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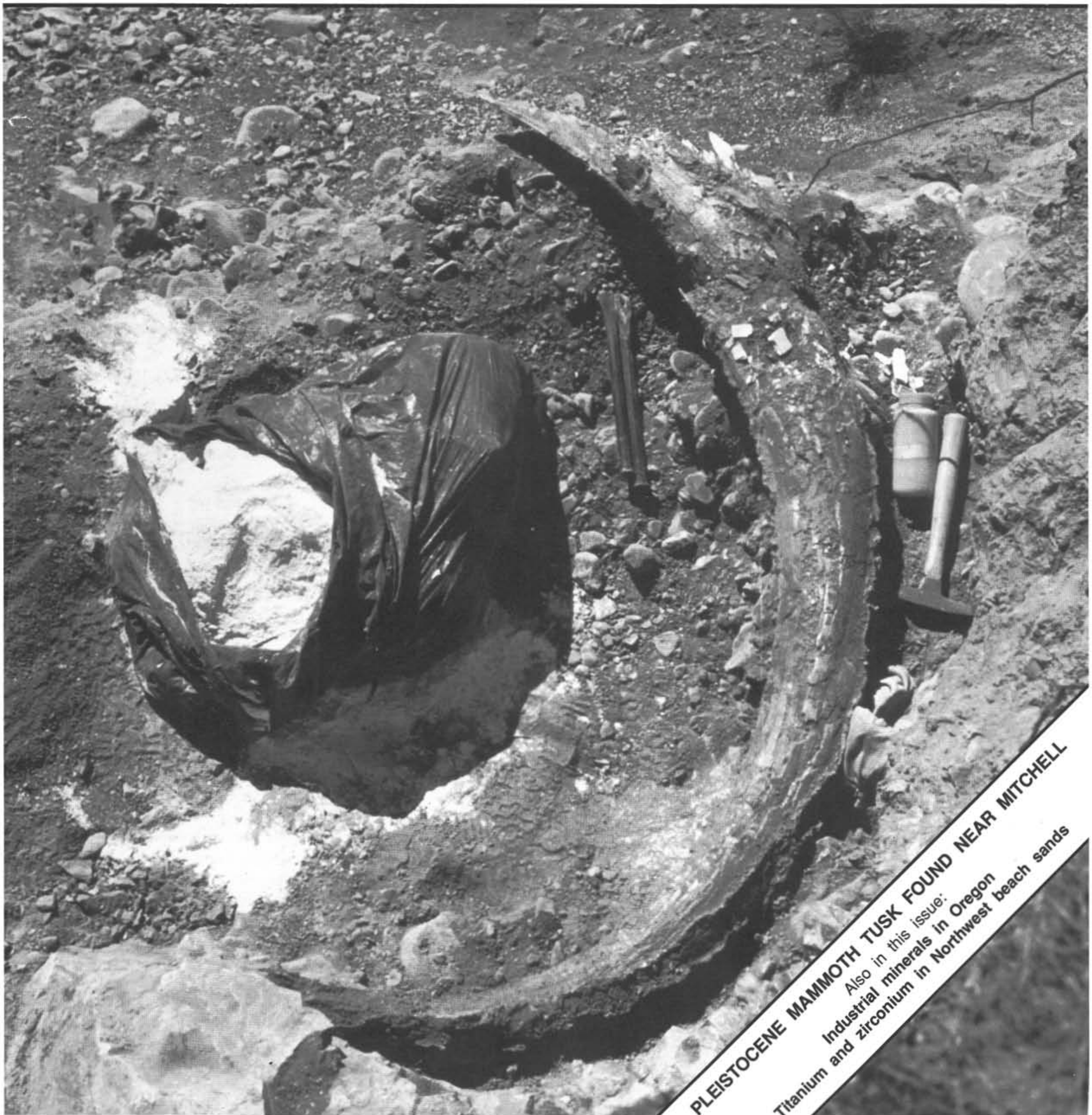

PLEISTOCENE MAMMOTH TUSK FOUND NEAR MITCHELL

Also in this issue:

Industrial minerals in Oregon

Titanium and zirconium in Northwest beach sands

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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 DOGAMI.

COVER PHOTO

Mammoth tusk found near Mitchell, Wheeler County. This top view shows tusk in place, prior to jacketing (coating it with a protective layer of plaster of paris). Article beginning on page 129 discusses the find and its display in the Prineville District Office of the U.S. Bureau of Land Management.

OIL AND GAS NEWS

Drilling activity at Mist

DY Oil drilled three wells at the Mist Gas Field during August. The Neverstill 33-30 was drilled to a depth of 2,225 ft and was completed as a gas producer. The Forest Cav 13-6 and Burris CC 24-8 were drilled to a depth of 1,796 and 2,684 ft, respectively, and both were plugged and abandoned.

ARCO commenced operations at Mist during August, drilling the CER 41-16-64 to a depth of 2,105 ft and suspending the well. Details have not been released. The CER 24-18-64 was drilled to a depth of 1,810 ft and was plugged and abandoned. ARCO plans to drill at least three more wells at Mist this year and will attempt recompletions and other work on wells at the field.

Rulemaking to begin on HB-2089

House Bill 2089 was passed during the 1989 legislative session. The bill is to provide for ground-water protection and surface reclamation when shallow exploration holes are drilled by the oil and gas industry in Oregon. These holes may be drilled for seismic surveys or other purposes. Interested parties may contact Dan Wermiel at the Oregon Department of Geology and Mineral Industries for details.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
434	ARCO Columbia Co. 13-3-55 36-009-00263	SW¼ sec. 3 T. 5 N., R. 5 W. Columbia County	Permitted; 1,655.
435	ARCO Columbia Co. 13-4-54 36-009-00264	SW¼ sec. 4 T. 5 N., R. 4 W. Columbia County	Permitted; 2,025.
436	ARCO Cav. En. Res. 13-1-55 36-009-00265	SW¼ sec. 1 T. 5 N., R. 5 W. Columbia County	Permitted; 1,645.
437	ARCO Oregon 34-25-66 36-007-00022	SE¼ sec. 25 T. 6 N., R. 6 W. Clatsop County	Permitted; 2,280.

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Contents

Industrial minerals in Oregon 123
Recently excavated mammoth tusk on display in Prineville BLM office 129
Elemental composition of the very heavy nonmagnetic fraction of Pacific Northwest beach sands 130
Records available at Wyoming 134
Photographer Leonard Delano dies 134
BLM names new state director 134
DOGAMI Governing Board appoints new chairperson . . 134
Industrial minerals: Can we live without them? 135
On recreational gold panning in Oregon 136
Industrial Minerals Forum meets in Portland 137
Mineral exploration activity 139
Eugene Mineral Club displays at Capitol 139
Electronic publishing begins 139
Abstracts of theses 140
Index to *Oregon Geology*, volume 51, 1989 142

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 clinoptilolite is processed for absorbents and odor-control products. Exploration and limited production of perlite continues, and emery is produced for nonskid surface coatings. Quartzofeldspathic beach dunes supply material for container glass production, and quartz is quarried for nickel smelting, filter beds, poultry grit, and decorative uses. Talc, in the form of soapstone, has an international market as fine-quality art-carving material, and gemstone production includes agates, opal, obsidian, and sunstone, a calcic plagioclase feldspar.

