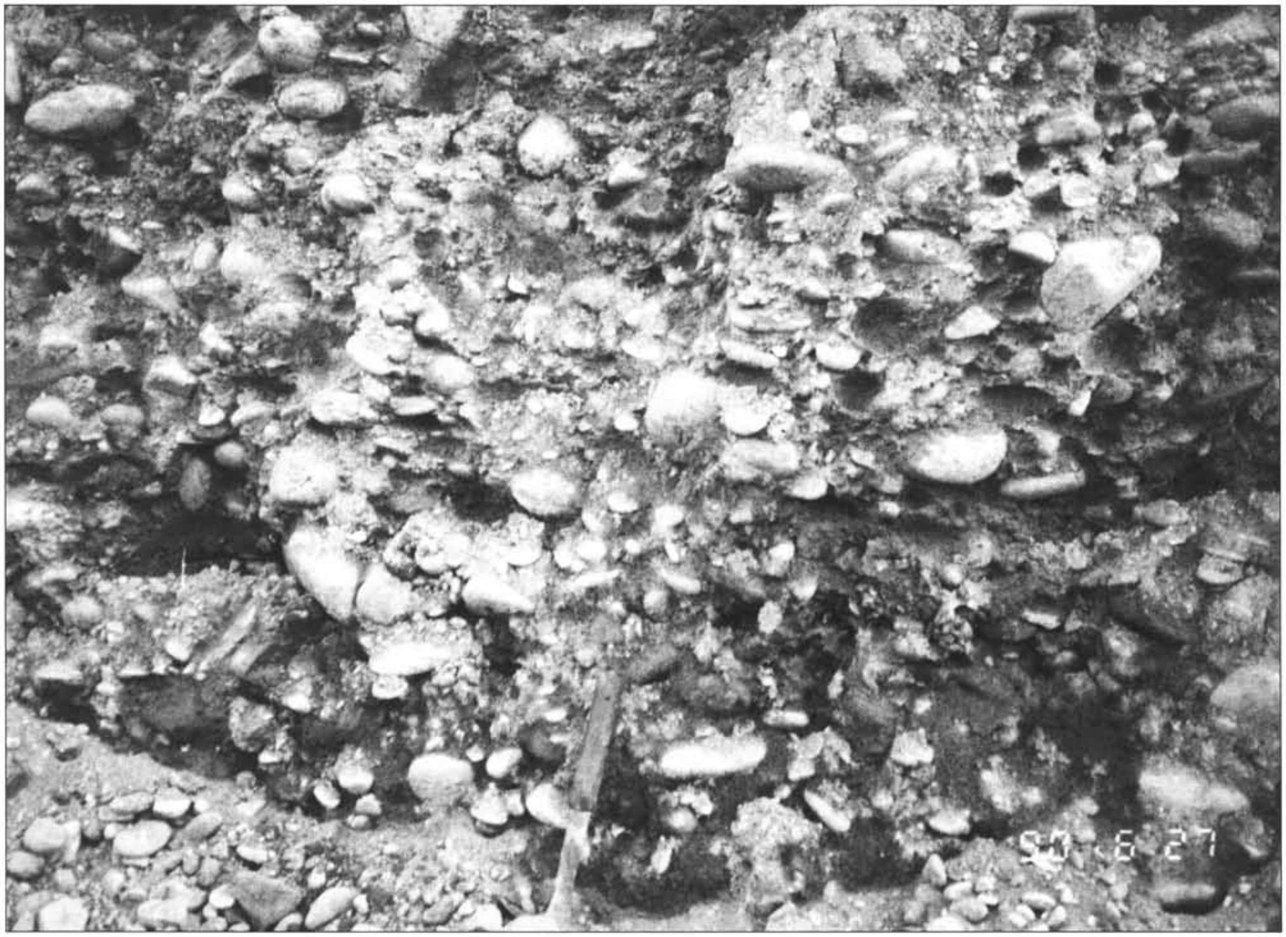


Figure 7. Unconformable contacts exposed during construction activities along NE Sandy Boulevard (see Figure 2 for location). Lower contact is the angular unconformity between Pleistocene gravel unit 2 and the underlying Troutdale Formation. Unit designations are the same as in Figure 5.

overlying portions of a major erosional surface at the top of the Troutdale Formation.

Troutdale Formation

Within the Blue Lake Park area, the Troutdale Formation can be subdivided into five mappable units, informally referred to as siltstone unit 1, sandstone-conglomerate unit 1, siltstone unit 2, sandstone-conglomerate unit 2, and Sandy River Mudstone.

Siltstone unit 1

We consider siltstone unit 1 to be the top of the Troutdale Formation in the study area, based on the following evidence:

- The presence of vitric sandstone associated with the onset of high-alumina basaltic volcanism, which is a diagnostic feature of the Troutdale Formation; vitric sandstone is generally not found in Pleistocene gravel unit 2 or other overlying units.
- The absence of deformation in the overlying units.
- The absence of weathering immediately above the unit.
- The unconformable contact with the overlying units.

Siltstone unit 1 consists of tan, brown, and blue-gray, micaceous, clayey siltstone with organic matter, interbedded with black to tan, vitric-lithic sandstone. The sandstone tends to occur near the top and bottom of the unit and is similar in composition to the sandstone found in sandstone-conglomerate unit 1. We observed deeply weathered sandstone throughout siltstone unit 1. The thickness of siltstone unit 1 ranges up to 120 ft. Hydrogeologically, Hartford and McFarland define siltstone unit 1 as confining unit 1 (see Figure 4).

