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APRIL—Earthquake and Tsunami Preparedness Month: New K–12 Curriculum for Oregon Schools

IN THIS ISSUE:

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Style is generally that of U.S. Geological Survey publications. (See USGS Suggestions to Authors, 7th ed., 1991, or recent issues of *Oregon Geology*.) Bibliography should be limited to references cited. Authors are responsible for the accuracy of the bibliographic references. Include names of reviewers in the acknowledgments.

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, letters, notices, and meeting announcements should be sent to Klaus Neuendorf, Editor, at the Portland office (address above).

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Cover photo

Teacher Kathy Malarkey and pupil Alisha Karel are working on an exercise during a workshop at the Hatfield Marine Science Center in Newport, testing a new curriculum for earthquake and tsunami preparedness. See article on activities and events for "April—Earthquake and Tsunami Preparedness Month" on page 50.

Roddey joins DOGAMI staff

James Roddey has joined the Oregon Department of Geology and Mineral Industries (DOGAMI) as Community Education Coordinator. He has an extensive background in educational and commercial media including over 20 years of marketing and public relations experience in the television industry. He joins the department from Boise, Idaho, where he was Promotion and Community Relations Manager of KIVI-TV, an ABC affiliate.

Prior to his service in Boise, Roddey worked at Northern Arizona University in Flagstaff, Arizona, where he produced and directed over 60 educational earth-science television programs for The Learning Channel (TLC). "GEONAUTS" was produced in partnership with the National Park Service and included a year-long curriculum for upper elementary students that could be used in conjunction with the twice-weekly television program. "GEONAUTS" explored the geology of the Colorado Plateau and featured many of the national parks in the area, including Grand Canyon National Park, Dinosaur National Monument, Petrified Forest National Park, and Canyonlands National Park.

As partner in the DOGAMI outreach and earthquake teams, Roddey will help the department promote its natural hazards awareness programs, including seismic rehabilitation and education, and landslide and tsunami awareness. "It's exciting to be able to combine my media skills with my love of geology to help the people of Oregon learn about the dynamic environment they live in," said Roddey. "DOGAMI's work has the potential to save lives. I can't think of anything that's more important than that."

Roddey grew up in Atlanta, Georgia, and attended Wofford College in Spartanburg, South Carolina, where he majored in English with a minor in Geology. He notes that Oregon and the Northwest have always intrigued him. "Ever since I visited the Northwest when I was 11 years old, I've wanted to know this area better. Portland makes a great home base for exploring," said Roddey. ☐

Meteorites from the Pacific Northwest

by George E. Mustoe, Geology Department, Western Washington University, Bellingham, WA 98225.

INTRODUCTION

One day, long before Europeans arrived in the Pacific Northwest, the fiery trail of a large meteorite illuminated the skies over southern Oregon. Unlike the distant shooting stars that can be seen on any clear night, the glow in the sky warned of an imminent arrival of a 1,167-kg (1.3-ton) mass of nickel-iron alloy that had once been part of the core of an asteroid. After more than 4 billion years in orbit, the eggshaped object hurtled into our atmosphere at a velocity of somewhere between 11 and 32 km per second. The meteorite's trajectory was toward the lava beds of southern Oregon and northern California, but the object's final resting place was a high mesa near Goose Lake in northern Modoc County, California, only a mile short of the Oregon border.

The meteorite was found on October 13, 1938, by three deer hunters and was recovered the following year by meteorite scientist H.H. Nininger, assisted by three professors from the University of California at Los Angeles, several local residents, and a team of boy scouts. The specimen was loaded onto a sturdy wagon and hauled by four draft horses over 2.5 mi (4 km) of muddy, boulder-strewn trail to reach the nearest road (Figure 1), ultimately headed for the exhibition halls of the National Museum in Washington, D.C. The Goose Lake meteorite is presently the largest meteorite in the Smithsonian's collection (Leonard, 1939).

Oregon's near-miss experience with the Goose Lake meteorite provides an appropriate background for this review of meteorites from the Pacific Northwest, because the state is better known by meteorite enthusi-

Figure 1. Goose Lake, California, meteorite loaded on cart for transport. From Nininger (1972), p. 177.

asts for tales of frustration rather than for happy discoveries. Examples include the Willamette meteorite, which triggered a bitter property-rights dispute that ultimately resulted in the removal of the nation's largest recovered meteorite to the east coast. The well-publicized story of the "lost" Port Orford meteorite has given several generations of Oregonians the hope of another spectacular find, but this legendary discovery now appears to have originated as a hoax (Clarke, 1993).

Disappointments continue to plague meteorite hunters: a spectacular fireball and smoke trail marked a meteorite arrival in Grant County on the afternoon of October 23, 1987. Witnesses described a "whomping" sound similar to the noise made by a helicopter, as well as an explosion that probably marked the meteorite's disintegration during its final passage through the atmosphere. The flight path was established by compass bearings made by a Forest Service archaeologist who happened to be working at a site in the Ochoco Mountains, and a logging crew at Pismire Camp on a ridge northwest of Mount Vernon happened to be almost directly beneath the object when it exploded at an altitude of 18,000 ft (5,500 m). This evidence allowed the impact site to be determined within a few miles. But the steep, forested terrain presents adverse conditions for meteorite hunting, which is made even more difficult by the abundance of black basaltic rocks that camouflage the presence of extraterrestrial arrivals. So far, the meteorite has not been found (Pugh and others, 1989; Norton, 1994). Fireballs are relatively common astronomical events, but meteorites are rarely recovered. Oregon fireballs have been described by Pugh (1982, 1984, 1987, 1993, 1995, 1997); Pugh and Stratton (1991); Pugh and McAfee (1993).

ORIGIN OF METEORITES

The vast majority of meteorites are fragments of asteroids, microplanets that orbit the sun within a series of well-defined belts that are located between Mars and Jupiter. Asteroids were once thought to be pieces of a single planet that broke apart billions of years ago, but the wide range of compositional variations observed in meteorites suggests that they derived from many different parent bodies (McSween, 1987).

Most asteroids travel in the same direction in which the planets in our solar system rotate but along paths that cause them to periodically approach the Earth. These orbital intersections may cause an asteroid to be captured by our planet's gravitational field. *Meteors* are bits of extraterrestrial matter that are accompanied by a blaze of light as they are heated by friction during their transit through the atmosphere. *Meteorites* are objects that actually strike the Earth's surface.

A few meteorites have been discovered that contain trapped gasses resembling the composition of the Martian atmosphere. This suggests that these objects originated as crustal rocks ejected from Mars by large meteorite impacts (Bartusiak, 1981; Vickery and Melosh, 1987). These specimens also show radiometric ages of only about 1.3 billion years, compared to the 4.5 billion years of meteorites derived from asteroids. Among the rarest of all are meteorites are fragments of the moon. Of the more than 10,000 meteorite specimens that have been recovered from Antarctica, eight appear to be of lunar origin.

DISTRIBUTION

Most asteroids travel in orbital planes that are approximately parallel to the Earth's equator. This causes impacts to be somewhat more abundant at middle latitudes than in the polar regions. Otherwise, meteorite impacts have a random distribution pattern, and they occur with surprising frequency. Perhaps 100 to 1,000 tons of extraterrestrial matter strikes our planet each day, mostly in the form of dust-sized particles (Dodd, 1986). Over the past 4.5 billion years, this volume is equivalent to a surface layer about 5 in. (12.7 cm) thick. Meteorites weighing 1 g (0.04 oz) or more arrive at an annual rate of about 8 per square mile, but only a tiny percentage of these are ever discovered. Several hundred meteorites weighing 1 ton or more strike the Earth each year, but most escape detection, partly because 72 percent of the planet is covered by water.

Geography plays an extremely important role in determining the success rate for meteorite recovery. Most meteorites are discovered in prairies, deserts, and other regions that contain few surface rocks. Antarctic glaciers have recently been discovered as particularly favorable collecting locations. Extensive ice sheets provide large areas where cosmic debris accumulates free of rocks. Ice that melts and evaporates in "ablation zones" causes meteorites to be concentrated in a relatively small area, where they are gathered by packs of scientists traveling on snow machines (Marvin and MacPherson, 1992).

Meteorites are susceptible to rapid oxidation, and the combined forces of weathering, erosion, and sedimentation cause most impact craters to be quickly obliterated. Without such geologic processes, the surface of our planet would resemble the Moon or Mercury, two locations where impact craters have been preserved for billions of years (Figure 2).

Meteorites that hit land are likely to be recovered only when they strike densely populated regions, particularly in nations where people have been educated in basic principles of geology and astronomy. This principle is well illustrated by the spectacularly successful efforts of Harvey Nininger, who abandoned his college teaching career to devote his life to searching for meteorites. Over a span of nearly 50 years, Nininger tirelessly spoke at schools, churches, taverns, and any other location

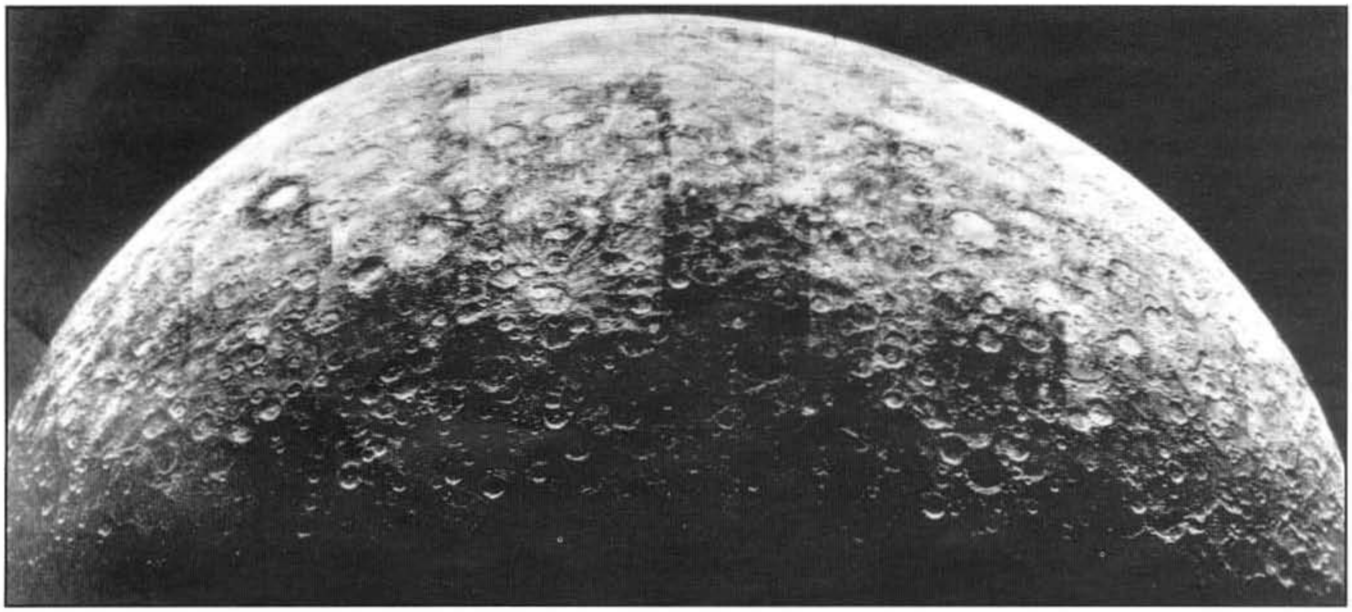


Figure 2. Meteorite impact craters on Mercury. From photos taken March 29, 1974, by the Mariner space probe. The largest craters are 200 km in diameter. Source: National Aeronautics and Space Administration.

where people gathered. Passing around a few specimens, the scientist asked his audience to contact him if they found any odd rocks. As a further reminder, he distributed as many as 200,000 leaflets. These efforts resulted in his acquisition of more than 2,000 meteorites, accompanied by a trove of new scientific information (Nininger, 1972).

On a much smaller scale, then Oregon State Geologist Hollis Dole, science writer Phil Brogan, and Portland State University professor Erwin Lange organized a publicity campaign to declare 1968 "The Year of the Meteorite," in the belief that more specimens might be found in Oregon if residents knew what to look for. This campaign failed to turn up any new meteorites, but the project resulted in the publication of a monograph that is still in print (Oregon Department of Geology and Mineral Industries, 1968). A similar plea by the Washington Division of Geology and Earth Resources produced no new specimens (Moen, 1973). In recent years, Portland science teacher Richard N. Pugh has been a leading investigator in the continuing search for meteorites from the Pacific Northwest.

Figure 3 shows the location of all known meteorite discoveries in the western United States. These data show the effect that geography and demographics have on the statistics of meteorite recovery. A multitude of meteorites probably remains undiscovered in the fields, forests, and deserts of the Pacific Northwest. Most discoveries have occurred in open, arid terrain, particularly in regions like eastern Colorado, where intensive agriculture causes the land to be inspected with great care. In addition, the presence of extensive loess deposits increases the likelihood that chunks of rock might be visitors from space. In contrast, Nevada and Utah both contain large desert areas where meteorites are likely to be preserved, but the scantness of population makes the odds of discovery very low, and the abundance of terrestrial rocks makes the recognition of meteorites difficult.

METEORITE RECOGNITION

Meteorites are seldom easy to recognize except in the rare cases where their arrival has been observed. Even alleged eye-witnessed impacts should not be taken for granted, and the literature contains many examples where nonmeteoritic specimens were collected from "observed" falls. These errors usually result from the failure of witnesses to realize that a meteorite's final impact site may be many miles distant from locations where the vapor trail was visible.

Meteorites can be divided into three main groups: irons, stones, and stony irons. Scientists further divide these categories into many additional subunits on the basis of data that can only be obtained by careful microscopic examination of thin sections (Mason, 1962; Wasson, 1974; Dodd, 1981; Sears, 1978).

