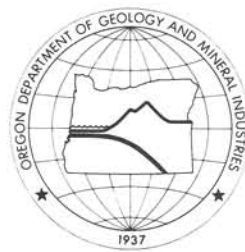


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A black and white photograph showing a complex industrial wellhead structure. The structure is made of metal and has many pipes, valves, and flanges. A worker wearing a hard hat and a light-colored shirt is visible in the lower right, working on the structure. The background shows more industrial equipment and a hazy sky.

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Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. If manuscript was prepared on common word-processing equipment, a file copy on 5-in. diskette may be submitted in addition to the paper copies. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

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

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

Cover photo

Workers install wellhead at the DY Oil well Neverstill 33-30 in the Mist Gas Field, northwestern Oregon. See related summary report on oil and gas exploration and development in Oregon for 1989, beginning on page 43.

OIL AND GAS NEWS

Mist Gas Field report revised

The Mist Gas Field Report published by the Oregon Department of Geology and Mineral Industries (DOGAMI) has been revised and is now available with all 1989 activity and changes included. This report includes the Mist Gas Field Map, which was revised to include the seven wells ARCO and the six wells DY Oil drilled during the year. The location, status, and depth of all wells are indicated on the map. The report also includes production figures for the wells at Mist from the initial production in 1979 through the end of 1989. Included are well names, revenue generated, pressures, annual and cumulative production, and other data. The Mist Gas Field Report, Open-File Report 0-90-1, sells for \$7.

Rulemaking continues

Draft rules to implement House Bill 2089 (1989 Legislature) are now available for review. These are to provide for ground-water protection and surface reclamation when shallow exploratory holes, such as seismic shot holes, are drilled by the oil and gas industry in Oregon. Administrative rules relating to oil and gas exploration and development in Oregon are also being reviewed at this time. These were last revised in November 1985, and revisions to these rules may be proposed. Public hearings for them and for House Bill 2089 rules will be scheduled for some time during February or March. Contact Dan Wermiel for details. □

New maps and reports released by DOGAMI

Geologic maps for southeastern Oregon

Two new geologic maps released by the Oregon Department of Geology and Mineral Industries (DOGAMI) describe the geology and mineral potential of the Double Mountain and Grassy Mountain areas in southeastern Oregon. These areas are currently the focus of intensive exploration for gold but show potential also for other mineral resources, such as feldspathic sands, limestone, bentonite clay, diatomaceous earth, perlite, natural gas, and geothermal energy.

DOGAMI geologists M.L. Ferns and L. Ramp produced both DOGAMI map GMS-57, *Geology and Mineral Resources Map of the Grassy Mountain Quadrangle, Malheur County, Oregon*, and DOGAMI map GMS-58, *Geology and Mineral Resources Map of the Double Mountain Quadrangle, Malheur County, Oregon*.

Both of the maps are two-color maps at a scale of 1:24,000. They show rock units and geologic structure on a topographic base and identify the locations of samples collected for analysis, fossils, and, in the case of GMS-58, gas-exploration wells. The price of each map is \$4.

The two publications were prepared in cooperation with the U.S. Geological Survey (USGS) and were partially funded by the COGEMAP program of the USGS.

The Grassy Mountain 7½-minute Quadrangle covers approximately 48 mi² south of Vale, Oregon. The map of the quadrangle, GMS-57, consists of two plates: The first plate contains the geologic map, two geologic cross sections, and a discussion of the mineral resources of the quadrangle; the second plate contains two tables of sample analyses.

The Double Mountain 7½-minute Quadrangle is the immediately adjacent quadrangle to the north. The map covering this quadrangle, GMS-58, consists of one plate that includes the geologic map, analytical tables, two geologic cross sections, and a discussion of the mineral-resource potential of the quadrangle.

(Continued on page 36, *Reports*)

Maps: the Earth on canvas

by Evelyn M. VandenDolder, Arizona Geological Survey

This paper first appeared in the Winter 1987 issue of *Fieldnotes* (v. 17, no. 4), published by the Arizona Bureau of Geology and Mineral Technology. Since that date, the name of the publication has been changed to *Arizona Geology*, and the name of the state agency has been changed to the Arizona Geological Survey, located at 845 N. Park Avenue, #100, Tucson, Arizona 85719, phone (602) 882-4795. The content of the original paper was modified to include information about Oregon instead of Arizona. It was also updated and expanded slightly by Glenn Ireland, State of Oregon Resident Cartographer, whose assistance is gratefully acknowledged.

—Editors

INTRODUCTION

Amelia Earhart, the plucky aviator whose 1937 round-the-world flight ended in disaster, may have been the victim of a mapmaker's mistake. Earhart's flight plan gave the wrong coordinates for Howland Island, the South Pacific sandbar that was only 2 miles (mi) long and that she and navigator Fred Noonan were trying to reach when they vanished. The faulty flight plan, which was based on inaccurate government charts, put Howland Island 7 mi to the northwest of its actual location. Earhart's flight plan listed the coordinates for the tiny island as latitude (lat) $0^{\circ}49' \text{ N.}$, longitude (long) $176^{\circ}43' \text{ W.}$, whereas the actual coordinates are lat $0^{\circ}48' \text{ N.}$, long $176^{\circ}38' \text{ W.}$ (Barker, 1986). Some investigators who searched for the possible causes for Earhart's disappearance believed that she and Noonan were on course and would have reached Howland Island if they had been given the correct coordinates. The first chart to list accurate coordinates was published four to five months after Earhart and Noonan vanished. It is therefore likely that the mapping mistake was discovered during the search for Earhart.

Earhart's story illustrates the importance of accuracy in maps and translates a seemingly inconsequential error on paper into the language of human tragedy. Accurate, detailed maps have enabled humans to chart not only their courses across vast oceans but also the progress of their civilizations. The following article gives an abbreviated history of cartography, the art and the science of mapmaking; explains scale, coordinate systems, and projections; illustrates how remote-sensing techniques aid mapmaking; describes various specialized maps and how they are used; and lists several sources of maps of Oregon.

HISTORY OF MAPMAKING

Maps are as old as human culture. The detail and accuracy of mapmaking have, in turn, both reflected and enhanced the advancement of civilization. From prehistoric hunters, who probably drew crude maps in the dirt, to Renaissance navigators, who explored and mapped the oceans and continents, to today's cartographers, who use satellite images, mapmaking has had a long and exciting history.



Figure 1. Today's cartographic instruments range from the compass, which was invented during the 11th or 12th century, to sophisticated computer systems that can increase the speed, accuracy, and quality of all mapmaking efforts. Drawing by Peter F. Corrao, Arizona Geological Survey.

As human culture evolved from a nomadic, hunting existence to a more settled, agrarian lifestyle, land ownership and determination of property lines became more important. The oldest known map, dated about 2500 B.C., is a small clay tablet that shows a man's estate nestled amid mountains and rivers in Mesopotamia (Chamberlain, 1950; Raisz, 1962). The Egyptians measured and mapped their countryside for property taxes to fuel their thriving civilization. These early peoples believed that Earth was flat, and their maps reflected this concept.

Ancient Greek culture emphasized logic, reason, and scientific thought, nurturing interest in the world as well as the mind. The Greeks conceived the idea of a spherical Earth. About 400 B.C., Aristotle offered evidence as proof: the shape of Earth's shadow on the Moon during an eclipse (Chamberlain, 1950). Eratosthenes (276-194 B.C.), mathematician and philosopher, estimated the size of Earth based on observations of shadows and a knowledge of geometry. Despite his crude methods (by modern standards), his

estimate of Earth's circumference of 28,000 mi was only 12 percent larger than its actual size (about 24,900 mi; Chamberlain, 1950). His map, which showed parts of Europe, Africa, and Asia, was the first to include parallels and meridians. The early Greeks also defined the poles, the equator, and tropics and developed several projections that are still used today.

Medieval cartographers, seeking a more simplistic view of the world to mirror their religious beliefs, chose more symmetrical, "divinely perfect" outlines for Europe, Africa, and Asia rather than the more accurate, irregular coastlines of earlier maps. In the late 13th century, however, the use of the compass burgeoned, as did the production of highly accurate maps known as "portolan charts," which were used with minor modifications for more than three centuries. Portolan charts were based on systematic compass surveys. Most charts included 16 or 32 compass roses with radiating rhumb lines (lines that show the compass directions), a design sometimes used on current maps as decoration (Raisz, 1962).

The discovery of the Americas effected a renaissance in cartography. As the number of trade routes increased, so did the need for more detailed maps. New discoveries from explorations modified humans' view of the world. The first map to include America, published in 1500, showed it as part of Asia (Raisz, 1962). It was not until after Magellan's voyage from 1519 to 1522 that maps accurately depicted the immensity of the Pacific Ocean. The invention of the engraving and printing processes during this period enabled wider and more timely distribution of new maps. The highest quality maps produced during the late 16th and 17th centuries were compiled by Dutch and Flemish mapmaking masters, such as Mercator, Ortelius, and Janszoon (Raisz, 1962).

The 18th century, known as the Age of Reason, brought a concomitant age of map accuracy. Instruments to measure latitude and longitude became more sophisticated. Triangulation and topographic mapping of France during this time, sponsored by the Cassini family, spurred interest in similar national surveys during the following century (Raisz, 1962). Cartographers of the 19th century also diversified and specialized their products,

creating geologic, economic, and transportation maps, among others. With the founding of the U.S. Geological Survey (USGS) in 1879, the systematic mapping of the United States became an organized effort.

In our own century, the advent of remote-sensing techniques such as aerial photography and satellite imagery has enabled the cartographers to create a "bird's-eye" view of the world and its features. Digital scanning systems and laser plotters have dramatically increased the accuracy and detail of modern maps (Figure 1). Technological advances and increasingly sophisticated instruments continue to enhance the quality and accuracy of human attempts at sketching the face of Earth.

SCALE

Scale defines the relationship between a distance shown on a map and the corresponding actual distance on the ground. Scale may be expressed in three ways (Zumberge and Rutford, 1983):

1. As a graph, line, or bar divided into units that represent ground distances.

2. In words that state the relationship between map distance and ground distance; for example, "1 inch (in.) equals 1 mile (mi)" means that 1 in. on the map corresponds to 1 mi on the ground.

3. As a fraction or fixed ratio between linear efforts in measurements on the map (the numerator) and corresponding distances on the ground (the denominator). For example, a scale of $\frac{1}{63,360}$ (or 1:63,360) means that one unit of measurement on the map (for example, 1 in.) represents 63,360 of the same units on the ground. In this example, 1 in. on the map corresponds to 1 mi on the ground (1 in. [map] = 63,360 in. [ground] = 5,280 feet [ft] [ground] = 1 mi [ground]). The first number (map distance) given in the ratio is always 1; the second number (ground distance) varies, but the *larger* the second number, the *smaller* the scale.

Many areas have been mapped several times, but at different scales. One should

choose a map with a scale appropriate for its intended use. For instance, a large-scale map shows more detail but less area; therefore, an urban planner might choose a 1:600-scale map that shows power and water lines, house lots, streets, etc. A small-scale map, on the other hand, shows less detail but encompasses a wider area. A geologist who is interested in the general geologic history of Oregon might choose a 1:500,000-scale geologic map of the state that shows major rock formations and geologic features. An exploration geologist looking for gold, however, would prefer a larger scale, such as 1:24,000, that would enable him or her to see more precisely the location of specific rock units or structures on the ground.

Large-scale topographic maps (see section titled "Types of Maps") of 1:24,000 show natural and manmade features such as important buildings, campgrounds, caves, ski lifts, watermills, bridges, and private roads. Intermediate-scale topographic maps scaled 1:50,000 and 1:100,000 usually omit these

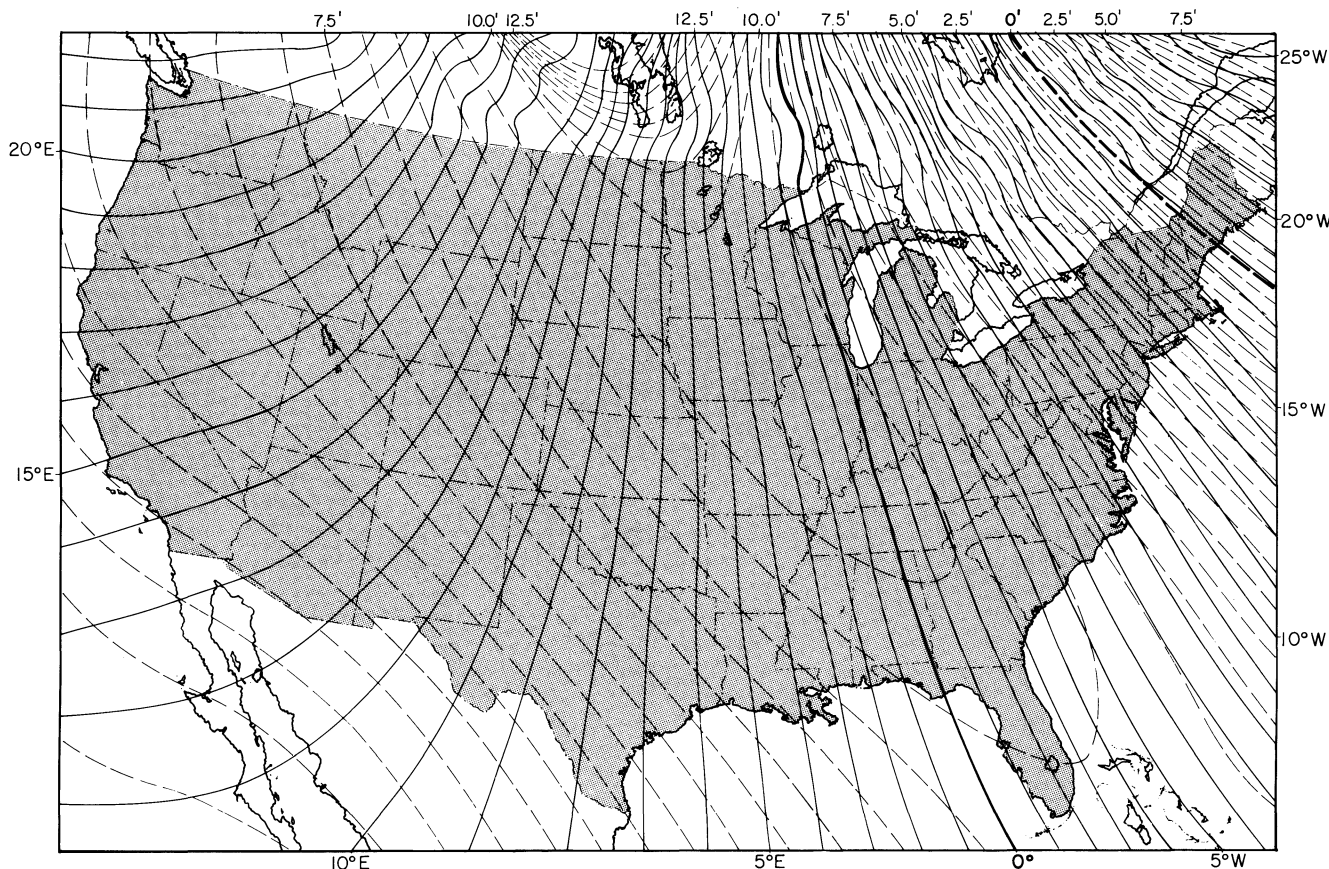


Figure 2. Magnetic declination, also known as compass variation, is the angle between true (geographic) north and the direction in which the magnetic compass points (magnetic north). Its value at the beginning of 1980 is indicated in this chart by isogonic lines, or lines of equal declination. Values along the top of the chart refer to dashed lines. Values along the sides and bottom of the chart refer to solid lines. Solid lines indicate the number of degrees between magnetic north and true north, with magnetic north east of true north at locations that are west of the 0° line (labeled on the bottom of the chart) and west of true north for locations that are east of the 0° line. Dashed lines indicate change in minutes per year in the direction of magnetic north, with change to more eastward direction east of 0° line (labeled on the top of the chart) and change to more westward direction west of 0° line. From Fabiano and Peddie, 1980.

features. Small-scale topographic maps of scale 1:250,000 and smaller (i.e., scales with a larger denominator) show only major features such as national and State parks, Indian reservations, airports, major roads, and railroads (U.S. Geological Survey, 1981b).