Figure 8. Eroded surface of sandstone-conglomerate unit 1, typical of outcrops south and east of Blue Lake County Park. Outcrop is located approximately 1,700 ft north of the intersection of 238th Drive and NE Sandy Boulevard.

Sandstone-conglomerate unit 1

Underlying siltstone unit 1 is sandstone-conglomerate unit 1 (Figure 8). Sandstone comprises the upper portion of this unit near the center of the study area. It consists of moderately cemented, black, vitric (sideromelane), medium to coarse sand with basaltic conglomerate lenses. Local alteration of vitric sand to clay (palagonite) forms the cementing agent (Trimble, 1963). Thickness for the sandstone portion of this unit varies from 40 to 80 ft.

The conglomerate underlying the sandstone is clast supported and consists of weakly to moderately cemented, vitric-lithic to arkosic, sandy basalt with quartzite and other metamorphic, volcanic, and plutonic pebbles and cobbles and also includes some thin lenses of blue or gray clayey siltstone and vitric sandstone. Conglomerate thickness varies from 40 to 90 ft. In the southeast portion of the study area, the unit becomes primarily conglomerate. A discontinuous siltstone unit up to 18 ft thick is also sometimes present between the sandstone and conglomerate portions of sandstone-conglomerate unit 1. When saturated, this unit forms the Troutdale sandstone aquifer (see Figure 4).

Sandstone-conglomerate unit 1 crops out at numerous locations in the eastern portion of the study area. We measured bedding attitudes at several outcrops and incorporated these data into the structure-contour maps. All outcrops of this unit examined in the study area displayed an erosional surface with little weathering.

Siltstone unit 2

Underlying the sandstone-conglomerate unit 1 is siltstone unit 2. Siltstone unit 2 is lithologically similar to siltstone unit 1. It consists of a blue-gray, micaceous clayey silt with organic matter and sandstone interbeds. Thickness of this unit ranges to over 100 ft. Hydrogeologically, this unit forms confining unit 2 (see Figure 4).

Sandstone-conglomerate unit 2

Underlying siltstone unit 2 is sandstone-conglomerate unit 2. Lithologically, this unit is somewhat similar to sandstone-conglomerate unit 1 but contains more conglomerate, more frequent interbedding of siltstone, and more interbedded siltstone near the base of the unit. Swanson (1986) identified the geochemical signature of vitric sandstone within this unit, indicating its affinity with the Troutdale Formation. The finer sediments near the base of the unit make it difficult to determine the boundary between sandstone-conglomerate unit 2 and the underlying Sandy River Mudstone. Thickness may be as much as 500 ft in the study area, but few wells have penetrated the unit. When saturated, sandstone-conglomerate unit 2 forms the sand and gravel aquifer (see Figure 4).

Sandy River Mudstone

Underlying sandstone-conglomerate unit 2 is the Sandy River Mudstone. The unit consists primarily of clayey siltstone and sandstone but may also contain some conglomerate. The Sandy River Mudstone unconformably overlies the Columbia River Basalt Group and other volcanic units (Trimble 1963).

STRUCTURE

We further defined structural deformation of the study area through cross sections and structure-contour maps. Structure-contour maps of selected stratigraphic contacts are shown in Figures 9 and 10. Cross section lines are shown in Figure 3. These figures indicate that the structure of the study area is the result of several processes, including folding, faulting, and possibly fluvial channel incision.

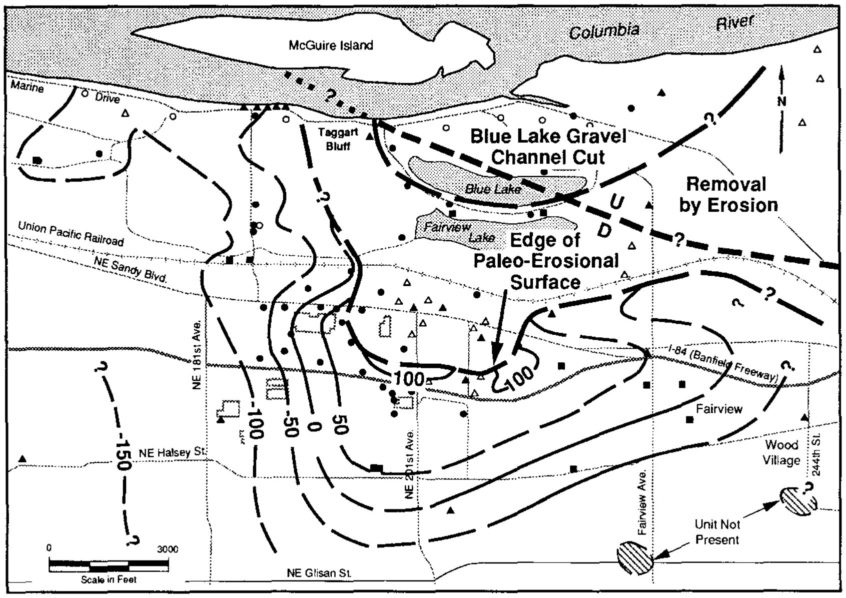


Figure 9. Structure-contour map of top of siltstone unit 1. This unit was partially or completely removed by erosion where indicated ("paleo-erosional surface").