As their name suggests, iron meteorites or "siderites" are composed mostly of interlocking crystals of nickel-iron alloy, often containing small inclusions of carbon and sulfur minerals. Iron meteorites are believed to originate within the inner core of asteroids, released when the parent bodies became fragmented during orbital collisions.

Such metallic meteorites are dark in color, strongly attracted to a magnet, and heavy for their size. The exterior surfaces rapidly alter to form a rusty rind. Unfortunately, these same

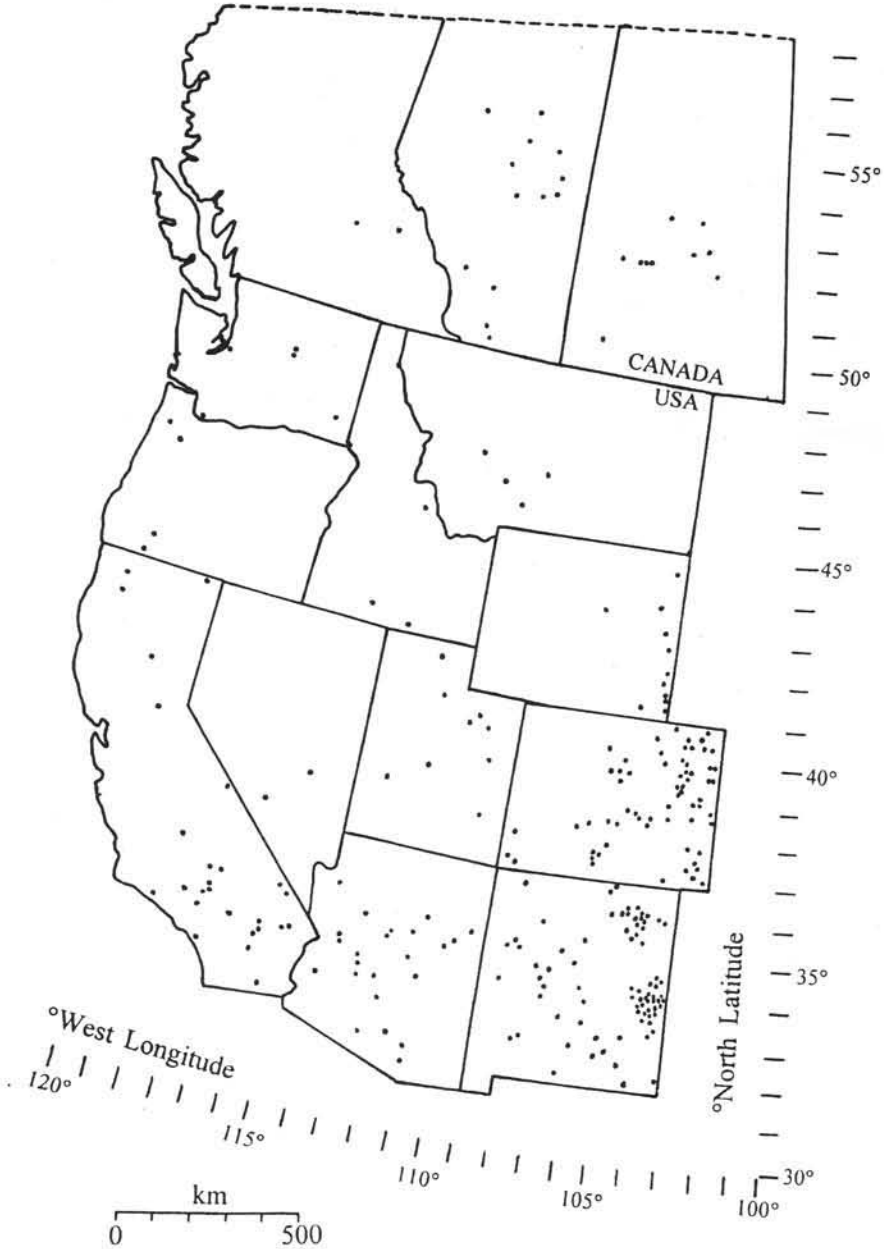


Figure 3. Known meteorite discoveries from the western United States. Data from Graham and others (1985).

characteristics are shared by slag, scrap metal, and some terrestrial iron ores. Metallic meteorites can most reliably be recognized by the presence of nickel, as revealed by chemical analysis. Etching sawn surfaces in dilute nitric acid sometimes reveals complex Widmanstätten patterns, which were created by crystals of kamacite and taenite, two types of nickel-iron alloy. Specimens from Sams Valley, Jackson County, Oregon, provide excellent examples of characteristics typically found in metallic meteorites (Figure 4).

Stony iron meteorites consist of approximately equal mixtures of nickel-iron alloy and crystalline silicates such as olivine and hypersthene. Pallasites are a variety that is particularly prized by collectors. They are composed of pea-sized crystals of olivine enclosed within a matrix of silver-colored metal. The only pallasite that has been reported from the Pacific Northwest is the meteorite fragment allegedly collected in 1856 near Port Orford, Oregon, a specimen now believed to actually have been found in Chile.

Stone meteorites are by far the most common variety to strike the Earth, although they are difficult to recognize because of their resemblance to terrestrial rocks. For example, a 26-kg (57-lb) rock was used as a door stop at Oklahoma's Beaver County jail for more than 40 years before it was identified as a meteorite. These asteroid fragments are primarily composed of mafic and ultramafic silicate minerals with small amounts of nickel-iron metal.

Stone meteorites are easy to identify only if they contain remnants of *fusion crust*, a glassy or sooty coating that forms from frictional heating (Figure 5). Otherwise, these meteorites may look much like various types of terrestrial rock, but magnetism remains a useful clue: Grains of nickel-iron alloy may not be visible to the naked eye, but stony meteorites are attracted to a magnet. Textures are commonly granular, resembling basalt or andesite, but some specimens show well-developed brecciation. Although some metallic meteorites contain rounded holes caused by weathering of inclusions, stony meteorites do not contain cavities, and nonmetallic rocks that show vesicular textures are almost certainly of terrestrial origin.

Careful examination of suspected meteorites by use of a hand lens (or better yet, a petrographic microscope) provides valuable evidence. Stony meteorites typically contain olivine, members of the pyroxene group (hypersthene, enstatite, and bronzite), and small amounts of plagioclase feldspar. Pyrite, mica, hornblende, and orthoclase feldspar do not occur in meteorites, and the presence of these minerals even in small amounts is clear evidence of the specimen's terrestrial origin. Quartz is exceedingly rare, and never present as a major constituent. Many stony meteorites contain *chondrules* (and are then called "chondrites")—tiny

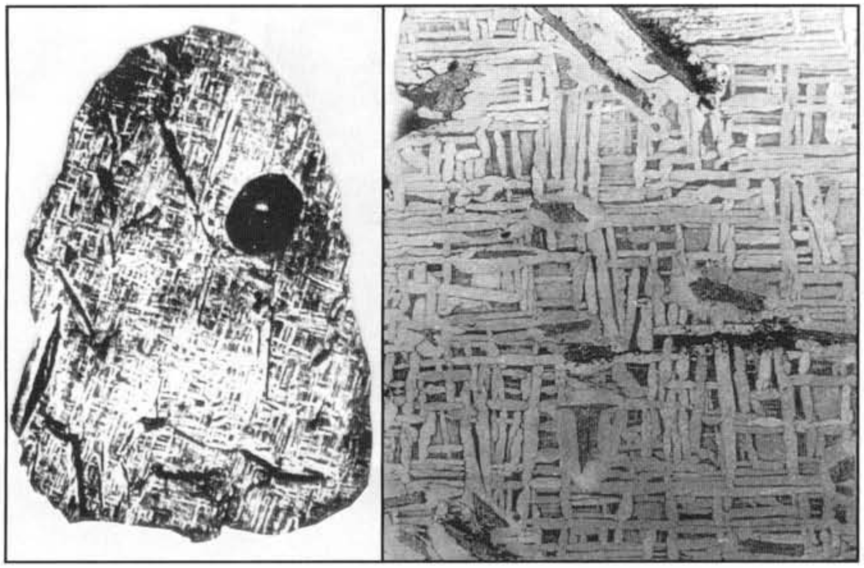


Figure 4. Widmanstätten pattern on etched slice of metallic meteorite from Sams Valley, Oregon. Actual size 12×17 cm. Right: Close-up of etched slab (magnification approximately 4X). Left picture from Foote (1915), right picture from Norton (1994).

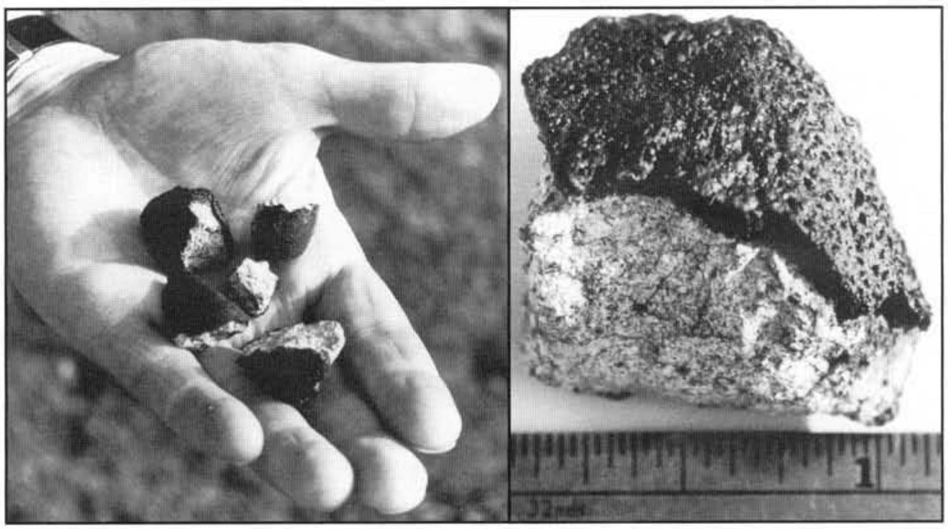


Figure 5. Fusion crust shown on the five recovered fragments of stony meteorite from Salem, Oregon (left), and in close-up view of one of the pieces (right). From Pugh (1983).

spherical grains that may be visible on broken surfaces or polished slabs. Metallic grains of nickel-iron alloy are almost always visible on polished surfaces as tiny silver specks dispersed within the silicate matrix.

Most geologists have little or no training in the recognition of meteorites, and identifications made by local universities or governmental agencies are not always reliable. Instead, meteorite identification is a task that should be left to experts. The appendix lists museums and universities that will identify specimens at no charge. In most cases, these institutions will offer to purchase samples that prove to be meteorites, but collectors need to keep in mind that meteorites legally belong to the person who owns the property on which they were found. Specimens found on state or federal land belong to the government, and legal ownership cannot be acquired by filing a mining claim, as meteorites are not considered to be a type of ore deposit. However, institutions such as the Smithsonian have sometimes been willing to pay finder's fees to people who report discovery of a meteorite on public land.

METEORITE OCCURRENCES IN OREGON

The following list includes alleged meteorite discoveries that have been described in publications ranging from scientific journals to local newspapers.

Willamette meteorite, Clackamas County, Oregon

The Northwest's most important meteorite discovery was made in the autumn of 1902 by Ellis Hughes, a 43-year-old emigrant from Wales. Hughes noticed an unusual rusty outcrop while he was cutting firewood near his farm just northwest of Willamette, a small community that has since been engulfed within the boundaries of West Linn, a Portland suburb. Previous experience as a prospector caused Hughes to believe that the rock was evidence of an ore deposit, and he notified his neighbor, William Dale. Dale pounded on the outcrop with a piece of stone, producing a metallic clang that led the