COORDINATE SYSTEMS

"Finding oneself" is not easy in this world, whether it be in the psychological or geographical sphere. Ever since the first map was compiled, cartographers have searched for an accurate system to locate points on the globe. Some map users, such as navigators, need a means to track their progress across oceans; others, such as land owners and government officials, need a method to establish property lines; still others, such as geologists, need a way to identify localities of outcrops, minerals, etc., so that future researchers can find and study them.

In the United States, three coordinate systems are generally used: (1) geographic coordinates (latitude and longitude); (2) Public Land Survey (PLS), also called the "Land Office Grid" or "township and range"; and (3) Universal Transverse Mercator (UTM) grid. A fourth system—State Plane Coordinates—is used extensively by state and local governments, in large-scale mapping, and in engineering and property surveys. Each of these systems is explained in the sections that follow.

LATITUDE AND LONGITUDE

Cartographers have arbitrarily divided the Earth's surface into a system of reference coordinates that are termed "latitude" and "longitude" and are based on a series of imaginary lines called "parallels" and "meridians," respectively, drawn on the surface.

If one imagines Earth as a globe with an axis through the North and South Poles, the meridians of longitude would be circles around the globe that pass through both poles. A meridian is labeled according to its distance, measured in degrees, east or west of the zero meridian, which was established in 1884 by international agreement as the meridian that passes through Greenwich, England, near London. Before this time, many countries used meridians that passed through their own capital cities as the 0° meridian for their own maps (Chamberlain, 1950). The zero meridian is also called the "Greenwich" or "prime" meridian. Because the globe encompasses 360°, the 180° west meridian (long 180° W.) and the 180° east meridian (long 180° E.) represent the same imaginary line known as the "International Date Line." Although this line mostly follows the 180° meridian, there is some variation to prevent separating land masses, such as the Aleutian Islands, into time zones with different days.

Midway between the North and South Poles, the Equator, an imaginary line that circles Earth, divides it in half into the North-

ern and Southern Hemispheres. Imaginary lines drawn concentrically around the poles and parallel to the Equator are called "parallels of latitude." They are labeled according to their distances, measured in degrees, north and south of the Equator. The Equator is 0° latitude (lat 0°), the North Pole is 90° north latitude (lat 90° N.), and the South Pole is 90° south latitude (lat 90° S.). Parallels of latitude, as their name states, always parallel each other; meridians of longitude, however, converge at the poles.

Each degree used to measure latitude and longitude may be divided for more precise location into 60 minutes, represented by the minute symbol ('). Each minute, in turn, may be subdivided into 60 seconds, identified by the second symbol ("). For example, the coordinates of the Portland office of the Oregon Department of Geology and Mineral Industries are lat 45°30'50" N., long 122°40'43" W.

Because the circumference of the Earth is about 24,900 statute (land) miles (21,600 nautical miles), each degree of latitude measures about 69.2 statute miles (60 nautical mi), each minute measures about 1.15 statute miles (1 nautical mi), and each second measures about 101 ft (Chamberlain, 1950). Distances represented by degrees of longitude vary depending upon the latitude. At both the North and South Poles, for example, one could walk through 360° of longitude by walking in a circle around the pole. At the Equator, such a walk would be a considerable undertaking, indeed! At the latitude of Portland, one second of latitude equals 71 ft. One second of longitude equals the same as at the Equator—101 ft.

Time zones are related to meridians because of Earth's rotation. A full rotation of Earth on its axis (360° of longitude) takes 24 hours, 15° of longitude takes one hour, and 1° takes four minutes.

The latitude-and-longitude system of coordinates is used worldwide. Similar systems have been extrapolated for use in space. Of the three systems discussed in this article, this is the only one that can be determined astronomically and without a map (Merrill, 1986a).

Meridians always run in a true north-south direction. True north, however, is not the same as magnetic north (the direction that the needle in a magnetic compass points), except on the meridian that passes through the magnetic North Pole (Zumberge and Rutford, 1983). This is because of polar wandering; the geomagnetic axis does not coincide with Earth's axis of rotation. The magnetic North Pole is actually at about lat 70° N., which is about 1,250 mi from the geographic (true) North Pole (Strahler, 1981).

The angle in any given location between true north and magnetic north is called the "magnetic" or "compass declination." Declination records have been kept in Paris and

London since about 1600 (Strahler, 1981). Local declination and its annual variation are usually shown in the lower margin of most maps published by the USGS. The correction for annual change, however, will be only approximate if the map is more than 20 years old (Compton, 1962). Declination can also be determined from an isogonic chart (Figure 2) or by setting a compass on a level surface and sighting on Polaris, the North Star (Compton, 1962). In Portland, the magnetic declination is 19.64° E., based on the International Geomagnetic Reference Field (Shaul Levi, Geophysics Group, College of Oceanography, Oregon State University, personal communication, 1989).

PUBLIC LAND SURVEY SYSTEM

The Public Land Survey System was instituted in 1785 by the Continental Congress from the recommendation of Thomas Jefferson. The system was instituted to get away from the metes and bounds surveys along creeks, stone walls, and ridges that characterized the surveys of the 13 colonies. The Public Land Survey System is the legal method of describing land in all states except the original colonies and Texas. A Spanish system is used in Texas.

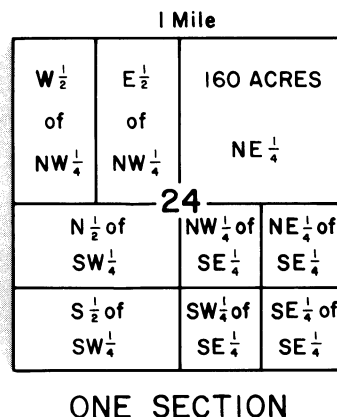
Township and range designations are used to locate property boundaries and describe land areas. The basic unit, called a "section," is a square-shaped area 1 mi long and 1 mi wide. One standard section contains 640 acres. A standard township is 6 mi on each side and contains 36 sections, or 23,040 acres. When the sections and townships were surveyed, each section was intended to encompass an exact square mile of land. Surveying errors, however, created irregularities in the shapes of many sections and townships in the United States (Zumberge and Rutford, 1983).

Township-range divisions are based on a grid of perpendicular lines. Township lines are numbered every 6 mi north and south from an initial point. Range lines are numbered every 6 mi east and west from the initial point. Instead of the Equator and zero meridian, reference lines for township designations are specific east/west and north/south lines called the "base line" and "principal meridian," respectively (Zumberge and Rutford, 1983). A township is located by giving its position north or south of the base line and east or west of the principal meridian. The notation "T. 4 S., R. 2 W." indicates township four south, range two west. Many base lines and principal meridians are used in the United States, so township and range coordinates are never very large. In Oregon and Washington, the townships are measured from the Willamette Base Line (about lat 45°31'11" N.) and Willamette Principal Meridian (about long 122°44'34" W.), which originate at the Willamette Stone in the West Hills of Portland (see USGS Portland, Oreg.-

Because the township, range, and section coordinate system is a flat grid made of perpendicular lines in 1-mi segments, there has to be something built into the grid to make it fit over the curved surface of the earth. Correction meridians and parallels are established every four townships (24 mi) from the initial point. These Guide Meridians and Standard Parallels adjust the alignment of the north-south lines to correct for the convergence of the lines toward the pole. Imagine two lines, 6 mi apart, running true north for 24 mi. In 24 mi, these two lines will be 5.96 mi apart because of convergence. At the 24-mi mark along the principal meridian, a standard parallel is established. The township lines are readjusted from 5.96 to 6 mi apart, and another 24-mi block is surveyed north from the standard parallel.

The Universal Transverse Mercator (UTM) grid was adopted by the U.S. Army in 1947 to assign rectangular coordinates on military maps of the world (Snyder, 1987). Although the original UTM grid used only numerals as coordinates, the U.S. Army simplified it by substituting letters for several numbers. In military parlance, the UTM is called the "Military Grid System." In scientific jargon, it is simply called the "UTM" (U.S. Department of the Army, 1969, 1983; Hines, 1986; Merrill, 1986b).

Diagram illustrating a township and range grid. The grid is divided into townships (T1N, T2N, T3N) and ranges (R2W, R1W, R1E, R2E, R3E). A thick vertical line is labeled "Principal Meridian" and a thick horizontal line is labeled "Base Line". The bottom-left corner shows a 6-mile square divided into 36 smaller squares, labeled "6 Miles" and "36 SQUARE MILES".



from lat 80° S. to lat 84° N. The polar regions beyond these parallels are assigned coordinates on the Universal Polar Stereographic (UPS) grid (Snyder, 1987), which will not be discussed in this article. The State of Oregon lies in UTM grid zones 10T and 11T, which cover a rectangular area from long 126° W. to 114° W. and from lat 40° N. to 48° N.

Each grid zone may be further divided into grid squares that measure 100,000 meters (m) (109,361 yards [yd]) on a side; these are given double-letter designations. In turn, grid squares may be subdivided with finer numerical grids that enable one to locate an area 10 m by 10 m (11 yd by 11 yd) on most current maps (Merrill, 1986a).

clude them. State base maps, new maps, and reprinted quadrangle maps, however, include UTM grid lines or tick marks (Merrill, 1986a). The UTM grid is significant to digital cartography in that it is widely used to encode map data for eventual computer handling.

The National Geodetic Survey, in coordination with each state legislature, has designed and mandated a projection system that will "fit" each state with a minimum of distortion. Property and engineering surveys are required by state law to show the State Plane Coordinates of the monuments and control points on the plats and maps. Most states are too large for one projection to cover the entire state without exceeding the distortion lines. When a state is divided into two or

more State Plane Coordinate projection zones, the boundaries of the zones are divided along county boundaries. This is so that a county survey will always be in only one zone. The State Plane Coordinate system is designed so that there can be some overlap from one zone to another without exceeding the accuracy standards of the zone in which most of the survey is taking place.

Oregon's State Plane Coordinate System is based on the Lambert Projection with two zones, a North Zone and a South Zone. This projection was chosen because Oregon is wider in an east-west direction and the Lambert Projection "fits" better in an east-west direction with minimum distortion. Idaho has a system based on the Transverse Mercator Projection because the state is longer in a north-south direction. Idaho has three zones: East, Central, and West.

USGS 7½-minute quadrangle maps show the State Plane Coordinate System ticks every 10,000 ft in black along the edges of the quadrangle. Ticks with complete numbers are located on the southwest and northeast corners of USGS maps. Other tick marks along the edge are unnumbered. Quadrangles with more than one state will identify each of the state's plane coordinate zone ticks.

In an unending quest for perfect accuracy, scientists continue to develop new location systems or modify old ones and debate the usefulness, precision, and accuracy of each (Hines, 1986; Merrill, 1986a,b, 1987; Nelson, 1987).

MAP PROJECTIONS

Earth is a sphere, actually a spheroid because it bulges slightly at the Equator and flattens at the poles. The most accurate map of Earth is a globe because, on it, scale is constant, and geographical relationships are true. Since a globe is cumbersome and impractical on a large scale, cartographers have developed ways to convert the three-dimensional spherical image to a two-dimensional flat image. A map projection is a systematic method of transferring the grid system of parallels and meridians from globe to paper using mathematical calculations to alleviate distortion (Chamberlain, 1950).

As the word "projection" implies, areas of the globe are projected onto another surface and then transferred to paper. This intermediate surface can be a cylinder, cone, or plane. The shape of the surface, the line of contact or point of tangency between the surface and the globe, and the point on Earth that is chosen as the center or starting point determine the type of the projection (Figures 4 and 5).

There is no best projection to portray the world. A cartographer determines which projection to use based on the characteristics deemed most important, such as area, shape, scale, or direction. Hundreds of projections have been developed throughout the history

of cartography, but only a few dozen are used to produce most of today's maps. Some of the more common or useful projections are briefly described below. Snyder (1987) has written an excellent book on projections that includes both historical and descriptive text for the layperson and mathematical calculations for the professional cartographer.