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, filters, 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

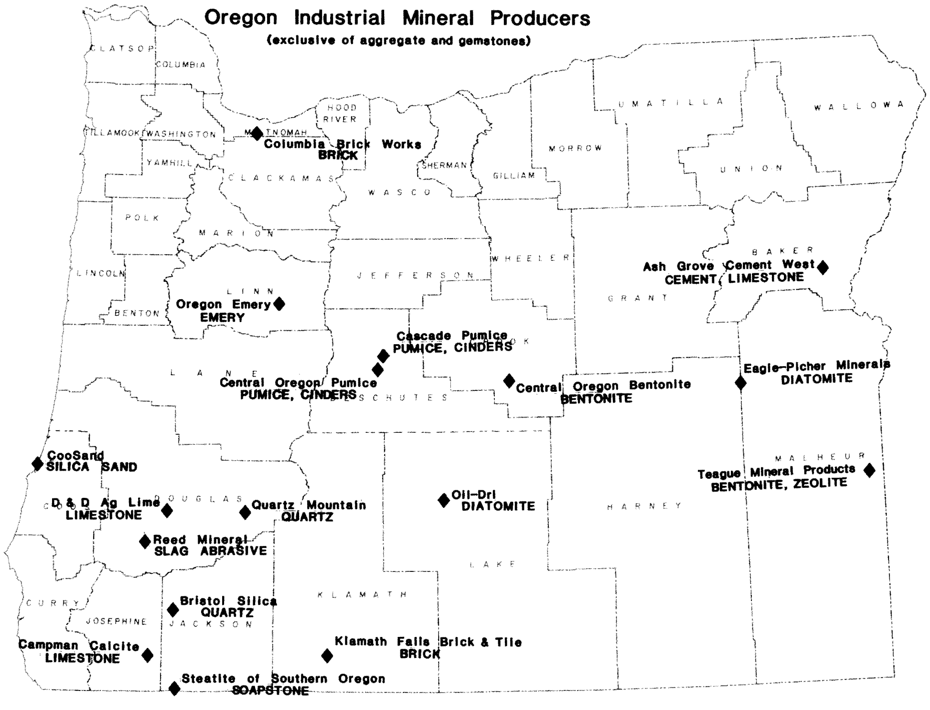

Figure 1. Current producers of industrial minerals in Oregon.

Table 1. *Production and occurrence of industrial minerals in Oregon. A=Documented occurrence. B=Past production. C=Present production.*

Mineral	A	B	C
Abrasives			
Alumina	X		
Emery	X		X
Garnet	X		
Silica	X	X	X
Slag	X		X
Aggregates			
Crushed stone	X	X	X
Sand and gravel	X	X	X
Alunite	X		
Asbestos, chrysotile	X	X	
Barite	X		
Bauxite, ferruginous	X		
Borates	X	X	
Building stone			
Basalt	X	X	
Granite	X	X	
Limestone	X	X	
Marble	X	X	
Sandstone	X	X	
Tuff	X	X	
Chlorite	X		X
Chromite	X	X	
Cinders	X	X	X
Clays			
Bentonite	X		X
Fuller's earth	X		
Kaolin	X		
Refractory	X	X	
Structural	X	X	X
Diatomite	X	X	X
Expandable shale	X	X	
Feldspar	X		
Fluorspar	X		
Foundry sand	X	X	
Gemstones			
Agate, jasper	X	X	X
Garnet	X	X	
Jade, nephrite	X	X	
Obsidian	X	X	X
Opal	X	X	X
Rhodonite	X	X	
Sunstone, feldspar	X	X	X
Graphite	X		
Gypsum/anhydrite	X	X	
Iron oxides	X	X	
Lithium minerals	X		
Limestone			
Agricultural	X	X	X
Cement	X	X	X
Sugar refining	X		X
Mica	X		
Nepheline syenite	X		
Olivine	X		
Optical calcite	X		
Peat	X	X	
Perlite	X	X	X
Pumice	X	X	X
Silica			
Cristobalite	X		
Quartzite	X	X	X
Sand	X	X	X
Sulfur	X		
Talc, soapstone	X	X	X
Vermiculite	X		
Wollastonite	X		
Zeolites			
Chabazite	X		
Clinoptilolite	X		X
Erionite	X		
Mordenite	X		
Phillipsite	X		

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 and for ice control on highways. Production 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 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.

Figure 2. Hard-rock quarry operation of Bayview Transit Mix, Inc., near Seaside in Clatsop County, producing crushed rock for road construction. The newly developed operation was honored with the 1988 Outstanding Operator Award of the Oregon Department of Geology and Mineral Industries, Mined Land Reclamation Program.

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-

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.

pany 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 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.

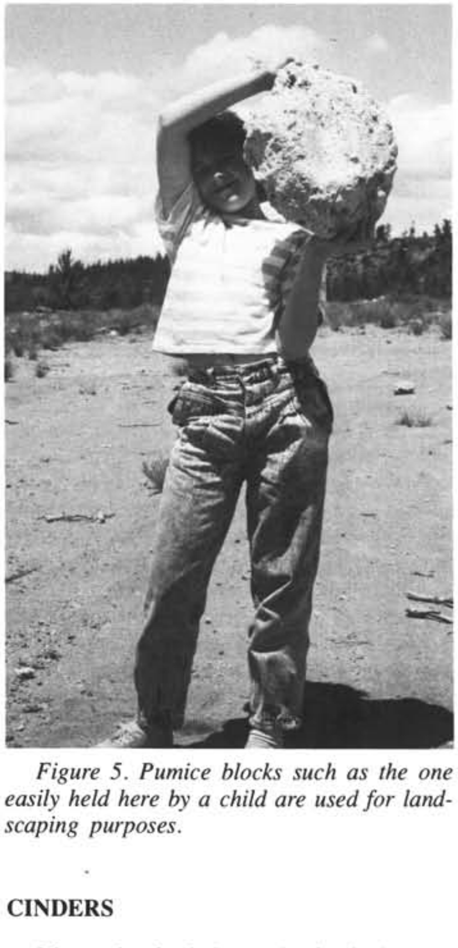

Figure 5. Pumice blocks such as the one easily held here by a child are used for landscaping purposes.

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 sell 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.

SILICA

Silica resources in Oregon include quartzofeldspathic 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 currently 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 quartzofeldspathic 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.

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

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.

Figure 7. Emery outcrop in Douglas County deposit currently held under claim by Oregon Emery Company.

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 Juntura (Figure 8) to its plant near Vale where the diatomite is crushed, dried, flux-calcined, 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).

Figure 8. View of Eagle-Picher diatomite mine (center of photo) in northeastern Harney County.

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.

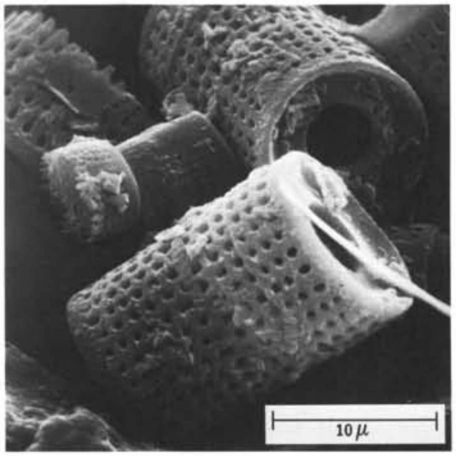

Figure 9. Scanning electron photomicrograph of diatoms. (μ = micron =one-millionth meter. One inch has 25,400 microns.