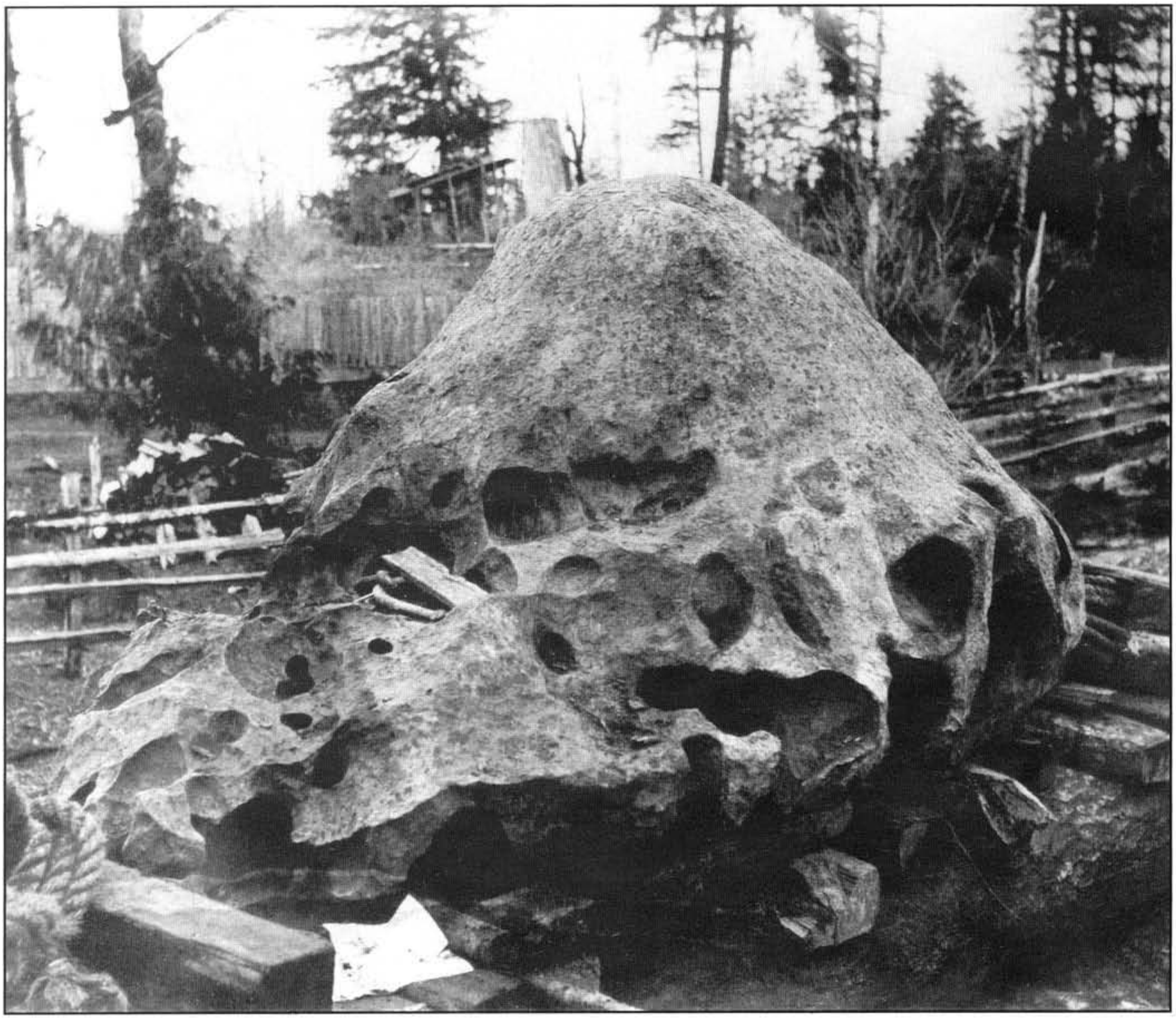


Figure 6. Willamette meteorite in front of the Johnson farm in the town of Willamette, on the southern outskirts of Portland, Oregon, at the time when it was being transported to its current location in New York. Photo by Harold Johnson from cover for Pugh and Allen (1986).

two men to conclude that they had discovered an enormous meteorite (Figure 6). Their excitement was dampened by the fact that the land was owned by the Oregon Iron and Steel Company, and they decided to hide the partially excavated meteorite under a layer of fir boughs, while they concocted a scheme to acquire ownership.

Dale traveled to eastern Oregon to sell a piece of property and thus raise money for purchasing the tract where the meteorite was located, but for reasons that are not clear he failed to return to Willamette. Lacking funds of his own, Hughes decided to transport the meteorite secretly to his farm. This ambitious task required moving the 15.5-ton (14,000-kg) mass three quarters of a mile through dense forest. Aided by his wife and their 15-year-old son, Hughes began excavating the meteorite in August 1902. During fall and winter, they cut a wagon road to the site, also constructing an additional stretch of road in the opposite direction as a distraction. By spring, they were ready to begin transporting the meteorite, using a massive wooden-wheeled cart attached to a hand-braided steel cable that was connected to a crude windlass. A single horse walked in circles around the capstan to provide the locomotion. Progress was tediously slow, on some days amounting to only a few feet; the best day's progress was only 150 ft (46 m). By summer's end, rain turned the path to a sea of mud, requiring construction of a plank road. After months of effort, the meteorite finally reached the Hughes family farmyard, and they attempted to profit from the enterprise by building a display shed and charging visitors 25 cents to view the largest meteorite ever found on United States soil. In North America, the Willamette meteorite is surpassed only by the 59-ton (54,000-kg) Ahnigito meteorite found at Cape York, West Greenland, in 1918.

The November 6, 1903, issue of the *Oregon City Enterprise* reported the rumor that the meteorite had been found on property adjoining the Hughes farm. On November 27, the Oregon Iron and Steel Company filed a suit demanding the return of the specimen after an unsuccessful attempt to purchase it for 50 dollars.

Hughes offered an innovative legal defense, claiming that the meteorite was an abandoned Indian relic that should be defined as personal property rather than land. Two elders from the Clackamas tribe testified that their ancestors had named the meteorite "Tomanawos" ("visitor from the Moon") and that it was considered a holy object that belonged to the Clackamas people. Earlier generations of warriors had dipped their arrows in rainwater that collected in cavities on the meteorite's surface to ensure success in battle, and young men were sent to the sacred stone to undergo secret initiation rites. This testimony is consistent with recent discoveries that Native Americans erected an adobe citadel around a 1.5-ton (14,000-kg) meteorite at Casas Grandes, Mexico (LeMaire, 1980). Other tribes may have made regular pilgrimages to meteorite sites at Red River, Texas, and Iron Creek, Canada (Nininger, 1952). Small meteorites have been found carefully wrapped and buried in Native American graves in Arizona and Montana (Lange, 1958b).

Hughes' lawyer expanded his arguments by pointing out the possibility that the meteorite had fallen at some other location and had been transported to the discovery site by glaciers, an argument that has been revived by scientists in recent years. The lawyer argued that the thorny property-rights issue could best be resolved by granting ownership of the meteorite to its discoverer, Ellis Hughes. Instead, the court awarded possession of the meteorite to Oregon Iron and Steel Company and assessed its value at $150. The decision was reaffirmed by the Oregon State Supreme Court on July 17, 1905, with the assessed value increased to $10,000.

The company announced that the Willamette meteorite would remain in Oregon forever, and it was displayed at the 1905 Lewis and Clark Exposition in Portland. When the exposition closed, a wealthy benefactor, Mrs. William E. Dodge, purchased the meteorite for $20,600 and donated it to the American Museum of Natural History in New York City. At that time, it was the highest price that had ever been paid for a specimen in the Museum's collection (Preston, 1988). In 1936, the Willamette meteorite was moved to the Museum's Hayden Planetarium, where it remains one of the most popular displays.

The Willamette meteorite has an asymmetric shape that indicates that the object maintained a constant orientation as it travelled through the atmosphere rather than tumbling randomly. The blunt side represents the leading face, and tapered bell-shaped sides formed as trailing surfaces. When it was initially discovered, the meteorite mysteriously rested in the soil in an upside down position. Prior to impact, the meteorite was possibly affected by air turbulence in the lower atmosphere. However, the immense mass of metal penetrated only about three feet into the soft forest soil, which suggests that the meteorite was not found at the original impact site. The meteorite may have been transported to its place of discovery by an iceberg during one of the great floods that swept across the Columbia basin during the late Ice Age. If so, the impact may have occurred in northern Idaho, western Montana, or southwestern Canada (Pugh and Allen, 1986). The story of this meteorite is also discussed in Lange (1958 a,b; 1962; 1968), LeMaire (1980), and Preston (1988).

Mulino meteorite, Clackamas County, Oregon

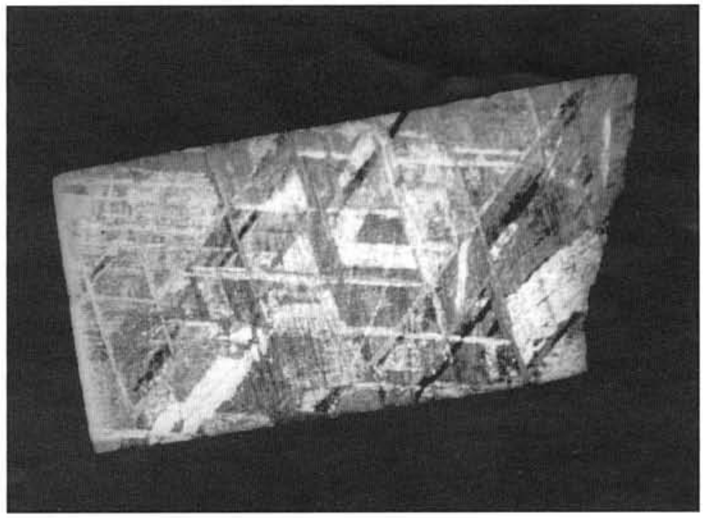
A very small chondrite in the U.S. National Museum is labeled as having fallen May 24, 1927, near Mulino. Later correspondence failed to reveal any local record of a meteorite fall on that date, and the authenticity of the specimen is ranked as "very doubtful" (Hay, 1966; Graham and others, 1985).

Sams Valley meteorite, Jackson County, Oregon

In 1894, a 6.8-kg (15-lb) metallic meteorite was found lying on rocky soil about 10 mi (16 km) northwest of Medford (Figure 7). The specimen was sold in 1914 to the Foote Mineral Company in Philadelphia, then one of the world's largest meteorite dealers. The meteorite was sawn into four main slices and several smaller remnants that were sold to museums and private collectors. A 1.1-kg (2.4-lb) specimen was purchased for $585 by the American Museum of Natural History in New York City, and a slightly smaller slice was purchased by Harvard University. Since then, four other Sams Valley specimens have been discovered, although the circumstances are poorly documented. In 1938, a 1.2-kg (2.6-lb) specimen acquired by the American Museum of Natural History from a Medford resident was forwarded to University of Oregon astronomer J.H. Pruett, who agreed to saw the specimen in exchange for a 1-lb portion. The actual cutting operation was performed by Eugene high school teacher C.A. Coulter and his teenage son Donald, an endeavor that took 11 hours and wore out 18 hack saw blades. Pruett's portion of the meteorite is now in the University of Oregon Museum of Natural History, along with a plaster cast of the

← Left: Figure 7. Two views of plaster cast of metallic meteorite found at Sams Valley, Oregon, in 1894. From Lange (1967).

↓ Below: Figure 8. Etched slice of Klamath Falls meteorite, showing Widmanstätten pattern. Photo courtesy O.R. Norton.



original 6.8-kg Sams Valley specimen. A 2-lb (1-kg) Sams Valley specimen on display at the Jacksonville Museum was discovered in 1949 among a box of uncurated minerals. This meteorite was one of three specimens that were found at Sams Creek in the 1880s by a local resident who was panning for gold. The other two pieces are presently unaccounted for. (See also Foote, 1915; Morley, 1950; Lange, 1967).

Klamath Falls meteorite, Klamath County, Oregon

In January, 1952, a resident in the area discovered a 17-kg (38-lb) metallic meteorite (Figure 8) somewhere in Klamath County. From examination of a small piece, meteorite expert H.H. Nininger confirmed that the sample was indeed a meteorite (Lange, 1968). The finder never returned to inquire about his discovery, and the location of his discovery site remains a mystery. The meteorite was acquired by the University of New Mexico and later subdivided. Small specimens have recently been sold to private collectors (Keith Kaler, Washington State Library, Olympia, oral communication, 1997). A 12.6-g (0.44-oz) sample is in the meteorite collection at the University of Arizona at Tempe.

Salem meteorite, Marion County, Oregon

At 1:05 a.m. PDT, on May 13, 1981, five small chondrite fragments struck the roof of the home of Deputy Sheriff James P. Price in Salem. At the time of the impact, Price was sitting on the curb talking to another deputy. Both men heard a peculiar "fluttering" noise that was followed by the sound of small rocks striking nearby. A search by flashlight produced a still-warm piece that had fallen within 10 ft of the officers. The next morning, four more fragments were recovered, consisting of angular gray stones with outer surfaces covered by a 1-mm-thick dark fusion crust (Figure 5). The specimens were sent to J.C. Evans, Senior Research Scientist at Battelle Pacific Northwest Laboratories in Richland, Washington, where they were analyzed by scanning electron microscopy and energy dispersive X-ray fluorescence analysis (Pugh, 1983). The specimens are now in the possession of Price. (See also Pugh, 1983; Clarke and Pugh, 1988).

South Slough meteorite, Coos County, Oregon

Dodge (1898, p. 442) recounts the tale of an alleged meteorite impact:

"One of the largest meteors on record fell on the head of South Slough, Coos County, January 17, 1890, at 11 o'clock at night, knocking a hole in the hill thirty feet across. It came from the northwest and lighted up the heavens in fine style. A report, as of thunder, awoke people for many miles around. It was plainly heard at Coquille City. Excavations reveal a chunk of lava twenty-two feet across that resembles slag from an iron furnace."

The reported size of the object far exceeds the 9'x9'x3' dimensions of the Hoba meteorite, the world's largest authenticated specimen, and a twenty-two foot meteorite would be unlikely to survive the thermal shock created during its passage through the atmosphere without being explosively fragmented. In the absence of additional information, the reliability of this historic report is very questionable.

Port Orford meteorite, Curry County, Oregon

A pallasite with an estimated weight of 10,000 kg (11 tons) was allegedly discovered in 1856 on a hillside about 40 mi east of Port Orford by John Evans, leader of a government-sponsored expedition to explore possible routes for the railroad. A 30-g (1.1 oz)specimen was turned over to the Boston Natural History Society. Several hundred parties have unsuccessfully attempted to locate this meteorite site in the Siskiyou National Forest in southwestern Oregon, beginning shortly after the discovery was publicly reported in 1859. The Smithsonian Institution organized searches in 1929 and 1939, and although these expeditions were unsuccessful, three articles written by University of Oregon astronomy professor J.H. Pruett triggered an avalanche of interest in the "lost meteorite" (Pruett, 1937, 1939a, 1950). For decades, professional and amateur treasure seekers have trudged the hills bordering the headwaters of the Sixes River looking for the "bald mountain" described by Evans as the site of the meteorite. Possible geographic clues have been described in detail by Henderson and Dole (1964).

Over the years, Evans' account of his discovery has continued to be the subject of considerable scrutiny, and the specimen he collected has been rigorously analyzed. A recent compilation of this information indicates that Evans made up the meteorite story as a hoax that was intended to attract funding for a future expedition and to generate money the geologist needed badly to repay the considerable personal debt that he had amassed from overspending his budget during the original trip.