CYLINDERS

Perhaps the best known and most easily drawn projection was developed by the Flemish cartographer Gerardus Mercator (1512-1594). The Mercator projection is drawn by wrapping a cylinder around the globe, with both surfaces touching along the Equator; meridians are then projected from the center of the globe (Snyder, 1987; Figures 4a and 5a). Mercator developed this projection to aid navigation. This is the only projection on which all points are shown at their true compass courses from one another; if a ship's direction remains constant with respect to north, the sailing route between two points is a straight line. Since 1910, this has been the standard projection used on the nautical charts of the U.S. Coast and Geodetic Survey, now called the National Ocean Service (Snyder, 1987). Areas in the polar regions, however, are greatly distorted with this projection. Greenland appears to be larger than South America, yet it is only one-eighth the size of the continent (Snyder, 1987; Figure 5a). Because most world maps in elementary and high school textbooks are drawn with the Mercator projection, students could be confused about relative sizes of land masses. This projection is best used on maps of equatorial regions and has been used to map those

areas on Earth, Mars, Mercury, Venus, the Moon, and the satellites of Jupiter and Saturn (Snyder, 1987).

Variations of the Mercator projection have been developed to handle special cartographic needs. In the Transverse Mercator projection, the cylinder and globe touch along a meridian instead of along the Equator (Figures 4b and 5b). Areas along the central meridian remain true to scale, no matter how far north or south of the Equator they are. This projection is used for areas in which the north-south dimension is greater than the east-west dimension. It is also the base for the USGS 1:250,000-scale maps (1° x 2° quadrangles) and some 7½- and 15-minute quadrangles (Snyder, 1987). In the Oblique Mercator projection, the cylinder touches the globe along a circle path specifically chosen to alleviate distortion in the mapped areas (Figures 4c and 5c). The USGS has further modified this to obtain the Space Oblique Mercator projection, which is used for continuous mapping of Landsat satellite images (Snyder, 1987).

CONES

Cylindrical projections are used mostly for maps of the world or narrow areas along the Equator, a meridian, or an oblique circle. Conic projections, on the other hand, are used to map areas in the middle latitudes that extend in mostly an east-west direction.

A regular conic projection is drawn by setting a cone on top of the globe, with the cone apex and globe axis aligned. The cone and globe touch along a specific latitude (standard parallel). Meridians are drawn from the apex to points at which corresponding meridians on

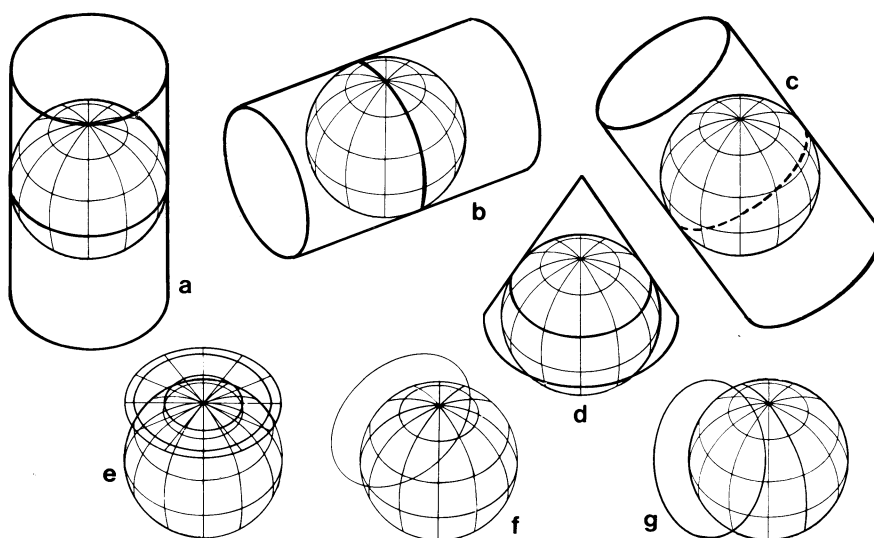


Figure 4. Projection of the globe onto three surfaces: (a) regular cylindrical (surfaces touch along Equator); (b) transverse cylindrical (surfaces touch along meridian); (c) oblique cylindrical (surfaces touch along circle path); (d) regular conic (surfaces touch along parallel); (e) planar or azimuthal, polar aspect (surfaces touch at pole); (f) planar or azimuthal, oblique aspect (surfaces touch at point between pole and Equator); and (g) planar or azimuthal, equatorial aspect (surfaces touch at Equator). From Snyder, 1987.

the globe intersect the standard parallel (Figure 4d). The cone is then cut along one meridian and unrolled (Snyder, 1987).

The simplest conic projection is the Equidistant or Simple Conic, which shows true scale along all meridians and one or two standard parallels (Figure 5d). It is the basic form developed about 150 A.D. by the Greek astronomer and geographer Claudius Ptolemy. This projection is the one most often used in atlases for maps of small countries (Snyder, 1987).

Variations of the simple conic projection include the Polyconic, which is mathematically based on an infinite number of cones tangent to an infinite number of parallels (Snyder, 1987). This projection was developed by Swiss-born Ferdinand Rudolph Hassler (1770-1843), who became first superintendent of the U.S. Coast Survey, precursor of the U.S. Coast and Geodetic Survey. Because of Hassler's promotion, the Polyconic projection was used on large-scale maps of the United States, such as USGS 7½- and 15-minute topographic quadrangles, until the 1950's. Quadrangle maps drawn with the Polyconic projection at the same scale and based on the same central meridian will fit exactly from north to south or east to west; however, they cannot be mosaicked in both directions without distortion (Snyder, 1987).

The Lambert Conformal Conic projection was developed by the Alsatian mathematician and cartographer Johann Heinrich Lambert (1728-1777). On this projection, local shapes, scale, and angles remain accurate, but area does not. It is used for mapping large countries and smaller regions with an east-west orientation such as the United States, North Carolina, Long Island, and Oregon (Snyder, 1987). It has been used on USGS 7½-minute quadrangle maps of Oregon prepared since the 1960's and is also the projection used for the USGS 1:500,000-scale State base-map series.

PLANES

Azimuthal (or zenithal) projections are drawn on a plane that touches the globe at one of the poles, the Equator, or some point between these. The center of the projection determines its aspect: polar, equatorial, or oblique (Figures 4e,f,g; 5e,f,g). The direction or azimuth from the center to every other point of the map is shown accurately. Because this projection has one standard point or center, it is used mostly to portray circular regions such as Antarctica, rather than areas that extend mostly in one direction (Snyder, 1987). On polar aspects, meridians are shown as straight lines that radiate at true angles from the center (pole), like the spokes on a wheel; the latitude lines appear as concentric circles around the pole (Figure 5e).

Except for the polar aspect, azimuthal projections are more difficult to draw than the cylindrical or conic versions. Azimuthal projections, however, portray Earth's roundness

and unity, features that are less apparent in the other two projections.

The Stereographic projection is the most widely used azimuthal projection. Hipparchus, the Greek astronomer and the father of trigonometry (2nd century B.C.), is credited with its invention, although it was probably known already to the Egyptians. The Stereographic projection was used only for maps of the heavens until the early 1500's (Snyder, 1987). This projection can depict only one hemisphere at a time. Its polar aspect is used extensively for maps of Antarctica and the polar regions of other planets and satellites (Figure 5e).

The Orthographic projection is probably the best known of the azimuthal projections. Because the perspective is from an infinite distance, maps drawn with this projection appear as they would from outer space, with a three-dimensional effect (Figure 5f). Its development, too, is credited to Hipparchus, who used it for astronomical calculations. The Orthographic projection became popular during World War II, as world leaders tried to emphasize the global aspects of the conflict (Snyder, 1987). It is seldom used in atlases today, except for pictorial views of the globe, because only one hemisphere can be shown at one time, and distortion near the outer edges is severe.

The Azimuthal Equidistant projection

shows distances and directions correctly from one point (point of tangency) on Earth's surface and any other point on the map (Figure 5g). Maps based on this projection usually show less than one hemisphere. The Egyptians probably used the polar aspect for star charts. Navigators have used it to chart coastlines based on distances and directions obtained at sea. This projection is used today in maps of the polar regions and continents and in world maps for radio and seismic use. The polar aspect is also used as the emblem of the United Nations.

REMOTE SENSING

Before the invention of the airplane, map-making was a down-to-earth profession based on observations made on land or sea. With the advent of aviation, cameras could record what only birds and balloonists had seen previously. Remote-sensing techniques, such as aerial photography and satellite imagery, are used by scientists, engineers, and cartographers to determine land features, to study seasonal changes in vegetation and wildlife habitats, and to evaluate damage caused by geologic hazards such as floods, landslides, and active volcanoes.

Vegetational differences are reflected in the shades and patterns that appear in black-and-white aerial photographs. Heavy vegetation such as forests are medium to dark

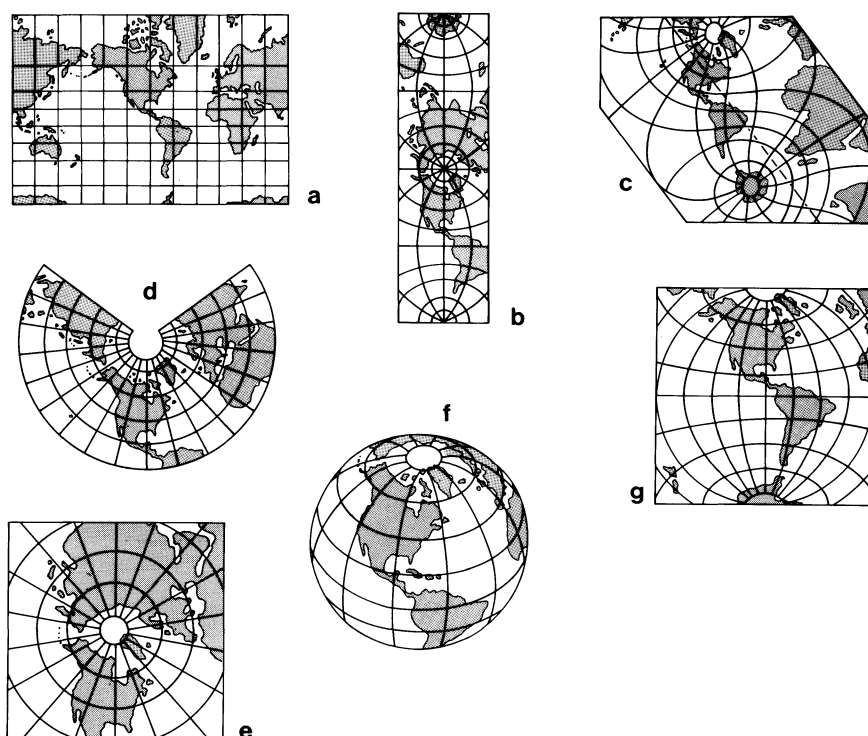


Figure 5. Selected map projections: (a) Mercator (regular cylindrical); (b) Transverse Mercator (transverse cylindrical); (c) Oblique Mercator (oblique cylindrical); (d) Simple Conic (regular conic); (e) Stereographic (planar or azimuthal, polar aspect); (f) Orthographic (planar or azimuthal, polar aspect); and (g) Azimuthal Equidistant (planar or azimuthal, equatorial aspect). From Snyder, 1987.

gray in color, whereas grasslands are light gray. Cultivated fields are usually rectangular in shape. Shades also give clues to soil and rock type. Clays that retain moisture, for example, appear darker than dry sand. Because the type of vegetation commonly reflects the bedrock on which it grows, vegetational variations can also be used to determine rock type (Zumberge and Rutford, 1983).

Photointerpretation can be enhanced by viewing aerial photos stereoscopically. Two photos of the same area taken from slightly different positions can be overlapped through the use of a stereoscope to show the relief of the land. Each eye sees only one of the photos, but the brain combines the two images to produce a three-dimensional view (Zumberge and Rutford, 1983).

False-color images are created by satellites that record infrared radiation from Earth. The measured differences are computer-enhanced to produce a picture in which the colors are not true to life; for example, green vegetation may show as red, and water may appear black (Zumberge and Rutford, 1983). Color variations result from differences in vegetation, soil, moisture, and rock types. False-color images created by Earth Resource Technology Satellites (Landsat) are byproducts of the U.S. space program. Each Landsat satellite circles the globe 14 times a day, scans a particular area of Earth more than 40 times a year, and creates images, each of which covers 115 mi² (U.S. Geological Survey, 1981a). The frequency and amount of coverage make satellite imagery especially useful in studying Earth's surface. Satellite images, however, cannot show the detail that aerial photographs can because they are taken farther from Earth's surface and thus, at a smaller scale. Because the satellites pass over the same point every nine days, comparative studies can be conducted on such topics as vegetation or human habitation.

TYPES OF MAPS

A map is a graphic representation of part of Earth's surface. Some types, such as road maps, show the distribution of features and manmade structures in two-dimensional form. Other types, such as topographic maps, illustrate the three-dimensional nature of Earth's features on a two-dimensional surface. Because geologic structures are three-dimensional, the latter type of map is more useful to geologists.

There are basically four types of maps: planimetric, topographic, thematic, and photoimage maps (U.S. Geological Survey, undated[b]). Planimetric maps show natural features, such as rivers and lakes, and cultural features, such as roads, railroads, towns, and land boundaries, but do not show relief features, such as hills or valleys. The latter may be labeled, however. A land map is a planimetric map. Topographic maps show both features and surface elevations. Photoimage maps, such as the orthophotoquads and or-

thophotomaps, are derived from aerial photographs that have been corrected to eliminate distortions due to perspective or camera tilt. These maps are related to standard coordinate systems but show photographic details that do not usually appear on conventional maps. Thematic maps show information about a specific theme or topic such as geology, rainfall, population, soil (pedology), or vegetation. Thematic maps include geologic maps, which show the position, structure, and composition of rock units and surficial materials and the nature of boundaries between rock types, such as faults and depositional contacts; geophysical maps, which show variations in the geophysical properties, such as gravity or magnetism (Figure 2); hydrologic maps, which show information about water resources; pedologic maps, which show distribution and character of soils; and land-use maps, which indicate the areas that are used for agricultural, recreational, wilderness, urban, or other purposes (U.S. Geological Survey, undated[b]).

Because of their usefulness to the professional geologist and because they are often confused by the layperson, topographic and geologic maps are described in the following sections.

TOPOGRAPHIC MAPS

Every geologic process leaves a mark on Earth's surface. Wind and water erosion, glaciation, and volcanism leave their respective signatures as characteristic landforms. Unlike other maps, a topographic map shows these three-dimensional imprints, as well as cultural features. Relief (mountains, hills, valleys, and plains), bodies of water (lakes, ponds, rivers, canals, and swamps) and cultural features (roads, railroads, towns, land boundaries, etc.) are depicted on topographic maps.