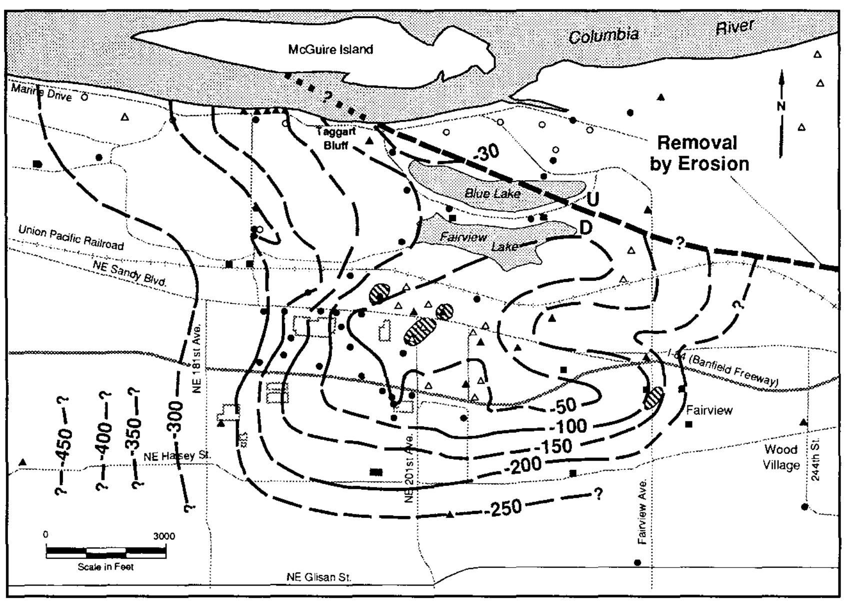


Figure 10. Structure-contour map of top of siltstone unit 2. This unit was removed by erosion north of the fault trace and is interpreted to be missing by channel incision near center of figure (hatched areas on map).

Folding

We conclude from well log data that the Troutdale Formation was folded into a large dome. Structure-contour maps of the top of siltstone unit 1 (Figure 9) and siltstone unit 2 (Figure 10) show the dome forming a structural high centered just south of Blue Lake. The upper portions of the Troutdale Formation (i.e., siltstone unit 1 and sandstone-conglomerate unit 1) have been severely eroded along the northeast flank of the structural high. This erosion presumably occurred during the catastrophic flooding events associated with Pleistocene-age glacial Lake Missoula. Figure 9 shows the lateral extent of this paleo-erosional surface.

Well logs show a general thickening trend in the Troutdale Formation toward the south and west of the study area, which may be related to contemporaneous basin deformation and fluvial deposition. The folding of the Troutdale units together in the study area (Figures 11, 12, and 13) suggests that basin deformation continued after the Troutdale Formation was deposited.

Faulting

Well log and natural gamma log data suggest a fault underlying the Blue Lake gravel north of Blue Lake. Erosion and deposition of Blue Lake gravel and flood-plain deposits apparently removed or covered any surface expression of the fault trace. Vertical offset, defined by the stratigraphy described in well logs, increases along the fault trace toward the northwest to as much as 500 ft. This faulting probably influenced the lateral migration of the ancestral Columbia River as it incised its channel.

Figure 9 shows the estimated trend of the fault. The cross sections shown in Figures 12 and 13 intersect this feature. The fault trace is bounded to the south by outcrops of sandstone-conglomerate unit 1. The northern extent of the fault trace is bounded by bore hole data from wells that penetrated beyond the Blue Lake gravel into what we infer as strata from either the lower portion of sandstone-conglomerate unit 2 or from the upper boundary of the Sandy River Mudstone.

At well 21DBBB1 (Figure 2), sediments below the Blue Lake gravel do not display the characteristic gamma signatures of siltstone unit 1, sandstone-conglomerate unit 1, or siltstone unit 2 seen in gamma logs from wells 20BDBB1, 20CBDC1, and 20CCAB3. However, well 21DBBB1 gamma signatures below the Blue Lake gravel can be correlated to a section near the boundary between sandstone-conglomerate unit 2 and Sandy River Mudstone seen in wells 20CBDC1 and 33ADDA1 (Figure 14). Data from the well 20CBDC1 indicate that the stratigraphic distance between siltstone unit 2 (south of the fault trace) and the boundary between sandstone-conglomerate unit 2 and Sandy River Mudstone (north of the fault trace) is approximately 500 ft. Figure 13 shows that, due to vertical offset, these units are at almost the same elevation near the fault trace. Well log descriptions of sediments underlying the Blue Lake gravel and locations farther east further support this interpretation (wells 21ADAA1, 22BBCA1, 22AA1, and 22AD1, for example). These sediments best correlate to the lower portion of sandstone-conglomerate unit 2 or the upper portion of the Sandy River Mudstone.

During excavation activities along NE Sandy Boulevard (Figure 3), we observed numerous conjugate fault sets near the top of sandstone-conglomerate unit 1 near the structural high. Slickenside features were also observed in siltstone unit 1 and sandstone-conglomerate unit 1 in this same area. These features are indicative of the expansion expected near the top of a structural high.