The texture and composition of Evans' specimen are nearly identical to the Imilac meteorite discovered in the Atacama desert of Chile in 1822, and its weathered surface seems more likely to have been produced in the arid environment of the Atacama region rather than in the humid coastal forests of Oregon. This evidence suggests that Evans might have acquired a fragment of the Imilac pallasite when he passed through the isthmus of Panama on his return from Oregon, hoping that the specimen could provide the means of allaying his pending financial troubles. At present, a 24-g (0.8 oz) "Port Orford" specimen is in the Smithsonian collection (Figure 9), and small fragments are located at the Vienna Natural History Museum and the India Geological Survey Museum, Calcutta. (See also Buchwald and Clark, 1993; Plotkin, 1993; Sedell, 1968).

OTHER NORTHWEST METEORITES

All of the meteorites that have so far been discovered in Oregon have come from the region west of the Cascade Range, even though the less vegetated terrain in the central and eastern parts of the state offer more favorable conditions for meteorite recovery. This discrepancy is explained by the low population density east of the Cascades. In Washington, the most important meteorite specimens were found in the wheat fields of the Columbia Plateau, where extensive cultivation increases the chances that unusual rocks will be noticed.

Waterville meteorite, Douglas County, Washington

The first meteorite to be found in Washington was a 37-kg (82-lb) nickel-iron specimen discovered in 1917 on the Fred Fachnie farm, 16 mi northeast of Waterville (Figure 10). Fachnie's combine struck the Waterville meteorite with such force that the machine's bull wheel was broken. No obstacles had been encountered when the same field had been planted in the spring—with equipment that drilled holes at a 6-in. spacing. The farmer took the specimen to William Schluenz, owner of the local hardware store. Schluenz recognized it as a meteorite, and for the next few years the rock was dis-

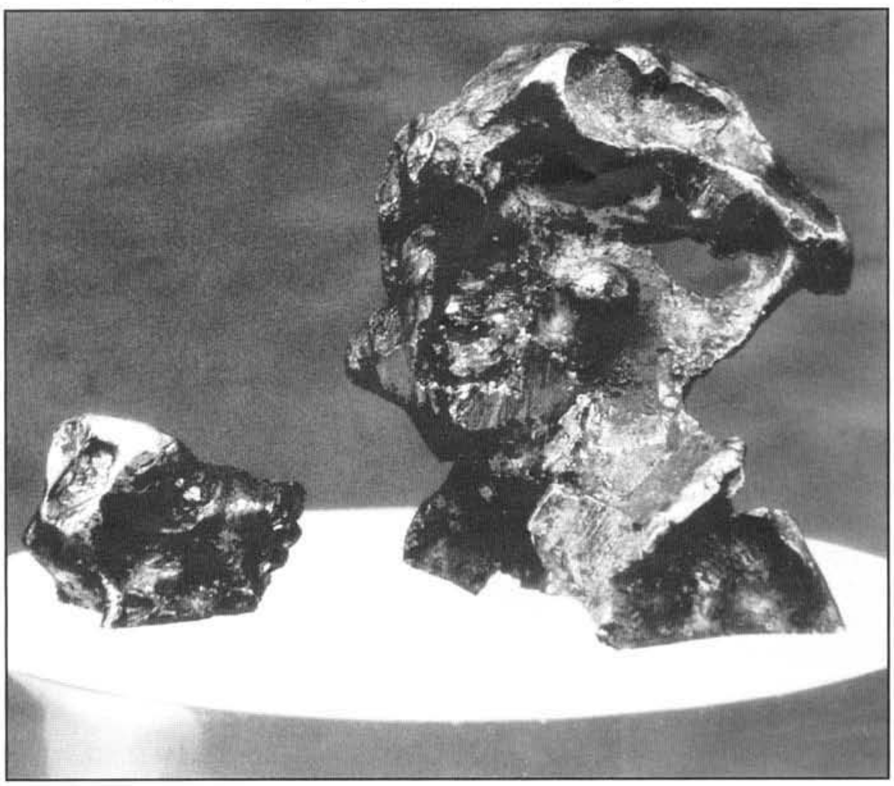


Figure 9. Fragments of meteorite allegedly found in 1856 near Port Orford, Oregon. The larger specimen weighs only 24 g. Photo by Chip Clark from Clarke (1993).

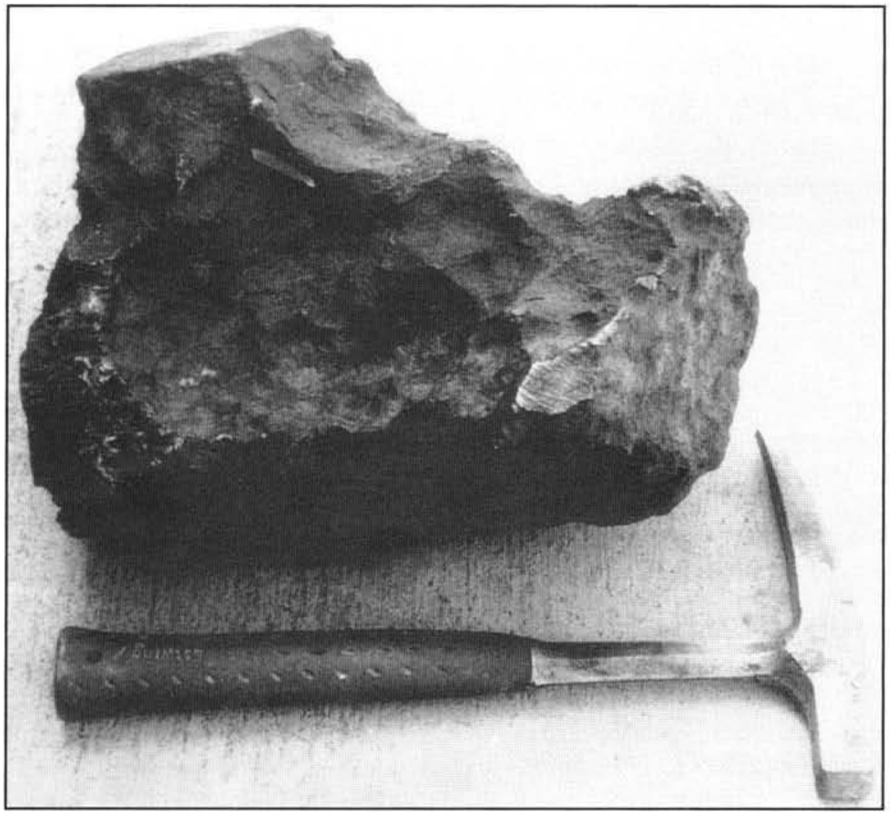


Figure 10. The 37-kg metallic meteorite from Waterville, Washington. From Knoblach (1994).

played in his store. Customers were permitted to try their hand at breaking the dense metallic mass with a hammer, and the meteorite's surfaces bear the scars of many unsuccessful attempts.

In 1921, Fachnie retrieved the somewhat battered specimen and used it as a decoration in his flower garden. In March 1925, a member of the Washington State Historical Society borrowed the meteorite for display at the Ferry Museum in Tacoma. In 1958, Wenatchee residents Mr. and Mrs. Walter Grizzle became disturbed by the museum's careless treatment of the specimen. Slices had been sawn from several of the surfaces, so that the original weight was reduced by nearly 4 kg (9 lb). The Grizzles instigated a four-year legal campaign to have the meteorite returned to the Fachnie family. The museum was unable to produce evidence that the specimen had been received as a donation rather than a temporary loan. In 1963, the meteorite was placed on permanent display at the Douglas County Historical Society Museum in Waterville. A large etched slice is in the Nininger collection at Arizona State University. (See also Read and others, 1967; Grizzle, 1963; Grizzle and Eller, 1961; Weinke and others, 1979).

Withrow meteorite, Douglas County, Washington

In the spring of 1950, an 8.75-kg (19.25-lb) metallic mass was found 1 mi west of Withrow in a wheat field owned by W.C. Nollmeyer, (Figure 11). Since 1966, the specimen has been on display at the Douglas County Historical Society Museum in Waterville. Another 5-kg (11-lb) meteorite found sometime prior to 1951 by a Withrow school teacher is presently unaccounted for. The Waterville and Withrow specimens are similar in composition and appearance, and they may have originated as part of a single shower (Read and others, 1967).

Albion meteorite, Whitman County, Washington

A 12.28-kg (27-lb) specimen found in the winter of 1966–1967 by Kenneth Oliphant in a wheat field adjacent to the Palouse River near Albion was confirmed to be an iron meteorite in 1991 by John Wasson, professor at the University of California at Los Angeles. The Albion meteorite is noteworthy because of the presence of irregular vacuoles that range in diameter from 4 to 9 mm (0.16–0.35 in.). These small cavities are lined with spherical masses that are covered with intergrown cubic crystals of almost pure iron, a feature never before observed in a meteorite (Kempton, 1995).

Washougal meteorite, Cowlitz County, Washington

On the morning of July 2, 1939, climbers on Mount Adams observed the glowing trail of a meteorite streaking across the western sky. Residents of the Portland area heard the accompanying sonic boom, and at 7:35 a.m. PST, a 225-g (8-oz) stony meteorite struck the ground near a person who was picking raspberries near the Columbia River town of Washougal, Washington. This arrival probably involved a mass that fragmented into many pieces just before impact, but searches failed to yield other specimens. The main body of the meteorite is at the University of Oregon Museum of Natural History (Figure 12), while small portions are in collections at Arizona State University and the British Museum. (See also Graham and others, 1985; Carver and Anders, 1975; Jerome and Michel-Levy, 1972; Nininger, 1939; Pruett, 1939b).

Tacoma meteorite, Pierce County, Washington

A single 16.7-g (0.6-oz) nickel-iron meteorite was found on a farm near Tacoma in 1925. Today, 12.1 g (0.4 oz) of it are left at the University of California, Los Angeles, and 2.2 g (0.08 oz) in the Smithsonian Institution. (Graham and others, 1985).

Colton meteorite, Whitman County, Washington

A highly oxidized metallic meteorite fragment was found a few years ago in the Palouse region of southeastern Washington. The specimen, which is presently at the Smithsonian Institution, has not yet been formally described (R.N. Pugh, oral communication, 1997).

Roy meteorite impact, Pierce County, Washington

On August 2, 1929, the *Tacoma News Tribune* reported the following story: "After a thorough investigation of the meteorite landing place on the farm of John L. Murray, two miles south of Roy, less than two weeks ago, it was discovered that the only trace of it left was a hole in the ground three feet in diameter and three feet deep, lined with grayish ash. This investigation led to the belief that in spite of the explosion, which broke windows and tore a door from its hinges on the Murray farm, the phenomenon was so hot as to be of a gaseous nature, when it reached the earth, disintegrating upon landing."

Small meteorites typically produce indentations that are only slightly larger than their own diameter, and failure to discover an object at the impact site is perplexing. Many incoming bodies undergo explosive disintegration as they make their final passage through the atmosphere, but the absence of fragments suggests that the Roy "impact" was possibly a lightning strike. As with many other anecdotal accounts of alleged meteorite impacts, the true story of this event may never be known.

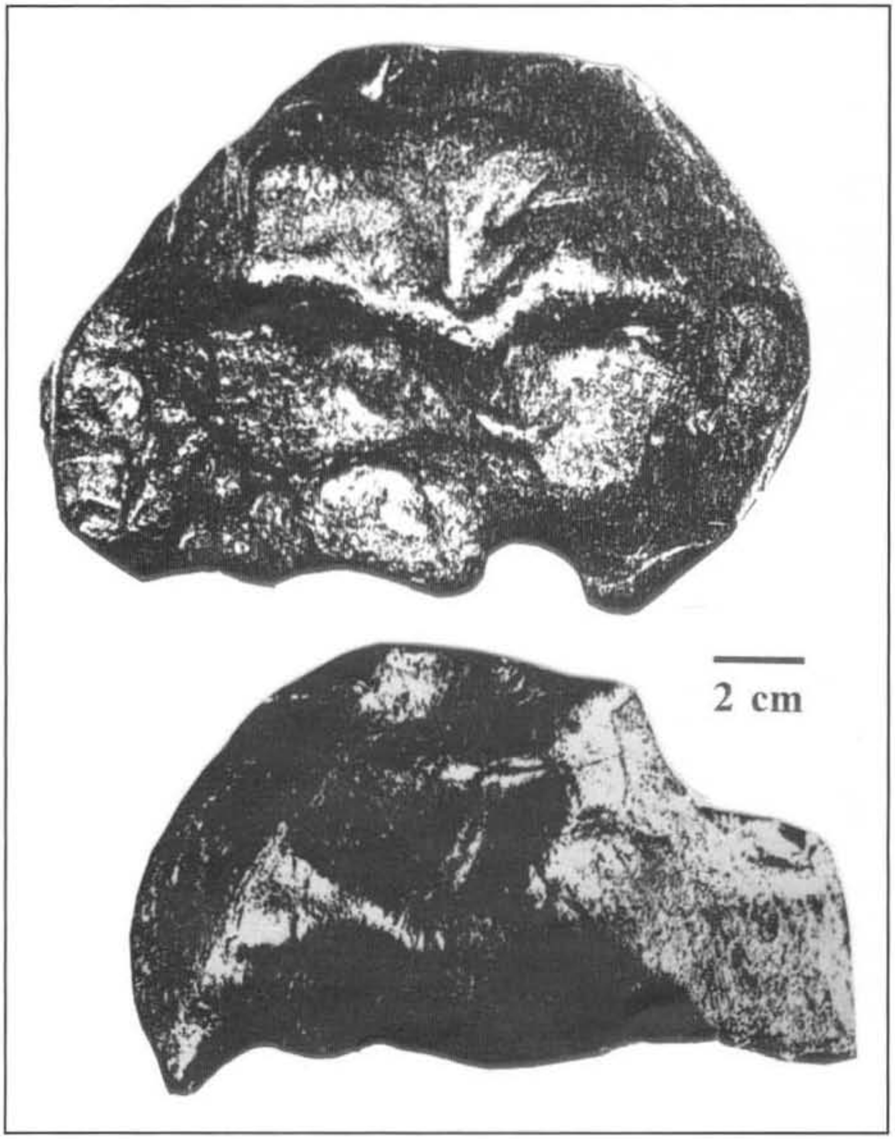


Figure 11. Two views of the 8.75-kg metallic meteorite found in 1950 at Withrow, Washington. Photos courtesy Douglas County Historical Society Museum, Waterville, Washington, which has the Withrow meteorite on display.

