This top view shows tusk in place, prior to jacketing (coating it with a protective layer of plaster of paris).
Industrial minerals in Oregon

by Ronald P. Geitgey, Oregon Department of Geology and Mineral Industries

ABSTRACT

A wide variety of industrial minerals is produced in Oregon for regional, national, and international markets. The estimated total value of nonfuel mineral production in Oregon in 1988 was $169 million, virtually all of which was from industrial minerals. Sand, gravel, and crushed rock accounted for approximately $115 million.

Limestone is quarried from one location for cement production and sugar-beet processing and from two other locations for agricultural uses. Diatomite is produced by two companies, one for filter aids and the other for pet litter and oil absorbents. Bentonite clay from two operations is used primarily for civil-engineering applications, and structural clays are used by two brick manufacturers. Pumice from two areas is sold to concrete-block producers, and lesser amounts are used for landscaping and for stone-washing certain garments. The zeolite mineral clinozoisite is processed for absorbents and odor-control products. Exploration by two brick manufacturers.

Many commodities produced in the past in Oregon merit reevaluation. Some of these are brick clays, chromite, expandable shales, foundry sands, gypsum, iron-oxide pigments, peat, and building stone, including gray granites, white marble, black marble, sandstones, and volcanic tuffs. Production ceased for most of these because of market conditions and increased costs rather than product quality or deposit reserves.

Several other commodities have the potential for new or increased production. Some have been evaluated; others are known occurrences that have geologic potential for commercial development. They include bentonite clay, borates, feldspar, ferruginous bauxite, fuller's earth, kaolin clay, nepheline syenite, perlite, and talc.

INTRODUCTION

Industrial, or nonmetallic, minerals are often unnoticed commodities, but their production is essential to nearly all phases of a modern economy, including construction, manufacturing, and production of food, fuels, and fibers. Their total value far exceeds that of the metals in both national and world markets.

The term "industrial minerals" defies succinct, comprehensive definition. It encompasses natural rocks and minerals as well as manufactured products such as cement and lime. While often termed "nonmetals", some industrial minerals are, in fact, metal ores that are utilized for properties other than their contained metal. Bauxite, for example, is the ore of aluminum metal but also the basis for some refractories (heat-resistant materials), abrasives, chemicals, and pharmaceuticals. Similarly, gemstones such as diamond and sapphire are included in some discussions of industrial minerals, in part because of their role as abrasives in the form of industrial diamonds and corundum. Perhaps it is simpler to say that industrial minerals are naturally occurring rocks and minerals and certain products manufactured from them that are not used as metal ores or as fuels.

The uses of industrial minerals are highly diverse. Some are dependent on physical properties such as strength, hardness, softness, color, and density, while other uses, including chemicals, fertilizers, ceramics, and glass, are dependent on chemical composition. Hard or tough minerals such as quartz, garnet, or emery are used as abrasives and on wear-resistant surfaces. Soft minerals such as talc and graphite are valuable for their lubricity (slipperiness) and for the minimal wear they have on the equipment used to make products containing them. Strength, flexibility, and density are among several characteristics of plastics that depend on industrial-mineral content. In construction, industrial minerals are used as aggregates (sand, gravel, crushed rock), building stone, cement, plaster, and roofing materials. In paints, industrial minerals determine color, covering capacity, gloss, toughness, washability, and sag resistance. The paper industry uses numerous minerals as fillers and coaters to control various properties of the paper, such as bulk, weight, smoothness, opacity, and ink retention. Numerous juices, beverages, oils, and other liquids are filtered through layers or beds of certain industrial minerals to remove impurities and to clarify the product.

Many industrial minerals can perform several different functions. For example, quartz in its several forms can be used in numerous applications, including glass, electronics, refractories, abrasives, aggregates, fillers, filter, and foundry sands. Limestone may be used for cement, aggregate, building stone, chemicals, glass, plastics, paper, agriculture applications, sugar refining, and treatment of waste liquids and gases.

As a result of this diversity of uses and properties, exploration for and evaluation of industrial minerals are often highly specialized fields. A chemical assay may be useful, but often physical properties, type of impurities, and distance from potential markets are far more important. In some applications, the precise
chemistry or mineralogy of the raw material may be less important than its uniformity or its performance in the finished product. Marketing and research and development are often critical to the economic viability of an industrial-mineral prospect. Unlike most metals, for which there are well-established markets and end uses, industrial minerals must often create their own markets by demonstrating a clear superiority in performance and, ultimately, cost over competing materials or sources.

In Oregon, a wide variety of industrial minerals is produced for regional, national, and international markets. The state's estimated total value of non-fuel mineral production in 1988 was $169 million, of which virtually all was from industrial minerals. Sand, gravel, and crushed rock accounted for approximately $115 million. Current producers are shown in Figure 1, and documented occurrences, past production, and present production of various industrial minerals are summarized in Table 1.

### AGGREGATES

Aggregate materials are produced by private companies and various federal, state, and county agencies. Crushed stone, almost exclusively basalt, is produced in all 36 counties (Figure 2); sand and gravel is produced in all but five counties; and volcanic cinders are produced in eight counties for construction uses. Methods include open pits, quarries, and floating dredges. Areas of high demand and production are areas of high population, and urbanization continues to encroach on aggregate sources. Some areas do not have adequate known reserves, particularly for concrete aggregate where critical specifications must be met. In the past, small amounts of material may have been imported for concrete aggregate when transportation costs were favorable. Offshore sand and gravel resources have been identified, but as yet they have not been fully evaluated.

### COMMON CLAY

Common clay is produced in 11 counties for engineering applications, for cement manufacture, and for brick production. Columbia Brick Works, Inc., at Gresham near Portland in Multnomah County, operates a high-volume facing brick plant utilizing clay mined on its property. Klamath Falls Brick and Tile Company in Klamath Falls (Figure 3) is a smaller specialty-brick company producing a wide variety of colors of facing and paving bricks from clays mined in Klamath County and several other western counties.

**Figure 3.** Klamath Falls Brick and Tile Company in Klamath Falls, Klamath County.

### LIMESTONE

Limestone crops out in the northeastern counties, the southwestern counties, and, to a lesser extent, in some northwestern counties of the state. Historically, these deposits have been utilized for agricultural lime, dimension stone (Figure 4), cement production, and the production of calcium carbide.

Limestone and shale are quarried near Durkee in Baker County by Ash Grove Cement West. The shale and some of the limestone is used to manufacture portland cement which is marketed in Idaho, Oregon, and Washington. Higher purity limestone from the same quarry is crushed and screened to various sizes and sold as sugar rock, that is, rock used in sugar-beet refining. Sugar-beet refiners calcine (fire) the limestone to quicklime which is then added to the sugar solution during processing to precipitate phosphatic and organic impurities. The lime is then precipitated by bubbling carbon dioxide (recovered from the calcining operation) through the sugar solution to form calcium carbonate, and the sugar solution is clarified by filtration. Sugar rock is sold to refiners in Idaho and eastern Oregon.

The combined value of portland cement and sugar rock from the Durkee operation has been about $25 million each year for the last five years. Ash Grove also operates a lime kiln in the Portland area, but its feed stock is high-calcium limestone barged in from the company's quarry on Texada Island near Vancouver, British Columbia.

Limestone is also produced from two quarries in southwestern Oregon. D and D Ag Lime and Rock Company produces a small amount of agricultural limestone southeast of Roseburg in Douglas County. Campman Calcite Com-
blocks. Both companies serve, by truck and by rail, markets in northern California, Oregon, Washington, and British Columbia. The market area for pumice as lightweight concrete aggregate will probably remain regional, limited by transportation costs and competing sources in Idaho and California.

Lesser amounts of pumice are sold for landscaping (Figure 5), roofing, floor sweep, pet litter, and horticultural soil mixes. Cascade Pumice is also marketing a small tonnage of 2- to 4-in. lump pumice mined in Klamath County for stone-washing jeans and other denim garments. This small segment of the pumice market is of high enough value to bear shipping costs to the midwestern and eastern parts of the country.

**Figure 4. Entrance to Oregon Department of Agriculture building in Salem, built approximately 20 years ago and faced with limestone from deposits in Benton County.**

A company has acquired the Jones marble deposit near Williams in Josephine County and is producing calcium carbonate products for agricultural and paper pulp uses.

A comprehensive study of limestone occurrences in the state prepared by Howard Brooks of the Oregon Department of Geology and Mineral Industries is currently in press (Brooks, 1989).

**PUMICE**

Oregon has ranked first in pumice production in the U.S. for seven of the last eight years. According to U.S. Bureau of Mines statistics, Oregon pumice production during that period has remained at about 200,000 short tons per year, valued at about $1.5 million per year. Pumice occurs in many counties, particularly in those east of the Cascade Range, but it is mined on a large scale only near the city of Bend in Deschutes County. Cascade Pumice and Central Oregon Pumice mine 15- to 40-ft-thick airfall-pumice beds with overburden ratios up to 1:1. Overburden is removed, stockpiled, and finally backfilled by pan scrapers, and the pumice is mined by front-end loaders. Pit-run pumice is stockpiled and air dried, then crushed and screened to various size ranges. The major end use for products from both companies is lightweight aggregate in poured concrete and in structural and decorative concrete and in cement and concrete blocks. Both companies serve, by truck and by rail, markets in northern California, Oregon, Washington, and British Columbia. The market area for pumice as lightweight concrete aggregate will probably remain regional, limited by transportation costs and competing sources in Idaho and California.