Channel incision

Well logs indicate that both siltstone unit 1 and siltstone unit 2 are locally absent within the study area. The relatively uniform

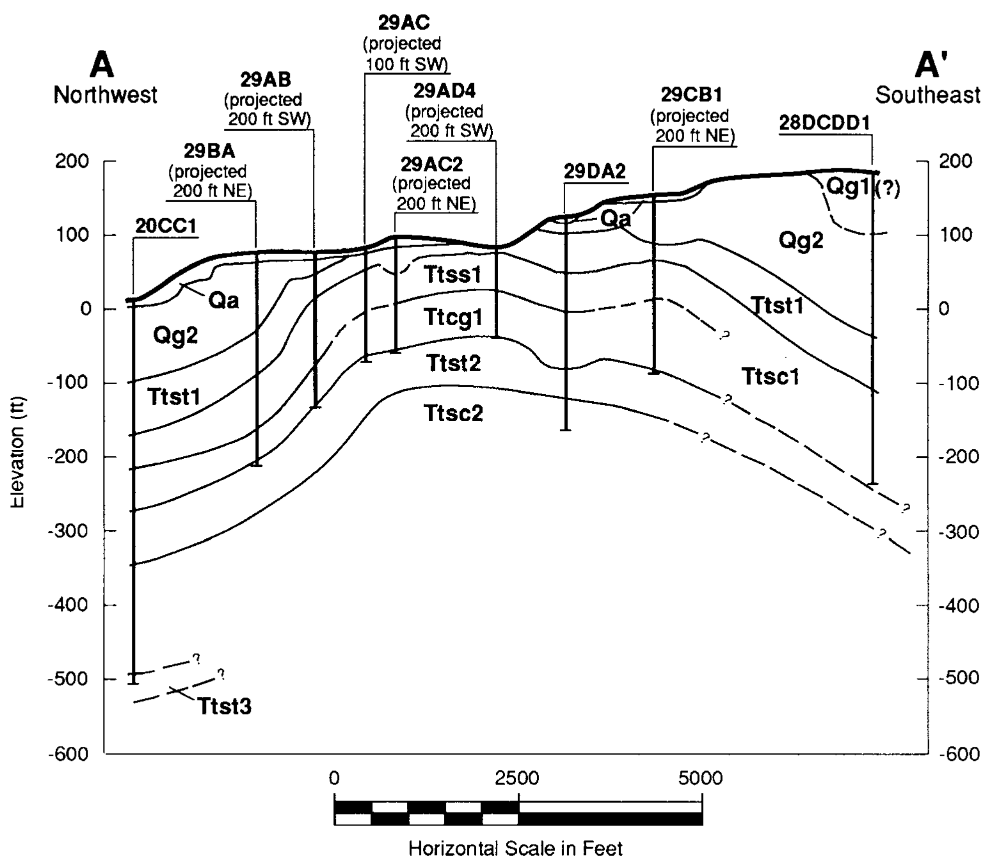
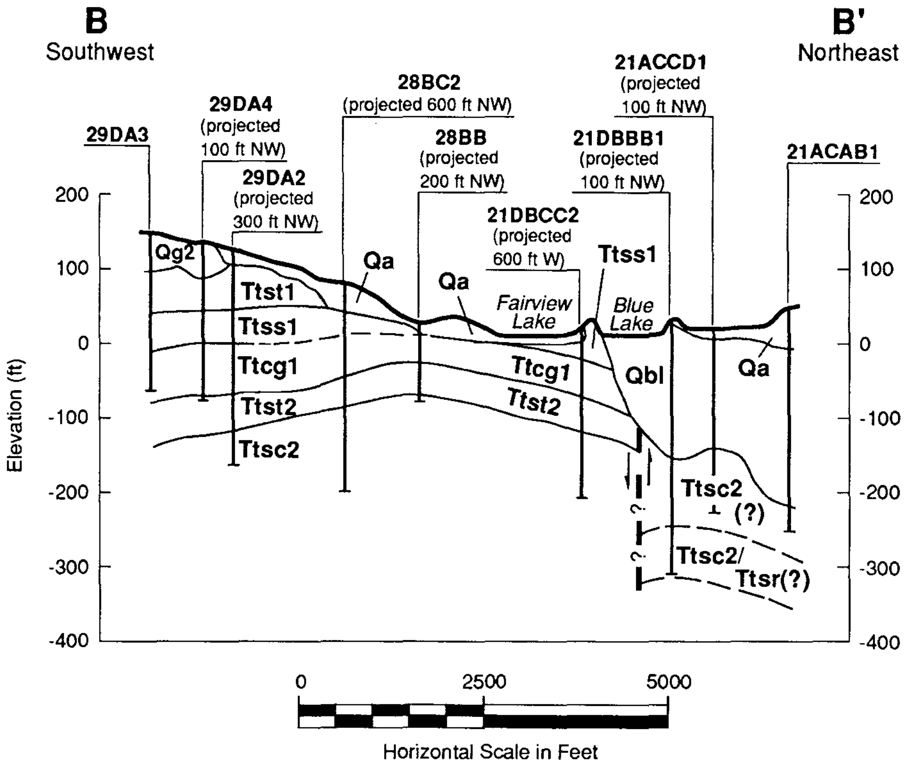
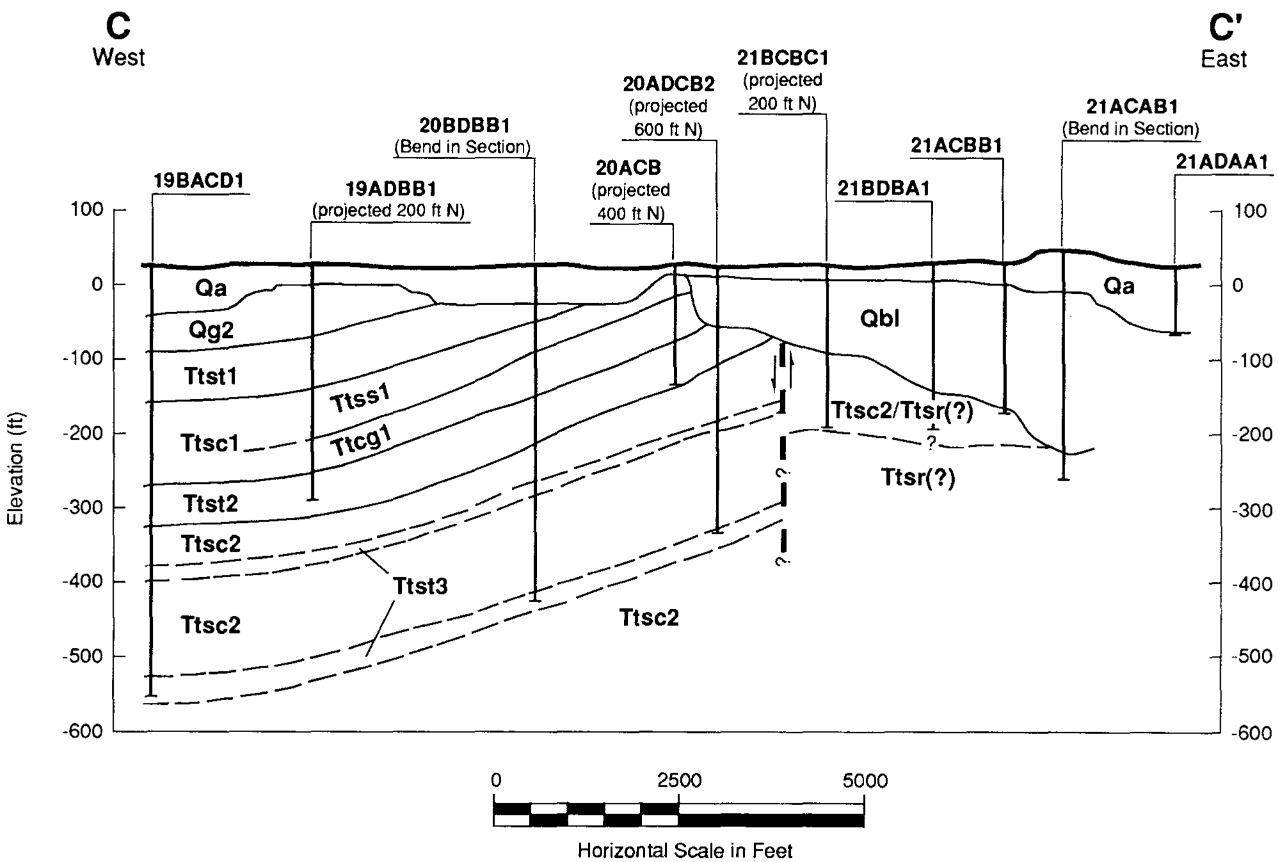


