The Scotts Mills, Oregon, Earthquake on March 25, 1993

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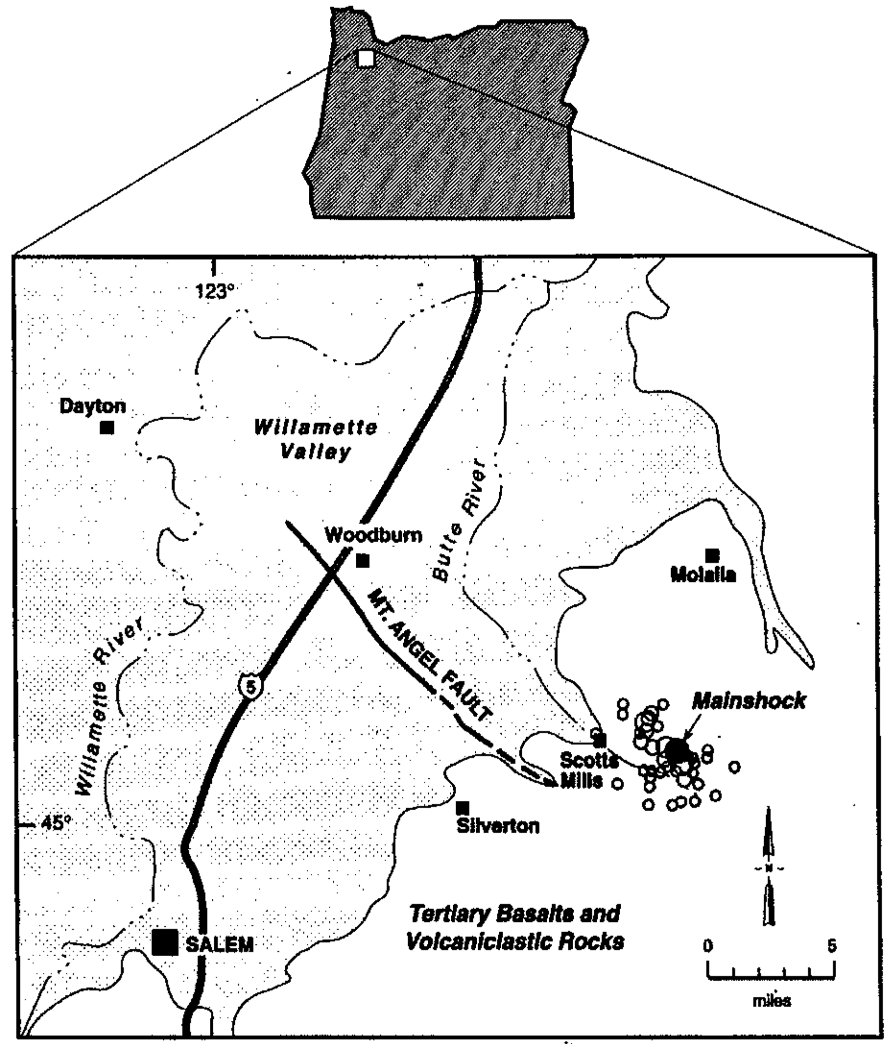
At 5:34 a.m. on March 25, 1993, much of northwestern Oregon and southwestern Washington was shaken by one of the largest historic earthquakes ever observed in the region. The Richter magnitude 5.6 earthquake occurred near the small town of Scotts Mills, 48 km south of Portland, Oregon. The March 25 earthquake was felt over a large part of the Pacific Northwest extending from Seattle, Washington, in the north to the town of Roseburg in southern Oregon. Due in large part to the moderate size of the event and its location in a rural setting, only minor injuries occurred, principally from falling objects and broken glass. However, the significance of the earthquake is clear. It reminded the people of southwestern Washington and northwestern Oregon that they are not immune from earthquake hazards.

Earthquakes in Northwest Oregon

Although it is not well known, the area centered on Portland, Oregon, is one of the more seismically active areas in the Pacific Northwest. Examination of the area's 150-year-long earthquake history reveals that six earthquakes of magnitude 5 or greater have occurred in the Portland area. Prior to the Scotts Mills earthquake, the largest known earthquake in the area was a widely felt, magnitude 5.5 earthquake on November 5, 1962. This earthquake, which caused minor damage in Portland, shook much of western Oregon and Washington.