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Figure 5. Pumice blocks such as the one easily held here by a child are used for landscaping purposes.

**CINDERS**

Most volcanic cinder production in the state is used for road surfacing and for ice control, and most is produced by various government agencies. Neither Central Oregon Pumice nor Cascade Pumice sells to this particular market, but both mine red and black cinders for concrete-block aggregate, landscaping, and other uses. Cinder aggregate produces a heavier but higher strength block than pumice aggregate alone, and both may be blended for various strength and color characteristics. Landscaping products range from pea-sized grains up to boulders several feet in diameter.

**Figure 6. Part of Bristol Silica and Limestone Company operation in Jackson County.**

**SILICA**

Silica resources in Oregon include quartzfeldspatic sands and quartz replacement bodies. The sands include coastal dune sands, interior dune sands, onshore marine sands, and fluvial and lacustrine sands. The high-purity quartz bodies are the result of silicification of carbonate units and of rhyolitic volcanics. A reconnaissance survey of silica sources in the state is being conducted by the author.

Silica is produced by three companies, in one case from dune sands and in two from quartz bodies. CooSand Corporation mines quartzfeldsparic dune sands on the north shore of Coos Bay in Coos County. The deposit has a particle-size distribution ideal for glass manufacture and is located on a rail line. The sand is shipped to a plant near Portland where magnetic separation is used to lower the iron content sufficiently to meet specifications for container glass manufactured by Owens-Illinois in Portland. CooSand also sells some material for construction sand and for engine traction sand. Beneficiation testing, which includes scrubbing, froth flotation, and magnetic separation, has shown that some of the coastal dune deposits could be upgraded to meet flat-glass standards. The deposits are also well situated for rail or barge transportation to domestic or offshore markets.

Bristol Silica and Limestone Company, near Gold Hill in Jackson County (Figure 6), produces crushed and screened quartz in various size ranges for filter beds, poultry grit, landscaping, and exposed-aggregate concrete panels. The quartz body was formed by replacement of a carbonate lens, and in the past the company has also produced limestone and dolomite products from unaltered portions of the deposit. Bristol has been in production at this location for over 50 years.

Crushed quartz is also produced from Quartz Mountain, a silicified rhyolite in eastern Douglas County. Formerly, all production went to Hanna Nickel Company at Riddle, Oregon, for use in nickel smelting. Glenbrook Nickel, the new operator of the Nickel Mountain property, also uses this same source for silica. The owners of Quartz Mountain are seeking additional markets for their high-purity quartz.
SLAG

During its smelting of nickel at the Nickel Mountain property in Douglas County, Hanna Nickel produced several million tons of granulated slag. Part of the slag was purchased by Reed Minerals and stockpiled in Riddle. Reed crushes and sizes the slag into several grades of air-blast abrasives, which are marketed under the Green Diamond brand name. The abrasive products have the advantage of high durability and absence of free silica, and they are marketed primarily to West Coast shipyards and steel-tank manufacturing and maintenance companies.

EMERY

Oregon Emery Company in Halsey, Linn County, produces abrasive and wear-resistant products from an emery deposit in eastern Linn County (Figure 7). The corundum-spinel-mullite-magnetite emery is apparently the result of contact metamorphism of ferruginous bauxites and is one of several such deposits owned by the company in the Cascade Range. Processing includes crushing and screening to produce specific particle shapes and size ranges. Oregon emery is used primarily in skid-resistant and hardened surfaces with concrete or epoxy systems in such areas as industrial floors, ramps, and traffic ways and on steel-bridge decking.

DIATOMITE

Central and eastern Oregon have had a long history of lacustrine environments and silicic volcanism, which resulted in numerous occurrences of fresh-water diatomite beds. Two companies currently are mining and processing diatomite in Oregon: Oil-Dri Corporation of America, at Christmas Valley in Lake County, and Eagle-Picher Minerals, in northern Harney and Malheur Counties.

Oil-Dri produces crushed and screened granules for floor absorbents and cat litter for several distributors as well as for the company's own brand name products. Eagle-Picher trucks diatomite ore from mines near Junta (Figure 8) to its plant near Vale where the diatomite is crushed, dried, flux-calcinined, and sized for filter-aid products. The robust skeleton of the dominant diatom species in this deposit is particularly well suited to high-pressure and high-volume filtration of a wide range of mineral oils, edible oils, juices, beverages, and food products (Figure 9).

PERLITE

Miocene silicic volcanism also formed perlite deposits in eastern Oregon. Some have been mined in the past, others have been drilled, and one, on Dooley Mountain in Baker County, is currently being mined by Supreme Perlite Company. Supreme Perlite has an expansion facility in Portland that processes raw perlite from Oregon and New Mexico to produce cryogenic, horticultural, masonry, and construction products.

A perlite deposit on Tucker Hill in southern Lake County has been drilled and evaluated by several companies. Although reportedly of commercial quality and quantity, the deposit is not well located with respect to market areas, and no development has yet been started.

BENTONITE CLAYS

Sodium and calcium montmorillonite clays, generally known as swelling and nonswelling bentonites, respectively, occur throughout the volcaniclastic sediments in eastern Oregon (Figure 10). A reconnaissance survey of occurrences was recently completed by Gray, Geitgey, and Baxter (1988) of the Oregon Department of Geology and Mineral Industries. Preliminary testing suggests that these clays have potential for civil engineering, foundry, drilling, filler, binding, and absorbent applications.

Two companies are currently producing bentonite: Central Oregon Bentonite, 40 mi southeast of Prineville in Crook County, and Teague Mineral Products in Adrian in Malheur County. The principal market for swelling Bentonite from both operations has been in engineering uses, including sealants for ponds, ditches, building foundations, and waste disposal sites.

ZEOLITE

Bedded deposits of several zeolite minerals including clinoptilolite, chabazite, mordenite, erionite, and phillipsite have been documented in eastern Oregon. Several deposits are held by various companies, and many have been drilled and evaluated, including occurrences in the Harney Basin in Harney County; the Durkee...
Basin in Baker County; and the “Rome Beds,” the Sucker Creek Formation, and the Sheaville area in Malheur County. These localities all have zeolites of sufficient accessibility, thickness, areal extent, cation-exchange capacity, and absorption characteristics to be of economic interest, but, as with natural zeolites in general, large-volume markets remain elusive. Only Teague Mineral Products is currently producing zeolite in Oregon. Teague mines clinoptilolite from the Sucker Creek Formation in Malheur County and processes it at a mill in Adrian for absorbent and odor-control products. The mineral has also produced favorable test results in preventing uptake of radioactive cesium by plants in contaminated soils on Bikini Atoll and in removing heavy metals from mine drainage waters.

Figure 10. “Popcorn” weathering is often the first surface telltale for a deposit of swelling bentonite. Photo is of an outcrop near Dayville, Grant County.

TALC
Ultramafic rocks crop out in northeastern and southwestern Oregon. Alteration of serpentinite bodies in these areas has produced talc and talc carbonate (dolomite or magnesite) deposits that may be of commercial importance. Amphiboles are present in some occurrences, but others are free of both amphiboles and chrysotile. Ferns and Ramp of the Oregon Department of Geology and Mineral Industries have recently reported on talc occurrences in the state (Ferns and Ramp, 1988).

Talc, or soapstone, is being produced by Steatite of Southern Oregon from deposits on Elliott Creek Ridge at the southern edge of Jackson County (Figure 11). The company’s principal product is asbestos-free art sculpture stone in a variety of colors for domestic and international markets. Recently, the company has also begun to supply dimensional blocks and crushed material for heat-storage liners in ovens and fireplaces.

GEMSTONES
Gem and lapidary material has been produced from Oregon for many decades, but, as is typical in most areas, it is very difficult to estimate accurately an annual value of production. Material is mined from lode claims, placer claims, private land, and free sites on federal land. Several varieties of agate are valued for their colors, banding, inclusions, and graphic patterns, and are often associated with areas of young volcanism and silicification. Specimens of petrified wood often show unusually well-preserved cell structure. One of the most highly prized materials is the thunder egg, a type of nodule or geode formed in silicic volcanics, particularly ash-flow tuffs. Thunder eggs may be filled with quartz crystals or with banded or patterned opal or chalcedony. Several varieties of opal, including a small amount of very high quality precious opal, are mined at Opal Butte in Morrow County.

Oregon sunstone, a faceting-grade, gemmy, calcic plagioclase feldspar, is mined near the Rabbit Hills in Lake County and in southeastern and northwestern Harney County (Figures 12 and 13). The sunstones occur in basalt flows as transparent megacrysts up to 3 in. long with compositions ranging from about Ab$_{40}$An$_{60}$ to Ab$_{25}$An$_{75}$. Colors range from clear to pale yellow, pink, red, green, and blue, with increasing copper content. Some specimens exhibit aventurinescence or schiller due to exsolved platelets of metallic copper. Current retail prices range from about $20 to $150 per carat, with the higher prices commanded by deeper colors, larger stones, or more elaborate cuts.