Figure 11. Cross section A-A′ as shown in Figure 3. Qa = alluvium; Qg1 = Pleistocene gravel unit 1; Qg2 = Pleistocene gravel unit 2; Ttst1 = siltstone unit 1; Ttss1 = sandstone unit 1; Ttcg1 = conglomerate unit 1; Ttst2 = siltstone unit 2; Ttsc2 = sandstone-conglomerate unit 2; Ttst3 = siltstone unit 3.



Left:

Figure 12. Cross section B-B′ as shown in Figure 3. Qa = alluvium; Qbl = Blue Lake gravel; Qg2 = Pleistocene gravel unit 2; Ttst1 = siltstone unit 1; Ttss1 = sandstone unit 1; Ttcg1 = conglomerate unit 1; Ttst2 = siltstone unit 2; Ttsc2 = sandstone-conglomerate unit 2; Ttsr = Sandy River Mudstone.



Bottom:

Figure 13. Cross section C-C′ as shown in Figure 3. Qa = alluvium; Qbl = Blue Lake gravel; Qg2 = Pleistocene gravel unit 2; Ttst1 = siltstone unit 1; Ttsc1 = sandstone-conglomerate unit 1; Ttss1 = sandstone unit 1; Ttcg1 = conglomerate unit 1; Ttst2 = siltstone unit 2; Ttsc2 = sandstone-conglomerate unit 2; Ttst3 = siltstone unit 3; Ttsr = Sandy River Mudstone.