The Scotts Mills earthquake in northwestern Oregon was centered near the eastern margin of the Willamette Valley. This valley and the adjacent Cascade Range are geologically linked to the convergence of the Juan de Fuca plate and the North American plate off the coast of Oregon. In this region, the Juan de Fuca and North American plates, individual elements in a network of rigid, 100-km-thick plates that form the earth's outer shell, are converging at an annual rate of a few centimeters per year. The plates collide about 100 km off the coast, creating the elongate Cascadia subduction zone. At this convergent boundary, the Juan de Fuca plate bends downward and slides beneath the less dense North American plate. The descending, or subducting, Juan de Fuca plate dips eastward beneath Oregon at a very gentle angle (≈ 13°). As it glides beneath the eastern edge of the



Location map:The Scotts Mills Earthquake in northwestern Oregon on March 25, 1993.

Fallen brick gable at Molalla High School resulting from the earthquake in northwestern Oregon on March 25, 1993.

Willamette Valley, the uppermost part of this sinking, lithospheric slab may be more than 45 km deep. However, evidence of its existence can be seen at the surface. The active volcanoes of the Cascade Range are the most striking result of the presence of the subducted plate. Buoyant bodies of melted rock from the subducting plate rise toward the surface to become sources of volcanic activity in the Cascades. The Willamette Valley, a less obvious example, is essentially a structural sag above the sinking slab. Due to tremendous stresses above the descending Juan de Fuca plate, the brittle failure of rock (earthquakes) occurs within the overriding North American plate. These stresses may have ultimately caused the Scotts Mills earthquake.

The fault contact between the subducting Juan de Fuca plate and the overriding North American plate is a special type of fault called a megathrust. Because they encompass extremely large surface areas, subduction zone megathrusts are capable of generating very powerful earthquakes. Many of the world's most devastating earthquakes have been associated with megathrusts. Speculation concerning the possibility of a great earthquake on the Cascadia megathrust has aroused great interest on the part of many geologists and other earth scientists.

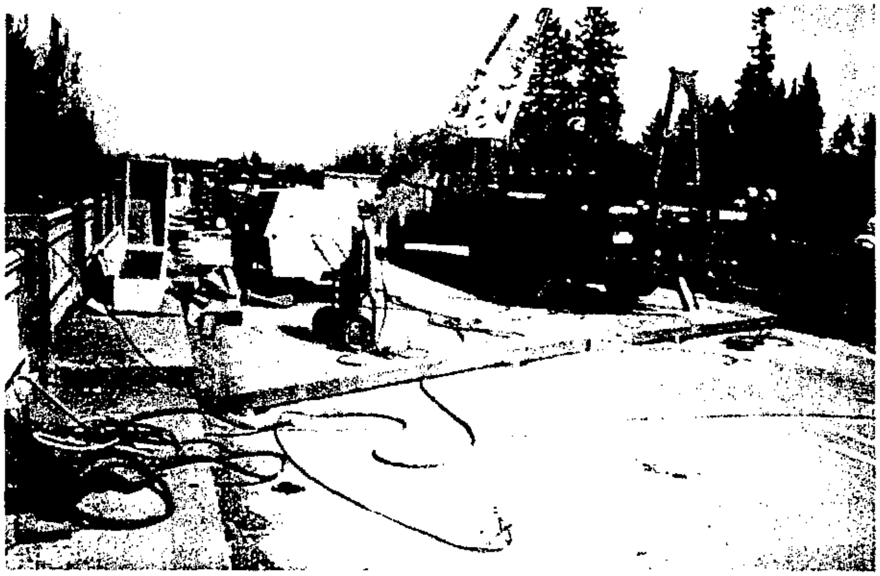
In the two months following the Scotts Mills mainshock, more than 100 aftershocks were recorded by a regional seismographic network in Washington and northern Oregon operated by the University of Washington. The largest aftershock had a magnitude of 3.2. Within two days after the mainshock, scientists from the U.S. Geological Survey, University of Oregon, and Oregon State University deployed portable seismographs in the epicentral region to provide additional coverage. Over a period of several weeks these close-in instruments recorded many more smaller aftershocks. As indicated on the accompanying plot, the mainshock and aftershock epicenters are clustered about 6 km east of the southern end of the Mount Angel fault. The associated hypocenters are about 15 km deep. Little is known about the Mount Angel fault; its existence is based principally on seismic reflection data. Small earthquakes near the town of Woodburn in August 1990 have been attributed to movement at the northern end of the Mount Angel fault. To date, no known surface deformation has been documented for the Scotts Mills earthquake; thus the source of the event is still unclear. Apparently, the earthquake did not cause ground failures, such as liquefaction, landslides, or ground cracking. Minor rockfalls were observed in roadcuts near the epicenter.

