The ORE BIN
Volume 27, No. 1
January, 1965

OREGON'S MINERAL INDUSTRY IN 1964

By Ralph S. Mason*

Oregon mines and metallurgical plants continued to pump large quantities of primary wealth into the state's economy in 1964. Indications are that the value produced during the past year will probably equal that of the record-shattering total turned in for 1963. Soaring metal prices on world markets, particularly for mercury, saw the reopening of six cinnabar mines and activity at several antimony properties which have been idle for many years. Production of aggregate, which accounts for approximately two-thirds of the total value of all minerals produced in the state, was close to that of last year, in spite of a lessened demand by large federal construction projects. The disastrous Christmas-week floods across the state temporarily paralyzed nearly all of the sand and gravel producers, who suffered high losses to stocks and equipment. The need for aggregate and stone of all types for the coming year will probably set new records as the state rebuilds its highways, jetties, dikes, plants, homes, and bridges. Offshore oil and gas leases for federal and state lands lying off the Oregon coast were granted to major oil companies last fall. The action marks an important milestone in the state's long search for petroleum.

Metals

Mercury

A continuing imbalance in the international mercury supply and demand forced prices up to all-time highs in 1964. As a direct result, interest in several Oregon mercury properties developed and at year's end activity was reported at six mines. The Black Butte mine in southern Lane County, idle

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Some of Oregon's Minerals at a Glance
Preliminary Figures for 1964
(in thousands of dollars)

	1963	1964
Clays	$ 330	$ 275
Gold	63	22
Lime	1,835	2,115
Sand and Gravel	18,850	17,500
Stone	24,197	24,000
Misc.*	17,417	17,191
Estimated total	$62,692	$61,103

* Copper, diatomite, lead, mercury, nickel, pumice & volcanic cinder, silver, zinc, cement, iron ore.

for several years, was reactivated by the American Mercury Corp. early in December, with production scheduled for January. The Black Butte has had a history of intermittent production stretching back to 1890. The mine has produced 16,000 flasks of metal. Another important mercury producer, the Bretz mine in Malheur County, was reportedly being reopened late in the year. Production from the Bretz since it was discovered in 1917 has totalled about 14,000 flasks. The property has been idle recently.

At the Canyon Creek mercury prospect near Canyon City in Grant County, Lawrence Roba and Banday Sintay produced a small amount of quicksilver from development ore during the year. The property was scheduled for stepped-up exploration by a major mercury producer early in 1965. The War Eagle mine west of Shady Cove in northern Jackson County was leased by Dave Chase, who conducted an exploration and development program. The Red Cloud mine in the upper Cow Creek area of Douglas County was leased by W.F.Sexton of Grants Pass. Plans for stripping, concentrating, and retorting the ore to start about April 1 were announced.

Activity was also reported at the Bonita mine in the Meadows district of Jackson County and at the Palmer Creek prospect in the Upper Applegate district of the same county. A federal Office of Minerals Exploration contract with Pacific Minerals & Chemical Co. for exploration at the Mother Lode, Cobar, and Lookout Mountain groups in Crook County is in recess until June 1965. Total estimated cost of the cooperative project is $63,000.

Gold and silver

Production of gold from placer and hard rock operations declined appreciably from 1963 levels as did the recovery of silver, principally from underground operations. Active during the year were 18 seasonal placer mines and 10 hard-rock mines.

The Buffalo mine in eastern Grant County produced from the lower level driven several years ago. The ore was treated in a flotation mill at the mine. Additional mill capacity was installed during the year. The mine is located in snow country and is virtually isolated during the winter months, but despite this handicap operations continue throughout the year.

At the Oregon King mine in the Ashwood district of Jefferson County, gold and silver were produced from development ore. Shipments to the smelter included both lump ore and flotation concentrates. Exploration was conducted under an O.M.E. loan with a total estimated cost of $55,150. Oregon King entered into an operating agreement with Ag. Boaz Inc. of Seattle, Washington. The new operators have installed additional mining equipment and have announced plans to drift east and west on the 400-foot level and to explore the side walls with long-hole drilling. Arthur J. Theis is president of Boaz and James P. Jackson, Jr. general superintendent.

Copper

Production of copper in Oregon came from two main sources, the Standard mine near Prairie City in Grant County and the Oregon King mine in Jefferson County. At the Standard, Jim Kinsella single-handedly mined, sorted, and shipped 60 tons of ore. Kinsella also saws wood and performs other work as time permits, which is pretty good for a man somewhat past 70 years of age. A small amount of by-product copper came from the Oregon King silver mine.

Nickel

The only nickel mine and smelter in the United States continued to produce at Riddle in Douglas County, where Hanna Mining Co. mined and its subsidiary, Hanna Nickel Smelting, refined slightly greater tonnages than in the previous year. With the installation of a natural gas line through the area, Hanna changed to the use of natural gas in its calciners and in the newly installed multiple-hearth roasters. The additional equipment will permit more efficient plant operation and will increase productive capacity. The Hanna operation has been in continuous production since July 1954, when the first garnierite ore was trammed down Nickel Mountain and smelted into pigs of ferro-nickel.

Antimony

Rising prices and increased demand for antimony encouraged activity at three Oregon mines. The Jay Bird mine in southern Jackson County was reopened by W.H. Holloway, who produced a small tonnage of development ore. The Coyote mine near Brogan, Malheur County, was scheduled for some exploration work by George Wicklander of Pendleton after the first of the year. A.W. Brandenthaler of Baker reopened the Gray Eagle mine near Baker with a small crew. Both the Jay Bird and the Gray Eagle produced during World War II, when antimony was in critically short supply.

Exploration projects

The Bunker Hill Co. of Kellogg, Idaho, explored the black sands at the mouth of the Columbia River early in the year to determine whether iron ore of commercial size and grade could be mined and beneficiated. The company terminated its leases in May after considerable drilling and sampling revealed insufficient ore for its purposes. In the Bohemia district, Federal Resources Corp. of Salt Lake City leased a group of mining properties and inaugurated an exploration program of diamond drilling and tunnelling to develop reserves of the complex gold, silver, copper, lead, and zinc ore exposed in numerous shallow workings. In the Blue River district of Lane County, minor work was done at the Lucky Boy mine by a California mining group. A lead-zinc property in Linn County was drilled by an Idaho mining company.

Industrial Minerals

Lightweight aggregates and pozzolan

Production of natural lightweight aggregates in the state was concentrated, as it has been for many years, in the Bend area of central Oregon. Two operators, Boise-Cascade Pumice Co. and Central Oregon Pumice Co., quarried and processed volcanic cinders and pumice. The carefully blended aggregates are extensively used in concrete block manufacture and for a variety of loose-fill applications. A new industry for the state commenced operations near Shutler in Gilliam County, when Permanente Cement Co. began processing volcanic ash for use as a pozzolan in large, monolithic concrete dam construction. The bulk of the plant's production was being used in the John Day dam on the Columbia River and the Green Peter dam on Quartzville Creek in Linn County. When used to replace a part of the portland cement in concrete mixes, pozzolans reduce costs, decrease heat of hydration during the curing stage, and increase workability and resistance to aggressive waters.

Artificial lightweight aggregates were made from expansible shale calcined at two plants in northwestern Oregon. Empire Building Materials quarried and furnaced a deposit of Keasey shale at Sunset Tunnel in Washington County. Empire began construction of a pozzolan processing mill at the plant site late in the year, with completion scheduled for May 1965. Finely ground, expanded shale has been used locally as a pozzolan for several years. Originally pozzolan was only substituted for a part of the cement in concrete mixes when large, monolithic masses of concrete were placed. The recent development of pumping techniques for placing smaller quantities of pre-mixed concrete has increased the demand for pozzolans, because they impart a greater workability to the mix. Thin-shell concrete forms, roof decks, and concretes for acid plants also use pozzolan in their mixes. Empire fabricated all of the concrete piling, caps, and beams for the Astoria bridge across the mouth of the Columbia River. The piles were four feet in diameter and from 90 to 112 feet in length. Although of hollow construction, they were jetted and then driven into place with a pile driver. Empire developed a novel technique of slip-forming the upper half of the piling, which was cast in a horizontal position. One of the most claustrophobic jobs in the state was held by the workman at the plant who had to crawl into each finished piling and remove the metal core. The 70,000- to 80,000-pound piles were trucked and barged from Portland to the bridge site.

A few miles south of Vernonia, Cloverleaf Mines, Inc., operated the old Smithwick expansible shale quarry and kiln under a lease-purchase agreement with the Vernonia Industrial Development Corp., a community development group which is seeking to firm up the area's economy by encouraging year-around mineral production.

Pacific Diatomite Corp. increased production of diatomite from its property near Silver Lake in Lake County, and trucked the raw material to Eugene for processing and packaging. Principal uses of the product are for kitten litter and for lining portable barbecues. The company also sold perlite from its quarry near Paisley in Lake County, and announced plans for erecting a plant at Eugene for the manufacture of sponge rock and insulation fill. At Riddle the Mining-Minerals Manufacturing Co. dried and screened material from the nearby Hanna Nickel Smelting Co. slag pile and marketed it as an abrasive for sandblasting. Most of their product was being used in shipyards in the San Francisco Bay area. Minor quantities of the slag were also used by the State Highway Department for sanding ice-covered roads. Test shipments of perlite from a property on Dooley Mountain in southern Baker County were made by Del Harmon to Supreme Perlite Co. in Portland.

The Department of Geology conducted expansibility tests on pumice samples from Deschutes County in central Oregon. The results indicated that some pumice has a capacity to develop a cellularity over and above that with which it was endowed by nature. Volume increase was greatest for fresh, commercial-grade pumice, with expansion ranging from 90 to 110 percent. A report on the project appeared in the April, 1964 ORE BIN.

A similar departmental project conducted during the year involved testing the expansibility of the volcanic ash near Arlington. It was found that volume increases of the order of 120 to 140 percent were possible when the ash was heated in a muffle furnace.

An occurrence of vermiculitized biotite near North Powder in northern Baker County was sampled and tested by the department. Although the vermiculite expanded sufficiently to make it economically interesting, the mineral was too thinly disseminated through a batholithic intrusive. Commercial crude vermiculite is currently imported into the state from Montana for expansion in Portland. A report on the department's study of the Baker County occurrence appeared in the October 1964 ORE BIN.

Silica

Bristol Silica Co. was the principal producer of metallurgical andother grades of quartz in the state. The plant, which was moved to its present location west of Gold Hill in Jackson County a year or so ago, suffered extensive damage to stockpiles and equipment during the Christmas flooding of the Rogue River. Small tonnages of silica were mined at Quartz Mountain east of Roseburg in Douglas County. Oregon dune sands were the subject of a study made by the U.S. Bureau of Mines at Albany. Tests indicated that the sands could be beneficiated sufficiently to make them suitable for clear container and amber grades of glass. Test results were published in the Bureau's Report of Investigations No. 6484.

Bentonite

Central Oregon Bentonite Co. produced crude bentonite from deposits on Camp Creek in eastern Crook County. The bentonite was sold for use in sealing stock ponds and irrigation ditches, in well-drilling muds, as a stock-feed binder, and as a carrier for insecticides in crop dusts.