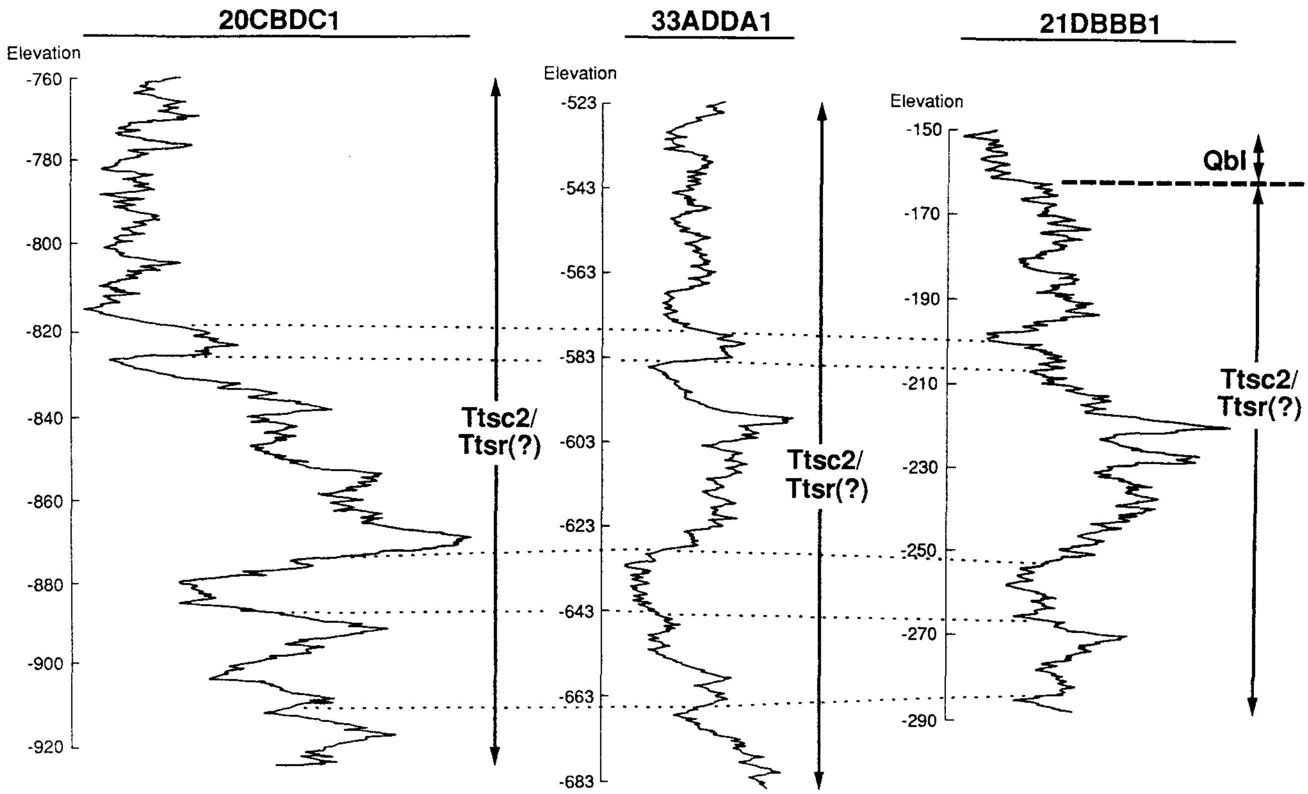


Figure 14. Natural gamma logs showing correlation of bottom of sandstone-conglomerate unit 2 and top of Sandy River Mudstone from three well locations. Dotted lines represent gamma correlations. Increasing radiation is from left to right. Elevations are in feet, mean sea level. Qbl = Blue Lake gravel; Ttsc2 = sandstone-conglomerate unit 2; Ttsr = Sandy River Mudstone. See Figure 2 for well locations.

thickness of mappable units within the Troutdale Formation, coupled with the apparent folding of these units, suggests that the absence of the siltstone units is the result of erosion rather than nondeposition. Based on the presence of the siltstone units at some locations and absence at other nearby locations (e.g., wells 29AD1 and 29AD4, wells 29AD2 and 29AD3, wells 27CBBB1 and 27CBBB2) (Figure 2), we conclude that siltstone units 1 and 2 were partially or completely eroded by channel incision during different erosional events. The channel associated with siltstone unit 2 near the structural high appears to have been filled with conglomerate from sandstone-conglomerate unit 1. Similarly, channels eroded into siltstone unit 1 have been filled with Pleistocene-age gravel or silt deposits.

We observed fluvial cut and fill features and erosional surfaces in the Troutdale Formation in outcrops both inside (Figure 5) and outside the study area (outcrops along the lower Sandy River).

SUMMARY

Through surface and subsurface mapping of the geology in the Blue Lake vicinity, we have identified a number of geologic processes that have combined to form complex stratigraphic and structural relationships within the Troutdale Formation and overlying sediments. Based on these relationships, we have divided the stratigraphy in the study area into flood-plain deposits, Blue Lake gravel, Pleistocene gravel units 1 and 2, and Troutdale Formation.

Evidence from outcrops and well logs indicates that the top of Pleistocene gravel unit 2 was weathered to a red or brown clayey silt that contains decomposed gravel. The presence of this weathered surface suggests that Pleistocene gravel unit 1 is a significantly younger deposit than Pleistocene gravel unit 2. The presence of boulders and matrix-supported clasts in massive bedding of Pleistocene gravel deposits appears to be related to the flooding events associated with Pleistocene outburst floods from glacial Lake Missoula.

Cross sections and field observations indicate that the contact between Pleistocene gravel unit 2 and the underlying Troutdale Formation is an angular unconformity, with Pleistocene gravel unit 2 thickening to the west. Siltstone unit 1, observed in outcrops, is deeply weathered, structurally deformed (fractured), eroded, and overlain by unweathered Pleistocene gravel unit 2 (Figure 5). In addition to the weathering contrast, Pleistocene gravel unit 2 was not structurally deformed and overall appears to be less indurated than the Troutdale Formation. We consider siltstone unit 1 to be the top of the Troutdale Formation in the study area because it contains vitric sandstones, which are not present in Pleistocene gravel unit 2 or any other overlying deposit, and because of the presence of the angular unconformity at the contact with Pleistocene gravel unit 2 or other overlying deposits.

Well log data indicate that the Troutdale Formation was folded into a large dome that forms a structural high near the center of the study area. Subsequent erosion has removed all of siltstone unit 1 and part of sandstone-conglomerate unit 1 along the northeast flank of the dome prior to the deposition of Pleistocene gravel unit 2. Much of this erosion may have occurred during Pleistocene outburst floods from glacial Lake Missoula.

Information from natural gamma logs and other well logs indicates that the northeast portion of the dome has been cut by a northwest-trending fault. Vertical displacement along the fault increases to the northwest to as much as 500 ft. Erosion has removed the upper units of the Troutdale Formation north of the fault trace, and the deep channel incision now occupied by the Blue Lake gravel removed the remaining Troutdale Formation to a point near the boundary between sandstone-conglomerate unit 2 and the Sandy River Mudstone. The fault probably influenced the lateral migration of the channel cut that is now occupied by the Blue Lake gravel.