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.

Figure 11. Talc outcrop in Jackson County deposit mined by Steatite of Southern Oregon.

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 aventurescence 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.

Figure 12. Information marker at public collecting area for sunstones near Rabbit Hills in Lake County.

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

Figure 13. Collectors in the field at sunstone area in Harney County. Area is very similar to the one shown in Figure 12 but is not open to the public.

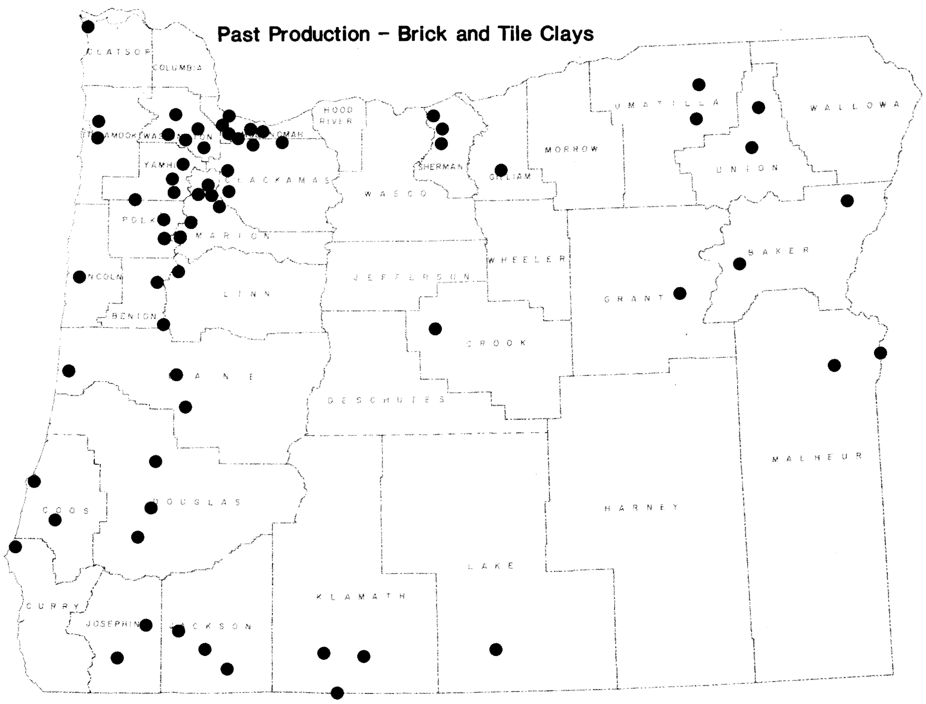

Figure 14. Location map of past production of brick and tile clays in Oregon.

shown in Figure 15. At the turn of the century, many dimension-stone quarries provided structural, decorative, and monumental stone for local and regional markets, including Portland and San Francisco. Rock types included buff to yellow sandstone, gray granites, white and black marbles, and variegated volcanic tuffs. Many quarries closed due to changes in architectural style, changes in construction techniques, and high costs of transportation from what were at that time remote locations. By mid-century, only highly colored and figured volcanic tuffs were being produced for decorative facing stone. The quality of many of the marbles, granites and tuffs is high, and with modern quarry methods and transportation they could again be marketable.

(3) Borates were mined from two locations at the turn of the century. Small pods of priceite in ultramafic rocks were mined in Curry County north of Brookings, and surface efflorescences were processed at Borax Lake in the Alvord Valley of southern Harney County—until more accessible deposits were discovered in California. It is unlikely that the Curry County occurrence could ever be economic, and shallow drilling has been unproductive in Harney County. However, the possibility of borates in the Alvord Valley at depths exploitable by solution mining remains untested.

DOCUMENTED OCCURRENCES

Table 1 also lists documented occurrences of industrial minerals that have not been produced in the state. Many have been documented only by brief, unpublished reports, and their potential is difficult to assess. For example, little information is available about an occurrence of massive garnet on Antelope Peak in Baker County, a wollastonite occurrence on Foster Creek in Douglas County, or nepheline syenite on Table Mountain and other peaks in Lincoln County. Others, such as the ferruginous bauxites in northwestern Oregon and kaolin on Hobart Butte in Lake County, have been studied in detail but are not amenable to processing approaches currently used in the United States.

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.

The Oregon Department of Geology and Mineral Industries has published a total of nine bibliographies of the geology and mineral resources of the state, the latest supplement ex-

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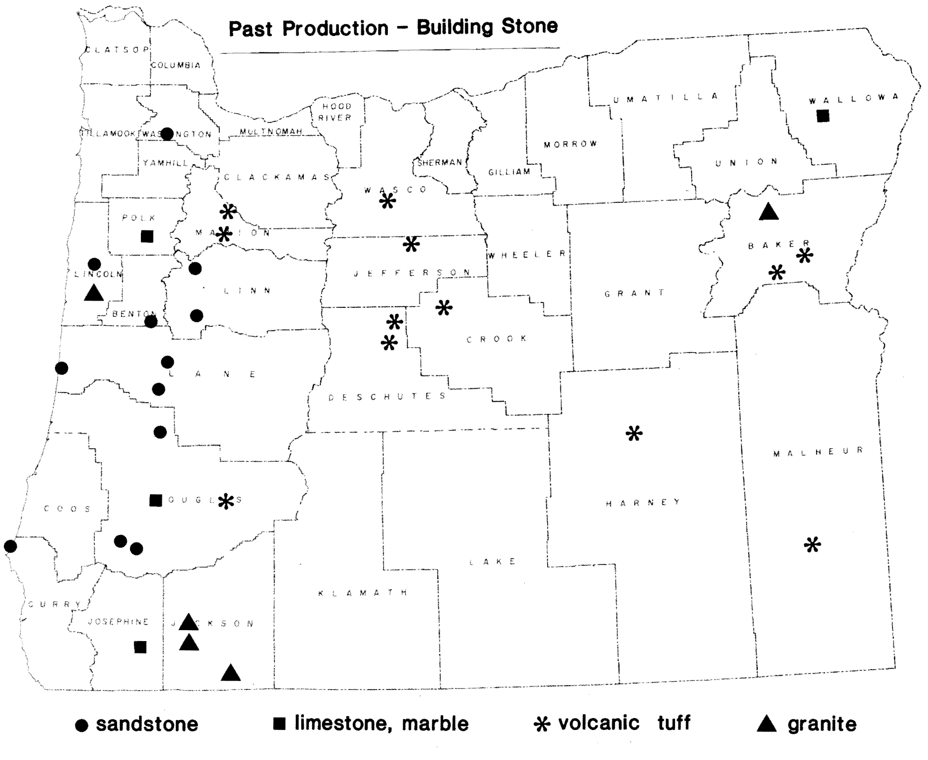

Figure 15. Location map of past production of building stone in Oregon.

Recently excavated mammoth tusk on display in Prineville BLM office

A mammoth tusk found eroding from a stream bank near Mitchell in May 1988 by Merle, 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). Merle, 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 patrolling 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, or *Mammuthus columbi*. The columbian mammoth was large, even for an elephant, attaining a height of up to 13 ft 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 Merle 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.