The hypocenter of an earthquake is the point in the crust where rupture begins. The corresponding epicenter is the projection of this point to the earth's surface.

Earthquake-generating faults are poorly known in western Oregon and Washington due to their general lack of surface expression, possibly because the associated earthquake activity is relatively deep. Although the epicenters of the Scotts Mills earthquakes appear to exhibit a general northwest trend consistent with the strike of the Mount Angel fault, other data are equivocal. Consistent with the epicentral trend, one interpretation is that the earthquake occurred along a north-northwest oriented strike-slip fault. However, data from the University of Washington suggest that mainshock was the result of rupture along an approximately east-west trending reverse fault. The resolution of this apparent ambiguity will have to await further data analysis of the aftershock sequence.

Although the estimated hypocentral depth (≈15 km) of the Scotts Mills earthquake is somewhat deep when compared to typical western U.S. earthquakes, it is not unusual for Pacific Northwest earthquakes, which may have focal depths of as much as 30 km. The relatively deep source of the Scotts Mills earthquake may also explain why the event was felt over such a relatively large area.

The Scotts Mills earthquake triggered strong-motion recorders at Detroit Dam, 36 km to the southeast, and



Damaged deck on the Highway 18 bridge over the Yamhill River near Dayton resulting from the earthquake in northwestern Oregon on March 25, 1993.

more distant instruments at Portland State University in Portland and at the Veterans Administration Hospital, Vancouver, Washington. Peak accelerations recorded at ground level at these sites were small—less than 6 percent of gravity. The corresponding estimates of the duration of shaking were as long as 45 seconds.

Structural Effects

Although the Scotts Mills earthquake produced relatively limited damage to buildings, lifelines, and earth structures, the total cost of damage may exceed $20 million. Damage was generally confined to unreinforced masonry (URM) structures. Reports of significant damage included the Highway 18 bridge near Dayton, the high school in Molalla, a church in Mount Angel, and damaged brick chimneys in several other nearby towns. With a few exceptions, most of the damage took place within approximately 20 km of the epicenter near Scotts Mills.

In the towns of Scotts Mills, Woodburn, Mount Angel, Silverton, and Molalla, many chimneys were toppled. The shaking caused shelves to fall and spilled goods at some stores in Woodburn. In Mount Angel, about 10 km northwest of the epicenter, the bell tower also cracked the walls of houses in the Woodburn, Silverton and Molalla areas.

In Molalla, the high school—a three-story, unreinforced-masonry building—lost its chimney and two brick gables. The timing of the earthquake—the earthquake occurred very early in the morning on a weekday during spring break—was fortunate and may have saved lives at the high school. In addition to structural damage to buildings and bridges, glasses and china were broken, and groceries were thrown from shelves in Molalla.

In Salem, 32 km southwest of the epicenter, the rotunda of the State Capitol building was cracked.

Near Dayton, a small town approximately 37 km northwest of the epicenter, a six-span bridge suffered damage which rendered the structure unusable. The southwest deck pulled away from the northeast deck at the separation joint and crushed the bearings on the top of the middle pier. In the town of Dayton, some bricks fell from an old two-story, unreinforced masonry building.

Surprisingly, at least 90 buildings, which were generally of URM construction, suffered some damage in the town of Newberg 45 km from the epicenter. This damage may have been due to local amplification of ground motion at this site.

In the city of Portland, more than 50 km from the epicenter, the earthquake reportedly cracked plaster and foundations.

Future Earthquakes

The earthquake on the March 26, 1993, was a not-so-subtle reminder to the residents of western Oregon that they live in earthquake country. Recent paleoseismic investigations have demonstrated that the coastal regions of Oregon and Washington have experienced very large, prehistoric earthquakes. Some of these earthquakes were in the magnitude 8-9 range, possibly representing rupture along the megathrust between the Juan de Fuca and North American plates. A repeat of such an earthquake could be catastrophic for the western, coastal portions of these states. If such an earthquake occurs, these areas will be subject to severe ground shaking, liquefaction, landslides, and possibly a tsunami. In addition, crustal earthquakes larger than the Scotts Mills earthquake occur in much of North America. Such shocks may represent even a greater hazard to ington (an earthquake of this category occurred recently, see sidebar). The Scotts Mills earthquake will provide an impetus to new scientific research improving our understanding of earthquakes in the Pacific Northwest. It is also hoped that the earthquake will stimulate government agencies, the engineering community, and more importantly, residents of the region to deal realistically with seismic hazards.