Limestone

High-grade limestone was quarried at widely scattered points in the state. Chemical Lime Co. operated a quarry high up in the Elkhorns of Baker County and calcined the stone at its kilns near Baker. Oregon Portland Cement Co. quarried limestone near its kilns at Lime in Baker County and at a quarry near Dallas in Polk County. Ideal Cement Co. produced rock from Marble Mountain south of Wilderville in Josephine County. Harmony Limestone, Inc., a newcomer to the state, erected a mill in Illinois Valley, Josephine County, and opened up a quarry on a marble deposit near

ACTIVE MINES IN OREGON, 1964

Gold Placer

Mine	County
DeJanvier	Jackson
Cowie	Jackson
Sunset	Josephine
Joe Joe	Josephine
Leland	Josephine
Speaker	Josephine
Wolf Creek	Josephine
Bear	Josephine
Gold Nugget	Josephine
Aphir	Josephine
Brown	Josephine
Gold Bar	Josephine
Leopold	Josephine
Maloney	Josephine
Upper Hogum	Douglas
Tennessee Gulch	Douglas
Suksdorf and Anderson	Malheur
Winterville	Baker

Gold Load

Mine	County
Oregon King	Jefferson
Buffalo	Grant
Dark Canyon	Josephine
Snow Bird	Josephine
Greenback	Josephine
Fleming	Jackson
Little Arctic	Jackson
Warner	Jackson
Ashland	Jackson
Lucky Bart	Jackson

Nickel

Mine	County
Hanna Nickel Co.	Douglas

Antimony

Mine	County
Jay Bird Mine	Jackson
Gray Eagle Mine	Baker
Coyote Mine	Malheur

Copper

Mine	County
Standard	Grant
Oregon King	Jefferson

Mercury

Mine	County
Bonita	Jackson
Palmer Creek	Jackson
War Eagle	Jackson
Canyon Creek	Grant
Bretz	Malheur
Black Butte	Lane

Limestone and Lime

Mine	County
Chemical Lime Co.	Baker
Ideal Cement Co.	Josephine
Oregon Portland Cement Co.	Baker, Polk
Harmony Limestone, Inc.	Josephine

Silica

Mine	County
Big Quartz	Douglas
Bristol Silica Co.	Jackson

Bentonite

Mine	County
Central Oregon Bentonite	Crook

Building Stone

Mine	County
Moon Mesa	Baker
Rainbow Rock	Wasco
Willowdale	Jefferson
Red Rock	Deschutes
Cinder Hill	Deschutes
Kahneeta Stone	Wasco

Lightweight Aggregates, Pozzolan

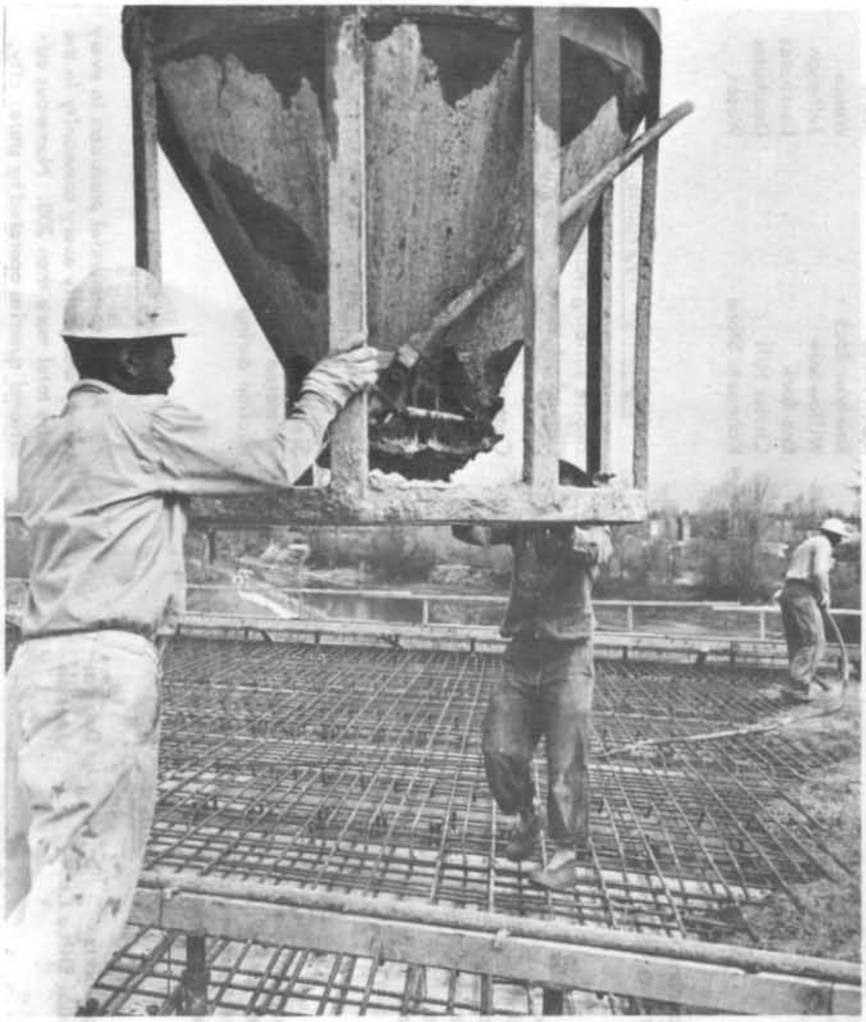
Mine	County
Empire Building Materials	Washington
Cloverleaf Mines	Washington
Permanente	Gilliam
Central Oregon Pumice	Deschutes
A. M. Matlock	Lake
Boise-Cascade Pumice	Deschutes

Brick and Tile

Sixteen brick and tile plants, largely concentrated in western Oregon, were in production during the year.

Sand and Gravel, Crushed Stone

Active commercial producers in every county and nearly every community in the state total more than 200. Numerous additional quarries operated by state, city, county, and federal agencies, and by logging companies using aggregate for private use.



Community growth is measured in buckets of concrete. Sand and gravel or crushed rock form the bulk of the concrete mix. They are rapidly becoming of critical importance in populous areas where demand is heavy and reserves are dwindling through depletion and spreading urbanization. (Photograph courtesy of Oregon Highway Department.)

the Oregon Caves National Monument. Products sold included agricultural stone and roofing granules. The plant suffered considerable flood damage in December. E. W. Morris is owner and operator of the quarry and mill.

Sand and gravel and stone

Slightly more than two-thirds of the total value of mineral and metallurgical products produced in Oregon in 1964 was represented by sand, gravel, and stone. These basic mineral commodities were dredged or quarried at numerous points throughout the state and for the most part were used close to the point of origin. Some gravel, however, was barged 100 miles to riverside communities having no sources less than 20 miles distant by road. Steadily improving techniques in mining, beneficiation, and re-use of wash water were apparent at many of the operations. Greater over-all efficiencies enabled operators to resist inflationary price increases in their product, and at year's end the unit price for sand, gravel, and stone was fractionally lower than for the previous year. A century ago the symbol for the colonization of the northwest was the woodsman's axe. A little later it was the plow. Today in every growing community in the state progress in the form of new roads, dams, bridges, plants, and homes is symbolized by the gravel truck and the bucket of concrete.

Metallurgical Plants

Exotic metals

Oregon continued to maintain its position as an important space-age metals center during 1964. In the Albany area, the complex of research and production facilities included the U.S. Bureau of Mines Electrodevelopment Laboratory, Wah Chang Corp., Oregon Metallurgical Corp., and Northwest Industries, Inc. Wah Chang reported development and fabrication of tungsten-rhenium and tungsten-rhenium alloys, fabrication of titanium and titanium alloys, and the commercial production of high-strength columbium alloys. The company also processes several exotic metal ores into finished products. Oregon Metallurgical continued its production of titanium and zirconium castings. The firm reported increased demand for its various titanium products. Northwest Industries machined various reactive metals for use in high-temperature and severe-corrosion applications. Many of the metals are difficult to mill and dimensional tolerances, particularly for missile components, are of a high order.

Pyroprocess industries

What is probably the most modern lime plant in the world was fired up in the Rivergate district in Portland in April. Ashgrove Lime & Portland Cement Co. of Kansas City, Missouri, built the fully automated, gas-fired, twin-kiln facility at a cost of $3 million. Raw limestone is barged to the plant from Texada Island, British Columbia. Also operating in the Portland

Metallurgical Plants in Oregon

Pyroprocess Plants	Product	County
Ashgrove Lime & Portland Cement Co.	Lime	Multnomah
Chemical Lime Co.	Lime	Baker
Oregon Portland Cement Co.	Cement	Baker, Clackamas
Ideal Cement Co.	Cement	Jackson
Empire Building Materials Co.	Expanded shale	Washington
Cloverleaf Mines, Inc.	Expanded shale	Washington
Pacific Diatomite Corp.	Perlite	Lake
Supreme Perlite	Perlite	Multnomah
Vermiculite-Northwest	Vermiculite	Multnomah
Owens-Illinois	Glass	Multnomah

Electrometallurgical Plants	Product	County
Harvey Aluminum Co.	Aluminum	Wasco
Reynolds Metals Co.	Aluminum	Multnomah
Oregon Steel Mills	Steel	Multnomah
Hanna Nickel Smelting	Ferronickel	Douglas
National Metallurgical Corp.	Silicon	Lane
Pacific Carbide & Allows Co.	Carbide	Multnomah
The Electrometallurgical Co.	Ferroalloys, Carbide	Multnomah

area was the Oswego plant of Oregon Portland Cement Co., which similarly uses high-grade limestone imported from Canada. Oregon Portland also operated its cement plant at Lime, Baker County, using local stone. Ideal Cement at Gold Hill, Jackson County, used stone from Wilderville in Josephine County. Extensive damage to the company power plant located on the Rogue River occurred during the December flooding. Supreme Perlite and Vermiculite-Northwest, both located in Portland, imported raw perlite and vermiculite from out of state and expanded them. Approximately 20 brick and tile plants were active in the state during the year, as they have been for long periods extending back, in some instances, to the mid-1800's.

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OIL AND GAS EXPLORATION IN 1964

By V. C. Newton, Jr.*

Offshore Developments

Twelve companies, representing the bulk of the United States oil industry, spent nearly $41 million for offshore exploration in Oregon and Washington during 1964. Federal offshore leases amounted to $37.3 million, while seismic operations and geologic studies last summer totalled an estimated $3.4 million. Results of the bidding by 11 companies on shelf lands adjacent to Oregon and Washington indicate that this region is one of the industry's main hopes for uncovering a new oil province in the United States. Chances for finding production offshore appear to be great enough to overcome the difficult environmental features of deep water and inclement weather.

Returns from federal offshore leases are deposited in the U.S. Treasury, and no benefits accrue to the bordering state from these payments. Nevertheless, if oil is found on the outer continental shelf lands the adjacent state will gain from ancillary businesses generated onshore. It can be hoped, too, that once oil is found on federal shelf lands development will move shoreward to probe for oil entrapped by facies changes in the marine sediments.

The lease sale held by the State Land Board in December showed that interest in the near-shore prospects is very low at present. Of 18 tracts offered for lease by the Land Board, only two brought bids. The geology farther out apparently offers a greater thickness of Tertiary marine beds and less intercalated volcanic rocks than can be found along the coast.

Summary of State Offshore Leases

Tract No.	Company	Acreage	Bonus	Rent	Total Paid	Location
37	Shell Oil Co.	6,900	$15,663	$6,900	$22,563	5 mi. S. of Winchester Bay
38	Standard Oil Co.	6,700	13,333	6,700	20,033	2 mi. S. of Winchester Bay

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Offshore Exploration Permits, 1964

Permit No.	Company	Geophysical	Geological
SL-2	Shell Oil Co.	Sparker Gas exploder Conventional seismic	Drill ship - M.V. Eureka
SL-3	Union-Standard	Gas exploder	Drill ship - Caldrill
SL-4	Standard, operator Standard of California Humble Oil & Refining Co. Pan American Petroleum Co. Superior Oil Co. Phillips Petroleum Co. Texaco, Inc.	Conventional seismic	
SL-5	Superior Oil Co.	Conventional seismic	Drill ship - Submarex
SL-6	Richfield-Mobil		Drill ship - Exploit
SL-7	Mobil-Richfield	Gas exploder	
SL-8	Humble Oil & Refining Co.	Conventional seismic	Drill ship - Submarex
SL-9	Atlantic Refining Co.	Sparker	
SL-10	Texaco-Mobil	Sparker	Drill ship - Western Explorer

Last summer 12 oil firms conducted geological and geophysical studies off the Oregon coast, these companies being primarily interested in the outer continental shelf region. Samples and cores were obtained from the ocean floor by drilling ships. Drilling was done as far as 40 miles from shore on several occasions and in water as deep as 2,000 feet. In 1964, five drilling ships, three conventional seismic fleets, two sparker ships, and two gas exploder ships were utilized in studies on the shelf lands bordering Oregon.

Onshore Developments

The Department issued one new drilling permit in 1964. This was for a shallow test well near Dallas in Polk County. Total footage drilled in 1964 was 1,718 feet, the lowest in 16 years. Footage includes that drilled by Gulf on its 8,470-foot test at Halsey in Linn County. Gulf abandoned the well in January 1964.