Sandra Simmons helping in excavating the mammoth tusk she and her family found near Mitchell in 1988.

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 mamagement and protection of fossils of major scientific value. Generally, common invertebrate and plant fossils may be collected by private individuals without a permit. Exceptions can occur when the fossils are of high scientific value. Vertebrate 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.

BLM News, Oregon and Washington

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tending 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.

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

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ABSTRACT

Sieving, 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. These 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.

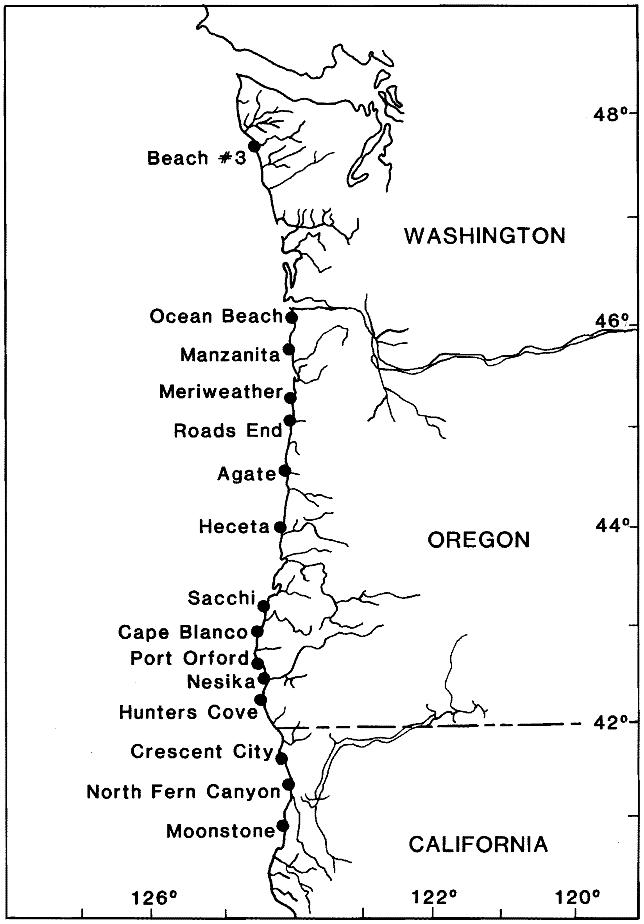

Figure 1. Location of beach sample collection sites on Pacific Northwest beaches.

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 analyzed were chosen 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.

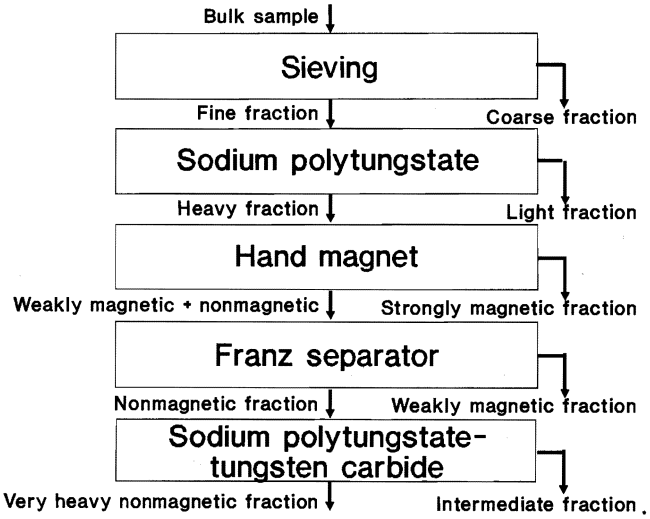

Figure 2. Schematic of bulk beach sample separation procedure.

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 nonisometric minerals and trace amounts of opaque minerals. The VHNM samples were then weighed and heat sealed with a quartz rod into clean 2/27-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. The 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 10^{13} n/cm^2-s in the pneumatic transfer system (for the short irradiations) and 3 x 10^{12} n/cm^2-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, Rb, 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, Zn, Se, Sr, Sb, Cs, Ce, Eu, Tb, Zr, 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.

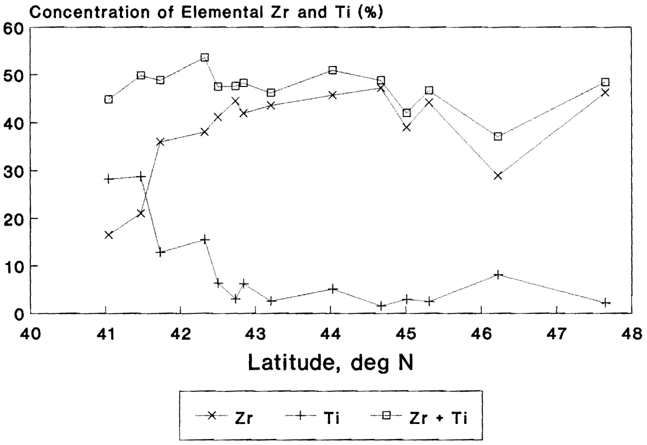

Figure 3. Zirconium and titanium concentrations in the VHNM fraction of beach samples.

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

Table 1. *Elemental composition of the VHNM samples (ppm)*

Sample	Lat.	Ti	Al	Ca	V	Mn	Na	K	Dy	Fe	Co	Rb	Ba	La
Moonstone	41.04	282359	8834	19864	664	0.0069	0.013	<0.90	44	0.8	<5.5	<88	21040	11
North Fern Canyon	41.47	287461	1964	4811	661	0.0018	0.020	<0.01	32	0.4	2.0	<11	1899	6
Crescent City	41.73	128864	7211	7828	175	0.0030	0.041	<0.08	59	0.2	<1.4	<10	<350	<0.1
Hunters Cove	42.32	155472	5568	6825	309	0.0041	0.033	<0.13	55	0.3	4.4	<18	16650	26
Nesika	42.50	63797	4768	7897	112	0.0043	0.071	0.02	71	0.2	4.2	<26	540	<0.2
Port Orford	42.73	30347	2880	2384	66	0.0010	0.009	<0.05	75	0.2	1.5	<7	5598	28
Cape Blanco	42.84	62526	9653	8067	138	0.0035	0.040	<0.12	74	<0.2	<2.0	<9	8536	18
Sacci	43.21	25585	2851	925	65	0.0010	0.012	0.05	75	<0.1	<0.9	<8	<370	25
Heceta	44.03	51573	5762	<500	130	0.0017	0.023	<0.05	96	<0.2	<2.3	<11	<500	29
Agate	44.67	15574	9401	<500	52	0.0012	0.012	<0.05	92	<0.1	<1.5	<8	<390	31
Roads End	45.01	29561	64962	8782	120	0.0041	0.047	<0.17	78	<0.2	<2.1	<16	2828	28
Meriweather	45.31	24615	5273	2007	79	0.0021	0.010	<0.05	80	0.2	<1.0	<9	<420	41
Ocean Beach	46.22	81349	56351	24879	277	0.0064	0.057	<0.17	91	<0.1	<0.3	<35	<410	<0.4
Beach #3	47.65	21774	1973	3678	56	0.0019	0.012	<0.05	74	<0.1	<1.2	<7	1463	27