On a topographic map, relief is shown through the use of contour lines, imaginary lines on Earth's surface that connect points of equal elevation above or below sea level (Figure 6a). A contour interval, the difference in elevation between two adjacent contour lines, is generally a constant value chosen according to the ground slope and map scale. Two contour intervals may be shown on a single map to show relief features more precisely. Contour intervals on different maps may range from 5 to 1,000 ft (Zumberge and Rutford, 1983). Widely spaced contours indicate flat areas or areas with a gentle slope, while closely spaced contours indicate steep terrain such as mountains or cliffs. When contour lines cross stream-filled valleys or canyons that are shown on a map, they bend upstream; the contour resembles the letter "V" with the apex pointing upstream (Zumberge and Rutford, 1983). Index contours, on which elevations are labeled, are usually every fifth contour line and are drawn with heavier lines than other contours. Spot eleva-

tions may be given for specific locations such as mountain summits, road intersections, or lakes. Bench marks indicate points at which the land elevations have been precisely determined by surveying techniques and are marked by brass plates that are permanently fixed in the ground. These can be found on the tops of remote mountains as well as on the sidewalks of major cities. Each bench mark is shown on a topographic map by the letters "BM," followed by a cross and the measured elevation.

A shaded relief map is darkened to simulate the effect that sunlight and shadow would have on terrain. The pattern of light and dark accentuates the shape of physical features and creates a three-dimensional effect. Slope maps create this same effect through the use of different colors and color shades to indicate steepness and slope (U.S. Geological Survey, undated[b]).

A topographic map covers a specific quadrangle, an area that is outlined by parallels of latitude (the northern and southern boundaries of the map) and meridians of longitude (the eastern and western boundaries of the map). Standard quadrangle maps are bounded by 7½ minutes each of latitude and longitude (7½-minute quadrangle), by 15 minutes each of latitude and longitude (15-minute quadrangle), by 30 minutes of longitude and 60 minutes of latitude (30-by-60-minute quadrangle), or by 1° of latitude and 2° of longitude (1° by 2° quadrangle; Table 1). The USGS has been producing standard topographic maps for 7½- and 15-minute quadrangles in the United States since the 1880's. Although the actual area shown on a quadrangle map is a trapezoid, the map appears to be rectangular because the meridians converge toward the pole by such a small amount for each map that the eye has trouble detecting the difference.

Government agencies and private industries use topographic maps as bases for more specialized maps, such as geologic, land-use, soil, and road maps. Specialized data are superimposed directly on the topographic base sheet. Topographic maps are also used by planning agencies to aid in selecting sites for highways, airports, industrial plants, pipelines, powerlines, communication facilities, and recreational areas (U.S. Geological Survey, 1983). These maps are especially important in assessing and managing natural resources. They can also serve as practical guides for any camping, hiking, fishing, or hunting trip.

GEOLOGIC MAPS

Just as a person's face may reflect his or her character, the face of Earth may reveal what lies beneath its surface. A geologic map shows how Earth would appear if materials, such as vegetation, were stripped away (U.S. Geological Survey, 1982). These maps use standard symbols, patterns, and colors to de-

pict the types and relative ages of rocks and surficial materials and the surface and sub-surface associations or rock units (Figure 6b).

A geologic map is not easy to create. It requires countless hours of fieldwork, keen observation skills, an ability to think three-dimensionally, and at times, X-ray vision. The first step includes studying areas where rocks are visible and can be identified in outcrops, such as ledges, fault scarps, and streambanks, or in excavations, such as roadcuts, mines, and wells. In areas where the bedrock is covered, geologists may be able to infer the underlying rocks by studying surficial materials, vegetation, landforms, and regional structure. Techniques for determining age are unique to each rock type. The age of each rock or surficial unit is identified from fossils or bits of other rocks included within it, from radiometric dating, or from its position relative to other units. (Barring an episode of geologic upheaval, a sedimentary or volcanic rock unit is always younger than the one below it, a natural law that geologists call the "law of superposition.") Geologists also study aerial photographs and preexisting maps to fill in missing data and to corroborate field observations (U.S. Geological Survey, 1982).

The geologist records the locations, types, and ages of the rock units and surficial materials by using various colors or patterns on a topographic base map. Standard patterns have been adopted to distinguish among rock types. The basic rock units shown on a geologic map are called "formations." A formation is usually named after a geographic feature (mountain, canyon, town, etc.) near the area where the unit was first identified and/or described. Using special symbols, the geologist records other significant observations on the map such as faults, folds, contacts between rock units, and the strike and dip of formations (respectively, the direction of a horizontal line within a unit and the angle that the unit slopes in outcrop).

The reliability of a geologic map depends on the number of observations made in the field and the competence of the geologist. If there are few outcrops, little contrast between rock types, and a history of complicated geologic events, geologists can produce many plausible interpretations and make several credible geologic maps of the same area (U.S. Geological Survey, 1982).

Geologic maps can be used to locate mineral or energy deposits because specific rock types or structures (e.g., faults) are often associated with specific deposits. They can also be used to locate sources of ground water or construction materials (sand and gravel, flagstone, etc.), to determine the suitability of areas for agriculture or urban development, or to identify potential geological hazards. Geologic maps provide an enormous amount of information needed for deciphering Earth's long and complex geologic history.

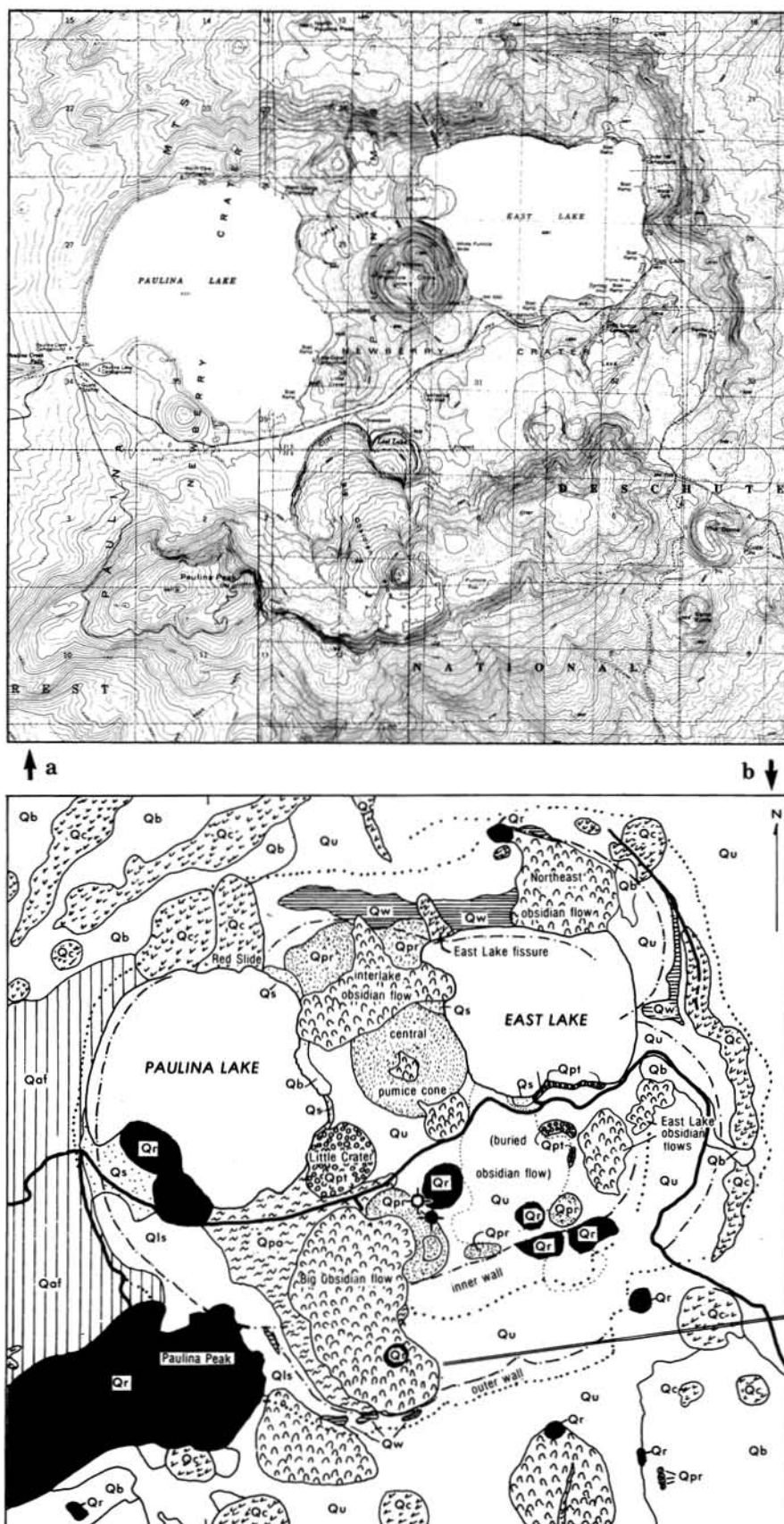


Figure 6. Comparison of topographic (a) and geologic (b) maps drawn at the same scale for the same region, the Newberry caldera in central Oregon. Note contour lines in (a) that indicate topographic relief and patterns in (b) that symbolize rock types.

WHERE TO OBTAIN MAPS

(Single copies of a limited number of brochures describing Oregon maps and aerial photography are available at no cost from the Portland office of the Oregon Department of Geology and Mineral Industries [see address and phone number on the inside front cover]. Produced in 1988 by the Oregon Mapping Committee of the State Map Advisory Council, the brochure is entitled "Oregon: Maps and Aerial Photography Information Guide," and it is a comprehensive listing of State, Federal, regional, and local map- and aerial photography-producing agencies in Oregon. The guide provides complete information on where to obtain the full range of maps available in Oregon. Most of the information about Oregon maps and aerial photographs presented below is taken from this brochure; the rest of the information is from the author of the original paper.—*Editor*)

An excellent source of information for map users is the book *Maps for America* (Thompson, 1987), published as a special volume by the USGS. This book presents the story of maps and mapping with the aim to provide a basis for an understanding of map content. The richly illustrated book originally commemorated the Survey's 100th anniversary in 1979 and is now available in its expanded, third edition from the Government Printing Office and its bookstores at a price of \$25.

The Earth Science Information Center (ESIC) of the USGS provides a nationwide information service for cartographic data of the United States, including maps, charts, aerial photographs, satellite images, and map data in digital form obtained by more than 30 Federal agencies. For information on Oregon, contact either the headquarters (Earth Science Information Center, U.S. Geological Survey, 507 National Center, Reston, VA 22092, phone 1-800 USA MAPS) or the Western Branch Office (Western Mapping Center-ESIC, U.S. Geological Survey, Mail Stop 532, 345 Middlefield Road, Menlo Park, CA 94025, phone [415] 329-4309).

The USGS has placed on microfilm virtually all of the topographic maps of the United States that it has published since 1884. These are available from the ESIC offices. Printed versions of USGS maps of Oregon (topographic, geologic, land-use, etc.) may be obtained from the Western Distribution Branch, Box 25286, Federal Center, Bldg. 41, Denver, CO 80225, phone (303) 236-7477.

Aerial photographs and Landsat images may be obtained from the USGS ESIC Menlo Park, California, office or the USGS Earth Resources Observation System (EROS) Data Center. Contact User Services Section, EROS Data Center, Sioux Falls, SD 57198, phone (605) 594-6151.

Another source of aerial photos is the U.S. Department of Agriculture (USDA). The Agricultural Stabilization and Conservation Ser-

Table 1. Map scales and corresponding areas on the ground. From U.S. Geological Survey, 1981b

Scale	One inch on map represents	One centimeter on map represents	Standard quadrangle size (lat x long)	Quadrangle area (square miles)
1:24,000	2,000 feet	240 meters	7½ x 7½ minute	49 to 70
1:62,500	nearly 1 mile	625 meters	15 x 15 minute	197 to 282
1:250,000	nearly 4 miles	2½ kilometers	1° x 2° or 1° x 3°*	4,580 to 8,669
1:1,000,000	nearly 16 miles	10 kilometers	4° x 6°	73,734 to 102,759

* 1° x 3° is the standard size for quadrangle maps of Alaska.

vice (ASCS) maintains an extensive file of aerial photographs. For more information, contact: Aerial Photography Office, ASCS-USDA, 2222 West 2300 South, Post Office Box 30010, Salt Lake City, UT 84130, phone (801) 524-5856. The Soil Conservation Service produces pedologic maps and soil-survey reports, which include aerial photos and describe the geology, properties, and management of soils within the survey area. In Oregon, contact the USDA Soil Conservation Service, Federal Building, 1220 SW Third Avenue, Portland, OR 97204, phone (503) 221-1794.

The USDA Forest Service prepares and distributes recreational, base, regional, and other specialized maps and survey data as well as aerial photos. For information, contact them at P.O. Box 3623, Portland, OR 97208, phone (503) 326-2877 (for recreation maps) and 326-4165 (for special map products).

The U.S. Bureau of Land Management (BLM) compiles and distributes maps that show land status, mineral status, Federal and State lands, and private properties. BLM also maintains land records and provides aerial photographs. For information, contact the Oregon State Office, 825 NE Multnomah St., P.O. Box 2965, Portland, OR 97208, phone (503) 231-6281 for maps and 231-6885 for photos.

The National Ocean Service provides aeronautical and nautical charts that are sold by authorized dealers. Catalogs are available upon request from National Ocean Service, Pacific Marine Center N/MOPX4, 1801 Fairview Avenue East, Seattle, WA 98102, phone (206) 442-7657.

The Oregon Department of Forestry produces maps showing forest protection units and land management and orthophotomaps and township aerial photomaps as well as high-altitude aerial photographs of portions of eastern and western Oregon and low-altitude aerial photographs of State Forest lands. For information, contact Graphic Services, 2600 State Street, Salem, OR 97310, phone (503) 378-2504.

The Oregon Department of Geology and Mineral Industries produces and sells geologic, mineral-resource, geologic-hazard, geothermal, geophysical, rock-resource, and regional oil and gas maps and also sells USGS topographic maps. For the Department's address and phone number, see the inside front

cover of this magazine.

The Oregon Historical Society has over 10,000 historical maps of the Pacific Northwest covering exploration, topography, and social development. For information, contact Map Library, 1230 SW Park Avenue, Portland, OR 97205, phone (503) 222-1741. In addition, old maps may be examined in public and university libraries. They may also be obtained from the National Archives (Publication Sales Branch, National Archives, 8th and Pennsylvania Avenue NW, Washington, D.C. 20408) or from the Library of Congress (Geography and Map Division, Library of Congress, Washington, D.C. 20540).