Permits Issued in 1964

Permit No.	Company	Well Name	Location	Depth	Status
54	John T. Miller	Adams 2	SE¼ sec. 11 T. 8 S., R. 5 W. Polk County	622'	Suspended

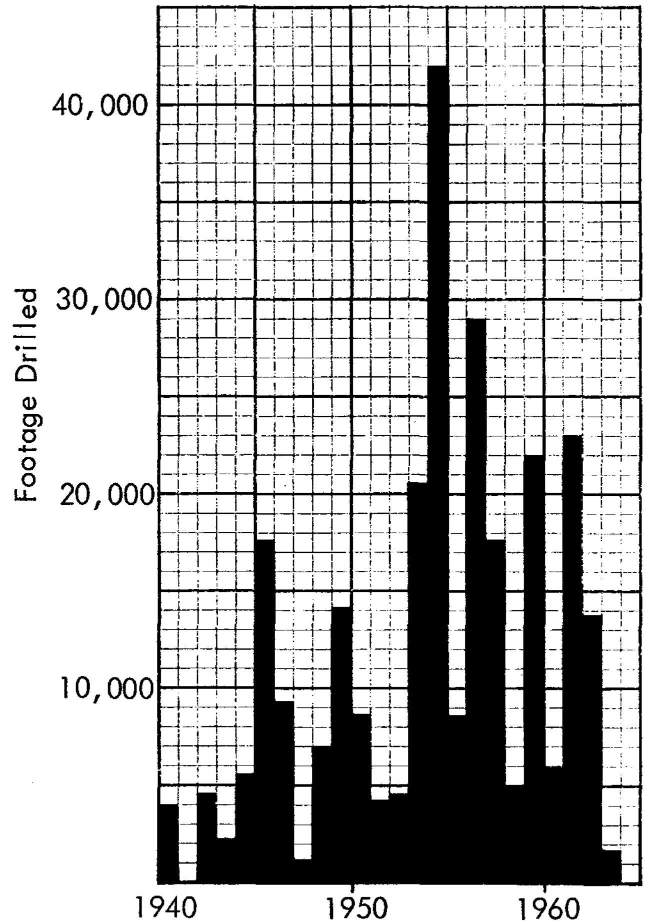
Records Released in 1964

Permit No.	Company	Well Name	Location	Depth	Records Available
45	Two State Oil & Gas Co.	Vale City 1	SW¼ sec. 21, T. 18 S., R. 45 E. Malheur County	1,185'	History Driller's log
46	Reserve Oil & Gas Co.	Bruer 1	NE¼ sec. 31, T. 6 S., R. 4 W. Polk County	5,549'	History Core descriptions Mud log Electric log Dipmeter Sonic log Samples
47	Humble Oil & Refining Co.	Wicks 1	NE¼ sec. 11, T. 7 S., R. 1 E. Marion County	7,797'	History Driller's log Mud log Electric log Samples
48	Humble Oil & Refining Co.	Miller 1	SE¼ sec. 10, T. 10 S., R. 3 W. Linn County	4,951'	History Driller's log Mud log Sonic log Electric log Samples
49	John T. Miller	Adams 1	SW¼ sec. 11, T. 8 S., R. 5 W. Polk County	410'	Driller's log Samples
50	J. Miller-R. Mitchell	Bliven 1	SW¼ sec. 11, T. 8 S., R. 5 W. Polk County	389'	Driller's log Samples
52*	Gulf Oil Corp.	Porter 1	NE¼ sec. 27, T. 13 S., R. 4 W. Linn County	8,470'	(See footnote)

* Gulf released records on this well to Salem Printing & Blueprint Co., 475 Ferry Street S.E., Salem, Oregon. Records in Department's files are confidential until January 1966.

Oregon was still without oil or gas production at the close of its 62nd year of exploration. Since 1902, 171 holes have been drilled without making a commercial discovery of oil or gas. The number of wells is not too significant, however, as only 33 were drilled to a depth greater than 4,000 feet.

Gulf Oil Corp. quitclaimed an estimated 200,000 acres in the Willamette Valley following abandonment of "T. J. Porter 1" near the town of Halsey. Reserve Oil & Gas Co. dropped approximately 50,000 acres of leases near Lebanon when it was evident Gulf's well was a dry hole. Others who held smaller acreages in the same general area gave up interests in their leases also.

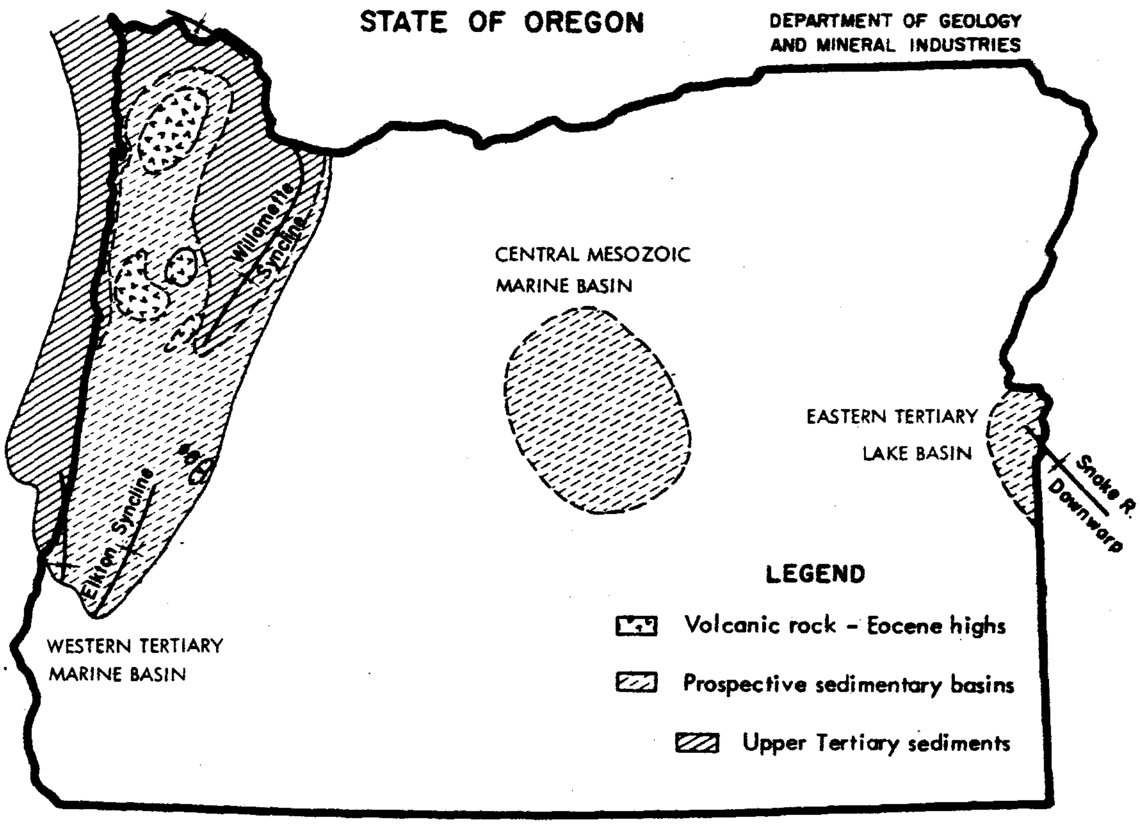


Oil test drilling in Oregon since 1940.

Superior, Texaco, and Richfield still have several thousand acres leased in northwestern Oregon. Wesley Bruer is believed to have retained his lease block near Salem in the Willamette Valley this past year. E. M. McDowell was reported to have a small lease block in Coos County, and D. F. McDonald holds leases bordering the shore north of Winchester Bay in southwestern Oregon. Pacific States Oil & Gas Co. of Portland leased approximately 2,000 acres in the Tualatin Valley, Washington County, in June and July 1964.

Sedimentary Basins Defined

Geologic data obtained by deep drilling in Oregon over the past 15 years indicates that certain areas of the state may still yield commercial quantities of oil and gas. The prospects have been limited to a much smaller portion of the state than was under consideration prior to 1950. Outlines of favorable basin areas are shown on the accompanying map. Synclinal axes are shown to express the idea that their locations are the deep portions of the sedimentary basins.



Map showing location of sedimentary basins in Oregon.

<u>Western Tertiary marine basin</u>

Eocene rocks comprise the major part of the western marine basin. Tuffaceous marine sediments are commonly intercalated with volcanic rocks in this region. The lower Eocene section in the northern part of the basin is predominantly volcanic, while the contemporaneous section in the southern part of the basin consists of several thousand feet of marine sediments overlying a great thickness of volcanic rock.

Middle Eocene to late Oligocene sediments in the northern part of the basin probably offer the best hope for oil production onshore, but lower Eocene sediments in the southern half of the basin should not be entirely discounted, since several interesting oil shows have been found in wells drilled in these rocks.

A thick section of marine sediments, ranging in age from Eocene through Pliocene, is believed to exist offshore. At present this submerged region appears to be the most promising for oil exploration.

Eastern Tertiary lake basin

The Snake River Basin in eastern Oregon may contain as much as 10,000 feet of intermixed lake sediments, continental detritus, and intercalated volcanic rocks. Numerous gas occurrences in the region have encouraged wildcat ventures for 50 years or more. Except for a few instances of domestic use, the gas has not been found in large enough quantity to be commercially valuable. Small percentages of petroleum condensate were noted in the gas at several locations.

Porous zones have been scarce in most of the wells drilled in the western part of the Snake River Basin, and sands encountered have often contained gassy water. Formation water is fresh to a depth of about 1,000 feet, but becomes brackish below that level. Salt springs issue at the surface, however, at a locality 6½ miles north of Vale, Oregon (The ORE BIN, September 1964). Faulting in the basin is probably associated with downwarp, and this, plus other structural elements, may provide suitable traps for accumulation of gas.

Central Mesozoic marine basin

Mesozoic marine sediments show through the younger cover of volcanic rocks over a fairly wide area in central Oregon and are possibly 30,000 feet in thickness in the Suplee-Izee region. Minor shows of asphalt, oil, and gas have been reported in this section of rocks. North and east of the basin, the Mesozoic sedimentary rocks are considerably folded and metamorphosed.

A covering of Tertiary volcanics has deterred extensive work in the central Mesozoic basin, but more drilling is expected to be done in this province. The sections explored to date have not been entirely discouraging. The Sunray-Mid Continent-Standard Oil Co. well drilled east of Prineville in 1958 found encouraging signs of gas in a Cretaceous section more than 3,500 feet thick.

Future Development

Union Oil Co. and Standard Oil Co. announced at a December meeting in Portland their plans to drill off the Oregon coast in the spring of 1965. The two firms have jointly contracted Western Offshore Drilling &

Exploration Co.'s drill-ship "Western Offshore III" for the work. The ship was used by Standard last summer to test federal leases 13 miles seaward of Santa Maria off the California coast. Water depth was 550 feet where drilling was done. An underwater television camera aided in the installation of well-head equipment.

Pan American Petroleum Corp. contracted Global Marine Exploration Co.'s "Submarex" for making ocean bottom stability tests off the mouth of Grays Harbor in Washington during December. Pan American is reportedly making plans to drill 15 miles west from Grays Harbor on the federal leases it acquired in October 1964. The company will use a bottom-supported jack-leg platform. The equipment will be floated to the site and the legs "jacked-down" to the ocean floor 250 feet below the water surface. A rig of this type, which is now operating in California, will probably be used

Caldrill I. (Caldrill Offshore, Inc.) A center-well core-drilling ship used by Standard Oil Co. and Union Oil Co. to drill shallow core holes off the Oregon coast in 1964. Large outboard motors position the vessel, so that no anchors are needed during the drilling operation..

for the work.

Early in 1965 the Shell Oil Co. made public its plans to drill off the Oregon coast. Shell probably will test its federal leases 20 miles off Newport. Water depth at this location is 300 feet. The company will move "Blue Water II" from San Francisco north to Oregon some time in the spring of 1965. The "Blue Water II" is a huge floating platform which was used by Shell to drill 12 miles off the California coast at San Francisco last winter.

The large platform proved itself during the drilling in northern California and should work as well in Oregon waters. The equipment floats half submerged when drilling is under way. For moves, the ballast water is pumped out of the lower structure so that the platform has a 15-foot draft while being towed.

This summer season will prove extremely interesting for those watching oil developments in the Northwest. If the preliminary deep drilling in 1965 finds encouraging signs of oil, a variety of development techniques are sure to be tried. Bottom-supported structures for operations in 400 feet of water are on the drawing boards and, perhaps more intriguing, numerous innovations are expected for sub-sea work.

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FIELD WORK IN OREGON, 1964

By R. E. Corcoran*

Field work in Oregon during 1964 increased again over that of the previous year, in the number both of graduate students doing thesis studies and of professional geologists involved in specific problems. Geologic mapping or field investigations of various types were carried out all over the state. Because of the increasing number of people who are presently undertaking geological studies in Oregon, we feel that a progress report will be of general interest to the public and may also encourage new studies that would contribute to the development of our mineral resources. The number of field parties in the state totaled at least 41, including 26 graduate students and 15 other geological investigators.

State Geologic Map Project

Probably the most important field study in Oregon concerns the State Geologic Map Project. The geologic map of the western half of Oregon was published in 1961; since that time most of the field work has been concentrated in the eastern part. The Department, in cooperation with the U.S. Geological Survey and aided by university professors and graduate students, is continuing this project. Preliminary geologic maps covering 1° by 2° areas at a scale of 1:250,000 (Army Map Series sheets) are being published soon after the field work is completed. More than 60 percent of the eastern half of the state has now been finished on a scale of 1:250,000 or larger (see figure 1). In eastern Oregon, Department geologists, professors and graduate students from Oregon State University and the University of Oregon, and graduate students from Princeton, Stanford, and Johns Hopkins Universities are conducting geologic studies in critical areas. The information developed from this research will be used in the final state map.

Geochemical and Geophysical Surveys

Perhaps the most significant new phase of geological exploration being carried on in Oregon is the geochemical and geophysical work by personnel

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* Stratigrapher, Oregon State Dept. of Geology and Mineral Industries.