Sample	Lat.	Sm	Yb	Lu	U	Sc	Cr	Zn	Sb	Cs	Ce	Eu	Tb	Zr	Hf	Th	Se
Moonstone	41.04	13	109	26	138	75	172	<67	<4	<5	800	2	5	165500	3659	82	<37
North Fern Canyon	41.47	10	113	23	121	39	343	<13	1	<1	8	1	4	210700	4673	132	55
Crescent City	41.73	5	1	<0.3	<1	77	153	**	1	<1	50	1	5	359400	7409	149	**
Hunters Cove	42.32	23	219	44	251	73	320	263	3	<2	30	2	8	380300	8385	148	28
Nesika	42.50	<1	<2	<0.3	<4	71	77	<3	<1	<2	148	2	6	411100	8932	364	<3
Port Orford	42.73	26	277	52	338	71	<64	**	1	<1	*	2	6	445300	9307	175	**
Cape Blanco	42.84	23	245	48	297	67	88	302	2	<1	35	2	10	419400	9606	183	43
Sacci	43.21	27	283	53	344	64	<74	**	1	<1	*	1	6	436000	9191	170	**
Heceta	44.03	34	298	57	398	68	93	244	2	2	58	2	12	457100	10410	215	43
Agate	44.67	29	308	58	386	68	<65	**	<1	<1	67	1	7	472200	9805	219	**
Roads End	45.01	30	245	47	306	57	73	192	2	<1	90	3	11	390300	8891	172	<2
Meriweather	45.31	35	328	61	426	64	167	**	1	<1	*	1	7	442400	9199	203	**
Ocean Beach	46.22	<1	<2	<0.3	<4	49	121	<41	4	<2	280	5	13	289800	6652	227	<29
Beach #3	47.65	29	279	55	351	79	<67	**	<1	<1	*	2	5	462800	9978	164	**

* Total concentration was due to ^{235}U fission.
** Concentration could not be determined.
Underlined values are questionable, based on limited concentration of sample.

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, Tb, Dy, Yb, and Lu were detected at trace levels, where the La and Ce concentrations were corrected for the contribution due to ^{235}U fission products (Sm had a negligible contribution from ^{235}U fission). Lanthanum, Sm, Yb, and Lu in the lanthanide group showed a similar concentration trend versus latitude, but the rest of the lanthanides showed no particular trend. Most of the rare earths in the VHNM samples followed the trend of the major element Zr.

Of the other elements in the VHNM samples, Sc and Cr occurred only as trace elements. Chromium concentrations were generally 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 in the parts per billion range in all of the samples. Potassium, Cs, and Rb concentrations were below the detection limit in all or nearly all of the samples. The same was true for Co in most of the VHNM samples. The Nd values were unreliable and were not reported.

DISCUSSION

The results in the previous section indicate that the sample-separation techniques employed specifically to separate the zircon from the bulk samples worked fairly well, although rutile was also present in the VHNM fraction. The zircon plus rutile concentrations (as determined by INAA results) were in the range of about 72 to 100 percent by weight. The degree of separation was further exemplified by the near absence of Fe (< 1 ppm), most of which was removed in the magnetic fraction. As an independent measurement, the VHNM sample from North Fern Canyon was analyzed qualitatively by X-ray diffraction; the result of this investigation clearly indicated the presence of rutile, thereby identifying the mineral form of the Ti observed by INAA.

A previous study by Peterson and Binney (1988) indicated that 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

Table 2. *Weight percent of zircon and rutile in the VHNM and heavy fractions*

	VHNM fraction			Heavy fraction	
Sample	Zircon	Rutile	Sum	Zircon	Rutile
Moonstone	33.3	47.2	80.5	0.01	0.01
North Fern Canyon	42.3	48.0	90.3	0.32	0.36
Crescent City	72.2	21.5	93.7	0.19	0.06
Hunters Cove	76.4	26.0	102.4	0.53	0.18
Nesika	82.6	10.7	93.3	0.13	0.02
Port Orford	89.5	5.1	94.6	6.46	0.37
Cape Blanco	84.3	10.4	94.7	2.27	0.28
Sacci	87.6	4.3	91.9	4.56	0.22
Heceta	91.9	8.6	100.5	0.93	0.09
Agate	94.9	2.6	97.5	7.56	0.21
Roads End	78.5	4.9	83.4	0.34	0.02
Meriweather	88.9	4.1	93.0	4.65	0.22
Ocean Beach	58.2	13.6	71.8	0.33	0.08
Beach #3	93.0	3.6	96.6	0.82	0.03

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 measured 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 for a predominantly binary mineral system.

As indicated earlier, the ratio of Zr to Hf is quite constant over the entire suite of samples, with Hf and Zr having a relatively high correlation coefficient (+0.986). In particular, the eight southernmost beaches, which are within the Klamath Mountain drainage, had a Zr/Hf ratio of 46.1 ± 1.6, while the six northernmost beaches (Coast Range drainages) showed no statistical difference in their Zr/Hf ratios (45.7 ± 2.2). This behavior is to be expected because of the similar chemical nature of Zr and Hf.

Most of the chromite in these beach sands was apparently combined in sand grains along with magnetite and hence was removed in the magnetic separation. Chromium had a moderately strong correlation with Ti (+0.708) in the VHNM samples. Although present only as a trace element, the higher Cr measurements in the four southernmost beaches are consistent with previous measurements (Peterson and Binney, 1988) of higher chromite concentrations in the magnetic fraction of the samples from these same beaches. The trace element V was also strongly correlated (+0.974) to the major element Ti, with its highest concentration in the two southernmost beaches.

Uranium had a relatively strong correlation with Zr (+0.937). Some of the lanthanides followed a similar trend with Zr, e.g., La (+0.820), Sm (+0.748), Yb (+0.737), Lu (+0.964), and Dy (+0.717). Such relatively large correlation coefficients suggest the possibility that these trace elements could be used as tracers for zircon source studies.

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 mineral 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 zircon and rutile served to substantiate the previously known economic importance of the Pacific Northwest beach and continental-shelf sands (Kulm and Peterson, 1989).

ACKNOWLEDGMENTS

Margaret Mumford, OSU College of Oceanography, provided valuable assistance during the sample-separation phase of this study, as well as the XRD analyses. Mike Conrady similarly assisted in the data collection and analysis at the OSU Radiation Center.