PAST PRODUCTION
Many industrial minerals produced in Oregon in the past are no longer mined. Some, such as chromite, were mined in small tonnages and only as a result of wartime shortages. Others, including building stone and brick clays, were victims of shifts in architectural tastes and changes in construction techniques with the increased availability of portland cement. Production ceased for most in response to changing market conditions and increases in mining costs rather than because of noncompetitive product quality or the lack of reserves. Many of the industrial minerals listed in Table 1 as having had past production merit reevaluation with respect to new mining, beneficiation, and transportation methods and with respect to changes in demographics and in domestic and offshore markets. Three examples are given below.

1. Historically, over 60 brick and tile plants have existed in Oregon, as shown in Figure 14. Many were small, local operations meeting immediate needs for construction materials and field tile. The number of active operations has dwindled to only two, but now there appears to be an increasing market for bricks in the Northwest. The larger volume producers were located in the far western quarter of the state, and this area still is highest in concentration of population and fuel, electric power, and transportation facilities. Most of the clays were simply dug as needed, and few deposits were drilled and evaluated ahead of production. The light firing clays in the area around McMinnville, Grand Ronde, and Willamina in Yamhill County are of particular interest, since yellow, buff, and white bricks were produced from those deposits.

2. Currently, no building stone quarries in Oregon are continuously active, although there have been numerous operations in the past as
Past Production - Brick and Tile Clays

SOURCES OF INFORMATION

By far the most comprehensive source of information on industrial minerals is the latest edition of Industrial Minerals and Rocks, published by the Society of Mining Engineers (Lefond and others, 1983). This and earlier editions describe the geology, exploration, production, uses, and specifications of a wide range of industrial minerals.

Information on specific industrial minerals is also included in two publications of the U.S. Bureau of Mines: the annual Minerals Yearbook, which contains summaries and statistical data (U.S. Bureau of Mines, 1989); and the reference work Mineral Facts and Problems, which reviews the geology, production, and uses for various mineral commodities (U.S. Bureau of Mines, 1985).

Still a very useful text is Geology of the Industrial Rocks and Minerals (Bates, 1960), which discusses industrial minerals in the context of the geologic settings of their occurrences. The book Geology of the Nonmetallics (Harben and Bates, 1984) gives a worldwide perspective on industrial mineral deposits and production. Current information is best obtained from Industrial Minerals, a monthly publication that contains short summaries on worldwide industrial mineral activity, detailed articles on specific commodities or regions, and current market prices for various industrial minerals.

(Continued on next page)
A mammoth tusk found eroding from a stream bank near Mitchell in May 1988 by Morle, Sandra, and Devin Simmons of Eugene (see cover photo) has been placed on prominent display in the lobby of the Prineville District Office of the U.S. Bureau of Land Management (BLM). Morle, a dental technologist, suspected that the rather strange looking white material was ivory from a tooth and alerted the John Day Fossil Beds National Monument. The staff there passed a sample and the information from Simmons along to BLM. Through an interagency agreement, the Park Service helped protect the tusk by applying glues to the weathered specimen and patterning the location until the tusk could be excavated by paleontologist Dave Taylor of the Northwest Natural History Association.

According to Taylor, the tusk is a greatly enlarged incisor tooth that most likely belonged to the columbian mammoth, *Mammutthus columbi*. The columbian mammoth was large, even for an elephant, attaining a height at the shoulders. It was common during late Pleistocene time and ranged throughout North and Central America.

BLM archaeologist Suzanne Crowley Thomas stated that the tusk, which was found in stream gravels with its tip lodged against a large boulder, was all that was left of a carcass that had probably washed downstream long ago.

The tusk was found on land in Wheeler County that was recently acquired by BLM in the Sutton Mountain land exchange. The area is known to be rich in paleontological resources dated 34 to 54 million years old. This find is unique, however, because it is so recent. Before the tusk could be excavated, 6 ft of earth had to be removed from above the fossil, and space to work had to be cut into the steep hillside. Taylor, who led the excavation one hot weekend in August 1988, was assisted in the process by archaeologist Thomas and volunteers Bob Tavernia, Scott Thomas, and Morle and Sandra Simmons.

The tusk was exposed, and plaster-soaked burlap strips were applied to form a protective jacket. Boards were added to stabilize the tusk, and finally the whole package was lifted onto a stretcher and carried downhill. The tusk then spent the next few months in a laboratory at Portland State University, while Taylor cut and peeled away the plaster jacket, applied more glues, and filled in some of the missing surface with plaster.

After its return to central Oregon, the tusk was placed in a specially designed case in the lobby of the Prineville BLM District Office along with photographs and descriptions of the excavation. The Bridge Creek mammoth tusk exhibit is proving to be a popular attraction and has been viewed by several hundred visitors since its unveiling on April 19, 1989.

This tusk is a classic example of the way in which private citizens who make an important scientific discovery on public lands can report the find to the appropriate land managing agency or to a member of the professional community, thereby assuring that the discovery will be properly treated and preserved for all to study and enjoy.

The casual use and collection of fossils have long been recognized as legitimate activities on public lands. Some restrictions do exist, however, which provide for the management and protection of fossils of major scientific value. Generally, commonly invertebrate and plant fossils may be collected by private individuals without a permit. Exceptions can occur when the fossils are of high scientific value. Veretebrate fossils generally may be collected under permits issued by BLM or other appropriate authorities, and these permits are issued only to bona-fide scientific researchers and institutions.

Opportunities are available, however, for private individuals to participate in scientific field studies through volunteer work with active research organizations such as colleges, universities, conservation organizations, and museums. For those who want to participate, there is ample opportunity to dig and learn through these organized research programs.

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(1) extending through 1984 (Neuendorf and Yost, 1987). The Department has a noncirculating library of current and out-of-print periodicals, theses and dissertations, and published and unpublished reports, including reports written for the War Office during World War II. The Department also maintains files of unpublished information on most of the commodities listed in Table 1. Summaries of these commodities were published in the Department's Bulletin 64, *Mineral and Water Resources of Oregon* (Weissenborn, 1969). Comprehensive Department studies on talc and bentonite have been published recently; a limestone survey is in press; a silica summary is in progress; and similar studies of other commodities are planned for future work.

**REFERENCES CITED**


Elemental composition of the very heavy nonmagnetic fraction of Pacific Northwest beach sands

by Stephen E. Binney and Bilqees Azim, Department of Nuclear Engineering; and Curt D. Peterson, College of Oceanography, Oregon State University, Corvallis, Oregon 97331

ABSTRACT
Sieveing, magnetic separation, and gravimetric separation were used to isolate the very heavy nonmagnetic (VHNM) fraction (specific gravity [sp gr] > 4.2) of a suite of Pacific Northwest beach samples. The VHNM samples were then analyzed by instrumental neutron activation analysis to detect the elemental concentrations present. Zirconium (Zr) and titanium (Ti) were the two most prominent elements observed, with Zr (as zircon) generally increasing and Ti (as rutile) generally decreasing from south to north. The zircon plus rutile concentrations were in the range of about 72 to 100 percent (mean and standard deviation of 91.7 ± 8.2 percent) of the VHNM mass. Several other element were closely correlated with the major elements Zr and Ti.

INTRODUCTION
The very heavy nonmagnetic (VHNM) fractions (sp gr > 4.2) of a suite of Pacific Northwest beach samples were analyzed to determine their elemental compositions. This data could be used along with other data to estimate the economic mineral content of the VHNM fraction of offshore sands. Recent measurements of the elemental content of coastal placers along the northern California, Oregon, and Washington beaches have concentrated on the heavy (sp gr > 3.0) magnetic fraction (Peterson and Binney, 1988) and the VHNM fraction (Azim, 1988) of these placers. This paper discusses the analysis of the VHNM fraction of samples collected from 14 beaches in this area. The study was originally designed to focus primarily on zircon, although the presence of rutile in the VHNM fraction expanded this scope somewhat.

In the Klamath Mountain source area (provenance) of southern Oregon and northern California, zircon is derived from a variety of igneous and metamorphic rocks. These primary source rocks range from Pre-Triassic to Late Jurassic in age and are distributed throughout the Klamath Mountain provenance (Irwin, 1960). Tertiary sedimentary rocks, derived in part from the Klamath Mountain terrane and from Rocky Mountain terranes to the east, might also supply second-cycle zircon to Oregon Coast Range drainages. Kulm and others (1968) report that the abundance of zircon varies from 1 to 13 percent in heavy-mineral assemblages (sp gr > 3.0) of the Klamath Mountain and Oregon Coast Range rivers.

SAMPLE DESCRIPTION AND PREPARATION
The beach samples that were collected were analyzed to span a wide geographic and geological range along the northern Pacific coast of the United States (Figure 1). Bulk samples were collected in March 1984 at mid-beach face sites on the southern side of headlands. Samples were taken down to 2 m below the winter-beach surface to obtain concentrated placer compositions at depth (Peter­son and others, 1986).

The first step in the sample separation process involved sieving about 100 g of the beach sand (0 to 2.5 φ at 0.25-φ intervals) to separate rock fragments and other larger particles from the remainder of the sample. All the particles coarser than 2.25 φ were discarded, leaving the fine grains consisting of relatively heavy particles.

The major steps (Figure 2) in preparing the sieved samples for analysis were as follows:
1. Removal of the light minerals from the heavy minerals at a sp gr of 3.0 by the use of sodium polytungstate.
2. Removal of the heavy magnetic minerals from the nonmagnetic heavy minerals by the use of a hand magnet and a Frantz magnetic separator.