Kirkland hoax (?), King County, Washington

Two small metallic objects pierced the dome of an amateur observatory just northeast of Kirkland at approximately 11 a.m. PST, January 17, 1955. The story began when Luther Hawthorne called the local fire department to report smoke issuing from his observatory, shortly after he had heard an explosive report. He discovered that the smoke was coming from a fire in a small shelf of reference books inside the building, and that two small holes were visible in one of the aluminum panels that formed the dome-shaped roof. He discovered two small metallic objects near the book shelf. The specimens proved to be metallic meteorites of somewhat different composition. Read (1963) provided a detailed discussion of this alleged fall, concluding that the event was a legitimate meteorite arrival. The implausible odds of a cosmic impact occurring at a back yard observatory causes most scientists to question the validity of this alleged meteorite arrival. Editions 3 and 4 of the *Catalogue of Meteorites* (Hay, 1966; Graham and others, 1985), a compendium of all known meteorite discoveries, rank the Kirkland fall as "very doubtful." The Kirkland specimens and the damaged dome panel were acquired by the Wenatchee meteorite enthusiasts

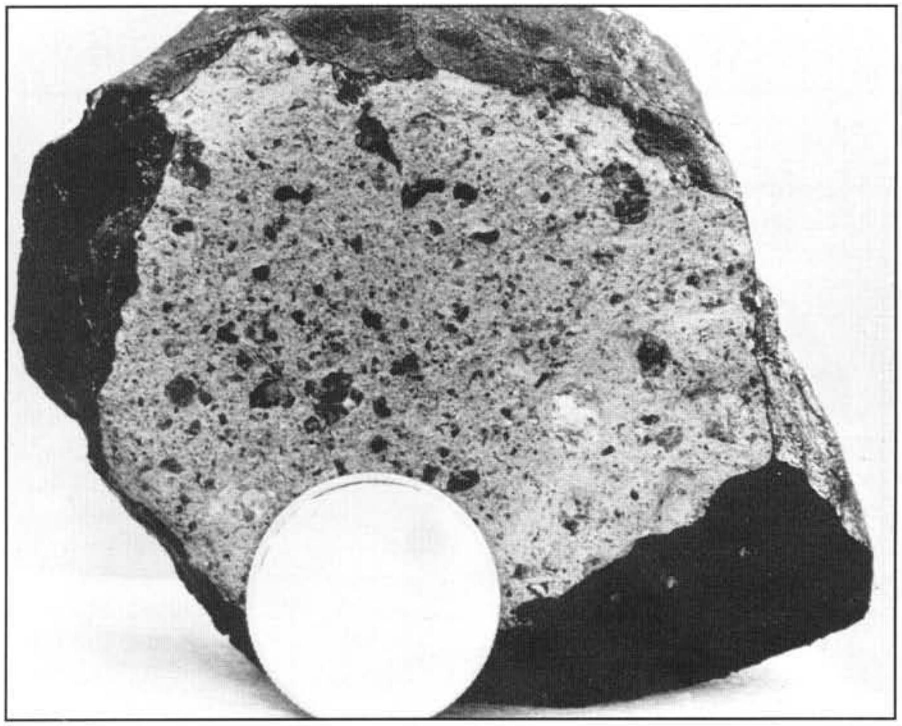


Figure 12. The 220-g stony meteorite that fell near Washougal, Washington, on July 2, 1939. Coin at bottom for scale is a dime (1.7 cm diameter). From Pugh (1982).

Walter and Ellen Grizzle and displayed in 1963 at the Douglas County Historical Society Museum in Waterville, Washington. The present whereabouts of the meteorites, however, are unknown.

Revelstoke meteorite, British Columbia, Canada.

The province of British Columbia ranks as one of the world's worst places to search for meteorites because of the rugged terrain, dense forests, and low population density. However, on the clear night of March 31, 1965, the spectacular arrival of a meteorite was witnessed by thousands of people in British Columbia and Alberta. An extraterrestrial object exploded high in the atmosphere somewhere above the peaks of the Monashee Range, producing shock waves that were detected by seismographs as far away as Colorado. These vibrations were evidence of a blast that had an estimated energy of 20 kilotons of TNT, approximately equal to the atomic bomb that destroyed Nagasaki in 1945 (Chyba, 1993; Carr, 1970, Folinsbee and others, 1967). The Canadian event caused no ground-level damage, however, and an extensive search failed to discover an impact crater. The only physical evidence consisted of millimeter-size meteorite fragments that two fur trappers found darkening the snow near Shushap Lake. Analysis of less than 1 g (0.04 oz) of recovered material revealed that the Revelstoke meteorite was a carbonaceous chondrite, one of the rarest types. As their name suggests, these meteorites contain significant amounts of carbon. Their overall chemical composition resembles the chemistry of the sun, and carbonaceous chondrites may provide us with samples of matter that existed during the earliest stages in the evolution of our solar system.

Beaver Creek, British Columbia, Canada.

Prior to the Revelstoke arrival, the only known meteorites from British Columbia were a pair of stones weighing 2.3 kg (5 lb) and 11.4 kg (25 lb) that struck Beaver Creek in the West Kootenay District on May 26, 1893 (Lange, 1973; Graham and others, 1985). These specimens were cut into slices that were dispersed among many collectors. The largest remnants are a 3-kg (6.6-lb) piece owned by the American Museum of Natural History in New York and a 2-kg specimen in the Field Museum of Natural History in Chicago.

All Pacific Northwest meteorites recovered to date came from relatively small impacts, but some think that the Pacific Northwest has also been the scene of very large cosmic events. Alt and Hyndman (1995) have suggested that an asteroid impact about 17 million years ago during the Miocene Epoch might actually have weakened the crust and triggered outpourings of basaltic lava over the Columbia Plateau and adjacent regions of Washington, Idaho, Oregon, and Nevada. Most geologists believe that conventional plate tectonic forces were responsible for this volcanism, but our increasing knowledge of numerous asteroids that travel in Earth-crossing orbits can suggest that some "extraterrestrial visitors" might play important roles in the geologic evolution of our planet.

ACKNOWLEDGMENTS

Helen Grande, Douglas County Historical Society Museum curator, provided historical information about the discoveries of the Waterville and Withrow meteorites. Dick Pugh and Beverly Vogt contributed helpful reviews of the manuscript.

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APPENDIX

Resource addresses for meteorite identification

Center for Meteorite Studies, Arizona State University, Tempe, AZ 85281.

Institute of Meteoritics, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131.

Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560.

The American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024.

Institute of Geophysics and Planetary Sciences, University of California, Los Angeles, CA 90024.

Lunar and Planetary Laboratory, Space Sciences Building, University of Arizona, Tucson, AZ 85721. ☐

Oil and gas exploration and development in Oregon, 1998

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

ABSTRACT

There was a small decrease in oil and gas leasing activity during 1998 compared to 1997. The decrease occurred primarily because Columbia County held no lease sales during 1998, whereas the County held two oil and gas lease sales during 1997, at which approximately 10,405 acres was acquired in the Mist Gas Field area. Four U.S. Bureau of Land Management (BLM) lease sales were held during the year, and no offers were received. During the year, the BLM sold five over-the-counter noncompetitive leases consisting of 11,622 acres located in eastern Oregon. A total of 31,734 federal acres were under lease at year's end. The state of Oregon conducted no lease sales during the year. Eight State of Oregon tracts were under lease at year's end, comprising 3,741 acres.

Six exploratory wells, two redrills, and two underground natural gas storage wells were drilled in Oregon during 1998. One of the exploratory wells was drilled by Jefferson Gas LLC in the Willamette Valley near Albany and was plugged and abandoned. Enerfin Resources shot 3-D seismic data at the Mist Gas Field, Columbia County, and drilled five of the exploratory wells and the two redrills. Of these, two exploratory wells and two redrills were successful gas wells, and three exploratory wells were plugged and abandoned. Northwest Natural drilled two underground natural gas storage service wells, which will be used for injection-withdrawal and monitoring at the Calvin Creek Underground Natural Gas Storage Project.

At the Mist Gas Field, 19 wells were productive during 1998. A total of 1.3 billion cubic ft of gas (Bcf) was produced during the year with a total value of $2.6 million.

The Oregon Department of Geology and Mineral Industries constructed an oil and gas internet webpage that contains production and other data, drilling application forms, statutes and rules, available publications and other information.

LEASING ACTIVITY

Oil and gas leasing activity was slightly lower during 1998 compared to 1997. The U.S. Bureau of Land Management (BLM) held four lease sales during 1998, at which no bids were received. The BLM sold five over-the-counter noncompetitive leases consisting of a total of 11,622 acres. These leases are located in eastern Oregon in the Prineville District. A total of 31,374 federal acres was under lease at year's end in Oregon, which is a decrease from the 39,131 federal acres under lease at the end of 1997. Total leasing income to the BLM was $43,500 for 1998.

Columbia County held no lease sales during the year, whereas two lease sales were held during 1997, at which four companies leased 10,405 acres, all located near the Mist Gas Field.

The State of Oregon held no lease sales during 1998. At year's end, eight State of Oregon tracts were under lease, comprising 3,741 acres. Total rental income was $3,741 during 1998.

DRILLING AND EXPLORATION ACTIVITY

Six exploratory gas wells, two redrills, and two underground natural gas storage wells were drilled in Oregon during 1998. This is an increase from the four underground natural gas storage wells drilled during 1997.

All but one of these wells were drilled at the Mist Gas Field, Columbia County, where most of the state's oil and gas drilling activity has occurred since the field was discovered in 1979. The other exploratory well was drilled by Jefferson Gas LLC of Park City, Utah, in the Willamette Valley about 5 mi north of Albany. This well, the Clayton #1, located in NW¼ sec. 20 (NE¼ sec. 58 land grant section), T. 10 S., R. 3 W., was drilled as an exploratory well for natural gas and also for possible use as an underground natural gas storage well. It was drilled to a total depth of 1,356 ft and was plugged and abandoned.

At the Mist Gas Field, Enerfin Resources Company, Houston, Texas, conducted a 3-D seismic program and, on the basis of the data obtained, drilled five exploratory wells and two redrills during the year. Of these, two exploratory wells and two redrills were successful gas wells.

The successful gas wells are the JH 22-27-64, located in NW¼ sec. 27, T. 6 N., R. 4 W., drilled to a total depth of 2,211 ft; and JH 32-27-64, located in NE¼ sec. 27, T. 6 N., R. 4 W., drilled to a total depth of 2,212 ft. These are both located in the Cedar Point area and are the easternmost successful gas producers discovered to date at the Mist Gas Field. At year's end, these two wells were suspended, awaiting pipeline connection.

Two redrills were also successful during 1998. The first is the CC 32-27-65 RD, located in NE¼ sec. 27, T. 6 N., R. 5 W. This well was a reentry of the Enerfin Resources well CC 32-27-65, drilled in 1996 and suspended, pending further evaluation, now redrilled to a depth of 2,092 ft and completed as a gas producer. The second successful redrill is the CC 41-6-65 RD, located in NE¼ sec. 6, T. 6 N., R. 5 W., originally drilled to a total depth of 2,975 ft and now redrilled to a total depth of 2,970 ft. This well is in the northwestern part of the Mist Gas Field and, at year's end, was suspended, awaiting completion and pipeline connection.

Redrilling the Enerfin Resources well CC 32-27-65 RD was completed in 1998 and resulted in successful gas production.

Three additional exploratory wells drilled by Enerfin and plugged and abandoned are the Busch 34-15-65, located in the SE¼ sec. 15, T. 6 N., R. 5 W., drilled to a total depth of 2,576 ft; the CC 22-26-65, located in the NW¼ sec. 26, T. 6 N., R. 5 W., drilled to a total depth of 1,743 ft; and the CC 41-6-65, located in the NE¼ sec. 6, T. 6 N., R. 5 W., drilled to a total depth of 2,975 ft.