Table 3. *Correlation coefficients for elements in the VHNM samples*

	Al	Ca	V	Mn	Na	Dy	Fe	Co	Ba	La	Sm	Yb	Lu	U	Sc	Cr	Zn	Se	Ce	Eu	Tb	Zr	Hf	Th
Ti	-0.1580	0.3697	0.9738	0.2863	-0.0206	-0.8671	0.8163	-0.1016	0.5163	-0.8279	-0.7772	-0.7461	-0.9485	-0.9349	-0.2517	0.7075	0.4168	0.4237	0.4665	-0.0172	-0.3687	-0.9111	-0.9084	-0.5238
Al		0.5695	-0.0242	0.5176	0.4934	0.3164	0.4834	0.9237	-0.1454	0.1152	0.1878	0.0375	-0.0147	-0.9325	-0.4412	-0.3997	-0.8156	-0.4102	0.0792	0.7661	0.6802	-0.1753	-0.0975	0.0699
Ca			0.4690	0.8723	0.4374	0.0422	0.8782	0.9312	0.6987	-0.5247	-0.4752	-0.5445	-0.6421	0.0040	-0.1776	-0.2630	-0.5105	-0.5610	0.7285	0.8157	0.4994	-0.6513	-0.5902	-0.0314
V				0.3362	-0.0395	-0.7849	0.8537	-0.1834	0.4973	-0.8266	-0.6727	-0.6382	-0.9555	-0.6477	-0.3794	0.6553	0.2652	0.5127	0.5440	0.1213	-0.2513	-0.9497	-0.9326	-0.5190
Mn					0.5305	-0.1471	0.5985	0.9972	0.6899	-0.2803	-0.3396	-0.4120	-0.4618	-0.4904	0.0041	-0.2142	-0.1701	-0.8291	0.6813	0.7096	0.2567	-0.5376	-0.4966	-0.0367
Na						0.0748	-0.2975	0.7724	-0.3117	-0.1737	-0.2904	-0.4135	-0.1663	-0.1936	-0.1534	-0.4631	-0.2378	-0.5013	-0.1871	0.5063	0.4052	-0.1178	-0.0400	0.5829
Dy							-0.6830	0.1347	-0.3985	0.7987	0.8254	0.7654	0.9233	0.9388	0.1090	-0.7361	-0.2739	-0.2718	-0.2354	0.2798	0.6570	0.7166	0.7479	0.5373
Fe								-0.1579	0.7043	-0.7350	-0.4056	-0.3724	-0.7922	-0.7848	-0.0096	0.1667	0.0000	1.0000	0.8917	0.5312	-0.3976	-0.8884	-0.8803	-0.5883
Co									0.3999	0.2757	0.1833	0.0054	0.0912	-0.0480	0.4866	-0.5025	0.0000	-1.0000	0.5606	0.4591	0.6582	0.2383	0.3191	0.4765
Ba										-0.2115	-0.3694	-0.4264	-0.3559	-0.4211	0.3749	0.2632	0.5562	-1.0000	0.6492	0.2584	0.0299	-0.4783	-0.4705	-0.5666
La											0.9375	0.9210	0.9131	0.9159	0.3746	-0.3892	-0.8021	-0.7592	-0.3961	-0.1230	0.3627	0.8205	0.7771	0.7505
Sm												0.9625	0.9519	0.9644	0.0786	-0.4242	-0.6377	-0.4838	-0.2520	0.1845	0.5813	0.7484	0.7762	0.7424
Yb													0.9956	0.9923	0.0223	-0.3096	-0.1456	-0.4933	-0.2768	0.0735	0.4578	0.7374	0.7519	0.7308
Lu														0.9915	0.4253	-0.5543	-0.0638	-0.5339	-0.4926	-0.1859	0.4106	0.9636	0.9372	0.8697
U															0.3612	-0.5814	-0.2062	-0.3968	-0.4752	-0.2043	0.4265	0.9365	0.9103	0.8897
Sc																-0.2774	0.7100	-0.8652	0.2155	-0.2417	-0.2664	0.4057	0.3615	-0.0059
Cr																	0.2348	-0.0110	-0.1057	-0.3631	-0.5185	-0.4701	-0.5033	-0.5112
Zn																		0.1953	-0.9087	-0.8493	-0.4108	0.2032	0.1742	-0.0014
Se																			-0.3758	-0.7688	-0.4104	-0.5754	-0.5334	-0.1037
Ce																				0.3743	-0.1632	-0.6503	-0.6441	-0.3123
Eu																					0.6734	-0.2885	-0.1923	0.1266
Tb																						0.1830	0.3071	0.2616
Zr																							0.9861	0.4622
Hf																								0.4802

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Phillips, W.R., and Griffen, D., 1981, Optical mineralogy of the nonopaque minerals: San Francisco, W.H. Freeman and Company, p. 677. ☐

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.

—I.A.E.G. news release

REMEMBER TO RENEW

If the code number on your address label ends in "1289," that means your subscription expires with the last issue of 1989. Please use the renewal form on the last page to make sure you will continue receiving *Oregon Geology*. And while you are at it—why not consider a gift subscription for a friend? ☐

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 Milwaukie 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** (silica, 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 chromite for fluxing, bentonite for pelletizing, and, perhaps, chromite 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 thay are in our homes.

Upon entering, we are often enclosed by **wallboard** or **sheetrock** (gypsum with fire retardant additives, such as clays, perlite, ver-

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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 clarification (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 swimming pools.

When we arrive home, we are not yet through with our exposure to our mineral friends. If we have to take **medicine** or **pharmaceuticals**, we may chew antacid pills essentially made of calcium carbonate. For **upset stomachs**, there are Milk of Magnesia (magnesia/dolomite) or Kaopectate (kaolin) and others made from clays such as attapulgite. And, who can forget the lovely **barium "cocktail"** (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 emphasize how much our lives would be altered without ready and economical 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 entry 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. ☐

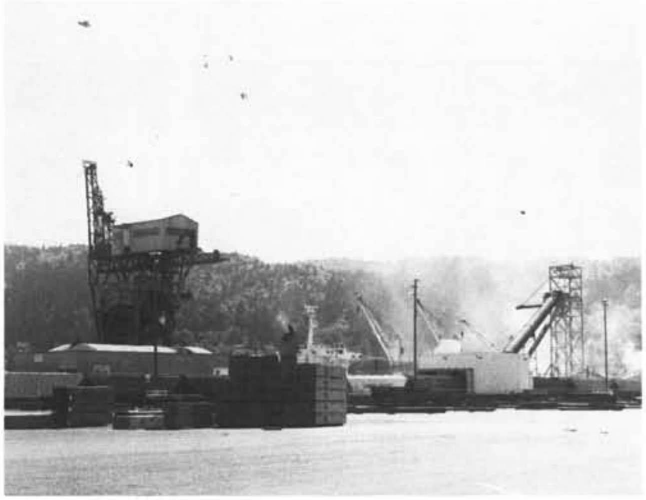
Industrial Minerals Forum meets in Portland

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.

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.

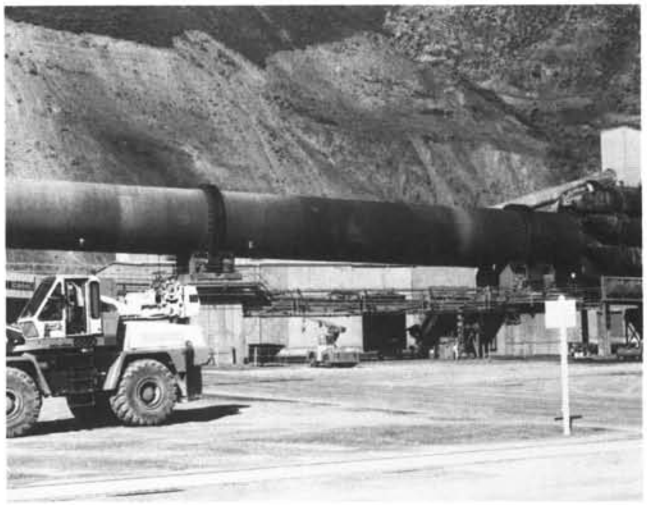


Hall-Buck Marine, Inc., bulk mineral loading facility at the Port of Portland Terminal 4. Soda ash from Wyoming is being transferred from unit train to freighter.