3. Removal of the intermediate minerals from the VHNM minerals at a sp gr of 4.2 by the use of a tungsten carbide-sodium polytungstate mixture.

The purpose of the sodium polytungstate separation was to achieve a separation of the fine fraction at a sp gr ≤ 3.0, e.g., removal of the light minerals such as quartz and feldspar. The sample was stirred into the solution and allowed to settle for about 12 hours. Once separation had occurred, the light minerals were isolated by carefully immersing the beaker of solution into liquid nitrogen. The lighter particles were decanted, and the heavier particles, after thawing, were thoroughly washed in a filter to avoid Na and W contamination. After washing, the heavy fraction was dried in an oven at 80 °C for 12 hours (or overnight).

The magnetic separation process removed the magnetic fraction of the sample. A hand magnet was used first for the removal of strongly magnetic substances such as magnetite. This method was efficient and averted subsequent clogging in the Frantz isodynamic magnetic separator, in which standard settings were used for a more complete separation of the magnetic and nonmagnetic fractions.

After the Frantz separation, a mixture of tungsten carbide and sodium polytungstate was used to separate the VHNM fraction from the less dense nonmagnetic fraction. Zircon and rutile resided in the VHNM fraction (sp gr 4.6-4.7 and 4.2-4.3, respectively). After the separation process was completed, the VHNM fraction was examined under a microscope using a standard petrographic analysis method (Phillips and Griffen, 1981) and was found to consist mainly of translucent nonsometric minerals and trace amounts of opaque minerals. The VHNM samples were then weighed and heat sealed with a quartz rod into clean 25-ml dram vials for analysis.

METHOD OF ANALYSIS

Sequential instrumental neutron activation analysis (INAA) was used to analyze the VHNM samples and determine elemental concentrations (Laul, 1979). Four reference standards were used: fly-ash powder (NBS 1633a), Columbia River Basalt Group powder (CRB3), a liquid U standard, and a liquid Zr standard. CRB3 standard is an Oregon State University (OSU) standard that has been calibrated with the USGS BCR-1 standard rock. The VHNM irradiation samples had masses in the range of 20 to 160 mg, although one sample had a mass of <10 mg (all that was available). The samples and the standards were irradiated under identical conditions in the OSU TRIGA Reactor. The reactor was operated at a power level of 1 MW, corresponding to a thermal neutron flux of 1 x 10¹³ n/cm²-s in the pneumatic transfer system (for the short irradiations) and 3 x 10¹³ n/cm²-s in the rotating rack (for the long irradiations).

For short irradiations, the samples were irradiated for two minutes and then allowed to decay for 10 minutes. The short-lived nuclides (representative of the elements Ti, Al, V, Mg, and Ca) were analyzed first for five minutes. After two to five hours, the samples were reanalyzed for 10 minutes to determine the elemental contents of Dy, Na, K, and Mn.

For the long irradiation, the samples and the standards were irradiated for seven hours. After a decay period of seven to 14 days, the samples were analyzed for three hours to determine the elemental concentrations of Fe, Co, As, Sb, Nb, Ba, La, Nd, Sm, Yb, Lu, W, and Np (representative of U). The samples were allowed to decay for an additional 20 to 30 days and then analyzed for six hours to measure the concentrations of Sc, Cr, Co, Zr, Sn, Sr, Sb, Cs, Ce, Eu, Tb, Hf, Ta, and Pa (representative of Th).

The data were collected using a p-type Princeton Gamma Tech Ge(Li) detector with a 13-percent efficiency (relative to a 7.62-cm by 7.62-cm NaI(Tl) detector at 1,332 keV) and a peak to Compton ratio of 47:1 at 1,332 keV. Dead times did not exceed 10 percent for any of the samples.

RESULTS

Results are referenced to the VHNM fraction sample masses, i.e., concentrations are expressed in parts per million (ppm) as μg of element per g of VHNM sample. Table 1 shows the concentrations (as ppm) of the major, minor, and trace elements in the VHNM samples.

Zirconium was the most prominent element measured (INAA is not very sensitive to O or Si), with its abundance ranging from about 17 to 47 percent by weight (as the element Zr). The highest concentration of Zr (47.2 percent) occurred at Agate Beach (latitude = 44.67° N). (Note: the maximum possible Zr concentration is 49.6 percent, the weight percentage of Zr in zircon.) Figure 3 shows the variation of Zr concentration as a function of latitude.

Titanium was the second most prominent element in the VHNM samples, with an elemental concentration ranging from about 2 to 29 percent. The highest concentrations of Ti occurred at the four southernmost beaches (northern California and southern Oregon). For the rest of the samples, the Ti concentration was less than about 8 percent of the VHNM sample mass, although Ocean Beach had a relatively higher concentration of Ti and a correspondingly lower Zr concentration than neighboring beaches. Figure 3 also shows the variation of Ti concentration as a function of latitude. Hafnium, which is always present with Zr in nature, closely followed the concentration trend of Zr in the VHNM samples. The concentration range of Hf was about 0.4 to 1 percent. The ratio of the concentration of Hf to the concentration of Zr + Hf varied only slightly, from 2.02 to 2.24 percent, with a mean and standard deviation of 2.13 and 0.08 percent, respectively.

The other elements that occurred as major elements in the VHNM samples were Al, Ca, Ba, and Mg. Aluminum occurred in the range of about 0.3 to 6.5 percent. Calcium had a concentration range of 0.2 to 2.5 percent in 11 of the 14 samples. Concentrations of barium varied widely, and it appeared as a major, minor, or trace element in the various VHNM samples. Although Mg was present in the VHNM samples, accurate amounts could not be determined because it was discovered after the analyses that the Mg standard had chemically decomposed; hence Mg values are not reported.

Vanadium occurred as a trace element in the VHNM samples, with concentrations ranging from 50 to 655 ppm. Uranium and Th were also present in the samples as trace elements with maximum...
concentrations of several hundred parts per million. Uranium and Zr had a strong positive correlation coefficient (+0.937).

Lanthanide group elements La, Ce, Sm, Eu, Th, Dy, Yb, and Lu in the lanthanide group showed a similar concentration trend versus latitude, but the rest of the lanthanides were higher in the southernmost beaches. Other trace elements present in the VHNM samples were Zn, Sb, and Se. There was a very small amount of Fe (< 1 ppm) in the VHNM samples, as expected for the nonmagnetic fraction. Concentrations of Mn and Na were present in the parts per billion range in all of the samples. Potassium, Cs, and Rb concentrations were below the detection limit in all of the samples. There was a very small amount of Fe for the nonmagnetic fraction. Concentrations of Mn and Na were

As indicated earlier, the VHNM fraction of the bulk sample consisted mostly of the mineral zircon. The concentration of zircon (Table 2) was largest (7.56 percent of the heavy fraction) at Agate Beach (Figure 1). There is a generally increasing trend of zircon concentration from south to north between 40° N. and about 43° N. North of about 43° N., the zircon concentration remains fairly constant in the VHNM fraction of the beach samples. In Figure 3, the sum of the elemental Ti and Zr concentrations is plotted as a function of latitude; the sum of the concentration of Ti present (as ilmenite) in the four southernmost beaches was in the range of 1 to 10 percent of the magnetic fraction of the bulk sample. In this study, the VHNM samples analyzed were the nonmagnetic portions of the heavy fraction from the same beaches. Hence the presence of Ti (as rutile) in the VHNM samples contributes to a higher total Ti concentration in the beach sands of northern California and southern Oregon than was established by the authors in their previous work, although the VHNM sample masses were not an appreciable fraction of the bulk sample masses. Also, a comparison of the results for these northern California and southern Oregon beaches between this study and the Peterson and Binney (1988) study could possibly imply two different sources of Ti minerals (ilmenite and rutile), although additional studies are necessary to investigate the sources of the ilmenite and rutile.

As indicated earlier, the VHNM fraction of the bulk sample consisted mostly of the mineral zircon. The concentration of zircon (Table 2) was largest (7.56 percent of the heavy fraction) at Agate Beach (Figure 1). There is a generally increasing trend of zircon concentration from south to north between 41° N. and about 43° N. North of about 43° N., the zircon concentration remains fairly constant in the VHNM fraction of the beach samples. In Figure 3, the sum of the elemental Ti and Zr concentrations is plotted as a function of latitude; the sum of the concentration of the two elements in the VHNM fraction is rather constant (average value of 47.2 ± 4.0 percent). The corresponding value is 91.7 ± 8.2.
percent when expressed as the mineral (zircon plus rutile) weight percent. Hence the Ti plus Zr concentrations in the VHNM samples vary less than 10 percent (1 σ) over a distance of more than 700 km along the Pacific coastline from northern California to central Washington and comprise nearly 100 percent of the VHNM sample.

A linear regression was performed between each pair of elements in the VHNM samples. The corresponding values of the correlation coefficient are shown in Table 3. The correlation coefficient for Ti and Zr was −0.911, which is a typical correlation coefficient for elements in the VHNM samples.

By far the most striking correlation observed was between Ti and Zr (+0.708). This behavior is to be expected because of the similar chemical nature of Zr and Hf.

Most of the zircon in these beach sands was apparently combined in sand grains along with magnetite and hence was removed for a predominantly binary mineral system.