The Oregon Department of Land Conservation and Development has numerous types of planning and land use maps for reference only. For information, contact them at 1175 Court Street NE, Salem, OR 97310, phone (503) 373-0050.

The Oregon State Library has a collection of Federal, State, and private and local agency maps. It also is ESIC affiliate office and a depository for U.S. government maps. These maps are for reference only. For information, contact them at the State Library Building, Salem, OR 97310, phone (503) 378-4368.

The University of Oregon has a large collection of maps from Federal, State, private and local agencies. The library is an ESIC affiliate office and is a depository for U.S. government maps. For information, contact the Map Library, 165 Condon Hall, Eugene, OR 97403, phone (503) 686-3051.

The Oregon Department of Revenue sells assessor's tax maps as well as U.S. Public Land Survey plats and timber ownership and tax district maps. For information, contact the Cartographic Unit, 955 Center St., Salem, OR 97310, phone (503) 378-3381.

The Oregon Division of State Lands supplies public ownership maps. For information, contact them at 1600 State Street, Salem, OR 97310, phone (503) 378-3805.

The Oregon Department of Transportation produces planimetric maps that outline roads, distinguish road surfaces (e.g., paved vs. dirt), and show other cultural features. Contact the Distribution Unit, Transportation Building, Room 17, Salem, OR 97310, phone (503) 378-6255 or 378-6254.

The Oregon Water Resources Department produces and sells drainage basin, land use, ground water, geology, and water-right maps.

For information, contact Oregon Water Resources Department, 3850 Portland Road NE, Salem, OR 97310, phone (503) 378-3671 or 378-3741.

Some private companies distribute maps produced by government agencies or commercial firms. These are generally listed in the Yellow Pages of telephone directories under the general heading "Maps."

In addition, the wide variety of maps produced by the National Geographic Society may be obtained by contacting the Society at P.O. Box 2806, Washington, D.C. 20013.

SELECTED REFERENCES

- Barker, V., 1986, Earhart's disappearance linked to map; *New Haven Register*, Dec. 21, p. A48.
Chamberlain, W., 1950, The round earth on flat paper; map projections used by cartographers: National Geographic Society, 126 p.
Compton, R.R., 1962, Manual of field geology: New York, Wiley and Sons, Inc., 378 p.
Fabiano, E.B., and Peddie, N.W., 1980, Magnetic declination in the United States—epoch 1980: U.S. Geological Survey Miscellaneous Investigations Series Map I-1283, scale 1:5,000,000.

- Hines, R.A., 1986, Map location literacy—how well does Johnny Geologist read? Discussion: Geological Society of America Bulletin, v. 97, no. 10, p. 1283.
Merrill, G.K., 1986a, Map location literacy—how well does Johnny Geologist read? Discussion: Geological Society of America Bulletin, v. 97, no. 4, p. 404-409.
———, 1986b, Map location literacy—how well does Johnny Geologist read? Reply: Geological Society of America Bulletin, v. 97, no. 10, p. 1284.
———, 1987, Map location literacy—how well does Johnny Geologist read? Reply: Geological Society of America Bulletin, v. 98, no. 5, p. 619-620.
Nelson, R.E., 1987, Map location literacy—how well does Johnny Geologist read? Discussion: Geological Society of America Bulletin, v. 98, no. 5, p. 618.
Oregon Mapping Committee, State Map Advisory Council, 1988, Oregon maps and aerial photography information guide: Oregon Department of Geology and Mineral Industries pamphlet, 12 p.
Raisz, E., 1962, Principles of cartography: New York, McGraw-Hill, 315 p.
Snyder, J.P., 1987, Map projections—a working

- manual: U.S. Geological Survey Professional Paper 1395, 383 p.
Strahler, A.N., 1981, Physical geology: New York, Harper and Row, 612 p.
Thompson, M.M., 1987, Maps for America (3rd ed.): Washington, D.C., U.S. Government Printing Office, 265 p.
U.S. Department of the Army, 1969, Map reading: FM 21-26.
———, 1983, Grids and grid references: TM 5-241-1.
U.S. Geological Survey, 1978, Topographic maps: USGS brochure, 27 p.
———, 1979, Topographic maps: Silent guides for outdoorsmen: USGS pamphlet.
———, 1981a, How to order Landsat images: USGS pamphlet.
———, 1981b, Map scales: USGS pamphlet.
———, 1982, Geologic maps; portraits of the Earth: USGS brochure, 19 p.
———, 1983, Topographic maps; tools for planning: USGS pamphlet.
———, undated (a), Map data catalog: 48 p.
———, undated (b), Understanding maps and scale: USGS poster.
Zumberge, J.H., and Rutford, R.H., 1983, Laboratory manual for physical geology, 6th ed.: Dubuque, Iowa, W.C. Brown Co., 187 p. □

Earthquake hazard workshop announced

The fourth annual workshop of the National Earthquake Hazards Reduction Program will be entitled *Earthquake Hazards in the Puget Sound and Portland Areas* and held April 17-19, 1990, at the Seattle Sheraton Hotel.

The Washington State Division of Geology and Earth Resources will conduct the workshop in cooperation with the U.S. Geological Survey and the Federal Emergency Management Agency. Topics will include the geologic and seismologic setting in western Washington and Oregon, site effects, lifelines, structural engineering with emphasis on building retrofit, and loss estimation. A field trip will let the participants inspect buildings undergoing retrofit in downtown Seattle.

A poster session is planned to present highly detailed information on any of the workshop's topics. To volunteer a poster or for more information, contact Timothy Walsh or Stephen P. Palmer at the Washington Division of Geology and Earth Resources, Mail Stop PY-12, Olympia, WA 98504, phone (206) 459-6372, FAX (206) 459-6380.

—Washington Division of Geology and Earth Resources release

(Reports, continued from page 26)

Tyee Basin project yields first report

A comprehensive report entitled *Geology and Oil, Gas, and Coal Resources, Southern Tyee Basin, Southern Coast Range, Oregon*, by A.R. and W.A. Niem of Oregon State University and with major contributions by E.M. Baldwin of the University of Oregon,

has been released as DOGAMI Open-File Report O-89-3 and sells for \$9.

The report is the first publication produced in a five-year study project, begun in mid-1988, to investigate the oil, gas, and coal potential of the Tyee Basin. This is an area of more than 4,000 mi² in the southern Oregon Coast Range that is underlain dominantly by Eocene sedimentary rocks. The project is funded by a consortium of public and private supporters, including the Douglas County Industrial Development Board, GCO Minerals Company, the Oregon Department of State Lands, Menasha Corporation, the U.S. Bureau of Land Management, the USDA Forest Service, and Weyerhaeuser Corporation.

The new report consists of (1) a blackline compilation geologic map including all relevant published and unpublished studies; (2) a map showing distribution of oil, gas, and coal geochemical data; (3) a plate containing three cross sections; and (4) a text containing preliminary assessment of the oil, gas, and coal potential of the southern Tyee Basin; a discussion of the stratigraphic problems that exist in the southern Coast Range; and tables of data on source rock and maturation, porosity and permeability, coal analyses, and oil and gas shows in exploration wells as well as in water wells and natural seeps.

Much of the information presented in the report consists of previously confidential research data and is made available here for the first time through the cooperation of several oil companies.

Placer minerals study group reports

Preliminary Feasibility Study: Oregon Placer Minerals presents a preliminary resource and economic evaluation of black

sand deposits on beaches, coastal terraces, and the continental shelf offshore along the coast of Oregon. Black sands may contain heavy minerals such as magnetite, chromite, ilmenite, garnet, rutile, gold, and platinum-group metals.

This approximately 180-page report was produced by the joint State-Federal Oregon Placer Minerals Task Force established by the U.S. Secretary of the Interior and the Governor of Oregon in September 1989 and funded by the U.S. Minerals Management Service. It has been published as DOGAMI Open-File Report O-89-12 and sells for \$8.

The report includes a summary of placer mineral resource information, an economic evaluation, an environmental review, a market definition, an economic and strategic analysis, and a set of recommendations for future study. In draft form, the report sections were made available for public comment, and responses to public and peer-review comments are summarized in an appendix.

Mist Gas Field map updated

All 1989 exploration and development activity at the Mist Gas Field, Oregon's only producing field, has been incorporated in the 1990 update of the *Mist Gas Field Map*, DOGAMI Open-File Report O-90-1 (\$7). For more details, see the "Oil and Gas News" on page 26 of this issue.

All publications mentioned above are now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, Oregon 97201-5528. Orders may be charged to credit cards by mail, FAX, or phone. FAX number is (503) 229-5639. Orders under \$50 require prepayment except for credit-card orders. □

Mining and exploration in Oregon in 1989

by Howard C. Brooks, Baker City Field Office, Oregon Department of Geology and Mineral Industries

PRODUCTION

The U.S. Bureau of Mines estimate of the value of Oregon's 1989 nonfuel mineral production is \$199 million, about 12 percent above the \$178 million value for 1988. The increase is largely due to higher output of cement and crushed stone and the resumption of nickel production. More than 95 percent of the value of Oregon's nonfuel mineral production is in the construction materials, sand, gravel, stone, and cement. Other nonmetallic commodities produced in 1989 were limestone, pumice (Figure 1), diatomite, clay, zeolite, and talc. Nickel and gold were the only metals produced in significant quantity. In recent years, the State commonly has ranked first nationally in the production of pumice and fourth in the production of diatomite and is a significant producer of processed natural zeolite.

Sand, gravel, and crushed stone for use in construction were produced from pits and quarries throughout the State.

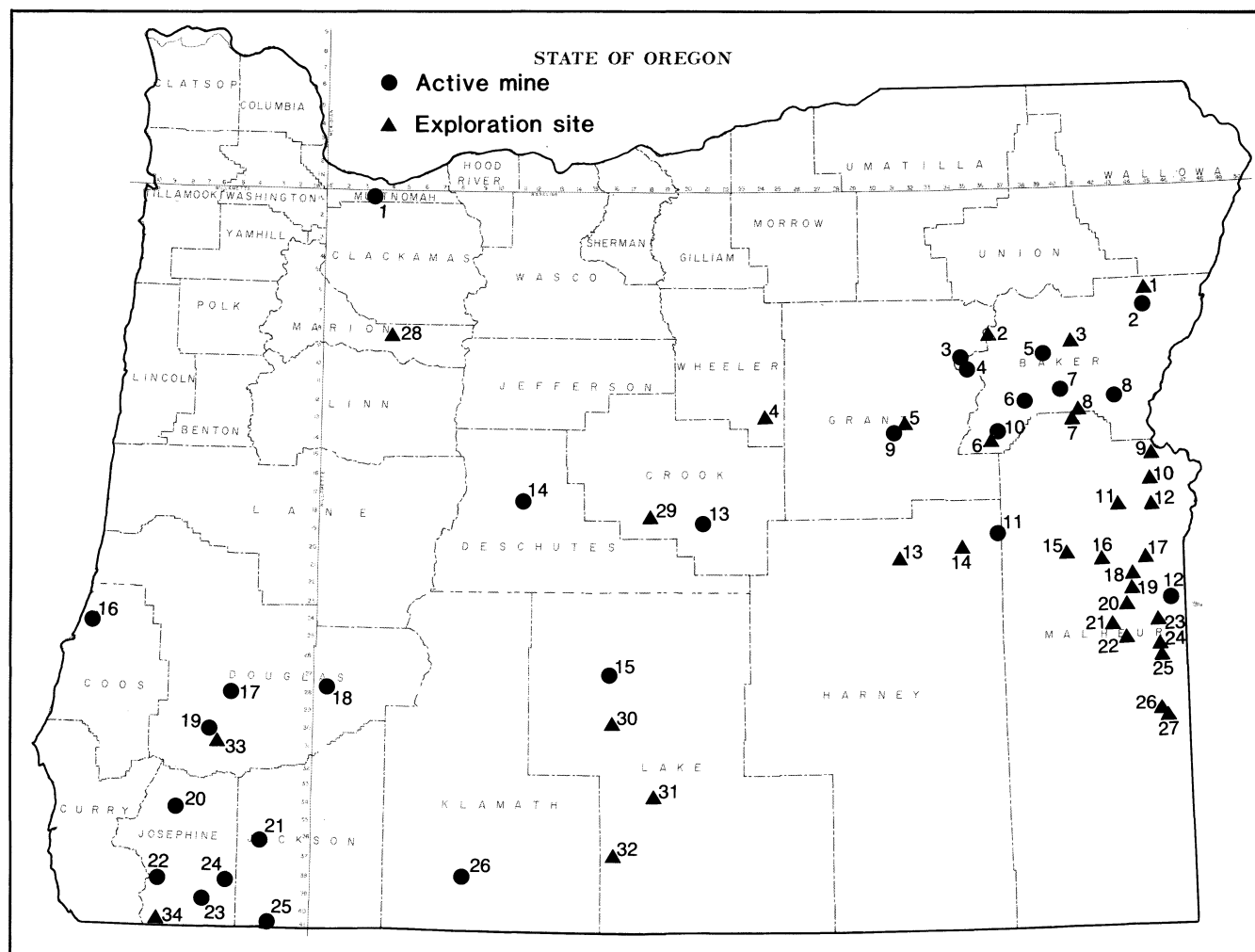
Crushed and screened silica rock was produced for a variety of uses from a quarry in Jackson County by Bristol Silica and Limestone Company (Figure 2, active mine site 21; Figure 3). Silica rock from Quartz Mountain (Figure 2, active mine site 18) in Douglas County was used by Glenbrook Nickel Company in its nickel smelting operation at Riddle.

Table 1. Summary of mineral production value (in millions of dollars) in Oregon for the last 18 years. Data for 1989 derived from U.S. Bureau of Mines annual preliminary mineral-industry survey and Oregon Department of Geology and Mineral Industries natural-gas statistics

	ROCK MATERIALS Sand, gravel, stone	METALS AND INDUSTRIAL MINERALS Cement, nickel, pumice, etc.	NATURAL GAS	TOTAL
1972	54	22	0	76
1973	55	26	0	81
1974	75	29	0	104
1975	73	33	0	106
1976	77	35	0	112
1977	74	35	0	109
1978	84	44	0	128
1979	111	54	+	165
1980	95	65	12	172
1981	85	65	13	163
1982	73	37	10	120
1983	82	41	10	133
1984	75	46	8	129
1985	91	39	10	140
1986	96	30	9	135
1987	102	52	6	160
1988	130	48	6	184
1989	134	65	4	203



Figure 1. Cascade Pumice Company: part of screening facility (Figure 2, active mine site 14).