Two underground natural gas storage service wells were drilled by Northwest Natural during 1998. The wells are part of the development of the Calvin Creek Underground Natural Gas Storage Project at the Mist Gas Field. This project is adding additional underground natural gas storage capacity by converting depleted, formerly producing reservoirs into use for underground natural gas storage. One of the wells drilled will be used for injection-withdrawal and the other well for monitoring of natural gas in the storage reservoirs. The injection-withdrawal well drilled and completed during 1998 is the IW 22dH-22-65, located in sec. 22, T. 6 N., R. 5 W., and drilled to a total depth of 2,746 ft. This well was horizontally drilled to avoid unfavorable topography and to expose a greater amount of the storage zone to the wellbore to maximize gas injection and withdrawal

Table 1. Oil and gas permit activity in Oregon, 1998

Permit number	Operator, well, API number	Location	Permit activity (TD=total depth)
324	Enerfin Resources CFI 23-15 36-009-00166	SW¼ sec. 15 T. 5 N., R. 4 W. Columbia County	Abandoned; TD 2,770 ft.
436	Enerfin Resources CER 13-1-55 36-009-00265	SW¼ sec. 1 T. 5 N., R. 5 W. Columbia County	Abandoned; TD 1,480 ft.
502RD	Enerfin Resources CC 32-27-65 RD 36-009-00322-01	NE¼ sec. 27 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD 2,092 ft.
507	Northwest Natural OM 32-22-65 36-009-00327	NE ¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Drilled; service well; TD 2,365 ft
508	Northwest Natural IW 22dH-22-65 36-009-00328	NW ¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Drilled; service well; TD 2,746 ft.
509	Enerfin Resources Busch 34-15-65 36-009-00329	SE ¼ sec. 15 T. 6 N., R. 5 W. Columbia County	Abandoned, dry hole; TD 2,576 ft.
510	Enerfin Resources CC 22-26-65 36-009-00330	NW ¼ sec. 26 T. 6 N., R. 5 W. Columbia County	Abandoned; dry hole; TD 1,743 ft.
511	Enerfin Resources Larkin 43-23-65 36-009-00331	SE ¼ sec. 23 T. 6 N., R. 5 W. Columbia County	Permit issued; proposed TD 2,240 ft.
512	Jefferson Gas LLC Clayton #1 36-043-00019	NW ¼ sec. 20* T. 10 S., R. 3 W. Linn County	Abandoned, dry hole; TD 1,356 ft.
513	Enerfin Resources CC 22-26-65 36-009-00330	SW¼ sec. 23 T. 6 N., R. 4 W. Columbia County	Application, proposed TD 2,390 ft.
514	Enerfin Resources CC 22-26-65 36-009-00330	NW¼ sec. 27 T. 6 N., R. 4 W. Columbia County	Completed, gas; TD 2,211 ft.
515	Enerfin Resources CC 22-26-65 36-009-00330	NE¼ sec. 27 T. 6 N., R. 4 W. Columbia County	Completed, gas; TD 2,212 ft.
516	Enerfin Resources CC 22-26-65 36-009-00330	SE¼ sec. 22 T. 6 N., R. 4 W. Columbia County	Application, proposed TD 2,453 ft.
517	Enerfin Resources CC 22-26-65 36-009-00330	SW¼ sec. 22 T. 7 N., R. 5 W. Columbia County	Permit issued; proposed TD 2,825 ft.
518	Enerfin Resources CC 22-26-65 36-009-00330	NE¼ sec. 28 T. 7 N., R. 5 W. Columbia County	Application, proposed TD 2,825 ft.
519	Enerfin Resources CC 22-26-65 36-009-00330	SE¼ sec. 22 T. 7 N., R. 5 W. Columbia County	Permit issued; proposed TD 2,550 ft.
520	Enerfin Resources CC 22-26-65 36-009-00330	SE¼ sec. 28 T. 7 N., R. 5 W. Columbia County	Application, proposed TD 3,000 ft.
521	Enerfin Resources CC 22-26-65 36-009-00330	NE¼ sec. 6 T. 6 N., R. 5 W. Columbia County	Abandoned; dry hole; TD 2,975 ft.
521RD	Enerfin Resources CC 22-26-65 36-009-00330	NE¼ sec. 6 T. 6 N., R. 5 W. Columbia County	Suspended, gas; TD 2,970 ft.

* NE¼ sec. 58 land grant section

efficiency. The well was drilled as a replacement to the IW 22d-22-65, which was drilled during 1997 but was lost and subsequently plugged because of echanical problems that occurred during cementing of the intermediate casing string. The monitoring well drilled and completed is the OM 32-22-65, located in NE¼ sec. 22, T. 6 N., R. 5 W., and drilled to a total depth of 2,365 ft.

Total footage drilled for 1998 was 22,715 ft. Average depth per well was 2,272 ft.

Enerfin Resources plugged and abandoned two depleted former producers at the Mist Gas Field during 1998. These are the CFI 23-15, located in SW¼ sec. 15, T. 5 N., R. 4 W., and the CER 13-1-55, located in SW¼ sec. 1, T. 5 N., R. 5 W. In addition, Enerfin did a workover at the formerly suspended LF 32-20-65R RD well to increase production capabilities, and the well was returned to gas production at year's end.

Enerfin Resources received permits and shot 2-D seismic programs at the Rocky Point Prospect located south of Vernonia, Columbia County, and the Looney Butte Prospect located in the Willamette Valley south of Salem.

During 1998, the Oregon Department of Geology and Mineral Industries (DOGAMI) issued 10 permits to drill. Permit activity is listed in Table 1.

PRODUCTION

The Mist Gas Field was operated by Enerfin Resources and Northwest Natural during 1998. During the year, 19 natural gas wells were productive at the Mist Gas Field, 15 operated by Enerfin Resources and four operated by Northwest Natural. This is the same number of productive wells at the Mist Gas Field as during 1997. Gas production for the year totaled 1.3 billion cubic feet (Bcf) of gas, which is slightly less than the 1.4 Bcf produced during 1997. Most of the decrease can be attributed to the normal decline from existing wells and the addition of only one new well during the year.

The gas price remained constant all year at about 23 cents per therm, which is slightly higher than the 21 cents per therm during 1997. The total value of gas produced at the Mist Gas Field during 1998 was about $2.6 million, which is about the same as during 1997. Cumulatively, the Mist Gas Field has produced about 63 Bcf of gas with a total value of $122 million since it was discovered in 1979.

GAS STORAGE

The Mist and the Calvin Creek Underground Natural Gas Storage Projects were both operational during 1998. The Mist Gas Storage Project has nine injection-withdrawal service wells and 13 monitoring service wells. The Calvin Creek Gas Storage Project has 3 injection-withdrawal service wells and four monitoring service wells. The two gas storage projects have a total storage capacity of about 15 Bcf of gas in the reservoirs at pressures between approximately 400 and 1,000 psi and will provide maximum daily peak delivery capability of approximately 145 million cubic feet (MMcf) of gas per day. During 1998, Northwest Natural began an evaluation of the depleted Busch Pool located in SW¼ sec. 15, T. 6 N., R. 5 W., to determine if it had any possible future use for underground natural gas storage. Previous gas injection testing of this pool was unsuccessful because of water invasion into the reservoir. Northwest Natural began an evaluation wherein gas would be injected into the reservoir at a pressure slightly greater than initial reservoir pressure, in an attempt to move the water from the reservoir and return it to usefulness for gas storage. This evaluation was ongoing at year's end.

OTHER ACTIVITIES

DOGAMI has constructed an oil and gas internet homepage. The webpage address is http://sarvis.dogami.state.or.us/oil/homepage.htm. Included on this homepage are Mist Gas Field production figures data, oil and gas statutes and administrative rules, drilling permit application forms and other forms, a publication list, and other information. Plans are to add a historical database to the homepage that will show wells drilled in Oregon, locations, and dates drilled, total depth, available well logs and samples, and other data.

The Northwest Energy Association (NWEA) remained active during 1998 with over 100 members. At its regular monthly meetings, speakers give talks on subjects related to energy matters in the Pacific Northwest. The annual fall symposium was held in the Portland area, and plans are being developed for the 1999 fall symposium. For more information, contact the NWEA, P.O. Box 6679, Portland, OR 97228.

Triennial revisions to Oregon Administrative Rules Chapter 632, Division 10 (oil and gas) and Division 15 (information and seismic test hole) will be performed during 1999. For information, contact DOGAMI.

The annually updated *Mist Gas Field Map,* DOGAMI Open-File Report O-99-1, shows the field divided into quarter sections. It displays location, status, and depth of all existing wells and serves as a basis for locating any new ones. It also shows the area and wells that are used for storage of natural gas. The attached production summary for 1993–1998 includes well names, revenue generated, pressures, production, and other data. The map and accompanying data are useful tools for administrators and planners, as well as explorers and producers of natural gas.

A cumulative report of past production at the Mist Gas Field between 1979 and 1992 is available in a separate release under the title *Mist Gas Field Production Figures* as DOGAMI Open-File Report O–94–6. Contact the Nature of the Northwest Information Center (503-872-2750) for a complete publication list. □

Geothermal exploration in Oregon, 1996–1998

by Dennis L. Olmstead, Oregon Department of Geology and Mineral Industries

ABSTRACT

Geothermal-resource drilling and leasing activity in Oregon passed its peak during the 1980s and the first half of the 1990s. Lease expirations and releases greatly outnumbered new filings from 1996 to 1998, and drilling activity was nonexistent during those years.

Several previously drilled wells still exist at Newberry volcano, and a small amount of well logging and instrument testing has occurred, but there is no promise of renewed activity in the near future. CE Exploration has moved its project from Newberry to Glass Mountain in northern California. Anadarko Petroleum plugged three wells in the Borax Lake area of Harney County, and no more drilling is likely in the Alvord Desert any time soon. The Bureau of Land Management compiled weather and water data from Borax Lake, covering several years in the 1980s and 1990s. These background data could be valuable in the event of future exploration in the Alvord Desert.

The Department of Geology and Mineral Industries produced a report on the geothermal resources of southeast Oregon. The study included air-photo fault analysis and satellite image analysis.

Direct use of hot water for space heating, snow melting, and greenhouses continues, primarily in the Klamath Falls, Lakeview, and Vale areas. The Oregon Institute of Technology Geo-Heat Center continues to publish its *Quarterly Bulletin* with national and international papers on direct use of geothermal energy and now maintains a web page.

LEASING

No geothermal lease sales were held during the 1996–1998 time period. Table 1 shows existing leasing levels for those years. USDA Forest Service (USFS) and USDI Bureau of Land Management (BLM) geothermal leasing consisted mainly of expiring or terminated leases and relinquished acreages. At the end of 1998, federal acreage under lease in Oregon for geothermal exploration totaled 58,027 acres.

DIRECT USE

The Geo-Heat Center at the Oregon Institute of Technology (OIT) in Klamath Falls has published its third edition of "Geothermal Direct-Use Engineering and Design Guidebook" (Lund and others, 1998). Last published in 1991, this update contains 19 chapters based on technical experience at OIT and reflecting current trends in the industry. The book covers material on the nature of geothermal resources, exploration for direct-heat resources, geothermal fluid sampling techniques, drilling and well construction, well testing and reservoir evaluation, materials selection guidelines, well pumps, piping, heat exchangers, space-heating equipment, absorption refrigeration, greenhouses, aquaculture, industrial applications, egineering cost analysis, regulatory and commercial aspects, and environmental considerations.

The Geo-Heat Center has also prepared a "Geothermal Greenhouse Information Package". It is intended to provide a foundation of background information for developers of geothermal greenhouses. The material consists of seven sections covering crop culture and prices, operation costs for greenhouses, heating system design vendors, and a list of other sources of information. Copies are available from the Geo-Heat Center. In addition, OIT has also published an update of greenhouse direct-use development (Lienau, 1997).

Technical assistance from the Geo-Heat Center is on the increase, due in part to their web page

http://www.oit.edu/~geoheat

Figures for 1996 and 1997 are 583 and 761 respectively for inquiries handled. Geothermal (ground-source) heat pumps seem to be a popular informational item, consuming about 30 percent of the OIT technical assistance activity. In addition to the web page, a publication on this topic is "An Information Survival Kit for the Prospective Geothermal Heat Pump Owner" by Kevin Rafferty. He has also written a paper for local Klamath Falls use concerning

Table 1. Geothermal leases in Oregon, federal land, 1996–1998

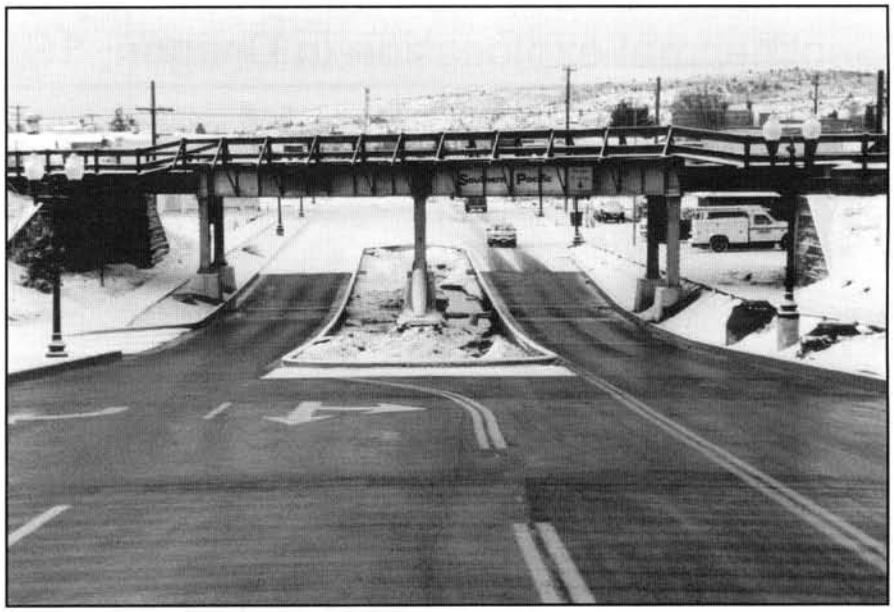
Activity	Number of leases, 1996	Acres, 1996	Number of leases, 1997	Acres, 1997	Number of leases, 1998	Acres, 1998	3-year total acres
Acres filed	1	680	0	0	0	0	680
Acres issued	1	320	0	0	0	0	320
Acres expired	1	623	3	1,961	0	0	2,584
Acres terminated/relinquished	7	13,580	3	3,627	5	6,858	24,065
Leases in effect as of 12/31/96	74	70,473	—	—	—	—	—
Leases in effect as of 12/31/97	—	—	68	64,885	—	—	—
Leases in effect as of 12/31/98	—	—	—	—	63	58,027	—

downhole heat exchangers: "Information for the Prospective Geothermal Home Buyer."