As indicated earlier, the ratio of Zr to Hf is quite constant in the magnetic separation. Chromium had a moderately strong correlation (+0.986) with the zircon. The zircon and rutile served to substantiate the previously known economic importance of the rare-earth concentrations (Ce, Nd, and Lu) in the VHNM samples.

Some anomalously low values were associated with some of the rare-earth concentrations (Ce, Nd, and Lu) in the VHNM samples from Crescent City, Nesika, and Ocean Beach. The U values were also questionable at these beaches. These anomalies have been attributed to the fact that (1) low gamma-ray energies were used for analysis of these elements and (2) the VHNM sample mass available was small (except for Crescent City), both of which produced large uncertainties in the results.

**SUMMARY**

A separation scheme was devised to separate the VHNM fraction from the bulk beach sample that contained minerals of various magnetic susceptibilities and specific gravities. The VHNM samples were analyzed by sequential INAA to detect the elemental concentrations present.

Zircon was present as the major element in the VHNM samples, with a weight percent ranging from 58 percent to 95 percent for most of the samples. Samples from the southernmost beaches (northern California) contained an appreciable amount of rutile along with the zircon. The rutile and zircon served to substantiate the previously known economic importance of the Pacific Northwest beach and continental-shelf sands.

**ACKNOWLEDGMENTS**

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Nuclear reactor services and INAA detection equipment were provided by the Radiation Center. Sample collection and initial processing were carried out with support from the Oregon State University Sea Grant Program, under Grants No. NA81AA-0-00086 (Projects R/CP-20 and R/CP-24) and No. NA85AA-0-SG095 (Project R/CM-31), and from the Oregon Division of State Lands. This research was conducted as a portion of the second author's master's thesis in Nuclear Engineering at Oregon State University.

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Records available at Wyoming

The International Archive for Economic Geology (I.A.E.G.) at the American Heritage Center of the University of Wyoming offers a remarkable collection of documents for public use as a tool for scientific, historical, and commercial research. For Oregon, this collection contains 130 report files, 520 documents, 46 maps, and 135 related documents.

Through a gift from the ARCO Coal Company, the I.A.E.G. now has made the records of the Anaconda Company Geological Department (1895-1985) available to the public. The collection represents the largest body of private mineral and geological data available.

The Anaconda Collection contains 1.8 million documents and maps including prospect evaluations, mine examinations, operating records from Anaconda properties, and studies of broad regional or topical interest. It is accessible through a computer inventory, from which printouts of specific searches are available. The collection is made available and supports itself entirely through user fees.

The I.A.E.G. is a repository and research facility for original manuscripts from the field of economic geology. In addition to the Anaconda Collection, it holds files from more than 170 individual geologists and corporations. More information on the collections, services offered, and fees for use can be obtained from International Archive of Economic Geology, University of Wyoming, Box 3924, Laramie, WY 82071, phone (307) 766-3704.

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DOGAMI Governing Board appoints new chairperson

Sidney R. Johnson, president of Johnson Homes in Baker, has been appointed chair of the Governing Board of the Oregon Department of Geology and Mineral Industries (DOGAMI) for a one-year term, succeeding Donald A. Haagensen of Portland.

Johnson is currently serving both his second four-year term as a member of the Board and his second term as chairperson. He has been a board member since 1983 and served as chairperson in 1985-1986. Ronald K. Culbertson of Myrtle Creek also serves on the three-member Board.

BLM names new state director

D. Dean Bibles, currently U.S. Bureau of Land Management (BLM) state director for Arizona, has been named BLM state director for Oregon and Washington. He will succeed Charles W. (Bill) Luscher who retired September 1.

Bibles is a 32-year veteran of BLM and has held key management positions in the agency since 1967. He became state director in Arizona in 1982.

Bibles has received several awards, including the Interior Department's top recognition, the Distinguished Service Award, and the federal government's top award for senior service leaders, the Distinguished Executive nomination. In 1985 and 1988, he received awards in Arizona by the state's Parks and Conservation Association, Wildlife Foundation, and Nature Conservancy chapter.

In making the appointment, BLM Director Cy Jamison said that Bibles "is fully committed to management of our nation's public lands in that multiple-use context which will position BLM to fully meet the public's demands for natural-resource uses in the 1990's and into the 21st century."

—BLM news release

Photographer Leonard Delano, Sr., dies

Leonard Delano, Sr., retired commercial photographer, died September 16, 1989, in a Milwaukee hospital. He and his wife Emily were active for more than 48 years in commercial photography, which included aerial-photography mapping work. Their companies, Delano Photographics, Inc., and Western Mapping Company, produced a significant collection of Pacific Northwest photographs, many of which have been given to the Oregon Historical Society.

John E. Allen, Emeritus Professor of Geology at Portland State University, said this of Delano, "Few professional photographers have contributed so much to geological understanding of the landscape as has Leonard Delano. This is because on every flight, Delano Photographics always made it a policy to also take a few spectacular oblique photographs. They were usually not paid for these, but when the shots were needed by a geologist for a superb illustration, Delano Photographics allowed them to be used for minimal or no charge."

Delano was one of the lucky few people who have the eye of an artist, the skill of a photographer, an interest in geology, and the opportunity to fly and photograph. Through his photographs, he shared his special vision with the rest of us. The Oregon Department of Geology and Mineral Industries used many of Delano's photographs—as did almost anyone else who has published information about the geology of the state.

Delano is survived by his wife Emily, sons Douglas and Leonard Jr., a brother, a sister, and seven grandchildren.
Industrial minerals: Can we live without them?

by Hal McVey, Mineral Marketing, Inc.*

Few people realize the importance of industrial minerals in our everyday lives. Perhaps a trip through a normal working day will underscore our reliance upon these nonmetallic minerals. The products and processes that contain industrial minerals or utilize industrial minerals in the manufacturing process are highlighted in bold face.

As we step out of bed in the morning, we place our feet on the carpet (calcium carbonate/limestone is used in the carpet backing). We find our way to the kitchen and switch on the electric light and the coffee pot, which are made of either glass or ceramics (both glass and ceramics are made entirely from industrial minerals—silica sand, limestone, talc, lithium, borates, soda ash, and feldspar). As we enter the kitchen, we find we are now on linoleum (calcium carbonate, clay, and wollastonite) or on ceramic tile.

While the coffee is being prepared, we sit down to read the newspaper and at the same time we realize that we have to take a trip today, so we consult our Official Airline Guide and then have to refer to the Yellow Pages of the phone book for the phone number of the airline. (All of these papers are filled with kaolin clay and use limestone, sodium sulfate, lime, and soda ash in the processing.)

The coffee is prepared, and we fix a piece of toast and sneak a piece of cake from last night’s party (bakery items such as bread contain gypsum as an ingredient, and cakes have a high content of gypsum in the icing). The plate from which we are eating is composed of glass, ceramics, or china, the last being a special form of ceramics. We might also feel inclined to have a full breakfast and even contemplate what we’ll have for lunch and what has to be prepared for the evening meal. Regardless, all of the food that we eat every day relies completely on industrial minerals for its growth and production. (All fertilizers are composed of some combination of potash, phosphates, nitrogen, sulfur, and other minor minerals. The acidity of soils must be regulated with gypsum, limestone, or sulfur. In fact, without industrial minerals, there could not be any modern-day agriculture as we now know it.)

Let’s now start getting to go to work. We brush our teeth with toothpaste (calcium carbonate/limestone/sodium carbonate). Women put on lipstick (calcium carbonate and talc) and powder (talcum), and men might prepare their hair with hair cream (calcium carbonate). Other forms of makeup would have various minerals as a constituent. The lavatory counter top in the bathroom where we are standing is a nice synthetic marble or synthetic onyx (titanium dioxide, calcium carbonate, and alumina hydrate). The sinks, lavatories, toilets, and similar fixtures throughout the house are kept shiny with cleansers (sila, pumice, diatomite, feldspars, and limestone). Kitchen and bathroom tiles are installed, are kept in place, and maintain their waterproof condition with putty and caulking compounds (limestone and gypsum).

Just before we leave, we want to brighten up our wardrobe with some form of jewelry (all precious and semiprecious stones—opal, amethyst, aquamarine, topaz, garnets, diamonds, etc., are industrial minerals). There is a less attractive task to do at the last minute, changing the kitty litter (attapulgite, montmorillonite, zeolites, diatomite, pumice, or volcanic ash).

As we walk outside, we make a mental note that we have to have the composite roof fixed. (Fiberglass is composed of almost the same ingredients as regular glass—silica, borates, limestone, soda ash, and feldspar. Fiberglass and asphalt, along with lesser quantities of either talc, silica sand, or limestone, comprise composition roofing.) We are pleased to see that the fiberglass siding on our home that we have just installed looks so nice. As we get in the car, we think that we will have to do planting and gardening this evening. In addition to fertilizers, we will have to buy some soil amendments and planting mixes today. (Vermiculite, perlite, gypsum, zeolites, or peat make for better growth.)

Once we leave for work, we are really employing industrial minerals. Our automobile is literally composed of industrial minerals. Starting from the ground up, tires contain clays and calcium carbonate, and the mag wheels are made from dolomite and magnesium. All of the glass in the car is made entirely from minerals, as is the fiberglass body now becoming popular on many models. Many of the components in a car are now being made of composites, which are usually combinations of fiberglass and plastics. Plastics require calcium carbonate, wollastonite, mica, talc, clays, and silica for their manufacture. So, as we drive to work, we are enjoying the value of numerous industrial minerals, from the bumpers to the dashboard to the radiator cap and the floor mats.