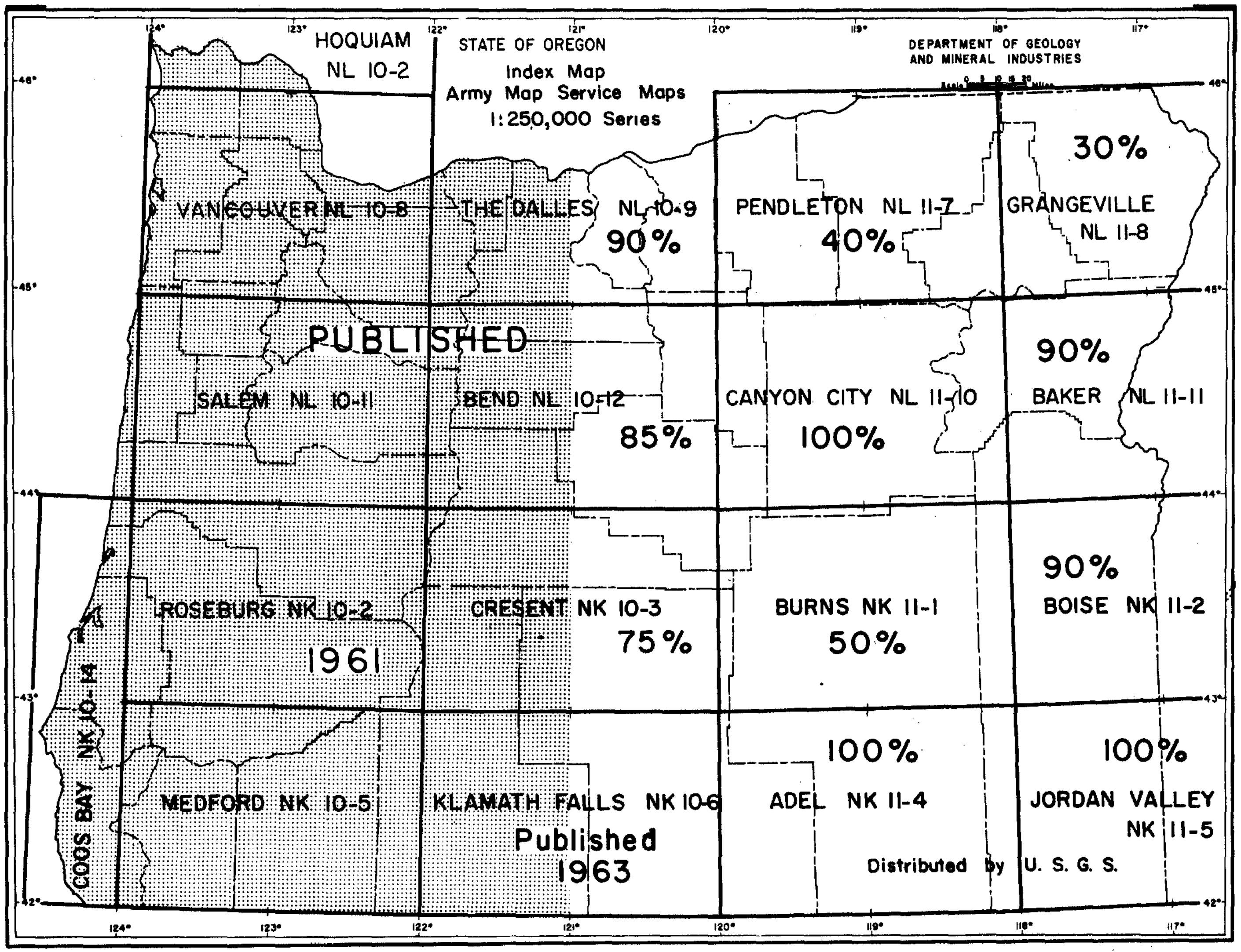

Figure 1. Index map showing progress of field studies in eastern Oregon. Percentage fig
indicates amount of work completed in each quadrangle.

from the Federal Survey, the geophysics group in the Department of Oceanography of Oregon State University, the Department of Geology at the University of Oregon, and the Oregon Department of Geology and Mineral Industries. These studies include gravity surveys of various types, seismicity of the Pacific Northwest, electrical resistivity of laterites, geochemical sampling of stream sediments, geothermal studies of Recent volcanic rocks, and paleomagnetism of Cenozoic lavas in eastern Oregon.

Field Studies

Listed below are the various field projects being furthered in the state. For convenience in showing where these studies are located, the state is divided on the accompanying index map (figure 2) into six districts. For each district, the letter opposite the name of the project on the list is keyed to the map.

1. Northwest Oregon

a. Geology of Astoria Submarine Canyon. P.R. Carlson, PhD candidate, OSU.
b. Sediments of Astoria Fan and adjacent abyssal plain. C.H. Nelson, PhD candidate, OSU.
c. Season studies of foraminifera of Yaquina Bay, Ore. D.C. Manske, PhD candidate, OSU.
d. Distribution of foraminifera in Netarts Bay, Ore. A.A. Hunger, MS candidate, OSU.
e. Origin and development of shoreline processes, Clatsop Spit to Tillamook Head. J. Livingston, PhD candidate, OSU.
f. Stratigraphy and petrology of a portion of the upper Nehalem River basin. R. Van Atta, PhD candidate, OSU.
g. Geology of the Newport Embayment. P.D. Snavely, Head, Pacific Coast Branch, U.S.G.S.
h. Electrical resistivity of ferruginous bauxites, Columbia County, Ore. R.G. Bowen and R.E. Corcoran, Oregon Dept. Geol. & Mineral Ind.
i. Engineering geology studies, northern Willamette Valley and Tualatin Valley, Ore. H. G. Schlicker, Oregon Dept. Geol. & Mineral Ind.
j. Foraminiferal study of the Miocene Astoria Fm. R. Gonsalves, PhD candidate, Univ. Calif.
k. Geology of the southern third of the Marcola quad. T. Maddox, MS candidate, U of O.

2. Southwest Oregon

a. Mesozoic stratigraphy of Curry County, Ore. R. H. Dott, Jr., Prof. of Geology, Univ. Wisc.
b. Foraminiferal study of the Eocene-Oligocene rocks near Coos Bay, Ore. G. Rooth, PhD candidate, OSU.
c. Foraminiferal study of upper Eocene sediments: Sacchi Beach, Elkton, Lorane. K. Bird, PhD dandidate, Univ. Wisc.
d. Geology of the southeast quarter of the Roseburg quad. W. Johnson, MS candidate, U of O.
e. Geology of the southwest quarter of the Dixonville quad. H. Hixon, MS candidate, U of O.
f. Geology and petrology of the Rogue Volcanic Series. R. Helming, MS candidate, U of O.
g. Geology and gravity survey of the Glendale quad. C. Forbes, PhD candidate, U of O.
h. Reconnaissance gravity survey of southwest Oregon. H.R. Blank, Jr., U.S.G.S.
i. Geochemistry of stream sediments in western Josephine County. R.G., Bowen, assisted by R. Newell and J. Blanchard, Oregon Dept. Geol. & Mineral Ind. and U of O.
j. Stratigraphy and sedimentology of some Cretaceous and Eocene rocks in the Medford-Ashland region, B. McKnight, PhD candidate, OSU.

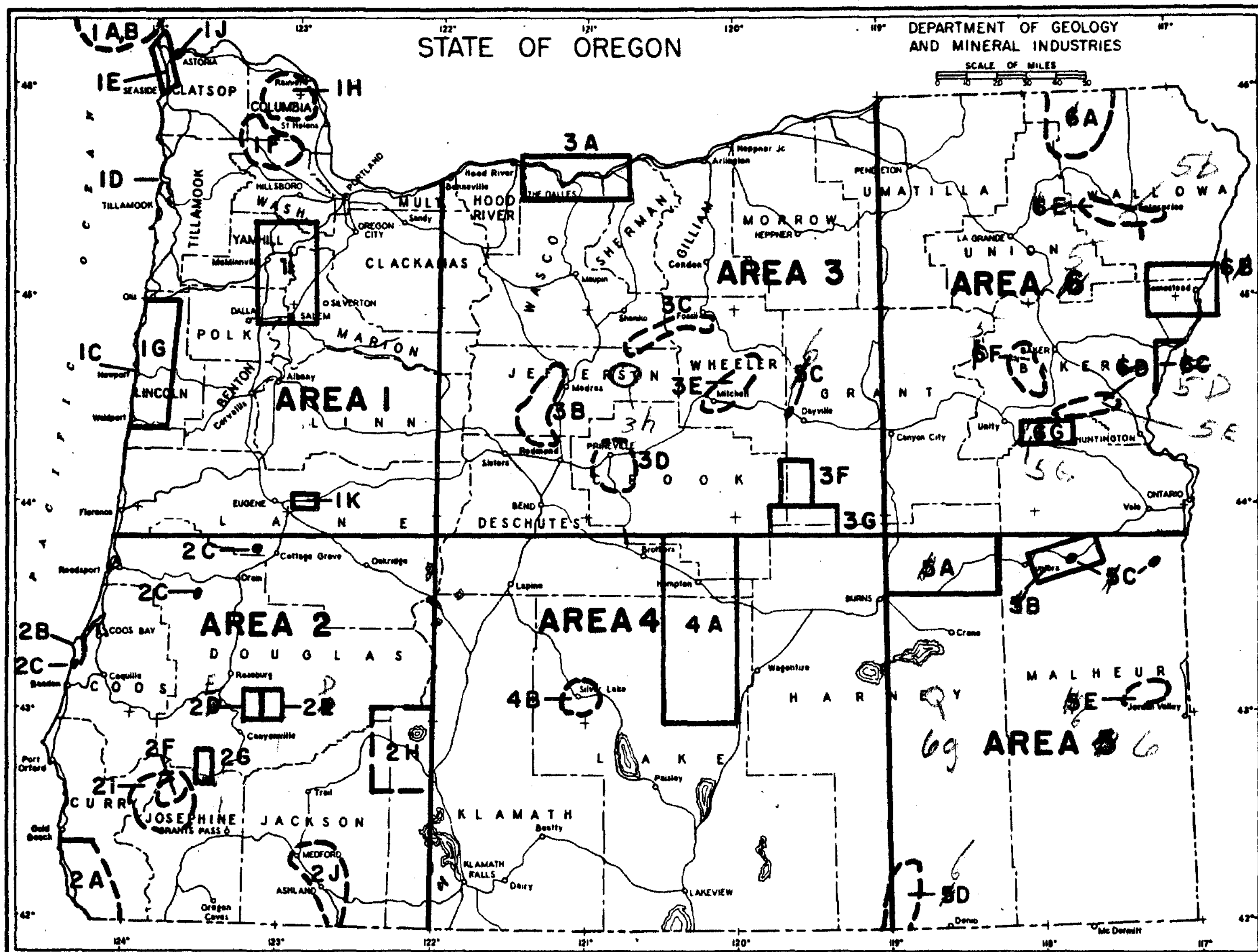

Figure 2. Index map showing location of field studies in Oregon.

3. North-central Oregon

a. Geology of the Wishram, White Salmon, The Dalles quads. R.C. Newcomb, U.S.G.S.
b. Petrology and stratigraphy of the Deschutes Fm., Madras area. D. Stensland, PhD candidate, OSU.
c. Petrology and stratigraphy of the John Day Fm., northern Wheeler County. P.T. Robinson, Prof. of Geology, OSU.
d. Petrology of the rhyolitic intrusives, John Day Fm., Prineville area. R.G. Fisher, Prof. of Geology, Univ. of Calif. at Santa Barbara.
e. Stratigraphy and petrology of the Cretaceous rocks in the Mitchell area. W.D. Wilkinson, Head, and K. Oles, Prof. of Geology , OSU.
f. Tertiary geology of the southwest quarter of the Dayville quad. M. Forth, MS candidate,OSU.
g. Geology of the Suplee-Izee area. H.J. Buddenhagen, consulting geologist.

4. South-central Oregon

a. Geology of the east half of the Crescent A.M.S. sheet. G.W. Walker, U.S.G.S., and N.V. Peterson, Oregon Dept. Geol. & Mineral Ind.
b. Geology of the Silver Lake area. F. Ikeagwuani, MS candidate, U of O.

5. Southeast Oregon

a. Geology of the northeast quarter of the Burns A.M.S. sheet. R.E.Corcoran, Oregon Dept. Geol. & Mineral Ind.
b. Geology of the Malheur River gorge between Harper and Juntura; emphasis on the petrology and areal extent of the Dinner Creek Tuff. G. Haddock, PhD candidate, U of O.
c. Paleomagnetism of Miocene basalts: Owyhee Gorge, Malheur River gorge, Picture Gorge. A.F.Frederickson, Head, Dept. of Earth and Planetary Sciences, Univ. of Pittsburgh.
d. Geology of the Pueblo Mountains region with emphasis on Cenozoic stratigraphy of the Pueblo Mts. and Thousand Creek valley. J.Avent, MS candidate, Univ. Washington.
e. Geology and petrology of the Cow Lakes lava field. G. Millhollen, MS candidate, U of O.
f. Tertiary mammalia from southeast Oregon. C.A. Repenning, PhD candidate, Univ. of Calif.