In 1997, the Geo-Heat Center published "Fossil Fuel-Fired Peak Heating for Geothermal Greenhouses" (Rafferty, 1997), outlining how a facility with limited geothermal flow can expand to provide a portion of the heating requirements with a conventionally-fueled peak heating system. The report examined the economics of fossil-fuel peaking for three different climates, including Klamath Falls, Oregon. Data included cost in dollars per square foot of greenhouse floor area and details on capitalization of the equipment, fuel costs, and maintenance for the fossil-fuel peaking system. An additional report (Rafferty, 1996) explored some of the issues related to costs in the installation of geothermal district heating in existing residential areas.

The Klamath Falls district heating system and the OIT geothermal system are still in operation, and status, challenges, and improvements have been summarized in two reports (Brown, 1996; Lienau, 1996). The two systems have added pavement snow melting. OIT now has two main stairs and two handicap ramps heated by geothermal energy; and in downtown Klamath Falls, almost all of the Main Street sidewalks are geothermally heated. In addition, the main downtown bus stop, the new Klamath County Building, and the Catholic church sidewalks are heated. The bridge deck and approach on Esplanade was recently reconstructed, and the 1948 snow melting system was replaced (Figure). About 20 buildings are now part of the downtown geothermal district heating system. These recent updates are documented in two papers presented at the Geothermal Resources Council annual meeting in September 1998 (Boyd, T.L., 1998; Brown, B., 1998). Finally, Lund has summarized geothermal research at the Geo-Heat Center (Lund, 1998).

Additional direct use geothermal heating is under construction in Lakeview, where the new USFS/BLM building will be geothermally heated. A 72°F water well has been drilled and completed, and an injection well is now planned. The building is currently being heated with propane, which will be the backup system after the geothermal system is in place.



Oregon Department of Transportation project on Esplanade in Klamath Falls. Buried warm-water pipes keep snow melted. Photo courtesy John Lund, Geo-Heat Center, Oregon Institute of Technology.

OREGON OFFICE OF ENERGY, DEPARTMENT OF CONSUMER AND BUSINESS SERVICES (OOOE)

With the apparent demise of the Newberry volcano project by CE Exploration, the OOOE has not had much geothermal activity in the past three years. A site certificate for the project was issued by OOOE in early 1996 and has never been terminated. Shortly afterward, the company decided to discontinue operations there and move their efforts to Glass Mountain in northern California (see BPA section below).

OREGON WATER RESOURCE DEPARTMENT (WRD)

WRD has a low-temperature geothermal program, primarily concerned with production and disposal wells for heat-pump space heating. Over the past three years, the program has seen very little activity, with only a handful of permits issued for disposal of spent warm water. Geographically, the permitting is widespread, however, including the Klamath basin, Willamette basin, Umatilla basin, and the Burns area.

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES (DOGAMI)

DOGAMI produced a report on the geothermal resources of southeast Oregon (Madin and others, 1996). The presence of numerous hot springs, high regional heat flow, several Known Geothermal Resource Areas (KGRAs), and broad geologic similarities with the geothermal zones of Nevada suggest significant potential. The study covered 11 major regions: North and south Steens, Catlow Valley, Guano Valley, Owhyee Uplands, Lake Abert, Antelope Valley, Turpin Knoll, Gold Creek, Christmas Lake-Summer Lake, and Drewsey. The study combined air-photo fault mapping and satellite-image analysis with some field visits to determine whether the local geology showed evidence of blind geothermal systems. Two areas, Lake Abert and Christmas Lake-Summer Lake, were the subject of more detailed studies of mineralization, oxygen-isotope geothermometry, and soil-mercury (Hg) anomalies. Some areas show low heat flows, no Holocene faulting, and few mineral occurrences, which indicates a poor chance for a blind late Quaternary geothermal sytem. Other areas, such as the southern Steens, have numerous Quaternary faults and extensive mineralization associated with range-front faulting, as well as many active geothermal systems.

Landsat thematic mapper imagery was examined for a large area of southeast Oregon to see whether mineralization at active hot springs could produce a signal to use in searching for inactive hot springs. Several targets were field-checked and some had a definite zone of mineralization and silicification. This technique therefore can be used to find some types (generally silicification) of bedrock units under some circumstances. Hot springs in desert environments are often surrounded by vegetation, which may mask local anomalous mineralization.

The study concluded that the use of indirect methods to prospect for undiscovered blind geothermal systems is only moderately useful. At best, the techniques can eliminate some areas and determine priorities for those that might be targets for further exploration.

INDUSTRY DRILLING ACTIVITIES AND REGULATORY ACTIONS

Anadarko Petroleum Corporation, former operator of three geothermal wells in the Pueblo Valley of southeast Oregon, failed to obtain a power contract and has plugged and abandoned its wells (Table 2). Permits G-153, G-154 and G-155 resulted in wells to depths of about 2,500 ft and capable of 250 gpm flows at around 300°F. The resource was therefore proven, but without a power contract the operator decided against developing the resource. The project had attracted widespread interest due to the existence of the Borax Lake chub in the nearby 10-acre Borax Lake. Ultimately, the three wells were plugged and abandoned in 1996.

At Newberry volcano, the wells at the CE Exploration project on the west flank of the volcano have been in suspended status since being drilled in 1995. Two will maintain this status through October 31, 1999. The DOGAMI Governing Board has extend the suspended status for the remaining three wells to October 2000. The company has moved its project to Glass Mountain in northern California and has made the Newberry wells available for scientific experimentation. A small amount of work has been done by the U.S. Geological Survey.

Vulcan Power Company, holder of large amounts of acreage on the west flank of Newberry volcano, has joined with Davenport Resources to form Northwest Geothermal Company. The new company has responded to a request for proposals from Portland General Electric (PGE) with a proposed 30-megawatt (MW) geothermal power plant (Freeman, 1999). The success of such a program is contingent in part on legislative approval for PGE to charge more for the "green" power. Northwest Geothermal is pursuing other potential avenues to make the power-plant plan viable.

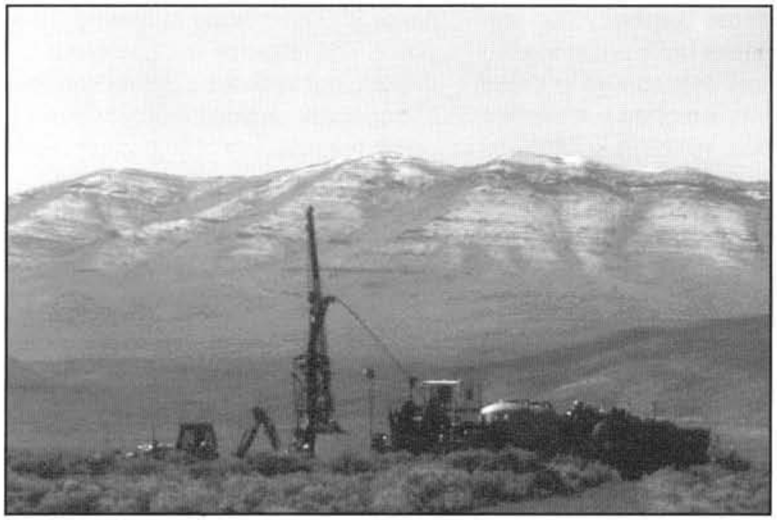
No statute or rule changes have taken place for geothermal drilling during the 1996–1998 period.

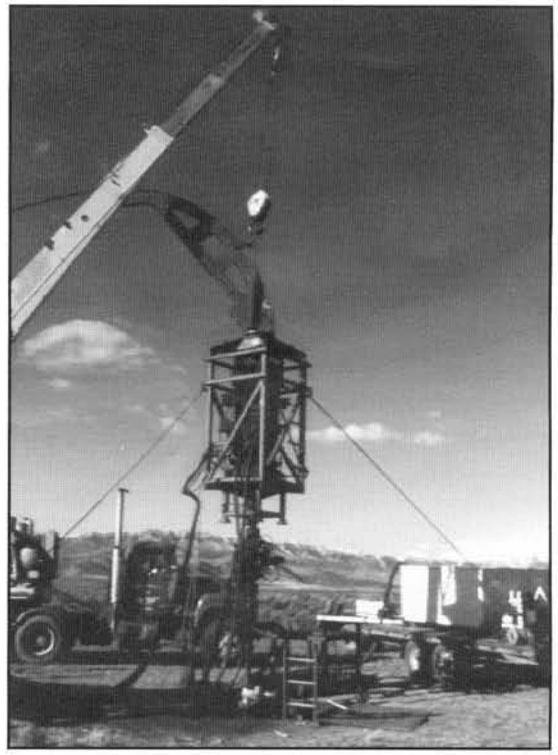
Table 2. Geothermal permits and drilling activity in Oregon, 1996–1998

Permit number	Operator, well, API number	Location	Status, date of action
G-153	Anadarko Petroleum Pueblo Valley 25-22A 36-025-90009	NW¼ sec. 22 T.37 S., R. 33 E. Harney County	Abandoned, 1996
G-154	Anadarko Petroleum Pueblo Valley 52-22A 36-025-90010	NE¼ sec. 22 T. 37 S., R. 33 E. Harney County	Abandoned, 1996
G-155	Anadarko Petroleum Pueblo Valley 66-22A 36-025-90011	SE¼ sec. 22 T. 37 S., R. 33 E. Harney County	Abandoned, 1996
G-174	CE Exploration 88-21 TCH 36-017-90035	SE¼ sec. 21 T. 21 S., R. 12 E. Deschutes County	Suspension status extended.
G-175	CE Exploration 76-15 TCH 36-017-90036	SE¼ sec. 15 T. 21 S., R. 12 E. Deschutes County	Suspension status extended.
G-176	CE Exploration 76-15 36-017-90037	SE¼ sec. 15 T. 21 S., R. 12 E. Deschutes County	Permit canceled, 1997
G-177	CE Exploration 47-15 36-017-90038	SW¼ sec. 15 T. 21 S., R. 12 E. Deschutes County	Permit canceled, 1997
G-178	CE Exploration 23-22 36-017-90039	NW¼ sec. 22 T. 21 S., R. 12 E. Deschutes County	Suspension status extended.
G-179	CE Exploration 86-21 36-017-90040	SE¼ sec. 21 T. 21 S., R. 12 E. Deschutes County	Suspension status extended.
G-182	CE Exploration 88-21 36-017-90041	SE¼ sec. 21 T. 21 S., R. 12 E. Deschutes County	Suspension status extended.

U.S. GEOLOGICAL SURVEY (USGS)

The USGS maintains three geothermal prospect wells that were drilled in the Western Cascades in 1991. Located in the Mount Hood and Willamette National Forests, the wells are part of a larger set of wells throughout the country and are used to monitor for contemporary climate change. The USGS periodically logs





Plugging of Anadarko Petroleum wells in Pueblo Valley, using Halliburton coiled tubing rig, 1996. Above: Well 52–22A. On right: Well 25–22A. The third well that was plugged was well 66–22A.

the temperatures in the wells. Comparison of the logs acquired over a number of years reveals whether climatic changes have occurred that affect the subsurface temperature regime. The data from the array of holes provide information on the magnitude of the climatic changes and their duration and spatial extent.

Charles Bacon and Manuel Nathenson have published a study of the Crater Lake area geothermal resources (Bacon and Nathenson, 1996). They found that the main heat source in the upper crust in the area is the magma chamber that was responsible for the caldera-forming eruption 7,700 years ago. The amount of heat transferred to the upper crust during development of the chamber and the heat stored in the remains of the chamber following the eruption have been estimated on the basis of geologic data and petrologic models. Some of the heat currently is being lost through discharge of the springs of the Wood River group and through venting of fluids into Crater Lake—manifestations of the Crater Lake hydrothermal system. The Mazama hydrothermal system is identified on the basis of data obtained from drill hole MZI-11A in Winema National Forest east of Crater Lake National Park. This system may be supplied by intrusions related to Pleistocene volcanic rocks near the east rim of the caldera.

USDA FOREST SERVICE (USFS)

USFS involvement in geothermal resources over the 1996–1998 time period consisted mainly of surface oversight for the Newberry volcano exploration activity by CE Exploration. This included sale of timber to be cut for pad construction, along with regulation of surface disturbance.

U.S. BUREAU OF LAND MANAGEMENT (BLM)

The BLM has released the results of several years of monitoring Borax Lake in Harney County. The unpublished report includes data on the lake itself as well as data from a Remote Automated Weather Station (RAWS) from 1990 to 1997. Borax Lake is located in the extreme southeastern corner of Oregon and is formed by a hot spring that formed the 10-acre thermal lake. It is located within the Alvord Known Geothermal Resource Area. The lake averages 3 ft in depth but has a main vent with a depth in excess of 90 ft.

Over the past 20 years, the Alvord basin was the subject of leasing and exploration by the geothermal industry. Significant wells were drilled near Borax Lake by Union Oil Company and Anadarko Petroleum Corporation. Bottom hole temperatures were in the 300°F range. Meanwhile, the U.S. Fish and Wildlife Service (USFWS) listed the Borax Lake chub as an endangered species in 1982. The threat of geothermal development on adjacent public lands was a factor in the listing.

Prior to 1980 lease agreements, the BLM consulted the USFWS and agreed to monitoring of the lake as a condition of geothermal development. The agreement resulted in the data collection on lake and weather conditions. Anadarko initiated a monthly monitoring program for the lake in 1981. Data collection included water temperature, water elevation, and air temperature, used three monitoring sites, and was carried out through 1983. The company also placed thermographs in the lake in 1989 when is was conducting drilling operations nearby. The BLM data collection at its RAWS site was carried out from August 1990 to November 1997. Water samples were analyzed for over 20 components.

In addition, the USFWS and the Nature Conservancy conducted quarterly fish population surveys of the Borax Lake chub from July 1986 to October 1987; then, in 1991, a multi-year study of the chub was started by the USFWS.