The paint that makes our car so attractive is composed in large part from industrial minerals—titanium dioxide, kaolin clays, calcium carbonate, micas, talc, silica, wollastonite, and others. In fact, every speck of all paints that we will encounter today, from that on our house to the stripe down the middle of the road and the interior of our offices and elsewhere, will be composed mainly of industrial minerals.

Modern transportation is almost entirely reliant upon industrial minerals, and this does not stop with just the car. Gasoline and lubricants depend on industrial minerals, since the drill bit that originally discovered the crude oil was faced with industrial diamonds. Drilling fluids, used for ease of well drilling, are made almost entirely from barites, bentonite, attapulgite, mica, perlite, and others. It is necessary to employ clays and zeolites in the catalytic cracking process for crude petroleum to arrive at gasoline and lubricants.

On our way to work, we don’t think about it, but we are literally riding on industrial minerals. Concrete pavement is composed of cement and aggregates. Aggregates are themselves industrial minerals—sand and gravel or crushed stone, such as limestone, dolomite, granite, lava, etc. Cement is manufactured from limestone, gypsum, iron oxide, clays, and possibly pozzolan. Even asphaltic pavement or blacktop has industrial minerals as aggregates.

The building we are about to enter is made of industrial minerals. If it is a concrete or stone or brick building, it is entirely made from industrial minerals. If there are steel structural members, the steel production process required chrome for fluxing, bentonite for pelletizing, and, perhaps, chromeite for hardening. The making of steel requires the use of high-grade refractory bricks and shapes made from bauxite, chromium, zircon, silica, graphite, kyanite, andalusite, sillimanite, and clays. Fiberglass batts may be used for insulation in our office buildings as they are in our homes.

Upon entering, we are often enclosed by wallboard or sheetrock (gypsum with fire retardant additives, such as clays, perlite, ver-
miculite, alumina hydrate, and borates) joined together with joint
cement (gypsum, mica, clays, and calcium carbonates). Certainly
the plate-glass windows are made entirely from industrial minerals.
The floors or decks between floors will probably be made from
concrete using lightweight aggregate (perlite, vermiculite, zeolites,
or expanded shales).

To begin our work, we may pick up a pencil (graphite and clays)
and make a list of things to do. One of the first items is to send out a few invoices that are backed with self-contained
carbon paper (bentonite or other clays or zeolites). There are
some articles to be ordered, so we pick up a catalog or magazine
and unconsciously like the glossy feel of the fine paper, which
is caused by a high content of kaolin clay or calcium carbonate
along with titanium dioxide for extreme whiteness. Almost every
sheet of paper that we use today will have used industrial minerals,
such as talc, in its manufacturing process or will contain minerals
as fillers and coaters. Even some inks will contain calcium carbonate
or other fillers.

The morning has worn on, and it is time for a break. In addition
to the coffee in the coffee cup (remember, it is made of industrial
minerals), we decide to heat up a roll, and we place it in or on
a microwaveable container (plastics filled and reinforced with
talc, calcium carbonate, titanium dioxide, or clays).

While on break, we commence to ponder what we will do
for the weekend and know that there are a lot of recreational
devices we would love to employ. These include golf clubs, tennis
rackets, fishing rods, and skis. All of these are now commonly
made from graphite, or, a slightly “older” material, fiberglass. Even
if we are planning a backpacking trip, our pack frame and pots
and pans will be made of aluminum (all aluminum, for whatever
usage, originates with bauxite, one of the most widely utilized
industrial minerals).

Communications equipment employs numerous industrial
minerals. The standard product of the industry for many years
has been the silicon chip, which is made from quartz or silica,
as the name implies. Optical fibers made from glass are replacing
some copper wiring. The television screen or computer monitor
is made of glass, but critical tubes contain phosphors made from
the rare earths or lanthanides, a family of industrial minerals. Even
the superconducting materials that are presently getting so much
attention utilize industrial minerals (yttrium, lanthanides, titanium,
zirconium, and barites) in their manufacture.

After a hard day at the office, we drop in for refreshments
with our friends. A glass of fruit juice, wine, or beer would
be refreshing, but all of these liquids use either perlite or diatomite
as filter aids in their purifying and clarifying processes. If we
should add sugar to any of our drinks, we are enjoying the benefits
of industrial minerals, since limestone and lime are basic to the
production of sweeteners. And, of course, our refreshments will
be served in ceramic mugs or glasses composed entirely of our
friends, the industrial minerals.

Filtering and purification are major duties of the industrial
minerals. Our drinking water uses minerals for purifying and clar-
ification (limestone, lime, and salt), as do the waste water treatment
plants (zeolites, soda ash, lime, and salt). The vegetable oils we
use are filtered by clays, perlite, or diatomite. And equally important
to recreation is the utilization of all the minerals mentioned in
this paragraph for the filtration and purification of water in swim-
mimming pools.

When we arrive home, we are not yet through with our exposure
to our mineral friends. If we have to take medicine or pharma-
caceuticals, we may chew antacid pills essentially made of calcium
carbonate. For upset stomachs, there are Milk of Magnesia (mag-
nesia/dolomite) or Kapectate (kaolin) and others made from clays
such as attapulgite. And, who can forget the lovely barium “cock-
tail” (barites), which it is necessary to drink before getting X-rayed
for gastrointestinal occurrences. Not to mention tincture of iodine
(iodine) for all those cuts and bruises. And, the lithium that is
used to treat mental disorders started out as an industrial mineral.

Rounding out the picture are such diverse uses as abrasives for
sandblasting ships or for making sandpaper for home or
workshop use, as well as emery boards for our fingernails or
polishing compounds for our silverware and other items. Abrasives
are made from pumice, diatomite, silica, garnet, corundum, and
emery. Or, porcelain figurines (silica, limestone, borates, and soda
ash) for our what-not shelf and plaster of paris statues (gypsum)
for our lawn.

Almost finally, it must be mentioned that one of the most basic
table ingredients is an industrial mineral, namely salt. In fact,
it is so basic that it was historically used as a medium of trade
or payment, as implied in our word “salary.” And truly finally,
our names and dates of birth and death will be inscribed on a
gravestone (marble or granite).

The foregoing is meant to provide a broad insight into the
importance of industrial minerals in our everyday life and to em-
phasize how much our lives would be altered without ready and
ecomonomical access to these fundamental constituents.

On recreational gold panning in Oregon

This article is adapted from “The Lure of Gold,” by Mel Ingeroi
of the U.S. Bureau of Land Management (BLM), Roseburg District,
and published in a recent issue of the newsletter BLM News,
Oregon and Washington.

“There’s nothing quite like seeing your first gold flake shining
against the sun. The yellow flakes sparkle like no other sight,
and the sense of finding a bonanza leaves at least a few first-time
miners giddy.” With that glowing description begins an article
on placer mining in the June 1989 issue of Trailer Life, a national
magazine for recreational-vehicle enthusiasts. The article talks about
the basic techniques (such as panning), equipment needed, and
possible locations.

Because the primary location recommended is on Cow Creek
in the BLM Roseburg District, BLM mining engineer John Kalvels
has been busier than usually answering questions from the public.
“We get all kinds,” said Kalvels, “from the casual tourist who
knows next to nothing about gold to the experienced dredger who
asks only about mining claims. Some weeks we might get a dozen
letters and another dozen walk-ins and telephone callers.”

The discouraging fact is that most of the public land on Cow
Creek is covered by mining claims. It is off limits, and miners
have been known to be rather testy when running off claim jumpers.
About the only spot on public land along Cow Creek still open
to the public is in the vicinity of Darby Creek, about 20 mi southwest
of Riddle. Currently, 20 acres have been withdrawn from mining
there, and BLM is considering the establishment of a five-acre
recreational gold-panning site within this area.

Kalvels has been a mining engineer for the Roseburg District
for quite a while, and his knowledge of local geology, promising
locations, and tall tales keeps his customers satisfied, even though
he does not have much prime real estate to offer to gold panners.
“There will always be people lured by the romance of gold mining,”
Kalvels says. “Part of it is the price paid for gold. At nearly $400
an ounce, it ranks among the most valuable materials on earth.
The rest is more intangible—tied in with mystery and challenge.”

These intangibles are behind the recreational aspects of placer
mining. Many of the first-time miners on Cow Creek do not leave
with enough gold to pay for the gasoline it took to drive out there.
But a fair number will come back, dedicated not to what
they take home but to doing it and being there.
Industrial Minerals Forum meets in Portland

by Ronald P. Geitgey, Oregon Department of Geology and Mineral Industries

The Forum on the Geology of Industrial Minerals is a loosely knit non-organization of specialists involved in various aspects of industrial minerals exploration, analysis, marketing, and production. Each year a different state or provincial geological survey hosts the meeting and publishes the papers presented at the Forum.

During the first week in May of this year, the 25th Forum on the Geology of Industrial Minerals was held in Portland, Oregon, hosted by the Oregon Department of Geology and Mineral Industries and the Washington Division of Geology and Earth Resources. This is the first time the Forum has met in a West Coast state, and for many of the 120 participants from the United States, Canada, and Great Britain, it was their first visit to this area. About 45 persons were from the Pacific Northwest. The remainder were from the eastern and midwestern states. Thirty-five percent were government employees, and sixty-five percent were employed in private industry. The Forum provided an opportunity for participants to learn about industrial minerals activities in the Pacific Northwest and to meet the industrial minerals specialists working in this region.