6. Northeast Oregon

a. The Grande Ronde dike swarm and its relation to the Columbia River Basalt. I.Gibson, Prof. of Geology, Univ. of Calif. at Santa Barbara.
b. Geology of the southeastern Wallowa Mountains, Oregon, and the southwestern Seven Devils Mountains, Idaho. T. Vallier, PhD candidate, OSU.
c. Geology of the Oregon portion of the Mineral quad. H. Brooks, Oregon Dept. Geol. & Mineral Ind.
d. Petrology and stratigraphy of the Burnt River Schist. R. Ashley, PhD candidate, Stanford U.
e. Geology of the pre-Tertiary rocks around the northern border of the Wallowa Batholith. B. Nolf, PhD candidate, OSU.
f. Stratigraphy and structure of the Elkhorn Ridge Argillite. M. Switek, PhD candidate, U of O.
g. Geology of the northern half of the Caviness quad. E. Wolff, PhD candidate, U of O.

Theses Completed in 1964

Doctoral Theses

Quaternary geology of the Willamette Valley; emphasis on the petrology and origin of the Willamette Silt. Jerry Glenn, OSU.
Subaqueous movement of sediment in the vicinity of the Oregon coastline. L.D.Kulm, OSU.
Petrography of the volcanic rocks in the Three Sisters area. Edward Taylor, Wash. State U.
Biostratigraphy of the Umpqua Formation, southwest Oregon. Richard Thoms, Univ. of Cal.

Master's Theses

Geology of a portion of the Picture Gorge quad. Willis White, OSU.
A stratigraphic study of the marine Cretaceous rocks near Mitchell, Ore. B. McKnight, OSU.
Continental shelf sediments in the vicinity of Newport, Ore. David C. Bushnell, OSU.
Coastal landslides of northern Oregon. William B. North, OSU.
Sedimentary petrology of the Umpqua Formation in the axial part of the southern Coast Range. Lawrence Burns, U of O.
Gravity studies over northeast-trending faults in the Klamath Mountains. Gerald Bruemmer, U of O.
Geology of the southwest quarter of Roseburg 15-minute quad. Donald Hicks, U of O.
Zeolites from Kings Valley and Coffin Butte, Benton County, Ore. Terry Clark, U of O.
Petrographic study of the rocks underlying Spencer's Butte. John Shaw, U of O.
Gravity profiles across the central Coast Range. Robert Witt, U of O.

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LAND WITHDRAWALS INCREASE 400 PERCENT

Withdrawals of public lands from mineral entry increased from 9,304 acres in 1963 to 46,658 acres in 1964, a growth of 400 percent. During the past year withdrawals by federal agencies were made in 16 counties in the state, all but three of them in western Oregon. Largest of the 12 withdrawals totalled 33,112 acres in Deschutes and Lane Counties, where a recreational area surrounding Waldo Lake was requested by the U.S. Forest Service. Recreation accounted for seven of the proposed withdrawals.

One withdrawal was requested by the U.S. Bureau of Land Management for the "protection of gravel deposits" needed for surfacing the Bureau's resource management roads in Douglas County. Another Bureau withdrawal was for protecting quarry sites for aggregate to be used on Bureau and private roads and for jetty rock. The quarries are located in Coos and Douglas Counties. Two withdrawals were proposed for the construction of reservoirs in Lane and Baker Counties, and one administration site covering 320 acres in Clackamas County was also listed. Since 1954 the total area involved in withdrawals is 424,961 acres, which is almost exactly equal to all the land in Benton County.

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The ORE BIN
Volume 27, No. 2
February, 1965

A BRIEF HISTORY OF THE OREGON PORTLAND CEMENT CO.

By F. E. McCaslin, President

The following article, "A Brief History of the Oregon Portland Cement Co.," was a speech presented to the Oregon Advertising Club of Portland on October 21, 1964 by Mr. F. E. McCaslin, president, Oregon Portland Cement Co. It is reproduced here for two reasons: 1) to illustrate the vital role played by this segment of the state's mineral industry in the development of the Northwest, and 2) to impress upon the people of Oregon that our mineral industry encompasses more than the mining of the glamour minerals gold, silver, and uranium. Cement, limestone, sand and gravel, shale, clay, stone, and silica -- all are mineral materials essential to the growth of the industrial world and all are available in Oregon.

As this article indicates, the companies engaged in supplying these basic materials are often business concerns formed by local citizens who have a genuine interest in their communities. In short, these are good businesses and a credit to their region. This article is timely in that 1965 marks the 50th anniversary of the Oregon Portland Cement Co. The Oregon Department of Geology and Mineral Industries congratulates the Oregon Portland Cement Co. for its part in the building of the state and wishes it well in the years to come.

Hollis M. Dole
State Geologist

Introduction

"Portland cement is the product obtained by finely pulverizing clinker, which is produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no addition subsequent to calcination except calcined or uncalcined gypsum."

This definition is not as austere as it sounds. It really means that we take two different types of rock, one a high-grade calcium (or calcareous) rock and the other containing iron, aluminum, and silica, found in clays or shales and technically known as argillaceous rock. We crush and mix them in proper proportions, then change the product into a slurry form by grinding the mixture into an extremely fine powder mixed with water. The slurry is then fed into the upper end of a sloping and revolving kiln. In some plants the kilns are as much as 450 to 500 feet in length. Into the kiln at the lower end is injected a flame, frequently produced by natural gas, which develops a temperature of 2,500° to 3,000° F.

The product which comes from the kiln, after an approximately two-hour exposure, is called "clinker." The clinker is treated to a finish grinding process, at which time gypsum is added to control the setting time of the finished product. The material produced is portland cement.

History of Portland Cement

In the days of the Roman Empire, a cement was used to produce concrete that rather closely approached the concrete of today. The ruins of many structures remain to attest to this fact. The Roman Forum, the Appian Way, the Aqueduct, and numerous other structures contain cement in somewhat the same form as we know it now.

During the Middle Ages the secret of making this type of cement seems to have been lost and not re-discovered until the 18th century. As early as 1756, Englishmen were working with mortars in an effort to develop a hydraulic cement -- a cement which would harden under water or when water was applied to it. One of the earliest of these experimentations was carried on by John Smeaton, an English engineer and builder of lighthouses, who discovered some of the intricacies of the process by heating mixtures on his kitchen stove.

In 1824, Joseph Aspdin, an English bricklayer, who had been experimenting since 1811, took out patents on an improved cement. He called it portland cement, because it resembled in color a building stone found on the Isle of Portland, an island off the English coast near the town of Leeds, England. One of the important parts of Mr. Aspdin's discovery was the necessity of burning his hard limestone at high temperatures.

The first portland cement to be produced in the United States was probably made by the Coplay Works at Valley Forge, Pennsylvania, around 1866. Shortly thereafter, several plants were built in the Lehigh Valley of Pennsylvania, which is still the largest producing area for portland cement in the country.

It was not until about 1900 that the quantity of cement manufactured in this country equalled the imports from Europe. In 1900, 8,482,000 barrels were manufactured in the United States. This figure grew rapidly. In 1910 it reached 76,549,000 barrels. Last year it was expected that the consumption of portland cement would reach an all-time high of 365 million barrels with a value of $1,171,000,000. The rated capacity of the industry today is approximately 481 million barrels. Thus, it will be noted that the cement business, in our generation, has become one of the major industries of the country.

Some 60 separate companies operate 180 plants in 39 states and Puerto Rico. The greatest concentration of plants is still in the Lehigh Valley of Pennsylvania, where 17 now have an installed capacity of 42 million barrels. On the west coast, the cement industry achieved its foothold between 1909 and 1920. Plants were built in the Los Angeles area, northern Washington at the town of Concrete, and in eastern Washington at Metaline Falls and Spokane.

The Organization of O.P.C.

The first news in Portland about the Oregon Portland Cement Co. was broken in the August 2, 1908 issue of the morning Oregonian. The announcement was made that portland cement was at last to be manufactured in Portland. The Oregonian article mentioned the site of the plant merely as being in the suburbs of Portland on the Willamette River, where both rail and water transportation were available. Actually, the location was in Oswego.

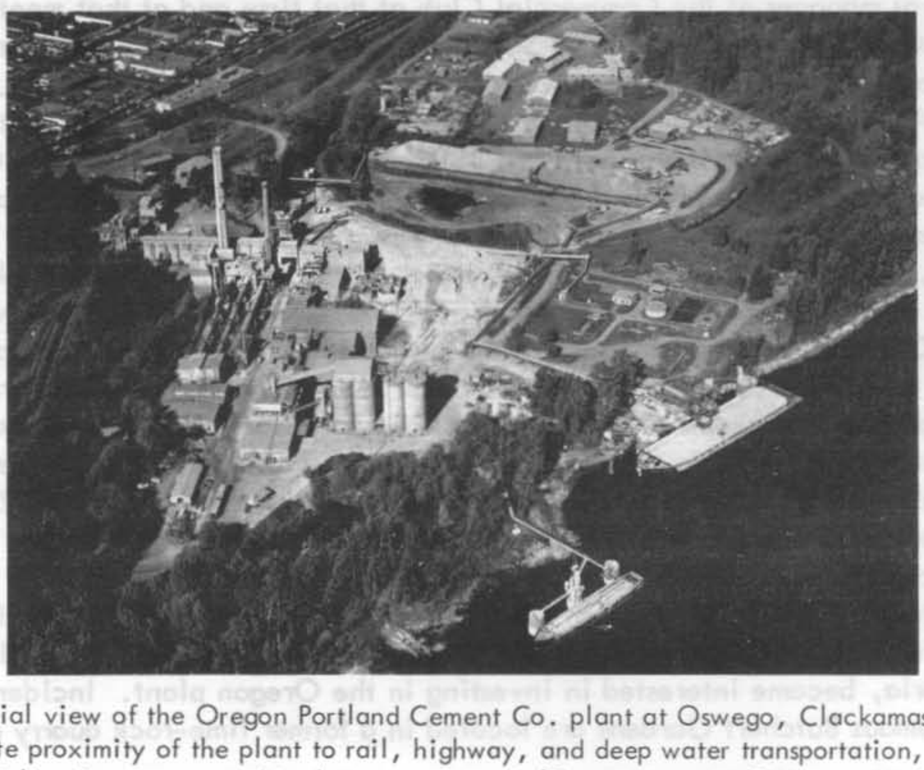
The origin of the new industry took place at a meeting of the Portland Commercial Club, now the Portland Chamber of Commerce. Tom Richardson was manager of the Commercial Club at that time and at that meeting he introduced C. W. Nibley of Salt Lake City to the prominent business-men of Portland. Mr. Nibley was president of a cement company in Utah.

A considerable amount of money was pledged for construction of the new cement plant. It was not until 1909, however, that the Portland Cement Co. was incorporated with the following directors: Aman Moore, Alex Nibley, Edward Cookingham, Tom Richardson, Andrew C. Smith, C. E. Ladd, W. F. Burrell, Paul C. Bates, Wirt Minor, A. L. Mills, Joseph N. Teal, T. B. Wilcox, W. A. Gordon, J.C. Ainsworth, and George Lawrence.

Construction work began on the plant in 1910. Machinery and equipment were ordered and the project appeared to be on its way. The new portland cement was to be known as the "Red Rose Brand." The organization was headed at that time by Aman Moore. Difficulty was experienced in assembling the total necessary funds to complete this approximately $2,000,000 project. That was a rather substantial sum for those pre-inflation days. In fact, it would be comparable to some $8,000,000 today.

In 1915, R.P. Butchart of Victoria, B.C., who was a prominent financier in Canada and president of the British Columbia Cement Co., Ltd., of Victoria, became interested in investing in the Oregon plant. Incidentally, the famous Butchart Gardens are located in a former lime-rock quarry of the

Aerial view of Oregon Portland Cement Co. quarry and preparation plant at Durkee, Baker County. High-grade limestone is shipped by rail and truck to sugar refineries, paper mills, and metallurgical plants in the Northwest. (Photo courtesy of Photo-Art)



Aerial view of the Oregon Portland Cement Co. plant at Oswego, Clackamas County. Note proximity of the plant to rail, highway, and deep water transportation, all used in delivering cement to Northwest customers. (Photo courtesy of Western Ways)

B.C. Cement Co. at Tod Inlet, near Victoria. Mr. Butchart was soon joined by Charles Boettcher of Denver, Colorado, president of several cement companies in the Middle West.

A complete reorganization of the company took place, the name was changed to Oregon Portland Cement Co., and the brand name of the product to "Oregon." Incorporation of the company under the present name took place August 15, 1915, which will result in the company's achieving its 50th anniversary this year. The new directorate in 1915 contained some of the original names and some new ones. They were: R.P. Butchart, Edward Cookingham, George Lawrence, Arthur H. Devers, F.I. Fuller, A. S. Pattullo, Chester V. Dolph, and L.C. Newlands. Lawrence C. Newlands came from Victoria, B.C., to become vice president and general manager, a position which he held until 1937, when he became president. He held the position of president until his death in 1942. I was chosen as his successor in September of 1942.