Acknowledgments

We wish to thank all those who graciously contributed to this brief account of the Scotts Mills earthquake. These investigators include scientists and engineers associated with, in no particular order, the University of Washington, the University of Oregon, Boise State University, the Oregon Department of Geology and Mineral Industries, and the U.S. Geological Survey.

Update: More Earthquakes in Oregon

A series of earthquakes, including a pair of mainshocks, ach of which was stronger than the Scotts Mills earthquake, truck the Klamath Falls area in southern Oregon on September :0, 1993.The first mainshock measured 5.9 on the Richter scale nd the second strong earthquake, which occurred about 2 ours later, had a magnitude of 6.0. The September earthquakes aused $ 7–8 million damage in the Klamath Falls area. During ne of the earthquakes, a rock slide triggered by ground shak-ng killed a motorist. Another person had a fatal heart attack.

The next issue of *Earthquakes & Volcanoes* will contain etailed accounts of the Klamath Falls earthquakes.

March–April 1993

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Worldwide, only one major earthquake (7.0≤M<8.0) occurred during this reporting period. This earthquake, a magnitude 7.2 shock, struck the Santa Cruz Islands region in the South Pacific on March 6. Earthquake-related deaths occurred in the Fiji Islands, China, and Peru.

In the United States, Oregon experienced a moderate earthquake on March 25, which caused injuries and some damage. Sharp earthquakes struck western Arizona on April 25 and April 29.

Missouri

Missouri experienced several small earthquakes during this reporting period. The first occurred on March 1 at 6:29 p.m. CST. This magnitude 3.1 earthquake was centered about 20 km south-southeast of Sikeston. Intensity MM IV effects were noted at East Prairie, Kewanee, and Lilbourn; MM III effects were noted at Matthews and New Madrid. The earthquake was also felt at Portageville.

On March 29 at 9:37 a.m. CST, a very minor earthquake struck the same general area in Missouri. This magnitude 2.7 tremor was felt at Catron.

A magnitude 3.3 earthquake occurred on March 31 at 2:23 p.m. CST. Centered about 20 km east-southeast of Sikeston, this earthquake produced intensity MM V effects at East Prairie and MM IV effects at Bertrond. The earthquake was also felt at Anniston, Kewanee, Matthews, Charleston, and Sikeston.

The Cape Girardeau area experienced two very minor earthquakes on April 1, the first at 7:29 p.m. CST and the second at 9:03 p.m. CST. The first earthquake had a magnitude of 2.6. Both were centered about 60 km east-northeast of Sikeston. Both earthquakes were felt at the intensity MM IV level at Cunningham, Kentucky. They were also felt at Kevil, Barlow, and La Center, Kentucky.

On April 28 at 5:40 p.m. CDT, a magnitude 3.6 earthquake shook the New Madrid area. Centered about 20 km north of Dyersburg, Tennessee, this earthquake produced intensity MM IV effects at Bogota, Finley, Lenox, Newbern, and Ridgeley in Tennessee and at Caruthersville in Missouri. The earthquake was felt with lesser intensity at Dyersburg, Somerville, Tigrett, and Trimble in Tennessee and also at Steele in Missouri.

Alaska

A moderate earthquake shook the Alaska Peninsula on March 5 at 12:30 a.m. ADT. This magnitude 5.0 earthquake was centered about 90 km southeast of Cold Bay. Intensity MM IV effects were noted at Cold Bay, King Cove, and Sand Point.

A magnitude 5.3 earthquake struck the Kodiak Island region on April 22 at 4:46 a.m. ADT. The epicenter of this moderate temblor was about 170 km southeast of Kodiak. Intensity MM IV effects were noted at Akhiak and Larsen Bay. The earthquake was felt at Karluk, Kodiak, Chiniak, and Old Harbor.

Santa Cruz Islands

A major earthquake struck this remote region in the South Pacific on March 6 at 2:06 p.m. local time. The magnitude 7.2 earthquake was centered about 250 km east-southeast of Kira Kira, Solomon Islands. No reports of damage were received. The shock was felt at Honiara on Guadalcanal.

Fiji Islands

On March 6 at 10:02 p.m. local time, a strong earthquake struck an area south of the Fiji Islands. This magnitude 6.7 shock