Neither the exact character of the geothermal system nor the interconnection of the lake, hot springs, and drilled acreage, if any, is known with any certainty. Additional monitoring of the lake and hot springs may be appropriate, should geothermal development occur in the future.

BONNEVILLE POWER ADMINISTRATION (BPA)

The BPA no longer has geothermal projects in Oregon but maintains involvement nearby in northern California. The BPA is considering power purchases from two geothermal power facilities proposed in the Glass Mountain Known Geothermal Resource Area, about 50 mi south of Klamath Falls, along the border between the Modoc and Klamath National Forests. The power facilities began as parts of a BPA geothermal pilot project program in 1991, formed to encourage the development of geothermal resources.

One of the geothermal projects was located near Vale in Malheur County. It was a joint project with the Springfield Utility Board. When test wells at the Vale site failed to discover hot water to run a power plant, the developer, TransPacific Geothermal Corporation, formed a joint venture with Calpine Corporation of San Jose, California (Calpine Siskiyou Geothermal Partners. L.P.), and asked BPA to consider a relocated project at Glass Mountain in northern California, still within BPA's marketing area. In December 1996, BPA ended its commitment to this facility at a cost of $12 million. Calpine is now developing a 49-MW dual-flash facility at Fourmile Hill, in the Medicine Lake Highlands northwest of the Glass Mountain caldera. The facility will also include the associated geothermal production and injection wells, well pads, roads, interconnected pipelines, and a 24-mi, 230-kV transmission line. BPA is considering buying output from the facility. The Final Environmental Impact Statement (FEIS) for the power plant and transmission line was issued in October 1998. If the project is approved, commercial operation could begin in 2001.

In September 1996, BPA agreed to pay Calpine Siskiyou Geothermal Partners up to a total of $14.5 million in exchange for a release of all claims related to the Vale Project and proposed relocation to Glass Mountain. As part of the agreement, BPA received an option on future development on Calpine's geothermal leases at Glass Mountain. Calpine also agreed to work toward the successful conclusion of the environmental work already underway. BPA and Calpine have negotiated a power purchase agreement, but BPA is under no obligation to execute it.

The second geothermal project was proposed for Newberry volcano in Deschutes County. CalEnergy Company (doing business as CE Exploration Company in Oregon) had proposed a 30-MW plant on the west flank of the volcano. BPA would have bought two-thirds of the plant's power production and subsidized the purchase of the remaining power by the Eugene Water and Electric Board (EWEB). CalEnergy explored for a resource by drilling several wells (Table 2) but without success. The wells are still suspended, pending data gathering and plugging. CalEnergy is now developing a 48-MW facility at Telephone Flat, located southwest of Medicine Lake, inside the caldera. A reservoir capacity of 15 MW has been confirmed by earlier wells drilled by Unocal. BPA is also considering buying output from this facility. CalEnergy acquired the leases in 1994, an environmental impact statement has been prepared, and permitting decisions will be made this year. The Glass Mountain KGRA could ultimately yield as much as 500 MW of power, according to U.S. Geological Survey estimates. If the project is approved, commercial operation could begin in 2001.

When CalEnergy determined that the geothermal resources at Newberry volcano were insufficient to meet its obligations under the power purchase agreement with BPA in a cost-effective manner, the company notified BPA that it was relocating the project to Glass Mountain. A dispute arose over whether CalEnergy had the unilateral right to move the project and contract. In December 1996, CalEnergy and BPA executed a settlement agreement under which CalEnergy, in return for an initial payment of $9 million, released BPA from all claims arising from the Newberry contract. A power purchase agreement for Glass Mountain was negotiated, which contains terms more favorable to BPA than those in the Newberry agreement. BPA is not under obligation to execute the Glass Mountain agreement, but must pay CalEnergy an additional $9 million if the project is approved by the USFS and BLM and BPA then decides not to execute the contract. If BPA executes the contract, it will instead pay CalEnergy $10 million upon commercial operatin.

RELATED ACTIVITIES

The Geothermal Resources Council (GRC) held its national convention in Portland in October 1997. Several companies had activities in the Northwest at that time, and attendance at the conference was good. The local GRC chapter is now inactive, however.

ACKNOWLEDGMENTS

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———1998, Recent direct-use technical assistance activity: Geo-Heat Center Quarterly Bulletin, v. 19, no. 4, p. 1–3. □

Residents feel small earthquakes shaking various parts of Oregon

A magnitude 2.7 (M 2.7) earthquake centered just west of Molalla ("epicenter"), about 25 mi northeast of Salem, was felt by people throughout the northern Willamette Valley on Wednesday morning, February 24, 1999, at 8:45 a.m. The earthquake originated at an estimated depth of 25–35 km ("hypocenter"). It caused minor damage to Oregon City High School and shifted an 83-year-old home in West Linn from its foundation.

From Salem to Hillsboro to Vancouver, people reported feeling the small earthquake, observing effects from lamps swinging to tables bouncing on the floor. Several people went outside to see whether a tree branch had landed on their roof but found nothing to explain the sound and shaking they had noticed.

Other earthquakes have occurred in the same area as the small February temblor: Two smaller earthquakes (M 2.1 and M 1.6) were recorded earlier in February, and a M 3.6 earthquake occurred in February 1995. Although the 1995 earthquake was larger, it was felt by few people because it occurred at night. Geologists throughout the state do not believe these earthquakes were aftershocks of the M 5.6 Scotts Mills earthquake that occurred on March 25, 1993.

Gerald L. Black, geologist with the Oregon Department of Geology and Mineral Industries (DOGAMI) said it was unusual for an earthquake of this small size to have been felt over such a wide area. "Typically, quakes of that strength are barely felt. Normally, if you're on the ground, you wouldn't feel anything unless you were on top of it," Black said. "It would be a gentle vibration."

One reason why shaking was felt and sounds were heard so widely is the depth of the event. For comparison, the Scotts Mills quake was only 15 km deep, while this event was about twice that. So the shock waves could spread farther in all directions before they reached the surface.

Another reason for the widespread shaking is the soil of the Willamette Valley. "We have a lot of alluvium, the loose, unconsolidated deposits from rivers that have been flowing through the Valley for thousands of years," explains Lou Clark, Earth Science Information Officer with DOGAMI. "Unfortunately, these are the perfect soils to amplify the effects of earthquakes."

At Oregon City High School, cracks were opened in walls and ceilings throughout the 67-year-old building. Bob Walker, a structural engineer, inspected the building and found no structural damage but did say the building could not handle a

Table 1. *List of some recent (1999) small earthquakes centered in Oregon*

Date	Location	Magnitude	Depth (km)
January 30	Northwest of Salem	2.1	25
January 31	Southwest of Coos Bay (offshore)	2.6	25
February 10	Southeast of Scappose	2.1	19
February 15	Southeast slope of Mount Hood	2.6	7
March 3	Southeast of Joseph	3.0	19
March 3	Southeast of Joseph	2.2	18
March 10	East of Milton-Freewater	2.6	5
March 15	North of Bend	2.0	28
March 17	East of Milton-Freewater	2.3	3

larger earthquake (M 5.0 or higher). School officials and structural engineers are also worried that the cumulative effects of many small to moderate earthquakes over the years could be undermining the building's structural integrity.

Clark notes that there are thousands of buildings in the state similar in design to the High School brick building. "Buildings have only so much ability to resist earthquake damage," she adds. "We know older, unreinforced brick buildings do not stand up well to earthquakes unless they've been specially strengthened." Without such improvements, each small earthquake robs the building of a little more of its ability to cope with the strain of shaking in the ground below it.

Small earthquakes are a daily event in Oregon, and events over a M 2.0 happen every week or so (See Table 1).

"We know there will be another damaging earthquake in Oregon," warns Clark. "We don't know where or when, so we all need to be prepared." □

Seeking a new Director for DOGAMI

The State of Oregon seeks a Director for the Oregon Department of Geology and Mineral Industries (DOGAMI). In concert with the Governing Board, the Director oversees the management of the Department, including goals, policy, budget, and legislative liaison in technical and regulatory programs.

The Department is responsible for developing information about and mitigation strategies for natural hazards such as earthquakes, landslides, floods, and tsunamis. The Department is also the leading regulatory agency for mining, oil and gas, and geothermal energy exploration, production, and reclamation.

Interested applicants can obtain a detailed job description and information on the application process by contacting Laura Trevizo, Recruitment and Career Services, 155 Cottage Street NE, Salem, Oregon 97310. Phone: 503-378-3040. Applications must be received by 5:00 p.m., May 14, 1999.

WSSPC *Award in Excellence* goes to Benton County

The Benton County Emergency Management Council (BCEMC) was honored with one of the 1998 "Awards in Excellence" by the Western States Seismic Policy Council (WSSPC). The "Excellence in Response Plans" award was presented at a banquet in Pasadena, California, at the WSSPC annual conference and was accepted by Diane Merten, the current chair of the BCEMC. The Council was nominated for recognition by the Benton County Board of Commissioners. In the words of WSSPC Executive Director, Steve Ganz, the BCEMC "is an outstanding example of a coordinated, public-private partnership focused on emergency preparedness."

The BCEMC is a partnership of regional government, business, and nonprofit professionals concerned with making the community safer and more resilient following a disaster. The brainchild of a dedicated and tenacious community volunteer, Diane Merten, the BCEMC was officially formed in April, 1991. Merten, a former California resident and advocate for emergency preparedness, has chaired the Council since 1991.

The BCEMC embraces all phases of emergency management: mitigation, preparedness, response, and recovery. Four subcommittees support the efforts of the full council: Plans; Training and Exercise; Logistics, Facilities and Equipment; and Public Education. Among the many Council-member initiatives have been the following:

- Sponsorship of regional disaster training and exercise.
- Coordinated and cooperative response to actual emergencies.
- Public education campaigns and presentations including the Linn-Benton Neighborhood Emergency Training ("LB-NET") program.
- Development of emergency operations plans and protocols.
- Seismic/structural and nonstructural hazard studies and retrofitting of critical community facilities, including Oregon State University and the Corvallis School District, the Corvallis Fire Department and the Law Enforcement Building (Sheriff/Police).
- Flood study and mitigation projects by the City and County.
- A regional, "all-hazards," mitigation study, involving Benton, Linn, Lane, and Lincoln Counties and State Economic Development grant funding.
- Support for the "Oregon Emergency Management Act" to establish a Governor's Advisory Council on Emergency Management, create an Oregon disaster relief fund, establish a competitive grant/mitigation fund and bolster Oregon's existing emergency management system.
- Designation as one of the Federal Emergency Management Agency's 50 pilot programs, "Project Impact: Building a Disaster Resistant Community," and eligibility for $300,000 in federal funding for mitigation projects.

The BCEMC works without a formal budget. It is largely funded by participating agencies, donations, and the Benton County Sheriff's Office, Emergency Management Division. The latter is the official administering agency and provides staff support, partly with its own volunteers—which has included the integral thesis work of two Oregon State University students.

For more information about the BCEMC, visit the web site that is being developed with BCEMC member and partner Oregon State University at

http://osu.orst.edu/groups/bcemc

Earthquake and tsunami preparedness month

Several activities and new products are available during April to help you prepare for earthquakes and tsunamis.

Duck, cover, hold drill

On April 22 between 9:30 and 10:00 am, schoolchildren and businesses across Oregon and Washington will be practicing how to duck, cover, and hold to stay safe in an earthquake (**duck** down, take **cover** under a sturdy piece of furniture, **hold** on until the shaking stops).

You may want to see if your school is participating, or even practice yourself.

Earthquake and tsunami curricula and videos

How do you explain plate tectonics to an 8-year-old? Or make high school students understand the probability of earthquakes in Oregon? These and many other topics are addressed in a new earthquake and tsunami curriculum available to Oregon schools.

Hands-on actitivities and a video are included in the materials for students Kindergarten through grade 12. A video shows students at Taft Elementary School in Lincoln City doing a duck, cover, and hold earthquake drill and a tsunami evacuation drill. The 13-minute video also contains explanations of the dangers of tsunamis and how to survive them.

All materials were designed with the cooperation of the Oregon Department of Education and an advisory group of teachers and should meet state educational standards. Three separate volumes are available: grades K–3, 4–6, and 7–12. Each volume is available for $25 from the Nature of the Northwest (order form on back of magazine).

Tsunami safety materials

The Oregon Department of Geology and Mineral Industries has produced everything from mugs to roadside signs explaining various aspects of tsunami dangers. Several products have been designed for hotels, motels, and restaurants along the coast to give potentially life-saving information to their guests. □

Sample exercise for grades 4-6

How Likely Are Earthquakes in Oregon?

1. Tell your students that scientists try to determine the chances of earthquakes happening.

- Have the students determine how old they would be in 50 years.
- In Oregon, the chances of a large earthquake are thought to be between 1 in 10 (1/10 or 10%) to 1 in 5 (1/5 or 20%) in the next 50 years.
- Ask your students how we might represent that kind of chance using blocks, a spinner, or a die.
- Show the students what this would look like with blocks (at least the 1 in 5).

2. Show the students 1 blue block and 4 orange blocks. This represents 1 in 5. Put the blocks in the bag.

Ask the students how likely they think it is that the blue block would be picked. Have a student ***reach in one time.*** This is our 1 in 5 chance in the next 50 years. It will probably be an orange block. No quake!

- Should we still be prepared? YES, because there **is** a chance. It may be slight, but it still could happen; therefore, we should be prepared.

3. This is a good time to relate to your students the connection between fire drills and earthquake drills. We practice and prepare for both dangerous situations, even though the chances of either one occurring are small.

These disasters are not likely to happen often, but if either one does occur, we will be much safer if we know about the safe thing to do.

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