The Forum consisted of technical sessions, a local field trip, and a three-day field trip to eastern and central Oregon. Seventeen technical papers were presented, including surveys of industrial mineral production and occurrences in Idaho, Montana, Oregon, Washington, and British Columbia. Other papers described specific commodities, including bentonite, limestone, pozzolans, rare earths, talc, and zeolites, and two papers discussed various methods and problems in laboratory analysis of industrial minerals.

The Portland portion of the Forum concluded with a field trip to local industrial mineral producers, shippers, and users. Ross Island Sand and Gravel provided a tour by barge of its Willamette River operation, which supplies aggregate for the Portland metropolitan area. The Port of Portland hosted a tour of the Hall-Buck Marine, Inc., bulk mineral loading facility at Terminal 4 through which talc, bentonite, and soda ash are transferred from unit trains to ocean freighters for export. A tour of the Blitz Weinhard Brewery included a discussion of the brewery’s diatomaceous earth filtration system and a stop in its hospitality room to test the efficacy of that system.

An optional field trip took 45 participants to industrial mineral operations in eastern and central Oregon. Stops included Ash Grove Cement West in Durkee, Teague Mineral Products in Adrian, Eagle-Picher Minerals in Vale and Juntura, Cascade Pumice Company in Bend, and stops and discussions at various points of historical and geologic interest.

Participants boarding barges for tour of Ross Island Sand and Gravel operation in the Willamette River in Portland, between the Sellwood and Ross Island Bridges.

Hall-Buck Marine, Inc., bulk mineral loading facility at the Port of Portland Terminal 4. Soda ash from Wyoming is being transferred from unit train to freighter.

The 216-ft. gas/coal-fired rotary kiln at Ash Grove Cement West in Durkee. Ground limestone and shale are fed in from the left, fused to clinker in the central 2,700 °F-hot zone, and the clinker is cooled and discharged at the right.

Ash Grove Cement West produces portland cement in a state-of-the-art plant, as well as high-purity limestone for sugar-beet refining. Its products are marketed in Northwest states, and for the last several years have been valued at about $25 million per year.

Teague Mineral Products produces bentonite clay and the zeolite mineral clinoptilolite. Its bentonite is marketed for foundry binder and for engineering applications, including pond and lagoon sealants and impermeable membranes for solid-waste disposal sites. Teague
Eagle-Picher Minerals diatomite mine near Juntura. Diatomite ore is trucked to the mill near Vale and processed into filter-aid products.

Cascade Pumice company loading facility near Bend. Crushed and sized pumice is shipped by truck or by rail.

Eagle-Picher Minerals mines diatomaceous earth or diatomite near Juntura and processes it at a plant near Vale. Carefully controlled processing results in diatomite products with specific size and shape characteristics valuable in the filtering of various juices, beverages, edible oils, and petroleum products.

Cascade Pumice Company produces pumice and cinder products in various size ranges. Most of the pumice is used as an aggregate to produce lightweight poured concrete and concrete blocks. Lesser amounts are used as absorbents, horticultural soil mixes, and to stone-wash blue jeans and other garments.

All of the producers on both field trips were very gracious hosts and major contributors to the success of the 25th Forum. Proceedings of the 25th Forum on the Geology of Industrial Minerals and an index of 25 years of Forum proceedings will be published later this year by the Oregon Department of Geology and Mineral Industries. The 26th Forum will meet in Charlottesville, Virginia, in May 1990, and the 27th Forum will meet in Banff, Alberta, in May 1991.

Forum participants at Teague Mineral Products zeolite pit about 20 mi south of Adrian. The zeolite clinoptilolite is used in odor-control products and as a heavy-metal and radionuclide absorber.

Clinker from the rotary kiln at Ash Grove Cement West in Durkee. It is subsequently ground to a fine powder and blended with gypsum to make portland cement.
MINERAL EXPLORATION ACTIVITY

Major metal-exploration activity

<table>
<thead>
<tr>
<th>Date</th>
<th>Project name, company</th>
<th>Project location</th>
<th>Metal</th>
<th>Status</th>
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<tr>
<td>April 1983</td>
<td>Susanville Kappes Cassidy and Associates</td>
<td>Tps. 9, 10 S, Rs. 32, 33 E, Grant County</td>
<td>Gold, silver</td>
<td>Expl, com</td>
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<tr>
<td>May 1988</td>
<td>Quartz Mountain Wavecrest Resources, Inc.</td>
<td>T. 37 S, R. 16 E, Lake County</td>
<td>Gold, silver</td>
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<td>June 1988</td>
<td>Noonday Ridge Bond Gold</td>
<td>T. 22 S, Rs. 1, 2 E, Lane County</td>
<td>Gold, silver</td>
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<td>September 1988</td>
<td>Glass Butte Galactic Services, Inc.</td>
<td>T. 23, 24 S, R. 23 E, Lake County</td>
<td>Gold, silver</td>
<td>Expl, com</td>
</tr>
<tr>
<td>September 1988</td>
<td>Kerby Malheur Mining</td>
<td>T. 15 S, R. 45 E, Malheur County</td>
<td>Gold, silver</td>
<td>Expl, com</td>
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<tr>
<td>September 1988</td>
<td>QM Chevron Resources Co.</td>
<td>T. 25 S, R. 43 E, Malheur County</td>
<td>Gold, silver</td>
<td>Expl, com</td>
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<tr>
<td>October 1988</td>
<td>Bear Creek Freeport McMoRan Gold Co.</td>
<td>Tps. 18, 19 S, R. 18 E, Crook County</td>
<td>Gold, silver</td>
<td>Expl, com</td>
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<td>December 1988</td>
<td>Harper Basin American Copper and Nickel Co.</td>
<td>T. 21 S, R. 42 E, Malheur County</td>
<td>Gold, silver</td>
<td>Expl, com</td>
</tr>
<tr>
<td>May 1989</td>
<td>Hope Butte Chevron Resources Co.</td>
<td>T. 17 S, R. 43 E, Malheur County</td>
<td>Gold, silver</td>
<td>Expl, com</td>
</tr>
</tbody>
</table>

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 rule making

The Mined Land Reclamation Program (MLR) of the Oregon Department of Geology and Mineral Industries has organized a technical advisory committee to make recommendations for appropriate exploration drill-hole abandonment procedures required as a result of House Bill 2088. Based on those recommendations, the Department will propose rules and conduct public hearings for evaluation prior to adoption. Rule adoption is now anticipated for early 1990.

Bond ceiling rule making

MLR has organized also a technical advisory committee to make recommendations for proposed rules required by Senate Bill 354.

The Senate bill authorizes the Department to set “the amount of the reclamation bond at an amount not to exceed the lower of the actual cost of reclamation or $100,000 per acre of land to be mined under the terms of the operating permit, if the operating permit applies to extraction, processing, or beneficiation techniques the result of which

(a) will increase the concentration of naturally occurring hazardous or toxic metals . . . to a significantly higher level than that occurring naturally within the permit area; and

(b) is reasonably likely to present a threat to public safety or the environment.”

Based on recommendations of the committee, the agency will propose rules and conduct public hearings for evaluation prior to adoption.

Status changes

A project coordinating committee has been formed for the Hope Butte project of Chevron Resources Company.

In addition to its application to MLR for a mining permit, Formosa Exploration, Inc., has also applied to the Oregon Department of Environmental Quality (DEQ) for the required permit. DEQ will hold public hearings on its water-pollution control permit, if sufficient interest is expressed.

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

Eugene Mineral Club displays at Capitol

The display case of the Oregon Council of Rock and Mineral Clubs (OCRMC) at the State Capitol in Salem currently houses an exhibit provided by the Eugene Mineral Club. The materials displayed were contributed by 14 of the club’s members and arranged by Dean and Betty Axtell, Marian Andrus, and Jean Long-fellow.

Ten Oregon counties are represented in the collection: Crook County with petrified wood, tube agate, and Carey agate; Harney County with thunder eggs and Paiute agate; Jackson County with jade; Jefferson County with thunder eggs, sunset agate, and petrified wood; Lake County with tumbled and faceted Oregon sunstones and obsidian; Lane County with carnelian and jasper; Lincoln County with jasper; Linn County with carnelian; Malheur County with Graveyard Point plume agate, petrified sagebrush, and pink, dendritic limb casts; and Wheeler County with Oligocene leaf and cone fossils in matrix.

One shelf of the display case shows samples of collected material in its raw form—unpolished. Another contains a beautiful display of Linn County carnelian.

The collection will be on display until January 15, 1990. It will be followed by an exhibit featuring Oregon’s State Rock, the Thunderegg, and prepared by Bert Same of the Far West Lapidary Society of Coos Bay.

—OCRMC news release

Electronic publishing begins

You may have noticed that this issue of Oregon Geology looks slightly different from earlier issues. That is because it is the first to be prepared electronically at the Department.