The first several years of operation were difficult, due to the various factors of low volume, the entry of our country into World War I, resultant high labor rates, etc. However, following the close of the war, business became better and all past dividends were paid up and have been paid regularly ever since.

It was decided by the stockholders to build a second plant in Oregon, and the Sun Portland Cement Co. was built at the town of Lime, near Huntington, Oregon. This plant was completed and placed in operation in November, 1923. It was built to serve western Idaho, eastern Oregon, and southeastern Washington. Original capacity was 500,000 barrels per year. Because of some overlapping of stockholders, the "Sun" company and the "Oregon" company were merged in September of 1926.

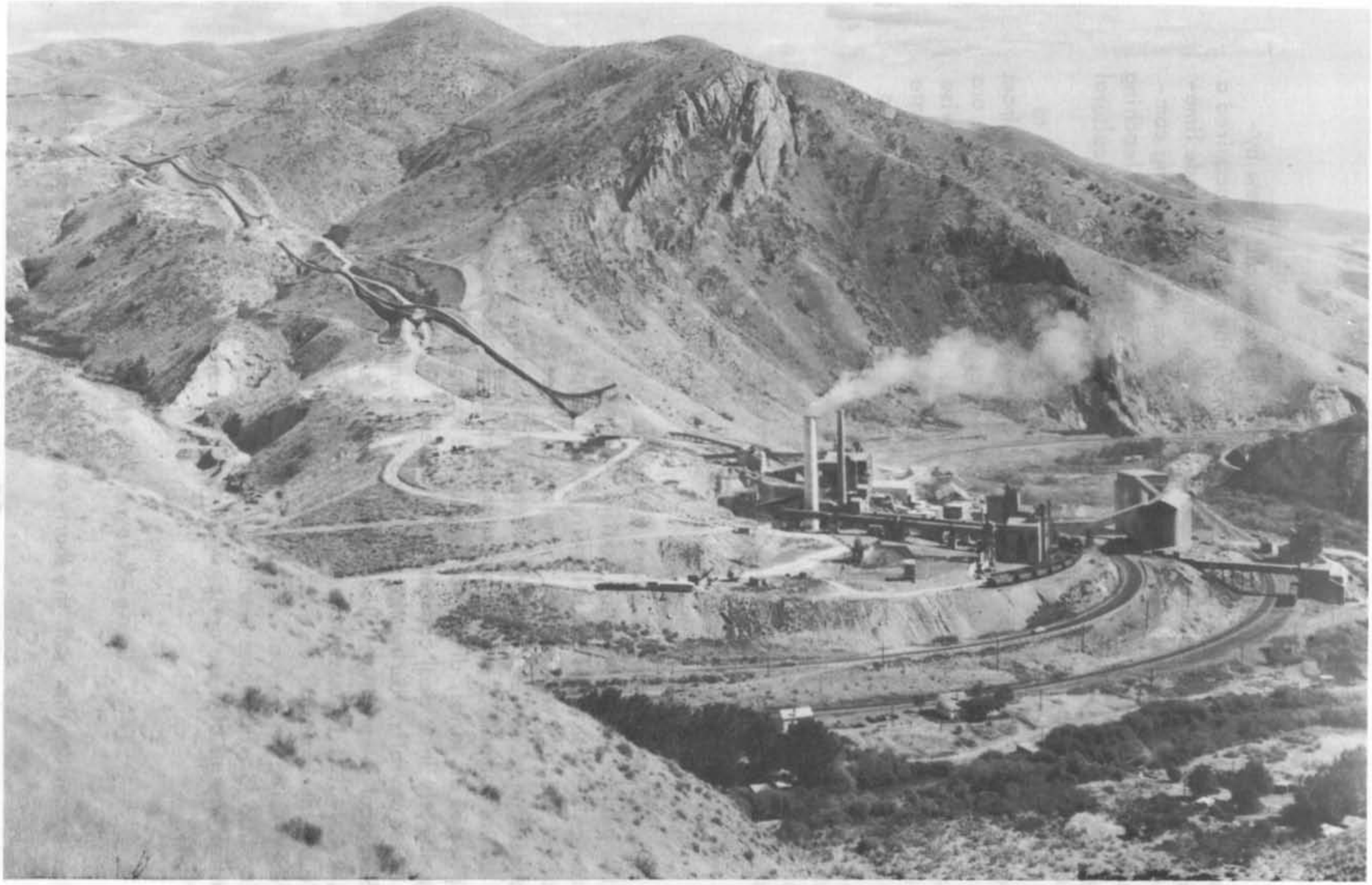
Business was reasonably good in the 1920's, and when the depression started in 1929, we had a contract at the Lime, Oregon plant for supplying cement to the Owyhee Dam in southwestern Idaho. This job lasted until 1932 and helped the company to maintain its dividend record throughout the depression years. The company has been able to maintain an unbroken dividend record since the early 1920's.

The company went through the thirties without spectacular incident. Between the late thirties and July of 1950, the corporation retired more than $2,500,000 of preferred stock, about one million of which was cumulative preferred. Since that time, the company has had only its present common stock outstanding. This stock has since been split four to one and has experienced numerous stock dividends. I have some brief data on the record of our common stock over the past 10 years. By buying 100 shares of this stock on January 10, 1954, at the then existing price of $21 per share, with total investment of $2,100, and retaining all stock dividends and splits until January 1, 1964, the purchaser would have 497 shares. At the current price of $23, this would amount to $11,431. In addition, cash dividends were paid him during that period of $2,965, making a total return of $14,396 from the $2,100 investment.

Plant Expansion

Throughout the early years, the company's capacity had remained at the original size with one 500,000 barrel kiln at each plant. In the mid-1940's, it became apparent that additional capacity was indicated, and in 1947 a second and larger kiln was installed at Oswego at a cost of $1,156,939. This new kiln had a capacity of 750,000 barrels of finished cement per year, bringing the total for the Oswego plant to 1,250,000 barrels per year. In the 1950's further expansion seemed to be in order, and in 1956 and 1957 another large kiln was installed at Oswego, bringing the capacity to two million barrels per year, or quadrupling the size of that plant. A second and larger kiln was also installed at Lime, Oregon, during this period, bringing the capacity of that plant to its present size of 1,200,000 barrels per year, which resulted in somewhat more than doubling its capacity. During the 10 years ending at the close of 1963, the company spent on new construction at its plants a total of $9,500,965.54. Approximately a half million was expended in 1964 on further expansion.

We are constantly endeavoring to widen our marketing area, and this year are constructing a distribution plant at Kennewick, Washington. This plant will serve the area which includes the cities of Kennewick, Pasco, Richland, Hanford, and Walla Walla. This is a rapidly growing area and one which we can serve readily either by water or by rail. We have at Kennewick a site containing approximately four acres which is not only on the Columbia River and the mainline railroad but is also convenient for trucking. The capacity of this distribution plant will be 1,000 barrels per hour. Bulk and sacked cement of all types will be available for loading on either customers' trucks or on common carrier. The plant will have a 3,000-barrel, 4-compartment storage capacity and a 60' by 60' warehouse and office. We are quite familiar with this area, having supplied the cement for both Ice Harbor and Lower Monumental Dams. We believe that this vicinity will develop into a good marketing area. The Battelle Memorial Institute has recently obtained the contract for future nuclear research at the Hanford Works and is committed to an expenditure of $9,000,000 within the next five years. This, we believe, will also attract industries of other types.



Aerial view of Oregon Portland Cement Co. plant at Lime, Baker County. Raw limestone from quarry is delivered to the kilns via the conveyor belt shown. (Photo courtesy of Oregon Portland Cement Co.)

By-Products

During rather recent years, the company has developed a few by-products which have proved profitable. In 1959, the company acquired a deposit containing approximately 40 million tons of chemical-grade limestone at Durkee, Oregon. This rock is used by sugar manufacturing companies in their refining process, by pulp and paper companies for bleaching purposes, by steel companies and others. We also manufacture agricultural lime and limestone flour at our Oswego plant.

As Oswego grew from a hamlet to a small city, we were obliged to make a substantial investment at the plant there to eliminate the dust from the stack. This was done at a cost of approximately $1,500,000. We are now collecting in excess of 99½ percent of all dust which would otherwise go up the stack. We are more than meeting the requirements of the State Air Pollution Authority. We check our stack regularly and frequently to see that this collection efficiency is maintained. We were fortunate in finding a ready market for the material so collected, and last year sold in excess of 25,000 tons, which was collected through our electric precipitators. It is used largely by manufacturers of asphalt roofing as a filler.

A Local Company

The Oregon Portland Cement Co. is the only locally owned and operated cement company in the Pacific Northwest. The present Board of Directors is made up of the following men: Ralph H. Cake, Arthur H. Fields, David H. Leche, Lawrence F. Newlands, Prescott W. Cookingham, Hillman Lueddemann, C.B. Stephenson, Kenneth T. Shipley, and F.E. McCaslin. All of the company's expenditures for payrolls, local purchases of fuel and supplies of all kinds, dividends distributed to stockholders, etc., find their way directly into local commercial channels.

Our payrolls, during the year 1963, amounted to $2,769,808.11. Other local expenditures, including supplies, fuel and power, amounted to $2,404,043.31. These two items totalled $5,173,851.42. Total dividends paid out during 1963 were $563,708.10. Eighty percent of our stockholders reside in Oregon, resulting in an additional amount of $450,966.48 going into local business channels. Further, if any profits are made, a substantial amount of these are plowed back into new construction, as noted earlier.

Long-Range Prospects

We consider that both the short- and the long-range prospects for the cement industry in the Pacific Northwest are favorable. The area appears to be on the threshold of rapid growth. The nation is now becoming more aware of the opportunities existing in this part of the country.

In the construction field, many large buildings and projects are planned for construction in the near future. In the current category of construction, one might mention several buildings, such as: the Urban Renewal Development at an estimated cost of $56,000,000 now under way; the Equitable Savings & Loan Assn. Building now approaching completion; the multi-million-dollar Coliseum Gardens, high-rise apartments and shopping center; Somerset West -- 1,000 new houses per year projected for 10 or 12 years; the Federal Office Building; the Bank of California Building; and the Georgia-Pacific Building, as well as others which will change the downtown skyline.

In the category of other major projects, we could mention such jobs as the following. Some of these contracts were awarded in 1964 and the others will be within a two-year period. These projects are:

Project Name	No. of Barrels
Little Goose Dam	800,000
Hells Canyon Main Dam (spring, 1965)	900,000
Blue River Dam	100,000
Lower Granite Dam	500,000
Dworshak Dam (Bruce's Eddy)	2,500,000
High Mountain Sheep Dam	1,000,000
Hells Canyon (fishways & tunnel)	47,000
Lower Monumental Dam, 2nd section	600,000
Mossyrock Dam	600,000
Foster Dam	90,000

Although these projects bring many millions of dollars into the economy of the area, we don't wish to leave the impression that we rely too heavily on jobs of this type. Large jobs such as these are in addition to our regular day-to-day commercial business. We serve approximately 75 ready-mix plants and many dealers in our area, the largest of which uses more than 200,000 barrels annually.

We look forward to a bright future for the Pacific Northwest and plan to grow with it. It is one of the least exploited areas in the nation. The Director of Business Research of the Pacific Northwest Bell Telephone Co. has recently compiled a rather exhaustive report on trends in population and households for the period of 1960 to 1975, for the Pacific Northwest states. This report shows that the population of Oregon will increase 19.06

percent between 1960 and 1970. In the next five years it will increase another 9.8 percent. For the State of Washington, the increase between 1960 and 1970 is similar to that of Oregon, 19.17 percent, and for 1970 to 1975 another 11.7 percent.

The Pacific Northwest is abundant in natural resources. Aside from its vast lumber and wood products industry, Oregon is rapidly obtaining a large and diversified industrial complex without major government installations.

Our significant advantages in natural resources, climatic conditions, plentiful hydroelectric power at desirable rates, favorable labor market, and excellent cultural, educational, and recreational facilities -- together with an unlimited supply of the purest water in the nation -- are certain to continue to attract industry and population, both of which strengthen and build our economy. We look forward to another 50 years of operation with renewed inspiration, optimism, and confidence.

Acknowledgments

No history of the Oregon Portland Cement Co., even though very brief, would be complete without giving credit to a few men who have devoted many years to the company advancement. First, I would mention L.C. Newlands, who served as chief executive officer from 1915 to 1942. His son, Lawrence F. Newlands, is now secretary and treasurer of the company. David H. Leche joined the company in 1916 and served as general superintendent at both Oswego and Lime for many years, but in more recent time has been first vice president and in charge of operations, and has supervised new construction and expansion. Another man who joined the company about the time we started at Oswego was H.R. Shipley. He advanced to the position of general superintendent of all our operations, which position he held until his death about a year ago. His son, Kenneth T. Shipley, is now vice president in charge of sales.