The variation in presence or absence of siltstone units 1 and 2 at well locations that are in close proximity to each other suggests lateral discontinuities that may have been formed by fluvial channel incision during different erosional events. Well log data indicate that these channels were filled with conglomerate and gravels similar to the overlying units (i.e., sandstone-conglomerate unit 1 and Pleistocene gravel units 1 and 2).

Post-Troutdale deformation, Pleistocene deposition, weathering, and erosion have complicated the stratigraphy in the study area. However, most of the Troutdale Formation and overlying sediment seem to correlate with other parts of the Portland Basin. Whether the major deformation occurring in the study area resulted from a localized event or was caused by other forces during the continued formation of the east Portland Basin is not clear. More detailed mapping and examination of well log data will be needed for a more complete stratigraphic and structural model of the east Portland Basin.

ACKNOWLEDGMENTS

The authors wish to thank Landau Associates, Inc., and the Boeing Company for their support. The authors also thank Terry Tolan, Marvin Beeson, and Rod Swanson for their help during the review process. We also wish to thank Linda Schwarz and Kim Reading for their work on the figures and John Leder, Anna Templin, and Brian Butler for their encouragement.

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NEW DOGAMI PUBLICATIONS

Geology and mineral resources map of the Shady Cove quadrangle, Jackson County, Oregon, by Frank R. Hladky, has been published as map GMS-52. Price is $6.

The two-color geologic map (scale 1:24,000) is accompanied by geologic cross sections and brief discussions of geologic history, structure, and mineral and water resources. A separate sheet contains tables listing geochemical data.

This map is the second of a series of maps planned to provide hazard and mineral-resource data as well as bedrock geology to aid regional planning in the Medford-Ashland area which is experiencing rapid population growth. A map of the Boswell Mountain quadrangle was published as DOGAMI map GMS-70; and an as yet unpublished map of the Cleveland Ridge quadrangle is available for inspection at the DOGAMI field office in Grants Pass (5375 Monument Drive, phone (503) 476-2496).

Geology and mineral resources map of the Harper quadrangle, Malheur County, Oregon, by Mark L. Ferns and James P. O'Brien, has been published as map GMS-69. Price is $5.

Geology and mineral resources map of the Little Valley quadrangle, Malheur County, Oregon, by Howard C. Brooks and James P. O'Brien, has been published as map GMS-72. Price is $5.

The two-color maps (scale 1:24,000) also include geologic cross sections, tables with geochemical data, and brief discussions of geology and resources. The resource potential includes hot-spring-type gold, silica sand, diatomite, and other nonmetallic minerals.

The maps are part of a cooperative effort to map the 1° by 2° Boise sheet in eastern Oregon. In addition the publication of these and earlier maps in this 64-quadrangle project, a group of 20 unpublished quadrangle maps has been placed on open file in the Portland and Baker City offices of DOGAMI.

Geologic map of the Camas Valley quadrangle, Douglas and Coos Counties, Oregon, by Gerald L. Black and George R. Priest, has been published as map GMS-76. Price is $6.

The two-color map (scale 1:24,000) is accompanied by three geologic cross sections. A separate four-page text contains discussions of the geologic history, structural geology, and hydrocarbon potential of the quadrangle. A similar map was published earlier for the adjacent Reston quadrangle as DOGAMI map GMS-68.

The new maps are now available at the Nature of Oregon Information Center, Suite 177, State Office Building, 800 NE Oregon Street #5, Portland, Oregon 97232-2109, phone (503) 731-4444. Orders may be charged to credit cards by mail, FAX, or phone. FAX number is (503) 731-4066. Orders under $50 require prepayment except for credit-card orders. Purchase by mail and over the counter is also possible at the DOGAMI field offices: 1831 First Street, Baker City, OR 97814, phone (503) 523-3133; and 5375 Monument Drive, Grants Pass, OR 97526, phone (503) 476-2496. □

USGS Director steps down

Secretary of the Interior Bruce Babbitt announced in mid-April that he has accepted, with regrets, the decision of Dallas Peck, Director of the U.S. Geological Survey (USGS), to step down from his post after a distinguished federal career spanning more than four decades, including 12 years as Director of the Survey. Peck, an internationally known authority on volcanism and the geology of California and the Pacific Northwest, will return to full-time research at the USGS. He will stay on as Director of the USGS until a successor is named. The director of the USGS has traditionally been appointed by the President from nominations provided by the National Academy of Sciences (NAS). Secretary Babbitt has begun the process of consulting with NAS about the selection of a new director.

—USGS news release

Ancient caldera complex revealed

From a news release issued by the Oregon Department of Geology and Mineral Industries, Grants Pass office, Frank R. Hladky and Thomas J. Wiley, geologists

Rocks of an ancient caldera complex are exposed 30 mi north of Medford. The southern margin of this volcanic feature was identified by geologists of the Oregon Department of Geology and Mineral Industries (DOGAMI), who were mapping the geology of the McLeod and Trail quadrangles in Jackson County. Calderas are large, circular volcanic basins such as Crater Lake or Yellowstone. The igneous rocks beneath a caldera are referred to as a caldera complex.