—Editors
**ABSTRACTS**

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


Pre-Tertiary metamorphic rocks, Jurassic granitic intrusions, and Eocene basalts are exposed along the North Fork John Day River at its confluence with Granite Creek. Geochemical and textural evidence suggests greenschist-metamorphosed, strongly sheared, volcanogenic rocks originated in an island-arc environment. These greenstones were apparently intruded during the Late Permian by a silicic pluton that is similarly metamorphosed and brecciated. South of this arc terrane, tectonically disrupted ophiolitic rocks are exposed. This east-west-trending belt of melange contains blocks of chert, metagabbro, and metabasalt in a serpentinite matrix. Titanaitugite indicates the original basalt may have been alkalic. Paleozoic or Triassic Elkhorn Ridge Argillite underlies much of the thesis area and consists mostly of contorted chert and argillite. Graywackes, greenstones, and limestones are intercalated with Elkhorn Ridge Argillite. Regional metamorphism is lower greenschist facies.

Two relatively fresh granitic stocks may be satellites of the Upper Jurassic Bald Mountain batholith exposed 9 km to the east. An intrusive sequence ranging from mafic quartz diorite to granite comprises the larger stock, exposed along Granite Creek. This pluton contains mostly quartz diorite and tonalite. A 0.5-km-wide stock of porphyritic tonalite intrudes argillite on the north side of the North Fork John Day River canyon. Mineral assemblages in the contact-metamorphic aureoles around the two stocks are characteristic of hornblende hornfels facies.

Tertiary dark-gray basalt overlies the Mesozoic and Paleozoic rocks at a profound unconformity. Geochemistry suggests the olivine-bearing, vesicular basalt is equivalent to the Clarno Formation.


Explosion structures occur in flows of Grande Ronde Basalt in the study area near Troy, Oregon. Data from nineteen stratigraphic sites indicate that the maximum number of flows that contain explosion structures at any one site is six. In the informally named Troy flow, explosion structures are widespread.

Each flow that contains explosion structures can be divided into two cooling units. The first cooling unit occupies troughs in the pre-eruption topography and are up to 10 m thick. The second cooling units contain the explosion structures and are up to 100 m thick. The thickness of flows that contain explosion structures ranges from 10 m to 150 m. A plot of the thickness of an explosion structure against the total thickness of the flow is linear with slope of approximately 0.5. The breccias within explosion structures average 42 percent of the total thickness of a flow.

The overall shape of an explosion structure is similar to a three-dimensional set of nested arches with a central spine of breccia that cuts through the uppermost arches. Joining patterns follow the shape of the arches. The linear trends of the central spines within explosion structures of the Troy flow parallel either the northeast-trending Grande Ronde (N. 3° E.) fault system or the northwest-trending dike system in the area (N. 15° W.).

Two processes operate during the formation of explosion structures: mixing and fragmentation. These two processes produce unique intraflow zones within the second cooling unit. Petrographic textures of these intraflow zones range from vitrophyric to interstitial to intergranular. All three textures can be observed in thin bands or layers in samples from the upper intraflow zones of the second cooling units. Individual bands or layers are twisted, pinched, and swirled due to mixing. Fragmentation and mixing produce a vertically stratified central spine composed of three main types of clasts: vesicular to nonvesicular, scoriaceous, and pahoehoe types. Clast sizes range from lapilli size in the outer, matrix-supported margin to block size in the inner, clast-supported core.

Broad overall trends occur in geochemical data for the Troy flow and a flow stratigraphically above the Troy flow. Concentrations of particular elements increase or decrease in samples toward the base of the flow relative to the uppermost sample. K, La, Eu, and Ta are enriched and Fe and Co depleted greater than 10 percent toward the base of a flow in areas away from explosion structures. Particular elements are enriched (Ce, Hf) or depleted (Th) less than 10 percent toward the base. Where explosion structures are present within the flow, these broad overall trends are less pronounced, and few elements display these trends of enrichment or depletion.


The recent contributions of several investigators have indicated the Portland basin may be a pull-apart structure associated with wrench tectonism. Because of the large density contrast between sedimentary and volcanic units and because of their reasonably uniform and continuous nature, gravity survey methods can be used to identify covered structures with considerable success. The study utilized gravity modeling techniques to investigate the structure and genesis of the Portland basin's eastern margin.

Two gravity surveys were completed across pronounced lineaments which form an apparent eastern boundary for the basin. In all, 175 stations were measured, bimodally distributed in regional control and detailed area section in the 9.47-km Fourth Plains and 11.43-km Interstate gravity lines. These values were reduced by standard methods to yield a free-air gravity anomaly value used in the computer modeling process. The Bouguer gravity was not used, since strata normally removed by the Bouguer correction were required for proper interpretation.

Both gravity lines revealed the existence of negative anomalies ranging in magnitude from 1 to 6 mgs, being areally consistent with the locations where the lines crossed lineaments.

Computer modeling indicated these anomalies were produced by strongly prismatic bodies occurring in the near-surface section. Some were small enough to be nearly undetectable under the given survey resolution, while others attained cross sections measuring nearly 3 km².

Folding, faulting, and erosion were investigated as reasonable generative processes for these bodies. Based on the synthesis of modeling and the known geologic history of the region, faulting is preferred. The study defines the Lackamas Creek and Sandy River faults. Each can be characterized as an extensive linear zone of locally normal and/or grabenlike failure where normal displacements approach 300 m. These structures combine to form a region nearly 50 km in length, trending N. 40° - 45° W., effectively paralleling the Portland Hills complex which bounds the basin to the west.

A dextral stepover, characteristic of dextral strike-slip failures, and a resulting concentration of extensional deformation is delineated in the region of the Interstate line. Dextral movement is suggested by this incipient pull-apart, the stepover itself, and the overall geometry of the faults.
Miocene volcanic and sedimentary rocks originally mapped as Sucker Creek Formation near Adrian, Oregon, and Sucker Creek State Park include a stratigraphic section of at least 1,539 m of westward-tilted and faulted deposits. Mapping indicates a stratigraphic section that can be divided into four mappable units in T. 23 S., R. 45 E.; T. 23 S., R. 46 E.; and T. 24 S., R. 46 E.

The main sedimentary section overlies basalts and silicic volcanic rocks at least 200 m thick, exposed along Sucker Creek. Starting with the basal unit, the section consists of 198 m of benthonic claystones containing a white volcanic ash and a prominent orange sandy siltstone; 31 m of alternating thinly bedded diatomite (partly altered to porcellanite) and bentonitic claystones; 279 m of olive-gray bentonitic claystones with several layers of white volcanic ash and, in the upper part, interbedded with 38 m or more of conglomerates and gravels. Above this dominantly claystone basal unit is a 594-m sequence of palagonite tufts containing minor basalt flows, dikes and sills, overlain by a rhyolitic dome complex that is locally 107 m thick, then a 19-m thick zone of thinly bedded pumice lapilli and ash. The uppermost unit in the section is a 92-m-thick pale-greenish rhyolite tuff. The basalt and palagonite unit is apparently localized near and north of Devils Gate, but the underlying lacustrine claystone section is more widespread in the region.

The section is broken and partially repeated in several normal fault blocks. Because the stratigraphic section includes considerable amounts of claystone, this section contrasts markedly with the volcaniclastic sandstone.

The differences in stratigraphic sections indicate that, in this report and the section described by Kittleman and others (1965) about 9 km south of this study area. That type section is 178 m of mostly volcanioclastic sandstone.

Comparisons of the concentrations of trace metals (Ag, Cu, Pb, Zn, and Mo) with those in average granodiorite, Caribbean intrusions associated with porphyry-copper deposits, and rocks of the Western Cascades indicate that samples of the Yellowbottom-Boulder Creek area are depleted in Cu, Pb, and Zn and enriched in Ag. Strong correlations are observed (Mo-Ag; Cu-Zn), whereas Pb has an antipathetic relationship to both Cu and Zn. Trends derived from data plotted on a Cu-Pb-Zn ternary diagram suggest that Pb and Zn metallizations are associated with vein-type deposition, whereas a one-sample Cu anomaly may be related to porphyry-type mineralization. Mineralized districts to the north in the Western Cascades are more enriched in copper than the Yellowbottom-Boulder Creek area, whereas those to the south contain more zinc. This change in the abundances of trace metals may be related to the depth of erosion that has exposed deeper levels of the hydrothermal systems in districts to the north.

Sulfur-isotope data suggest a magmatic source of sulfur. De­positional temperatures (157°C to 260°C) obtained from sulfur­isotope fractionation and fluid-inclusion data derived from a quartz-calcite-galena-sphalerite veinlet suggest mineralization during late-stage gradual cooling of the hydrothermal system. Several geologic features, including mineralized breccia pipes and zones, quartz-bearing porphyritic intrusions, and anomalous metal concentrations, suggest the presence of a porphyry-type hydrothermal system at depth in the Boulder Creek area. Additionally, linear zones of intense silicification may be associated with shallower mineral deposition in the epithermal environment. The future mineral resource potential of the area is therefore largely, but not completely, dependent on the discovery of porphyry-type mineralization that might be enhanced by association with anomalously high gold and silver concentrations.
AVAILABLE DEPARTMENT PUBLICATIONS

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<td>20 Bentonite in Oregon: Occurrences, analyses, and economic potential. 1989</td>
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<tr>
<td>21 Field geology of the NW½ Broken Top 15-minute Quadrangle, Deschutes County. 1987</td>
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- Oregon rocks and minerals, a description. 1988 (DOGAMI Open-File Report O-88-6; rev. ed. of Miscellaneous Paper 1) | 5.00 |
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