EXPLANATION

ACTIVE MINES AND AREAS

1. Columbia Brick and Tile
2. Bonanza Mining(placer gold)
3. Pyx Mine (lode gold)
4. Greenhorn area (placer gold)
5. Elk Creek (placer gold)
6. Pine Creek area (placer gold)
7. Dooley Mountain area (perlite)
8. Ash Grove Cement West (cement and crushed limestone)
9. Canyon City Placers (placer gold)
10. Lower Grandview Mine (lode gold)
11. Eagle-Picher Industries (diatomite)
12. Teague Mineral Products (bentonite and clinoptilolite)
13. Central Oregon Bentonite/Oregon Sun Ranch (bentonite clay)
14. Cascade Pumice/Central Oregon Pumice (pumice)
15. Oil Dry Production (diatomite)
16. CooSand (Silica sand)
17. D and D Ag Lime and Rock (agricultural limestone)
18. Quartz Mountain (silica)
19. Glenbrook Nickel (nickel)
20. Galice area (placer gold)
21. Bristol Silica and Lime (silica)
22. Josephine Creek area (placer gold)
23. Sucker Creek area (placer gold)
24. Campman Calcite (agricultural limestone)
25. Steatite of Southern Oregon (soapstone)
26. Klamath Falls Brick and Tile (brick)

EXPLORATION SITES AND AREAS

1. Cornucopia Mine (gold)
2. Herculean Mine (gold, base metals)
3. Flagstaff Mine (gold)
4. Spanish Gulch (gold)
5. Prairie Diggings (gold)
6. Grouse Creek project (gold, copper)
7. Racey property (gold)
8. Malheur City area (gold)
9. Kerby (gold)
10. Tub Mountain area (gold)
11. Hope Butte (gold)
12. Vale Butte (gold)
13. Idol City area (gold)
14. Drewsey area (gold)
15. Gold Creek area (gold)
16. Harper Basin (gold)
17. Shell Rock Butte (gold)
18. Grassy Mountain (gold)
19. Burnt Mountain area (gold)
20. Dry Creek Buttes area (gold)
21. Quartz Mountain (gold)
22. Red Butte (gold)
23. Katey (gold)
24. Bannock (gold)
25. Mahogany (gold)
26. Hillside (gold)
27. Anderson (gold)
28. Bornite (copper, gold, silver)
29. Bear Creek Butte area (gold)
30. Summer Lake area (gold)
31. Paisley area (gold)
32. Quartz Mountain (gold)
33. Silver Peak (gold, silver, copper)
34. Turner-Albright (copper, zinc, gold)

Figure 2. Mining and mineral exploration sites in Oregon in 1989 (excluding sand and gravel and stone). Active mines are keyed to Table 2; exploration sites and areas are keyed to Table 3.

Table 2. Active mines in Oregon, 1989

1. Columbia Brick Works

Sec. 14, T. 1 S., R. 3 E., Multnomah County. Plant produces facing brick using clay from a company-owned pit nearby.

2. Bonanza Mining Company—placer gold

Sec. 3, T. 7 S., R. 45 E., Baker County. Largest mine in Oregon, located on Pine Creek about 3 mi below the old Cornucopia gold mine. Employed 26 people in 1989. Gravel depth varies from 20 to 70 ft; values are concentrated near bedrock. Washing plant handles 60 yd per hour and operates eight months per year, six days per week, three shifts per day. The pit operates two 10-hour shifts per day. Backfilling and reclamation in one part of the pit are concurrent with stripping and mining in another part.

3. Pyx Mine—lode gold

Sec. 1, T. 10 S., R. 35 E., Grant County. Small operation in early summer; ore milled in a small gravity separation plant in Sumpter.

4. Greenhorn area—placer gold

Tps. 9, 10 S., Rs. 35, 35½ E., Baker and Grant Counties. Several small, seasonal operations, including parts of Snow Creek, upper North Fork of Burnt River, Parkerville, and Winterville areas.

5. Elk Creek—placer gold

Tps. 9, 10 S., R. 39 E., Baker County. Several small, seasonal operations.

6. Pine Creek area—placer gold

T. 12 S., R. 38 E., Baker County. Small seasonal operations including Goldwater, Inc., which has been active for several years.

7. Dooley Mountain area—perlite

Tps. 11, 12 S., R. 40 E., Baker County. Mined and used by Supreme Perlite Company to produce expanded perlite at a facility in Portland.

8. Ash Grove Cement West, Inc.—cement and crushed limestone

Sec. 11, T. 12 S., R. 43 E., Baker County. Annual sales were about 500,000 tons of cement and 220,000 tons of crushed limestone valued at over \$25 million. Employs 105 people. The crushed limestone is shipped to sugar refiners in Oregon and Idaho for use in the process of extracting sugar from sugar beets. Markets in place for capacity production in 1990.

9. Canyon City Placers—placer gold

Sec. 6, T. 14 S., R. 32 E., Grant County. Washing plant and dragline operation by Cammex International, Inc.

10. Lower Grandview Mine—lode gold

Sec. 6, T. 14 S., R. 37 E., Baker County. Small, seasonal underground mine; new ownership in 1989.

11. Eagle-Picher Industries, Inc.—diatomite

Processing plant is 7 mi west of Vale in sec. 6, T. 19 S., R. 44 E., Malheur County; open-pit mine sites are 70 mi west of plant in Tps. 19, 20 S., Rs. 35, 36 E., Harney and Malheur Counties. Products are used as filter aids in clarifying fluids including water, beverages, juices, syrups, edible oils, fuels, and pharmaceuticals. Total employment (mining, trucking, processing) about 50 people.

12. Teague Mineral Products—bentonite and clinoptilolite

Plant is in sec. 8, T. 23 S., R. 46 E.; mines are in secs. 28, 29, T. 23 S., R. 46 E., Malheur County, Oregon, and nearby in Idaho. The bentonite is used chiefly as soil sealant for waste disposal sites, ditches, and ponds, for drilling mud and absorbent, and as binder for cattle food pellets. Uses of the clinoptilolite include pet litter, odor control products, fungicide carrier, and ammonia absorbent. The plant includes five mills, which allows for production of a full range of sized products from coarse granules to micronized powders. Research in the uses of bentonite and zeolite is being continued.

13. Central Oregon Bentonite Company/Oregon Sun Ranch, Inc.—bentonite clay

Both in sec. 4, T. 19 S., R. 21 E., Crook County. Small production from adjacent properties near Camp Creek.

14. Cascade Pumice Company/Central Oregon Pumice Company—pumice

Tps. 17, 18 S., R. 11 E., Deschutes County. Combined annual production about 200,000 tons. The major use is lightweight aggregate in poured concrete and in concrete blocks.

15. Oil-Dri Production Company—diatomite

Secs. 14, 21, 23, T. 27 S., R. 16 E., Lake County. Product is packaged and sold to several different companies for resale, mainly as pet litter.

16. Coosand Corporation—silica sand

Sec. 34, T. 24 S., R. 13 W., Coos County. Uses of product include glass manufacture (Owens Corning in Portland), construction, sand blasting, and railroad traction.

17. D and D Ag Lime and Rock Company—agricultural limestone

Sec. 20, T. 28 S., R. 5 W., Douglas County. Small producer of ground limestone from quarries operated before 1935 by Oregon Portland Cement Company.

18. Quartz Mountain—silica

Sec. 2, T. 28 S., R. 1 E., Douglas County. Produced silica for the Glenbrook Nickel Company operation of the nickel smelter at Riddle.

19. Glenbrook Nickel Company—nickel

Secs. 28, 29, T. 30 S., R. 6 W., Douglas County. Company reactivated former Hanna Nickel Company smelter to process 6-million-ton stockpile of lateritic material grading 0.7 percent nickel left at the site when Hanna closed the smelter in January 1987. The Company has not decided whether to reopen the Nickel Mountain Mine; the equipment was removed when the mine closed.

20. Galice area—placer gold

Tps. 34, 35 S., R. 8 W., Josephine County. Small, seasonal operations.

21. Bristol Silica and Limestone Company—silica

Sec. 30, T. 36 S., R. 3 W., Jackson County. Crushed and screened silica rock sold for a variety of uses including poultry grit, sand blasting, and decorative stone. Small amounts of dolomite have been sold from an occurrence on the margin of the silica quarry.

22. Josephine Creek area—placer gold

Tps. 38, 39 S., R. 9 W., Josephine County. Several small, seasonal operations.

23. Sucker Creek area—placer gold

Tps. 39, 40 S., Rs. 6, 7 W., Josephine County. Several small, seasonal operations.

24. Campman Calcite Company—agricultural limestone

Sec. 31, T. 38 S., R. 5 W., Josephine County. Company mined, crushed, and ground limestone from the Jones Marble Quarry for agricultural use mainly in southwestern Oregon.

25. Steatite of Southern Oregon—soapstone

Secs. 10, 11, T. 41 S., R. 3 W., Jackson County. Block soapstone sold mainly for carving.

26. Klamath Falls Brick and Tile Company

Sec. 19, T. 38 S., R. 9 E., Klamath County. Plant produces a variety of facing and paving bricks using clays from pits in several western Oregon counties and northern California.

Cement was produced only by Ash Grove Cement West, Inc. The plant and quarries (Figure 2, active mine site 8) are near Durkee in Baker County. Small amounts of limestone were produced for agricultural use by Campman Calcite Company at the Jones Marble quarry (Figure 2, active mine site 24) in Josephine County and by D and D Ag Lime

and Rock Company from a quarry (Figure 2, active mine site 17) in Douglas County.

Diatomite was produced by Eagle Picher Industries (Figure 2, active mine site 11) for use as filter aid and by Oil-Dri Production Company (Figure 2, active mine site 15) for use as pet litter.

Pumice was produced by Cascade Pumice

Company and Central Oregon Pumice Company (Figure 2, active mine site 14) from several quarries near Bend in Deschutes County. Combined annual output has averaged about 200,000 tons for several years.

Bentonite clay and zeolite were produced by Teague Mineral Products Company from its plant (Figure 2, active mine site 12) 2 mi



Figure 3. Bristol Silica and Limestone Company: silica quarry and primary crusher. Dolomite occurs along the upper left edge of the quarry (Figure 2, active mine site 21).

south of Adrian in Malheur County. Bentonite also was produced by two small operations (Figure 2, active mine site 13), Central Oregon Bentonite Company and Oregon Sun Ranch, Inc., in Crook County.

Clay was produced by Ash Grove Cement West, Inc., for use in making cement. Clay for brick making and engineering applications was produced in several western counties. Two brick plants were operated, one in Multnomah County by Columbia Brick Works, Inc. (Figure 2, active mine site 1), the other in Klamath County by Klamath Falls Brick and Tile Company (Figure 2, active mine site 26).

Carving-grade talc was produced by Steatite of Southern Oregon (Figure 2, active mine site 25).

The nickel plant (Figure 2, active mine site 19) near Riddle was reactivated by Glenbrook Nickel Company.

Gold production was dominated by the Bonanza Mining Company, placer operation (Figure 2, active mine site 2). Some gold was produced at the Lower Grandview lode mine (Figure 2, active mine site 10) and at several dozen small, intermittently operated placer mines in northeastern and southwestern parts of the State (Figure 4).

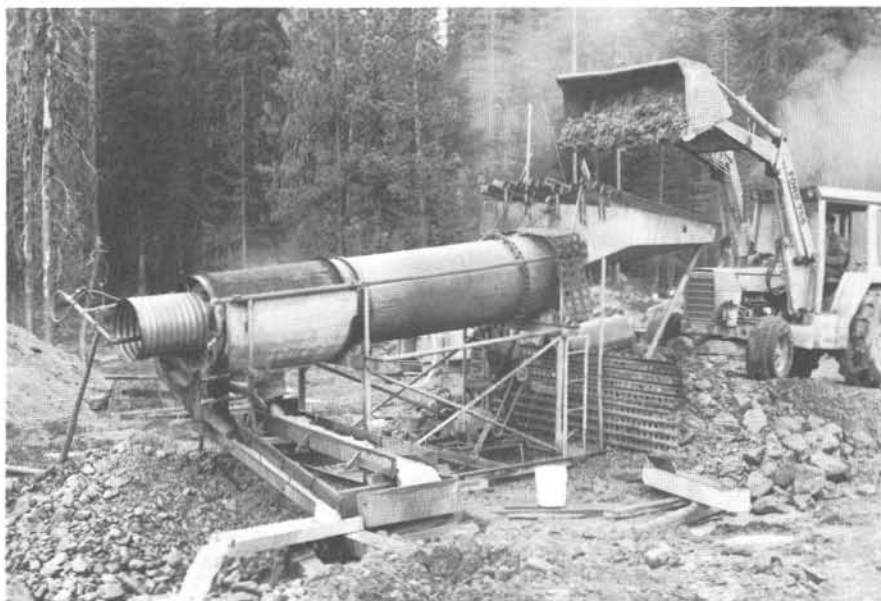


Figure 4. Trommel and sluice washing plant: Ray Tracy placer mine on Snow Creek in the Greenhorn area (Figure 2, active mine site 4).

Table 3. *Exploration sites in Oregon, 1989***1. Cornucopia Mine—gold**

Sec. 27, T. 6 S., R. 45 E., Baker County. Small underground exploration-drilling program by owners, UNC Corporation.

2. Herculean Mine—gold and base metals

Sec. 22, T. 8 S., R. 36 E., Baker County. Small exploration and development program by Cable Cove Mining Company.

3. Flagstaff Mine—gold

Sec. 6, T. 9 S., R. 41 E., Baker County. Drilling program by Hecla Mining Company.

4. Spanish Gulch—gold

Secs. 12, 13, T. 13 S., R. 24 E., and secs. 7, 18, T. 13 S., R. 25 E., Wheeler County. Small drilling program by ASARCO.

5. Prairie Diggings prospect—gold

Sec. 33, T. 13 S., R. 32 E., Grant County. Drilling program by Goldsearch Resources, Inc.

6. Grouse Creek prospect—copper, silver

Secs. 24, 25, T. 14 S., R. 36 E., Baker County. Drilling program continued by Golconda Resources, Ltd.