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SCIENTIFIC SOCIETIES TO MEET IN PORTLAND

The Oregon Academy of Sciences and the Northwest Scientific Association will hold a joint meeting at the Sheraton Hotel in Portland April 9 and 10, 1965. The eight sections at which papers will be presented include Botany-Zoology, Chemistry-Physics-Mathematics, Engineering, Forestry, Geology-Geography, Science Education, Social Sciences, and Soil and Water Conservation. Details of the program will be announced later.

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ALBANY-NEWPORT AREA AEROMAGNETIC MAP PUBLISHED

U.S. Geological Survey map, Geophysical Investigations 481, was published this month. The map is entitled "Aeromagnetic map of the Albany-Newport area, Oregon and its geologic interpretation" by R.W.Bromery.

The survey was made in 1954 to assist with the state geologic mapping project. The map covers an area of 1,200 square miles. Thirty-four east-west traverses were flown, one-half mile apart and approximately 750 feet above the ground.

A preliminary aeromagnetic map of the Albany-Newport survey was released to open file in February 1962 by the U.S. Geological Survey. The preliminary map and accompanying text have been revised in the recent publication. Maps are available from the Geological Survey office at Federal Center, Denver, Colo., 80225. The price has not yet been announced.

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COAL STUDY IN OPEN FILE

"The Correlation of Coal Beds in Squaw Basin and Part of Eden Ridge, T. 33 S., R. 11 W., Southwestern Oregon," by Russel G. Wayland, has recently been made available by the U.S. Geological Survey as an open-file report. Included in the 34-page record are cross sections, correlation diagrams, logs of holes, coal analyses, and a geologic map.

The open-file report is not intended for future publication. Its purpose is to present new information in order to resolve a conflict in correlation of Squaw Basin and Eden Ridge coal beds dating back to 1914. New core-hole data, photogeologic interpretation, and a broader understanding of the stratigraphy of the area have allowed reinterpretation of the distribution and relative position of the coal beds.

The coal occurs in the Tyee Formation of middle Eocene age. Typical Tyee consists of sandstone units 2 to 10 feet thick that grade upward into carbonaceous siltstone. In the map area, carbonaceous shales and coal partings occur at the tops of most graded units of the Tyee.

It was determined that any land in the township (T. 33 S., R. 11 W.) underlain by the Tyee Formation may contain coal and that local coal zones exist at many levels in the stratigraphic section. More drilling for coal was believed warranted.

The report may be consulted at the Department's office in Portland and at its branch office in Grants Pass. Copies from which reproductions can be made at private expense are available at 1031 Bartlett Bldg., 215 West 7th St., Los Angeles, Calif.

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LUNAR CONFERENCE SCHEDULED

Distinguished volcanologists from throughout the world are being invited to an International Lunar Geological Field Conference in the Bend, Oregon area August 22-28, 1965, Governor Mark Hatfield announced in a press release February 5.

The conference is under the joint sponsorship of the University of Oregon Department of Geology and the New York Academy of Science. It is an extension of a symposium on lunar geology held by the New York Academy last year. The program includes a one-day symposium at Bend for the presentation of technical papers, and five days of field tours to geological interest points in the central Oregon area. Internationally known scientific authorities from a dozen countries, including Russia, Japan, Norway, and West Germany are expected to attend.

The conference will focus worldwide attention on the central Oregon area and its potential for lunar base research. Increasing interest is being shown in the area because of last summer's "Astronaut Walks" and astronaut geological field training, as well as several small private research projects.

Because of the combination of volcanological features in the area, some authorities believe it is ideally suited for the development and testing of lunar base facilities and equipment that will be needed in connection with the lunar and space exploration programs.

Conference co-chairmen are Dr. Lloyd Staples, head of the University of Oregon Department of Geology, and Dr. Jack Green, New York Academy of Science. Other members of the general committee are Hollis M. Dole, Oregon State Geologist; Marion Cady, secretary, Lunar Base Research Facilities, Inc., Bend; and Lawrence Dinneen, deputy administrator, Division of Planning and Development, Oregon Department of Commerce.

Financial support to make the conference possible has been committed by a number of Oregon firms and organizations. Supporting sponsors include Pacific Northwest Bell, First National Bank of Oregon, U.S. National Bank of Oregon, Pacific Power & Light Co., Tektronix Foundation, Battelle Memorial Institute, Pacific Trailways, and Bend-Portland Truck Service.

Cooperating State agencies include the Division of Planning and Development of the Department of Commerce, the Department of Geology and Mineral Industries, and the Highway Department.

The schedule of field trips includes visits to inspect lava flows, volcanic terrain and other volcanological features at Mt. Bachelor-Three Sisters area, Newberry Crater, Lava Butte, Devils Hill, Lava River Cave, Belknap Crater, Devils Garden, Derrick Cave, Fort Rock, and Crater Lake.

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THE AGE OF CLEAR LAKE, OREGON

By G. T. Benson*

Clear Lake, in Linn County, is located at the head of the McKenzie River, about seven miles west of the crest of the Cascade Range between Santiam and McKenzie Passes (see accompanying map). The lake, which is close to U.S. Highway 126, is noted for its drowned forest; tall trees still standing on the lake bottom are easily seen in the cold, clear water.

The lake was formed when a lava flow poured into the upper McKenzie Valley, damming the river and ponding its water. The lava came from one of the vents marked by the Sand Mountain line of craters (Williams, 1957). This basalt flow is part of the group of young volcanic rocks in the Santiam-McKenzie Pass area shown on the map. That this volcanism occurred a geologically short time ago is evident from the lack of soil and vegetation on the flows.

The dramatic sight of miles of bare, jumbled lava at McKenzie Pass (see photograph) has long caught the fancy of motorists. To increase the benefit of the area to the public, the U.S. Forest Service is preparing exhibits explaining the geology in the vicinity of Dee Wright Observatory at the Pass. In the course of planning the Forest Service project, the question of the absolute age of the flows at McKenzie Pass was raised. It was apparent that an answer might be obtained from radiocarbon dating.

Carbon-14, a radioactive carbon isotope with a half-life of about 5,570 years, is produced continuously in the atmosphere by cosmic-ray bombardment. The rates of production and decay result in an equilibrium concentration of radiocarbon, or, stated differently, in an equilibrium ratio between radiocarbon and non-radiogenic carbon. Carbon in living tissue is constantly replaced, so that radiocarbon and non-radiogenic carbon are present in the equilibrium ratio. When the tissue dies, however, replacement ceases, and the ratio changes as the radiocarbon atoms decay. The difference between the ratio in dead tissue and the ratio in living tissue is a measure of how long ago the former died. In practice, the date of death of once-living tissue can be determined with adequate accuracy back to about 40,000 years before present (y. b. p.).

Charcoal from trees burned by the hot lava at McKenzie Pass could be used to date the flows. Several searches were made, but no charcoal that could be attributed definitely to burning by lava was found either in the

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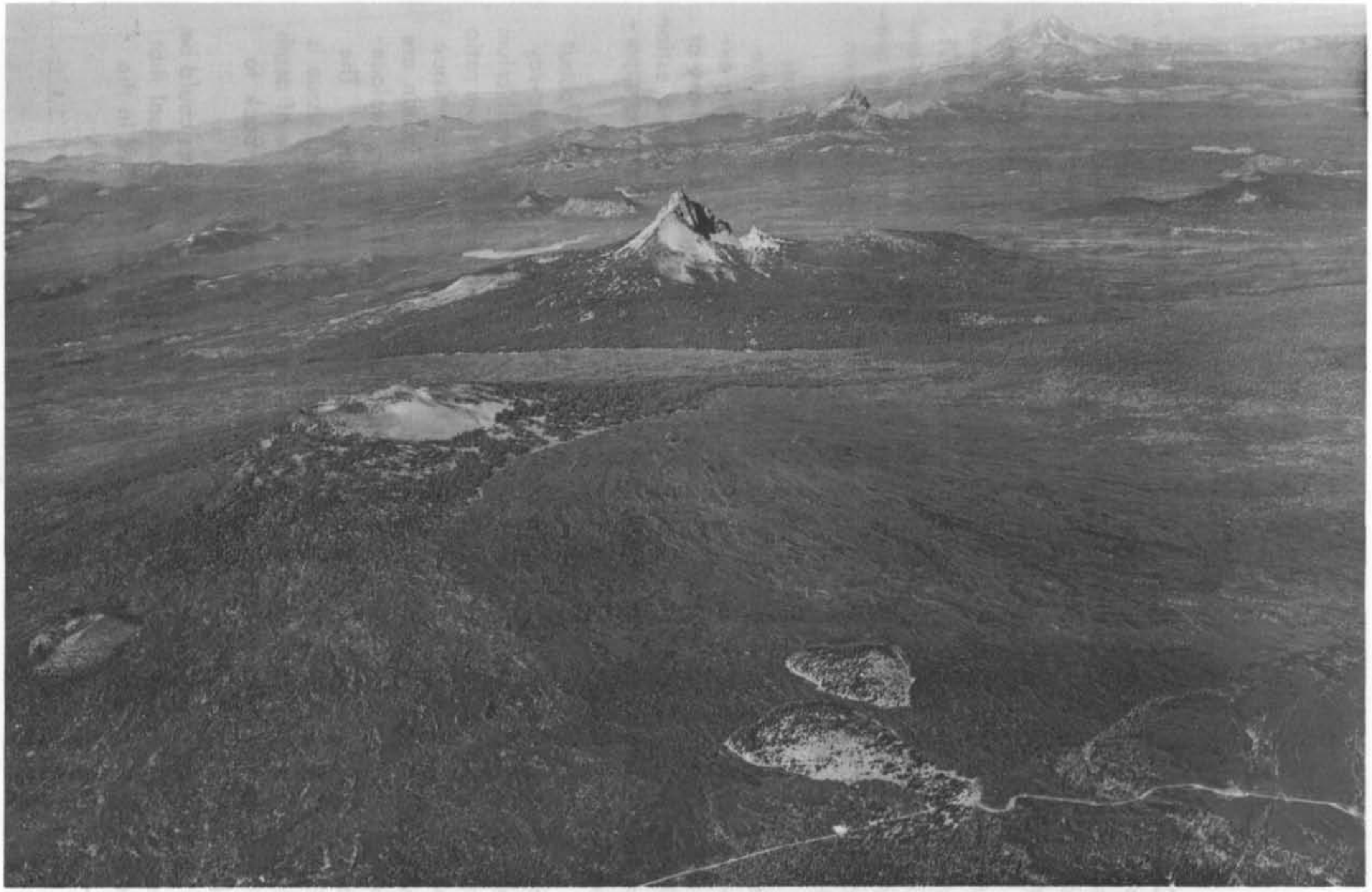
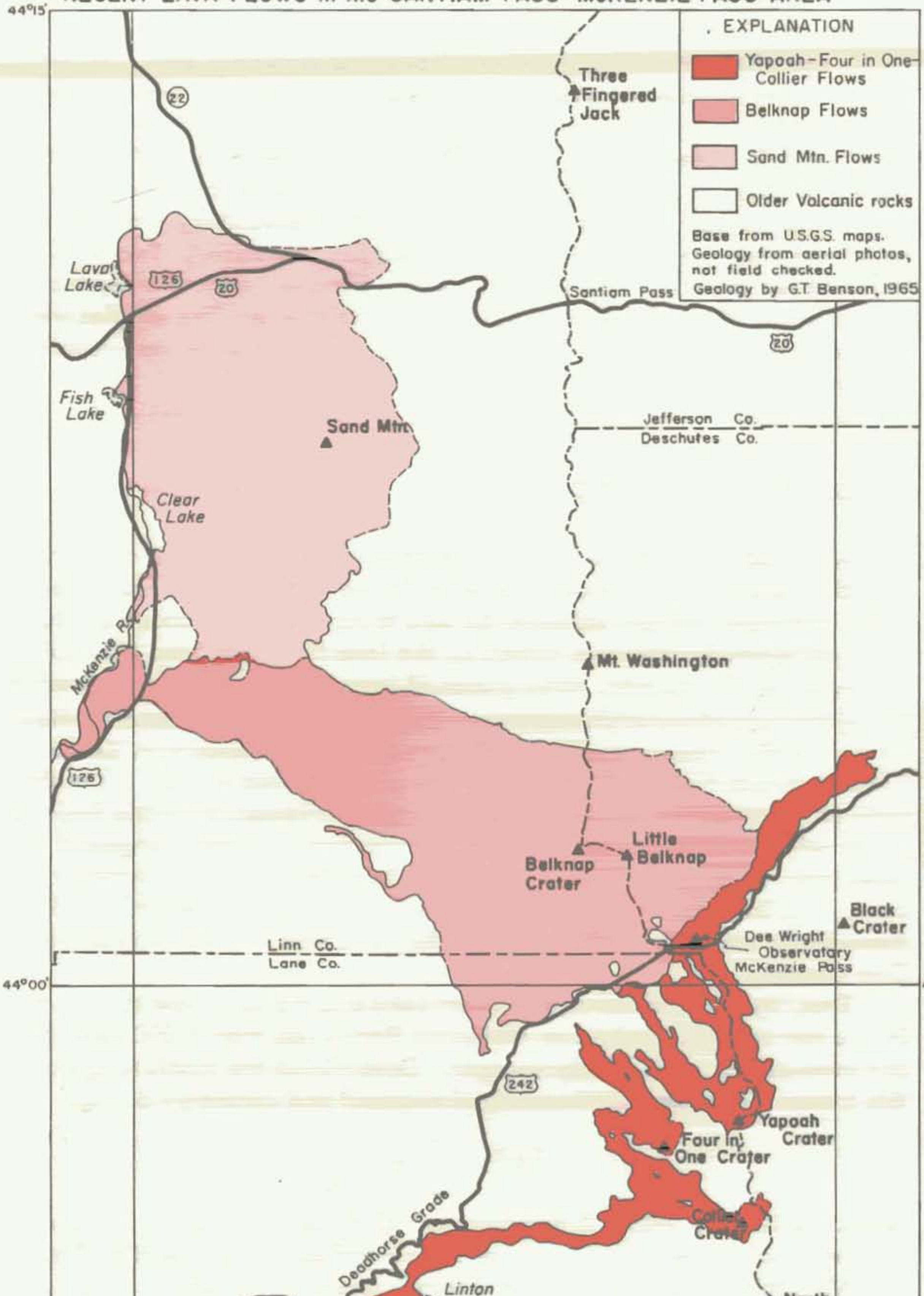


Aerial view of McKenzie Pass looking north toward Mt. Washington, Three Fingered Jack, and Mt. Jefferson. Belknap Craters and lava flows in foreground. (Courtesy of Delano Photographics)

RECENT LAVA FLOWS in the SANTIAM PASS-McKENZIE PASS AREA



flows from the Belknap Craters or in the flow from Yapoah Crater, upon which Dee Wright Observatory is located. A direct answer to the question of absolute age of the McKenzie Pass Lava flows must await the discovery of charcoal; but an indirect answer could be obtained from the trees in Clear Lake.