The 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 laborabory 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.



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.

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.

zeolite is used for odor control products and for heavy metal and radionuclide absorption.

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. ☐

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

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.	T. 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

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 Longfellow.

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 Sanne 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.

THE GEOLOGY OF THE EAST-CENTRAL DESOLATION BUTTE QUADRANGLE, GRANT COUNTY, OREGON,

by Neil Elfrink (M.S., Oregon State University, 1988 [compl. 1987]), 123 p.

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. Titanaugite 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 meatamorphism 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 exposed farther to the west.

EXPLOSION STRUCTURES IN GRANDE RONDE BASALT OF THE COLUMBIA RIVER BASALT GROUP NEAR TROY, OREGON,

by Leonard L. Orzol (M.S., Portland State University, 1987), 220 p.

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 units occupy 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. Jointing 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 intersertal 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.

AN ANALYSIS OF THE EASTERN MARGIN OF THE PORTLAND BASIN USING GRAVITY SURVEYS,

by Steven A. Davis (M.S., Portland State University, 1988), 135 p.

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 mgals, 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 km^2.

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.

GEOLOGY AND REVISED STRATIGRAPHIC INTERPRETATION OF THE MIOCENE SUCKER CREEK FORMATION, MALHEUR COUNTY, OREGON, by David C. Lawrence (M.S., Boise State University, 1988), 54 p.

Miocene volcanic and sedimentary rocks originally mapped as Sucker Creek Formation near Adrian, Oregon, and Succor 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 Succor Creek. Starting with the basal unit, the section consists of 198 m of bentonitic 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 tuffs containing minor basalt flows, dikes and sills, overlain by a rhyolite 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 type section, described by Kittleman and others (1965) about 9 km south of this study area. That type section is 178 m of mostly volcaniclastic sandstone.

The differences in stratigraphic sections indicate that, in this report and the section described by Kittleman and others, beds and no one type section can be considered typical. Similar rocks occur at depths of 2,865-3,828 m beneath the Snake River Plain near Meridian, Idaho, in the J.N. James well, in a section containing about 950 m of claystone.

Preliminary synthesis of detailed sections of the formation mostly indicates that the Sucker Creek Formation indicates bimodal volcanic rocks, and sedimentary-facies rocks. Volcanic ash layers in the lacustrine claystones are the best marker beds for regional correlation, and their recognition may provide a basis for understanding the basin evolution.

GEOLOGY, GEOCHEMISTRY, AND MINERALIZATION OF THE YELLOWBOTTOM-BOULDER CREEK AREA, LINN COUNTY, OREGON, by David K. Nicholson (M.S., Oregon State University, 1989 [completed 1988]), 186 p.

The Yellowbottom-Boulder Creek area is immediately west of the Quartzville mining district in the Western Cascades of Oregon. Volcanic rocks comprise a series of basaltic to rhyodacitic flows and volcaniclastic deposits that are believed to correlate with the Sardine Formation (mid-Miocene). These volcanic rocks dip to the southeast (5° to 25°), presumably into the hinge zone of the Sardine syncline located immediately to the east.

Intrusive rocks consist of small stocks of intermediate composition (quartz diorite, quartz monzodiorite, quartz monzonite, granodiorite, and tonalite), and dikes and plugs of basaltic to rhyolitic composition. The largest intrusion is a quartz monzodiorite stock that covers approximately 1 km^2, for which the name Yellowbottom Stock is proposed here.

Pliocene flows of diktytaxitic basalt and porphyritic andesite of High Cascade origin are preserved on the crests of Galena Ridge and Packers Divide. A Quaternary flow of trachybasalt partly fills the valley of Canal Creek and is associated with two cinder cones: They presumably represent the last pulse of volcanic activity in the Quartzville area.

Major-oxide concentrations in the volcanic and plutonic rocks display systematic trends (decreasing Al_2O_3, TiO_2, FeO_T, MgO, CaO, and P_2O_3, and increasing BaO and K_2O, with increasing SiO_2 content) on Harker variation diagrams. These trends may suggest differentiation from a single batch of magma. The chemistry of plutonic rocks from the study areas, and from the Western Cascades in general (calc-alkaline, low K_2O content), is similar to that of some island-arc terranes, including the Southern California batholith, Caribbean, southwestern Pacific, and Pacific Northwest areas, and largely suggests that the magma was derived from the mantle with little if any crustal contamination.

Hydrothermal alteration has affected all rocks of Miocene age. Propylitic alteration is widespread in areal extent and is thought to have been produced by the interaction of magmatic fluids with the host rocks. In contrast, argillic-phyllic alteration is structurally controlled, and may have resulted from hydrolysis reactions between the hosts and meteoric waters that invaded the structures subsequent to propylization. Zones of brecciated and silicified rock range from linear to cylindrical in shape and are commonly mineralized.

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° to 260 °C) obtained from sulfur-isotope 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. □

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Beverly F. Vogt, Publications Manager

Index to *OREGON GEOLOGY*, volume 51, 1989

Numbers refer to volume and beginning page of entry. Most subject entries include cross-references to author entries (in parentheses).