7. Racey property—gold

Secs. 19, 20, 21, T. 13 S., R. 41 E., Malheur County. Continued drilling by Ican Minerals, Ltd., and, late in the year, by Ican and Billiton Minerals U.S.A., Inc., joint venture.

8. Malheur City area—gold

Tps. 12, 13 S., Rs. 40, 41 E., Baker County. Land acquisition, surface exploration, and some drilling by Earth Search Sciences, Inc., and Beaver Resources joint venture.

9. Kerby—gold

Secs. 22, 27, T. 15 S., R. 45 E., Baker County. Drilling continued by Malheur Mining Company. Feasibility and base-line environmental studies underway.

10. Tub Mountain area—gold

Secs. 4, 5, 6, 7, 8, T. 17 S., R. 45 E., Malheur County. Malheur Mining, Atlas Precious Metals, and Euro-Nevada Mining Corporation, Inc., have claim groups in the area. Malheur Mining's group was leased to Echo Bay. Some drilling on all three properties.

11. Hope Butte—gold

Sec. 21, T. 17 S., R. 43 E., Malheur County. Chevron continued drilling.

12. Vale Butte—gold

Secs. 28, 29, T. 18 S., R. 45 E., Malheur County. Under evaluation by Atlas Precious Metals Company.

13. Idol City area—gold

Tps. 20, 21 S., R. 32 E., Harney County. Drilling by Newmont Mining Company.

14. Drewsey area—gold

Tps. 20, 21 S., Rs. 34, 35 E., Harney County. Exploration and evaluation programs by Cyprus Gold Exploration Company, Battle Mountain Gold Corporation, Reserve Industries, Corona Gold Corporation, and others. Cyprus drilled several holes at the Red Butte prospect in sec. 35, T. 20 S., R. 35 E., and later dropped the claims.

15. Gold Creek area—gold

Secs. 3, 4, T. 2 S., R. 40 E., Malheur County. Geochemical sampling and geophysical surveying by Manville Corporation.

16. Harper Basin—gold

Secs. 22, 23, T. 21 S., R. 42 E., Malheur County. Exploration drilling by American Copper and Nickel Company and Atlas Precious Metals Company on adjoining properties.

17. Shell Rock Butte—gold

Sec. 18, T. 21 S., R. 45 E., Malheur County. Small drilling program by ASARCO, Inc., on property owned by Western Epithermal; lease dropped later. Small drilling program by Atlas Precious Metals Company on its own property.

18. Grassy Mountain—gold

Sec. 8, T. 22 S., R. 44 E., Malheur County. Atlas Precious Metals Company continued drilling, began base-line environmental studies, and submitted operating plan and permit application to the U.S. Bureau of

Land Management. Announced reserves total 1.2 million oz of gold in ore averaging 0.065 oz gold per ton.

19. Burnt Mountain area—gold

Secs. 4, 5, 6, 7, 8, 9, T. 23 S., R. 44 E., Malheur County. Land acquisition and sampling by Noranda Exploration, Inc.

20. Dry Creek Buttes area—gold

Tps. 23, 24 S., Rs. 43, 44 E., Malheur County. Rotary drilling by Noranda Exploration, Inc., on the Lavery claims. Manville, ASARCO, and Noranda hold large claim blocks in nearby areas.

21. Quartz Mountain—gold

Sec. 6, T. 25 S., R. 43 E., Malheur County. Chevron drilled one hole for water and set up a prefab camp in preparation for an extensive exploration program in 1990.

22. Red Butte—gold

Secs. 26, 27, 34, 35, T. 25 S., R. 43 E., Malheur County. Hand sampling program by Chevron. Prospect is in a Wilderness Study Area.

23. Katey—gold

Tps. 24, 25 S., R. 45 E., Malheur County. Small rotary drill program and soil and rock-chip sampling by ASARCO.

24. Bannock—gold

Sec. 11, T. 26 S., R. 45 E., Malheur County. Small drilling program by Manville.

25. Mahogany—gold

Secs. 25, 26, T. 26 S., R. 46 E., Malheur County. Small drilling program by Chevron.

26. Hillside—gold

Secs. 26, 27, 34, T. 29 S., R. 45 E., Malheur County. Surface sampling and geophysical surveys by Manville Corporation.

27. Anderson property—gold

Sec. 35, T. 29 S., R. 45 E., Malheur County. Surface sampling and small drilling program by Nerco Exploration Company.

28. Bornite—copper, gold, silver

Sec. 36, T. 8 S., R. 4 E., Marion County. Plexus Resources Corporation obtained development rights. Company reports that drilling by AMOCO and others in late 1970's and early 1980's indicates reserves of 3.1 million tons averaging 2.49 percent copper, 0.023 oz per ton gold, and 0.067 oz per ton silver.

29. Bear Creek Butte area—gold

Tps. 18, 19 S., R. 18 E., Crook County. Drilling program continued by Freeport-McMoRan Gold Company.

30. Summer Lake area—gold

Sec. 14, T. 30 S., R. 16 E., Lake County. Small drilling program by N.A. Degerstrom, Inc.

31. Paisley area—gold

T. 34 S., Rs. 18, 19 E., Lake County. Surface investigation by N.A. Degerstrom, Inc.

32. Quartz Mountain—gold

Secs. 26, 27, 34, 35, T. 37 S., R. 16 E., Lake County. Pegasus Gold, Inc., joint-ventured with Quartz Mountain Gold Corporation, agreed to continue exploration, conduct feasibility studies, and develop a mine plan. A feasibility study completed in August 1989 delineates proven and probable reserves of 9.8 million tons for the combined Crone Hill and Quartz Butte deposits, with an average grade of 0.045 oz per ton gold. Drilling by Quartz Mountain Gold Corporation indicates reserves of 64 million tons averaging 0.025 oz gold per ton. More than 625 holes aggregating about 250,000 ft have been drilled on the 9,700-acre property.

33. Silver Peak Mine—gold, silver, copper

Sec. 23, T. 31 S., R. 6 W., Douglas County. Drilling continued by Formosa Mining Company.

34. Turner-Albright—copper, zinc, gold

Secs. 15, 16, T. 41 S., R. 9 W., Josephine County. Savanna Resources, Ltd., and Aur Resources, Ltd., agreed to joint venture; Aur to spend \$2.5 million on exploration. Company reports that drilling indicated reserves of 3.3 million tons averaging 1.46 percent copper, 3.3 percent zinc, and 0.11 oz gold per ton.



Figure 5. Drilling at the Hope Butte prospect by Chevron Resources Corporation (Figure 2, exploration site 11).



Figure 6. Chalcedony vein exposed on Gold Creek prospect (Figure 2, exploration site 15) of Manville Corporation.



Figure 7. Mineralized hydrothermal breccia exposed on the east side of Red Butte (Figure 2, exploration site 22).

EXPLORATION

The southeastern Oregon gold rush accelerated following the announcement in late 1988 of a discovery in the Grassy Mountain area. Atlas Precious Metals continued drilling its Grassy Mountain site (Figure 2, exploration site 18) through most of 1989 and announced an increase in geologic reserves to 1.2 million oz of gold in ore averaging 0.065 oz per ton. Feasibility studies and collection of baseline environmental and water-quality data are underway. An operating plan was submitted to the Bureau of Land Management in November. Extensive drilling was also done at the Hope Butte (Figure 2, exploration site 11; Figure 5) and Kerby prospects (Figure 2, exploration site 9). Evaluation of the results is in progress.

Exploration activity still is concentrated in northern Malheur County but is spreading to other areas. Nearly 8,000 claims were located in Malheur County in 1989, bringing the total number of claims in the county to more than 21,000. Exploration drilling was done on at least 16 different properties in the state. Figure 2 shows the location of properties where extensive surface sampling or drilling has been done.

All but two of the deposits in Malheur County are in rocks of Miocene or Pliocene age. The northern two deposits (Figure 2, exploration sites 7 and 8) are partly hosted in an altered quartz diorite porphyry. The mineralization may be Tertiary in age. Most of the other Malheur County deposits are sediment hosted; some of them occur in silicic volcanic rocks. Associated basalt is locally mineralized.

The deposits typically are of epithermal origin (Figures 6 and 7). Hot-spring sinter are associated with several of them. Silicification and argillic alteration of the host rocks is common. Anomalous levels of arsenic are also common and may or may not be associated with gold. Chevron geologist David Bush reported that mineralization at Quartz Mountain and Hope Butte has been dated at 17.8 and 3.9 million years, respectively (personal communication, October 1989). The dates are based on multiple radiometric analyses of adularia.

Geologic mapping of the Boise 1° x 2° quadrangle (scale 1:250,000) in central Malheur County continued. The mapping involved workers from the Oregon Department of Geology and Mineral Industries (DOGAMI), the U.S. Geological Survey, and Portland State University. Geologic maps of the Graveyard Point, Owyhee Dam, and Adrian quadrangles were released in 1989 by DOGAMI. Similar geologic maps of the Double Mountain and Grassy Mountain quadrangles were released in early 1990. □

Oil and gas exploration and development in Oregon, 1989

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

ABSTRACT

Oil and gas lease activity declined in 1989. Five U.S. Bureau of Land Management lease sales were held, with no leases purchased. There were filings for 99,351 federal acres. The total of federal acres under lease was 463,528 acres at year's end. No state or county lease sales were held during the year.

Thirteen wells were drilled in the Mist Gas Field and vicinity, of which seven were drilled by ARCO and six by DY Oil. Three ARCO wells and one DY Oil well were successful gas completions. The field had 18 gas producers and seven gas wells awaiting pipeline connection at year's end. A total of 2.6 billion cubic feet (Bcf) of gas was produced during 1989, with a value of \$3.5 million. ARCO also drilled an unsuccessful Astoria Basin test in Clatsop County.

The Mist natural gas storage project became fully operational on November 1, 1989. The redesign of the Miller Station was completed during the year.

Northwest Natural Gas Company has constructed a 49-mi natural-gas pipeline from Mist Gas Field to Portland, providing a pipeline loop through the field.

The Department of Geology and Mineral Industries continued the study of the Tyee Basin in Douglas and Coos Counties and will publish the first phase of maps and reports during the year.

Rulemaking is now underway to implement House Bill 2089 and to revise the oil and gas exploration and development rules in Oregon.

LEASING ACTIVITY

There was a decline in leasing activity during 1989. Leasing activity included five public land lease sales by the U.S. Bureau of Land Management (BLM) plus over-the-counter filings of BLM property. No leases were purchased at any of the lease sales. There were filings for 30 parcels totaling 99,351 acres located in Wheeler, Crook, and Wasco Counties. F and F Georesources filed for two of the parcels in Wheeler County, and D.M. Yates filed for the remainder. A total of 183 parcels consisting of 463,528 acres were under lease at year's end. This is a decline from the 876,138 acres in 397 parcels under lease at the end of 1988. The total rental income during 1989 was about \$519,000, a decline from the \$1,139,000 during the previous year.

At the end of 1989, active State of Oregon leases numbered 58, totaling 73,428 acres. Total rental income was \$73,428 for the year.

No state or county lease sales were held during 1989.



Figure 1. ARCO well OR 21-33-86, the deepest well drilled in Oregon during 1989, was a wildcat test in the Astoria Basin in Clatsop County.

DRILLING

A total of 14 exploratory oil and gas wells was drilled in the state in 1989. This is the same number of exploratory oil and gas wells that were drilled during 1988 but is an overall decrease in total wells because during 1988, in addition, five gas-storage wells were drilled and three redrills undertaken. All but one of the wells were drilled in the Mist Gas Field area, a pattern that has continued since the

field was discovered in 1979. The other well was a wildcat well drilled by ARCO in the Astoria Basin of northwestern Oregon. This well, the OR 21-33-86 (Figure 1), was located about 12 mi northwest of Mist Gas Field in Clatsop County near the town of Westport. The well was drilled to a total depth of 5,896 ft, making it the deepest well drilled in Oregon during 1989, and it was plugged and abandoned as a dry hole.



Figure 2. Preparations to perforate for a flow test at the DY Oil well Neverstill 33-30, the only gas producer at Mist Gas Field not operated by ARCO.

At Mist Gas Field, two operators were active during the year. As has been the case for the past several years, ARCO Oil and Gas Company was the most active operator, drilling seven exploratory wells. Of these, three were successful gas completions, and four were dry holes. DY Oil drilled six exploratory wells at Mist, one of which was a successful gas completion (Figure 2), and the rest were dry holes.

Total drilling footage for the year was 33,823 ft, a decrease from the 61,523 ft drilled during 1988. The average depth per well was 2,416 ft, a small decline from the 2,797 ft per well drilled during the previous year.

During 1989, the Oregon Department of Geology and Mineral Industries (DOGAMI) issued 19 permits to drill (Table 1), while 13 permits were canceled during the year (Table 2).

DISCOVERIES AND GAS PRODUCTION

Mist Gas Field saw four new producers, a decrease from the seven producers drilled during 1988. ARCO Oil and Gas Company is the operator of three of the discovery wells, which are the CER 13-1-55, CER 41-16-64, and CC 34-28-65. With the successful completion of the Neverstill 33-30 well, DY Oil became the only other gas producer at Mist. There were 18 producers at year's end, up from 14 producers at the end of 1988. In addition, seven gas wells were awaiting pipeline connection. Eight additional wells are shut-in former producers. One of these, the CC 44-21, has been converted by ARCO Oil and Gas Company to a water-disposal well. This will add an additional water-disposal well at the field to supplement the CC 13-1, which is currently the only well used for this purpose.