The caldera complex is located 4 mi north of Lost Creek Lake along the upper reaches of Elk Creek in the Western Cascades. It is comprised mostly of silicic rocks, generally rhyodacitic in composition, that define a chaotic assemblage of dikes, sills, stocks, vent breccias, and tuffs several miles across. U.S. Geological Survey (USGS) scientists led by James G. Smith reconnoitered the area during the late 1970s and determined that broad sheets of ash-flow tuff had been erupted 28 to 25 million years ago during late Oligocene time. They also mapped silicic intrusive stocks along the upper reaches of Elk Creek and the Rogue-Umpqua divide. Stocks originate as large bodies of viscous igneous magma that migrate upward through the Earth's crust and sometimes breach the surface. The field evidence led the USGS geologists to first suspect the existence of a large caldera complex.

DOGAMI's new, more detailed mapping confirmed the presence of a caldera complex of great size and locally delineated its southern margin. The new mapping is sufficiently detailed to differentiate between the chaotic collage of silicic tuffs, dikes, and breccias, which is indicative of intracaldera rocks, and bedded ash-flow tuffs, which are indicative of extracaldera rocks.

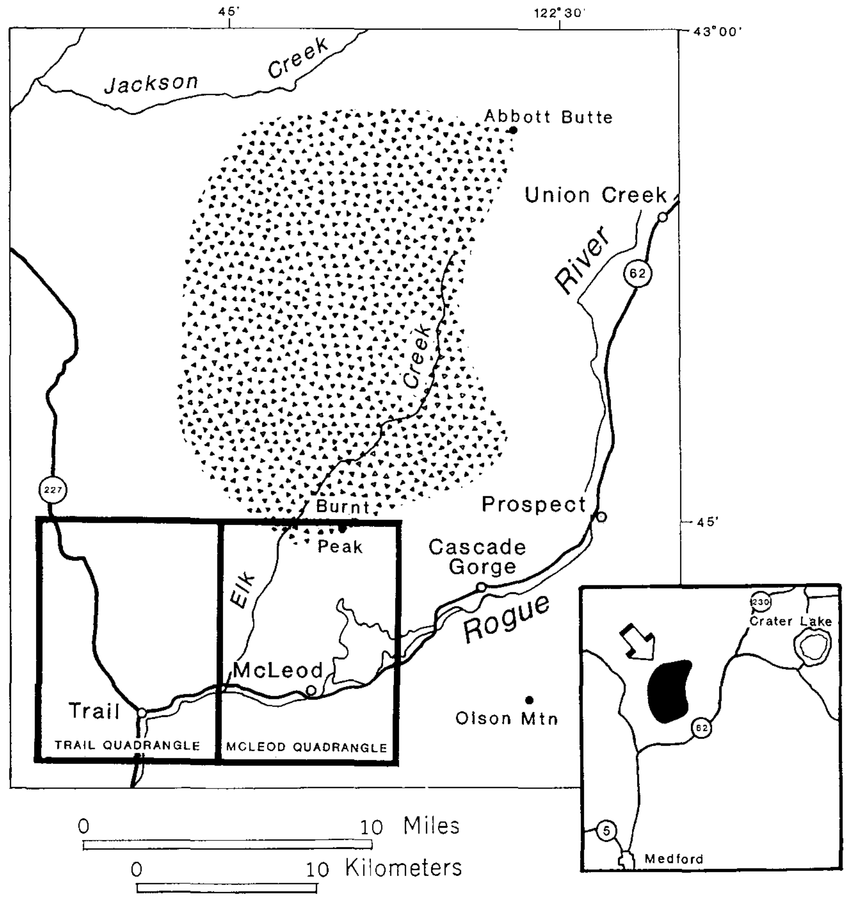

Figure 1. Sketch map showing location of caldera complex (patterned area), including relation to the quadrangles DOGAMI geologists have been mapping.

The size of the caldera complex has not yet been fully determined. Similar rocks, however, have been found to crop out in an area of roughly oval shape that extends approximately 15 mi north-south and 10 mi east-west. Further study will also be required to determine whether this tract of silicic rocks represents a single caldera system or several.

The original caldera shape has been nearly obliterated by 25 million years of erosion and burial by younger volcanic rocks. In most places, the rocks of the caldera complex have deteriorated from millions of years of weathering. Basalt and andesite lava flows have covered much of the caldera complex, especially on its east side. Thick soil, landslides, and dense vegetation have obscured many of the rocks of the caldera complex. These conditions have hampered efforts to map the caldera complex. Other conditions, however, have helped geologists: Elk Creek and its tributaries have cut deeply into the volcanic structure for perhaps millions of years; the Burnt Peak forest fire of 1987 removed large tracts of vegetation north of Burnt Peak; and logging roads have cut through the soil cover of mountain slopes.

Caldera complexes sometimes contain bodies of metal ore, originally deposited from hydrothermal fluids. USGS geochemists sampled the area during the late 1970s and early 1980s and determined that many of the rocks within the caldera complex were mineralized. DOGAMI geologists also found evidence of hydrothermal alteration in rocks of the caldera complex, this time near the old Burnt Peak lookout. Located 8 mi northeast Burnt Peak, the old Al Sarena gold and silver mine is thought to lie within the caldera complex. Between 1909 and 1918, the Al Sarena mine produced precious metals then valued at $24,000. Two years ago, the Al Sarena mine was redrilled and sampled by the Fisher-Watt Gold Company. Although the company decided not to pursue exploration any further, company geologists did identify as much as 2 million tons of low-grade ore containing gold, silver, and lead. □

Culbertson reappointed to Board

Ronald K. Culbertson, member and currently chairman of the Board of the Oregon Department of Geology and Mineral Industries, has been reappointed to another term on the Board by Governor Roberts, and the reappointment has been confirmed by the Oregon Senate. Culbertson's new term in this position will extend until mid-1996. □

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