Abstracts of theses 3:68, 4:94, 5:118, 6:140
Agnew, A.F., Review: Clark, The odyssey of T. Condon 5:113
Allen, J.E., Ice-age glaciers south of Columbia River Gorge 1:12
Anaconda geologic records at University of Wyoming 6:134
Ashwill, M.S., Collecting fossils in Oregon 4:81
Azim, B., coauthor, Binney and Azim 6:130
Baldwin, E.M., Eocene unconformities, Camas Valley Quad. 1:3
Barker, R.M., Collecting rocks 1:15
Binney, S.E., and Azim, B., Very heavy nonmagnetic fraction
of Pacific Northwest beach sands 6:130
Bishop, E.M., Smith Rock and the Gray Butte complex 4:75
Black, G.L., coauthor, Priest and Black 5:99
Bodvarsson, Gunnar, Prof. Emer., OSU, died in May 4:93
Building material decomposition by microbes (Neuendorf) 1:14
Camas Valley Quadrangle, Eocene stratigraphy (Baldwin) 1:3
Cascades ....3:60 (Sherrod), 5:118 (Clingman), 6:141 (Nicholson)
———Mount Hood area glaciation (Allen) 1:12
———Western, glaciation (Sherrod and Pickthorn) 3:60
Clingman, W.W., Lookout Mtn., centr. Cascades (thesis abs.) ... 5:118
Collecting crystals and minerals (Lawson review) 3:70
Collecting fossils in Oregon (Ashwill) 4:81
Collecting Thundereggs in Oregon (Lawson) 4:87
Columbia River Basalt Group, Explosion structures (Orzol) 6:140
Concrete, production and uses (Dupras) 2:37, 3:51
Cyanide in mining (Throop) 1:9
Darden, C.F., Geophysical exploration for petroleum 3:61
Davis, S.A., Portland basin gravity study (thesis abs.) 6:140
Douglas County, Camas Valley Quadrangle (Baldwin) 1:3
Dupras D., The grandeur of concrete: 2:37, 3:51
Earthquakes, 15 most significant in U.S. history 4:91
———hazard assessment (Yeats) 4:90
———hazard evaluation (Madin) 5:106
———severity of (USGS pamphlet reprint) 1:17
Elfrink, N., Desolation Butte Quad., Grant County (thesis abs.) 6:140
Eocene stratigraphy, Camas Valley Quadrangle (Baldwin) 1:3
Evans, C.S., Red Butte, Malheur County, alteration (thesis abs.) 5:118
Ferns, M.L., Mining activity and exploration in Oregon, 1988 .. 2:27
Field trip guides, available from AGU 3:65
Fossil collecting (Ashwill) 4:81
Geitgey, R.P., Industrial Minerals Forum meets in Portland 6:137
———Industrial minerals in Oregon 6:123
Geophysical exploration for oil and gas (Darden) 3:61
Geothermal exploration in Oregon, 1988 (Priest and Black) 5:99
Glass Buttes complex evolution (Roche) 3:68
Gold mining and metallurgy (Throop) 1:9
Gold panning in BLM Roseburg district 6:136
Grant County, Desolation Butte Quadrangle (Elfrink) 6:140
Gray Butte/Smith Rock area volcanic rocks (Obermiller) 4:94
Gray Butte complex (Bishop) 4:75
Hazards, Assessment of earthquake hazard (Yeats) 4:90
———severity of earthquakes 1:17
———earthquakes in Portland area (Madin) 5:106
Ice-age glaciers and lakes, Mount Hood area (Allen) 1:12
Industrial minerals ..6:123 (Geitgey), 6:135 (McVey), 6:137 (Geitgey)
Kraus, D.J., coauthor, Pugh and others 5:111
Lake County, Glass Buttes complex evolution (Roche) 3:68
Lawrence, D.C., Sucker Creek Formation (thesis abs.) 6:141
Lawson, P.F., Additional sources of information on Thundereggs 5:117
———Book review: Gladwell, Crystals and minerals 3:70
———Thunderegg collecting in Oregon 4:87
Linn County (Nicholson) 6:141
Lookout Mountain, Cascades (Clingman) 5:118
Madin, I.P., Evaluating earthquake hazards in Portland 5:106
Malheur County, Red Butte (Evans) 5:118
———Sucker Creek Formation (Lawrence) 6:141
McVey, H., Industrial minerals: Can we live without them? ... 6:135
Meteorites and fireballs (Pugh and others) 5:111
Mined land reclamation, Mining operators honored 3:66
Mineral exploration activity, metal mining 4:92, 5:115, 6:139
Mineral industry .... 2:27 (Ferns), 4:93
Mining activity and exploration in Oregon, 1988 (Ferns) 2:27
Mist Gas Field, first gas storage site in Oregon 5:112
Mount Hood area, Pleistocene glaciers (Allen) 1:12
Nazy, D.J., Tualatin Valley, seismic refraction (thesis abs.) 5:118
Neuendorf, K., Rock eaters at work 1:14
Nicholson, D.K., Yellow Bottom/Boulder Cr. area (thesis abs.) .. 6:141
Nickel facility in Riddle starts production 4:93
Obermiller, W.A., Smith Rock/Gray Butte area (thesis abs.) 4:94
Oil and gas .... 1:3 (Baldwin), 3:61 (Darden), 3:69 (Wermiel), 5:112
Oil and gas exploration and development in Oregon, 1988 ...... 2:33
Oil and gas news 1:2, 2:26, 3:67, 4:74, 5:117, 6:122
Olmstead, D.L., and Wermiel, D.E., Oil and gas exploration
and development in Oregon, 1988 .... 2:33
Orzol, L.L., Explosion structures near Troy (thesis abs.) 6:140
Paleontology .... 4:81 (Ashwill), 5:113 (Agnew)
Pickthorn, L.B., coauthor, Sherrod and Pickthorn 3:60
Portland basin, Gravity study (Davis) 6:140
Priest, G.R., and Black, G.L., Geothermal exploration, 1988 .... 5:99
Publications by DOGAMI announced
  GMS-48, McKenzie Bridge Quadrangle, Cascades 1:18
  GMS-53, Owyhee Ridge Quadrangle, Malheur County 1:19
  GMS-54, Graveyard Point Quadrangle, Malheur County 2:45
  GMS-55, Owyhee Dam Quadrangle, Malheur County 5:116
  GMS-59, Lake Oswego Quadrangle, Portland area 5:116
  O-88-05, Breitenbush area geology 1:18
  O-88-06, Description of some Oregon rocks and minerals ... 1:18
  O-89-01, SMAC report for 1988 .... 2:45
  O-89-02, Mist Gas Field map, 1989 update 2:45
  O-89-04, Gorda Ridge sediments, 1988 *Sea Cliff* dives 3:65
  O-89-05, Gorda Ridge vent communities 3:65
  O-89-06, Gorda Ridge biology, *Sea Cliff* dives 3:65
  O-89-07, Gorda Ridge hydrothermal effluents 3:65
  O-89-08, Gorda Ridge, Sea Cliff Hydrothermal Field 3:65
  O-89-09, Gorda Ridge minerals, *Sea Cliff* dives 5:116
  O-89-10, Bibliography, oil and gas exploration, 1896-1989 .. 5:116
  O-89-11, Gorda Ridge, SESCA samples, *Sea Cliff* dives 5:116
  OGI-15, Hydrocarbon exploration and occurrences in Oregon 5:116
  Special Paper 20, Bentonite in Oregon 4:80
Publications by others announced and reviewed
  Assoc. of Amer. State Geologists, History of State Surveys .. 3:70
  Clark, R.D., The odyssey of Thomas Condon (Agnew) 5:113
  Gladwell, J., Crystals and minerals (Lawson) 3:70
  Harris, S.L., Fire mountains of the West 2:46
  International Geologic Congress, 1989 field trip guides 3:65
  Moores, E.M., The art of geology 2:44
  Northwest correlation chart, COSUNA project 2:44
  U.S. Bureau of Mines, State mineral summaries 1989 .... 3:70
Pugh, R.N., and others, The great Grant County fireball,
1987 .... 5:111
Quartzville area, Linn County (Nicholson) 6:141
Reclamation of exploratory drill sites (Wermiel) 3:69
Red Butte, Malheur County, geochemistry and alteration (Evans) 5:118
Roche, R.L., Glass Buttes complex evolution (thesis abs.) 3:68
Rock collecting (Barker) 1:15
Sand, Pacific Northwest beaches (Binney and Azim) 6:130
Schmeer, B.A., coauthor, Pugh and others 5:111
Sherrod, D.R., and Pickthorn, L.B., A note on the origin of
Bull Run and Lost Lakes, Western Cascades, Oregon 3:60
Smith Rock and the Gray Butte complex (Bishop) 4:75
———Volcanic rocks (Obermiller) 4:94
Sucker Creek Formation (Lawrence) 6:141
Throop, A.H., Cyanide in mining 1:9
Thundereggs, collecting in Oregon (Lawson) 4:87, 5:117
Titanium in beach sands (Binney and Azim) 6:130
Tualatin Valley, geologic structure (Nazy) 5:118
Wallowa County, Troy area (Orzol) 6:140
Wermiel, D.E., coauthor, Olmstead and Wermiel 2:33
———Reclamation of exploratory drill sites in Oregon 3:69
Yeats, R.S., Current assessment of earthquake hazard in Oregon . 4:90
Zirconium in beach sands (Binney and Azim) 6:130

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