Gas production for the year totaled 2.5 Bcf. This is a decline from the 4.0 Bcf produced during 1988. Part of the decline is

Table 1. Oil and gas permits and drilling activity in Oregon, 1989

Permit no.	Operator, well, API number	Location	Status, depth (ft) TD = total depth PTD = proposed TD RD = redrill
418	ARCO Oregon 21-33-86 36-007-00020	NW¼ sec. 33 T. 8 N., R. 6 W. Clatsop County	Abandoned, dry hole; TD: 5,985.
420	ARCO Col. Co. 34-28-65 36-009-00249	SW¼ sec. 28 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 2,240.
421	ARCO Col. Co. 42-32-74 36-009-00250	NE¼ sec. 32 T. 7 N., R. 4 W. Columbia County	Permit issued; PTD: 1,750.
422	ARCO CER 24-18-64 36-009-00251	SW¼ sec. 18 T. 6 N., R. 4 W. Columbia County	Abandoned, dry hole; TD: 1,810.
423	ARCO CER 41-16-64 36-009-00252	NE¼ sec. 16 T. 6 N., R. 4 W. Columbia County	Completed, gas; TD: 2,105.
424	ARCO Hamlin 33-17-65 36-009-00253	SE¼ sec. 17 T. 6 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 3,150.
425	DY Oil CER 23-22-64 36-009-00254	SW¼ sec. 22 T. 6 N., R. 4 W. Columbia County	Abandoned, dry hole; TD: 2,680.
426	Leadco CC-Jackson 23-17 36-009-00255	SW¼ sec. 17 T. 5 N., R. 4 W. Columbia County	Permit issued; PTD: 2,500.
427	DY Oil Neverstill 33-30 36-009-00256	SE¼ sec. 30 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 2,225.
428	DY Oil Forest Cav 13-6 36-009-00257	SW¼ sec. 6 T. 5 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 1,796.
429	DY Oil Burris CC 24-8 36-009-00258	SW¼ sec. 8 T. 5 N., R. 4 W. Columbia County	Abandoned, dry hole; TD: 2,684.
430	DY Oil Lane CC-24-5 36-009-00259	SW¼ sec. 5 T. 5 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 1,473.
432	ARCO Col. Co. 34-8-75 36-009-00261	SE¼ sec. 8 T. 7 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 2,706.
434	ARCO Col. Co. 13-3-55 36-009-00263	SW¼ sec. 3 T. 7 N., R. 5 W. Columbia County	Permit issued; PTD: 1,655.
435	ARCO Col. Co. 13-4-55 36-009-00264	SW¼ sec. 4 T. 5 N., R. 4 W. Columbia County	Permit issued; PTD: 2,025.
436	ARCO CER 13-1-55 36-009-00265	SW¼ sec. 1 T. 5 N., R. 5 W. Columbia County	Completed, gas; TD: 1,645.
437	ARCO OR 34-25-66 36-007-00022	SE¼ sec. 25 T. 6 N., R. 6 W. Clatsop County	Abandoned, dry hole; TD: 2,452.
438	ONGD Oregon State 32-26 36-067-00004	NE¼ sec. 26 T. 1 S., R. 4 W. Washington County	Permit issued; PTD: 2,000.
439	DY Oil Lane CC-24-5-A 36-009-00266	SE ¼ sec. 5 T. 5 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 1,126.

Table 2. Canceled and denied permits, withdrawn applications, 1989

Permit no.	Operator, well, API number	Location	Issue date	Cancellation date	Reason
378	ARCO Longview Fibre 23-33-65 36-009-00215	SW¼ sec. 33 T. 6 N., R. 5 W. Columbia County	3-9-87	3-9-89	Permit canceled; expired.
379	ARCO Col. Co. 11-7-65 36-009-00216	NW¼ sec. 7 T. 6 N., R. 5 W. Columbia County	2-19-87	2-21-89	Permit canceled; expired.
381	ARCO Col. Co. 23-18-65 36-009-00218	SW¼ sec. 18 T. 6 N., R. 5 W. Columbia County	2-19-87	2-21-89	Permit canceled; expired.
382	ARCO Col. Co. 32-26-65 36-009-00219	NE¼ sec. 26 T. 6 N., R. 5 W. Columbia County	2-19-87	2-21-89	Permit canceled; expired.
384	ARCO Col. Co. 24-26-65 36-009-00221	SW¼ sec. 26 T. 6 N., R. 5 W. Columbia County	2-19-87	2-21-89	Permit canceled; expired.
385	ARCO Col. Co. 22-27-65 36-009-00222	NW¼ sec. 27 T. 6 N., R. 5 W. Columbia County	2-19-87	2-21-89	Permit canceled; expired.
389	Leadco CC-Jackson 23-17 36-009-00226	SW¼ sec. 17 T. 5 N., R. 4 W. Columbia County	7-1-87	7-1-89	Permit canceled; expired.
390	ARCO CFI 31-1-65 36-009-00227	NE¼ sec. 1 T. 6 N., R. 5 W. Columbia County	5-21-87	5-21-89	Permit canceled; expired.
411	ARCO Hamlin 33-17-65 36-009-00245	SE¼ sec. 17 T. 6 N., R. 5 W. Columbia County	7-5-88	4-4-89	Permit canceled; per permittee's request.
413	ARCO Col. Co. 22-17-75 36-009-00247	NW¼ sec. 17 T. 7 N., R. 5 W. Columbia County	9-26-88	9-26-89	Permit canceled; expired.
419	ARCO Oregon 13-33-86 36-007-00021	SW¼ sec. 33 T. 8 N., R. 6 W. Clatsop County	11-16-88	11-16-89	Permit canceled; expired.
431	Northwest Fuel Dev. Hammerberg 32-14-65 36-009-00260	NE¼ sec. 14 T. 6 N., R. 5 W. Columbia County	7-7-89	11-8-89	Permit canceled; per permittee's request.
433	ARCO Meridian 34-31-65 36-009-00262	SE¼ sec. 31 T. 6 N., R. 5 W. Columbia County	—	—	Application withdrawn.

attributable to the shutdown of pipeline for construction and maintenance at Mist Gas Field. The cumulative field production as of the end of 1989 was about 38.4 Bcf. The total value of the gas produced for the year was \$3.5 million, a decrease from the \$6.4 million during 1988. Gas prices ranged from 14 cents to 15 cents per therm, a decrease from the range of 14 cents to 20 cents per therm during 1988.

GAS STORAGE

During the year, Northwest Natural Gas Company completed its redesign of the Miller Station at Mist Gas Field, including installation of two new compressors. This completed construction at the natural gas storage project, which became fully operational on November 1, 1989. Natural gas was injected

into the Bruer and Flora Pools, each having three injection-withdrawal wells. Natural gas was withdrawn from these pools starting in December 1989.

OTHER ACTIVITIES

During 1989, Northwest Natural Gas completed construction of the Mist South feeder gas pipeline. This 49-mi pipeline connects the natural gas storage project at Mist Gas Field to the Portland area via a 16-in. pipeline (see *Oregon Geology*, v. 51, no. 5).

DOGAMI continues the study of the oil and gas potential of the Tyee Basin, located primarily in Douglas and Coos Counties in southwestern Oregon. The first phase of the study is now completed and includes production of a regional geologic map and cross sections and a source-rock report of the area.

These will be published and available for purchase from DOGAMI. The study is intended to investigate those characteristics needed to generate and trap gas and oil, namely, source rock, stratigraphy, and structural framework. The study, which is being funded by landowners in the study area and by county, state, and federal agencies, will publish surface geologic maps and a fence diagram of the Tyee Basin using surface and subsurface well control during 1989.

The Northwest Petroleum Association remained active during 1989, with about 125 members at year's end. At monthly meetings, papers related to the oil and gas industry are presented. For 1990, plans are to hold the annual field symposium during September in Roseburg, Oregon, including a field trip to observe the structure and stratigraphy of the Tyee Basin.

Offshore oil and gas exploration is still many years away in the region, but planning is underway at the state and federal levels. The Oregon Ocean Resources Management Task Force, established by the 1987 Legislature, has continued to hold meetings and workshops to gather input regarding planning for new uses of the ocean, primarily mineral development. The Task Force will issue an interim report during early 1990. The general consensus from the public has been that existing uses such as fishing and tourism should be preserved, whereas oil and gas exploration or mining should be prevented. A final plan is scheduled for release in July 1990.

The U.S. Minerals Management Service plans to hold an April 1992 oil and gas lease sale for the Outer Continental Shelf off Oregon and Washington. Planning continues for the sale despite opposition from the State of Oregon, which feels this sale should be delayed or possibly canceled, pending completion of detailed studies of the affects of this activity. Industry interest will be gathered this year, which may ultimately determine whether there will be a 1992 offering.

During 1989, DOGAMI published its Oil and Gas Investigation 15, entitled *Hydrocarbon Exploration and Occurrences in Oregon*. This publication lists all known oil and gas occurrences in Oregon in wells and on the surface such as oil and gas seeps. Its cost is \$7. As a companion to OGI-15, DOGAMI published Open-File Report 0-89-10, *Bibliography of Oil and Gas Exploration in Oregon, 1896-1989*. This provides a comprehensive listing of references relevant to oil and gas exploration in Oregon. The cost is \$5. DOGAMI also has recently revised the Mist Gas Field Report, described in the "Oil and Gas News" (p. 26 of this issue).

DOGAMI has continued the development of rules to implement House Bill 2089 and to revise administrative rules relating to oil and gas exploration and development in Oregon. This work is scheduled for completion during 1990. □

MINERAL EXPLORATION ACTIVITY

Major metal-exploration activity

Date	Project name, company	Project location	Metal	Status
April 1983	Susanville Kappes Cassiday and Associates	Tps. 9, 10 S. Rs. 32, 33 E. Grant County	Gold	Expl
May 1988	Quartz Mountain Wavecrest Resources Inc.	T. 37 S. R. 16 E. Lake County	Gold	Expl
June 1988	Noonday Ridge Bond Gold	T. 22 S. Rs. 1, 2 E. Lane County	Gold, silver	Expl
September 1988	Angel Camp Wavecrest Resources, Inc.	T. 37 S. R. 16 E. Lake County	Gold	Expl
September 1988	Glass Butte Galactic Services Inc.	Tps. 23, 24 S. R. 23 E. Lake County	Gold	Expl
September 1988	Grassy Mountain Atlas Precious Metals, Inc.	T. 22 S. R. 44 E. Malheur County	Gold	Expl, com
September 1988	Kerby Malheur Mining	T. 15 S. R. 45 E. Malheur County	Gold	Expl, com
September 1988	QM Chevron Resources, Co.	T. 25 S. R. 43 E. Malheur County	Gold	Expl
October 1988	Bear Creek Freeport McMoRan Gold Co.	Tps. 18, 19 S. R. 18 E. Crook County	Gold	Expl
December 1988	Harper Basin American Copper and Nickel Co.	T. 21 S. R. 42 E. Malheur County	Gold	Expl
January 1989	Silver Peak Formosa Exploration, Inc.	T. 31 S. R. 6 W. Douglas County	Copper, zinc	App, com
May 1989	Hope Butte Chevron Resources, Co.	T. 17 S. R. 43 E. Malheur County	Gold	Expl, com
September 1989	East Ridge Malheur Mining	T. 15 S. R. 45 E. Malheur County	Gold	App

Explanations: App=application being processed. Expl=Exploration permit issued. Com=Interagency coordinating committee formed, baseline data collection started. Date=Date application was received or permit issued.

Exploration and bond ceiling rule making

Advisory Committees organized to make recommendations on exploration permits (HB 2088) and bond ceilings for some metal mines (SB 354) likely will have concluded their work by the time you read this. For a copy of either set of draft rules and a schedule of rulemaking hearings, contact Doris Brown at the Oregon Department of Geology and Mineral Industries (DOGAMI) Mined Land Reclamation Office, 1534 Queen Avenue SE, Albany, OR 97321, phone (503) 967-2039.

Mining issues forum

In order to bring together all groups concerned with mining in Oregon, DOGAMI and others will sponsor a forum to review potential beneficial and negative impacts from large-scale mining in Oregon. Representatives of a wide range of interests, including mining companies, environmental groups, state and local elected officials, and regulatory agencies will be invited to participate.

Additional information will be presented in this column in the May and July issues of *Oregon Geology*.

Status changes

Pegasus Gold is taking over the property currently permitted to Wavecrest Resources at Quartz Mountain and Angel Camp in Lake County. A project coordinating committee meeting was held with Pegasus and the regulatory agencies on February 22 to review the adequacy of the baseline data collected to date.

The operating plan of Formosa Exploration, Inc., was approved for completeness in December by DOGAMI. Final approval of the permit by DOGAMI is possible this spring. The Water Pollution Control Facility Permit issued by the Department of Environmental Quality has been drafted. Contact Jerry Turnbaugh, phone (503) 229-5374, for further information.

An initial project coordinating committee meeting for Chevron's Hope Butte property was held in February.

All readers who have questions or comments should contact Gary Lynch or Allen Throop at the MLR office in Albany, phone (503) 967-2039. □

Capitol display celebrates 25th anniversary of State Rock

The display case of the Oregon Council of Rock and Mineral Clubs (OCRMC) at the State Capitol in Salem currently houses an exhibit that celebrates the 25th anniversary of the adoption of the Thunderegg as Oregon's State Rock. The exhibit, which will remain until May 15, 1990, was provided by the Far West Lapidary and Gem Society of North Bend/Coos Bay and arranged by Bert Sanne and Cecelia Haines.

The display features a framed copy of Senate Joint Resolution 18, adopted March 29, 1965, and signed by Governor Mark O. Hatfield. Ten color photographs encased in lucite present the theories of the Thunderegg's origin.

—OCRMC news release

Corrections

The rush to meet deadlines and the complexity of the Department's new desktop publishing system resulted in errors in the January 1990 issue of *Oregon Geology*. We apologize for any inconvenience this may have caused.

1. Figure 16 caption, p. 8, last sentence should have the words "stream channel" added at the end.

2. Figure 20 caption, p. 10, should read "Reworked airfall deposit exposed in roadcut on the Crooked River grade."

3. Figure 23 caption, p. 11, should read "Dark, cross-bedded sands are interspersed with laminated sheet-flood deposits in the Deschutes Formation near Round Butte."

4. Figure 24 caption, p. 11, delete the words "Hyperconcentrated flow."

5. Figure 25 caption, p. 11, change first three words to "Extremely coarse conglomerates."

6. Complete sentences 7 and 8 in "Cove Palisades State Park Field Trip Guide" on p. 13 should read "Flows exposed at the rim of Dry Canyon are Round Butte flows."

7. Stop 4, p. 14, paragraph 5, sentence 2, delete "both" and "and dark (andesite?)." Sentence 4, same paragraph, should be changed to two sentences that read "The second is the light-colored Cove ignimbrite. A white to gray reworked tuff unit overlies a conglomerate and cross-bedded sandstone about halfway down the grade."

8. Stop 5, p. 14, paragraph 1, next to last sentence should be changed to read "Their exceptional thickness may be the result of ponding behind a basalt dam downstream, although there is no direct evidence of this other than their thickness and behavior in places as a single cooling unit."

9. Stop 6, p. 15, paragraph 1, sentence 3, change "lower unit" to "upper unit." □

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