The U.S. Forest Service arranged to have members of the Whitewater Divers, a group of skin divers from Eugene, take samples of the drowned trees. Several sections of trees were obtained in November, 1963, in what must have been one of the first aqualung logging operations. Two samples from one section of a tree about one foot in diameter taken at a depth of about 13 feet below the surface were chosen for dating. The samples were analyzed by Isotopes, Inc., of Woodlawn, N.J., and dates were reported as follows:

Sample a	3,200 ± 220 y. b. p.	sample from center of tree section
Sample b	2,705 ± 200 y. b. p.	sample from outer part of tree section

The two dates appear to be in adequate agreement. Part of the differences should be due to locations of the samples in the tree section. From these dates, the trees in Clear Lake can be said to have drowned about 3,000 years ago when the lake was formed by the lava flow from Sand Mountain.

As shown on the map, three groups of lava flows have been delineated through the use of aerial photographs. The oldest is the Sand Mountain flow, which we now know is about 3,000 years old. Lava flows from Belknap Crater lap onto flows from Sand Mountain, and thus are younger. On the basis of superposition and lack of vegetation, the lavas from Little Belknap Crater which are so conspicuous at McKenzie Pass, are the youngest of the flows from the Belknap Craters. But even these lavas are not the most recent. The Dee Wright flow from Yapoah Crater overlaps the Little Belknap flows and is therefore younger, as are the flows from Collier and Four-In-One Craters.

Thus, by knowing the age of Clear Lake and the lava flow that formed it, we can say that the lava at McKenzie Pass is less than 3,000 years old, and some of it is considerably younger. Determining the absolute age of this freshest lava requires discovery of charcoal and carbon-14 dating.

Reference

Williams, Howel, 1957, A geologic map of the Bend quadrangle and a reconnaissance geologic map of the central portion of the High Cascade Mountains: Oregon Dept. of Geology and Mineral Industries map.

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OREGON'S LOST METEORITES

By Dr. Erwin F. Lange*

Oregon's Port Orford meteorite has gained worldwide fame as a lost meteorite. Interest in the search for this meteorite has now extended over a period of a hundred years without success. In addition to the Port Orford meteorite, there is evidence that other lost meteorites exist in Oregon. The writer has received a number of letters from various places in Oregon referring to locations of supposed meteorites. To date, however, no samples have been received. The following three examples seem to be more authentic and perhaps more information concerning these specimens might be forthcoming.

1. In Pioneer History of Coos and Curry Counties, by Orvil Dodge, p. 442, is the following:

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

2. Listed as a doubtful fall in the Prior-Hey catalog of meteorites published by the British museum is a stony meteorite from Mulino, Oregon. A small stony meteorite was sent to the U.S. National Museum in 1927. The meteorite supposedly fell May 4, 1927. The records of the National Museum fail to indicate what happened to the specimen. Newspapers of the area fail to list any unusual meteoritic activity for that date.

3. In January, 1952, an unidentified rancher brought in to J. D. Howard of Klamath Falls a small pice of nickel-iron for analysis. This piece was broken off of a 30-pound mass.

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Mr. Howard, suspecting the specimen to be meteoritic, forwarded it to Dr. H.H. Nininger at Winslow, Arizona for verification. Dr. Nininger found it to be a meteorite. He then attempted to learn the location of the main mass, but so far has been unsuccessful. The small piece of the so-called Klamath Falls meteorite is in the Nininger collection at Arizona State University in Tempe. Somewhere in the Klamath Falls area there must be a 30-pound meteorite.

Persons having specimens thought to be meteoritic in nature are urged to send them to the State Department of Geology and Mineral Industries or to the writer for examination. A meteorite has value as an object of scientific value only and every one is different in form and composition.

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DALLAS-VALSETZ BULLETIN REVISED

"Geology of the Dallas and Valsetz Quadrangles, Oregon," by Ewart M. Baldwin, published originally in 1948 as Department Bulletin 35 and long out of print, has been revised and is now available in a new edition.

The Dallas and Valsetz quadrangles lie along the eastern slope of the Coast Range and western edge of the Willamette Valley. The area is underlain by a thick sequence of marine volcanic and sedimentary rocks, ranging in age from early to late Eocene, intruded by gabbro and diorite sills and dikes. Impure limestone at one stratigraphic horizon occurs as isolated deposits of varying sizes.

The Department's decision to revise the text and geologic map of Bulletin 35 was based on several factors, namely, easier accessibility into the area than in 1946-47 when it was first mapped; better understanding of the stratigraphy of the Coast Range after 16 years of field mapping by the U.S. Geological Survey and this Department; and lastly, an increased demand for information on the Coast Range as an aid to interpretation of the geology of the Willamette Valley and the continental shelf. The author, Dr. Baldwin, professor of geology at the University of Oregon, who did the original work in the Dallas and Valsetz quadrangles as a member of this Department, has, in the past 20 years, mapped or cooperated in the mapping of approximately 4,000 square miles in the Coast Range of Oregon. The revised edition of these two quadrangles embodies the knowledge he has gained over the years.

Bulletin 35, revised, may be obtained from the Department's Portland office. The price is $3.00.

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OFFSHORE MINING BILL INTRODUCED

Senator E.D. (Debbs) Potts, Josephine County, announced in a press release February 18 that he was introducing a bill to authorize the leasing of the state's submerged lands for mining. Senator Potts stated that the placer minerals gold, platinum, chromite, magnetite, ilmenite, garnet, and zircon have been found on modern beaches and in adjacent marine terraces since shortly after gold was first found on Josephine Creek, a tributary of the Illinois River in Josephine County in 1850, and that there is every reason to believe these minerals occur in untapped commercial quantities beyond the water's edge.

The bill, Potts explained, would place the responsibility of leasing in the hands of the Land Board and all revenues obtained by the board would go to the Common School Fund. Before leasing, the board must find and determine that offshore exploration and mining on a lease would not be inconsistent with the public interest. In making the determination, consultation must be had with other state agencies, including the State Geologist, Highway Engineer, Game Commission, and Fish Commission. Maximum size of individual lease blocks would be 5,760 acres (3 miles by 3 miles). The first two years of the lease would be considered a prospecting period and the board would prescribe the minimum amount of work that must be done in this period. The primary term of the lease would be 10 years, but would continue in effect up to 50 years, so long as minerals were produced in commercial quantities. The rental and royalty charges for the various minerals would be set by the board and would be subject to adjustment at the end of each 20-year period. On areas that are not known to contain minerals, leases would be granted to a qualified person upon application, and on areas known to contain mineral the board would call for sealed bids after a public hearing.

Potts said that specific onshore areas near the ocean which have been mined in the past are Gold Beach, Pistol River, Ophir, Port Orford, Cape Blanco, Bandon, Old Randolph, Whisky Run, and South Slough, all in Coos and Curry Counties. He said that, although there is no record of production for the pioneer period, indications show it could have been substantial. For instance, one report gives the production from Whisky Run as "more than $100,000" during the 1850's-60's. During World War II, Potts stated, the beaches and terraces south of Coos Bay were mined for chromite. It was from the mineral zircon found in these beach sands that the Kroll process for production of the space-age metals, zirconium and hafnium, was perfected at the U.S. Bureau of Mines research center in Albany. The first atomic submarine, Nautilus, utilized these Oregon-produced metals in its nuclear reactor, plumbing, and utensils.

In recent years, Potts noted, a little mining has been done adjacent to the beaches but, mainly, man has looked wistfully toward the sea wondering if the waters of the ocean cover deposits as rich as those the pioneers worked a hundred years ago on land. Dr. John V. Byrne, Department of Oceanography, Oregon State University, answered this question satisfactorily in the April, 1964 issue of The ORE BIN, and concluded by saying:

> "It is inevitable that the known commercial mineral resources on land will be expended and new deposits must be found to take their places. The day will certainly come when the mineral prospector will be forced to look to the sea for ore deposits. In all likelihood the sea will be exploited successfully long before that day arrives. Advancing technology is bringing us closer to the time when those with initiative and imagination will turn to the sea simply because it is easier to make a profit there than on land. That day may not be far away. In fact - it may be at hand."

Senator Potts remarked that, although Dr. Byrne had indicated placer minerals would be the most likely material to be sought, there was a possibility that the mineral glauconite (a potential source of potash), phosphorite (a potential source of phosphate fertilizer), and even manganese (an essential alloying material for the making of steel) might be found in commercial quantities off the shore of Oregon. Potts stated that passage of this bill would be consistent with the research work at the new Oceanographic Laboratory at Newport and could well restore to its former importance the now depressed mining industry of southwestern Oregon. In addition to supporting research and broadening the state's economic base through increased mining activity, Potts stated, the possible revenues that might accrue to the Common School Fund should not be overlooked.

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SOUTHWEST OREGON GRAVITY DATA AVAILABLE

The U.S. Geological Survey has released for consultation gravity data for southwest Oregon by Richard H. Blank, Jr. consisting of 63 computer printout sheets and one map on a scale of 1:250,000. This report is available for inspection at the Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon. Copies from which reproductions can be made at private expense are available at 504 Custom House, San Francisco, California.

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The ORE BIN
Volume 27, No. 3
March, 1965

OREGON'S ASBESTOS POTENTIAL

By

James H. Bright* and Len Ramp**

Introduction

Asbestos is an essential industrial mineral for which the United States does not have an adequate domestic source. Although this nation is one of the largest users of asbestos in the world, it produced only 66,600 tons in 1963, or less than 10 percent of the domestic consumption. World production of asbestos is shown in Table 1. The principal source of asbestos imported into the United States is Canada, which has been the world's leading supplier for many years. Production of asbestos in the United States has been growing, however, and nearly doubled the 1963 figure to 100,000 tons in 1964, according to U.S. Bureau of Mines preliminary estimates. The increase is due to recent developments in California, which now outranks Vermont in being the leading asbestos producer in the United States.

Certain grades of asbestos are indispensable to our transportation and construction industries, and all grades occupy an important place in our economy. The lack of adequate production, therefore, creates an opportunity for domestic mining if ore bodies can be found. The authors of this article are particularly interested in the development of asbestos in Oregon in sufficient quantity and quality to create a local asbestos industry.

Asbestos Minerals

The term "asbestos" is applied to a group of naturally fibrous, non-combustible minerals. These minerals differ in chemical composition and in the strength, flexibility, and usefulness of their fibers. The physical and chemical properties of asbestos fibers are compared in Table 2. Asbestos

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* Regional Manager, Asbestos Corp. (Explorations), Ltd., Canada.
** Staff Geologist, Oregon Dept. of Geology and Mineral Industries.

TABLE 1. World Production of Asbestos (thousands of short tons)
(Figures from U.S. Bureau of Mines Minerals Yearbook, 1963)

Country	1954-58 average	1959	1960	1961	1962	1963
Canada (sales)	995	1,050	1,118	1,174	1,216	1,272
USSR (estimate)	475	600	660	880	1,100	1,200
Republic of South Africa	140	182	176	195	221	206
Southern Rhodesia	113	120	134	162	142	142
China (estimate)	33	90	90	100	100	110
United States	44	45	45	53	53	67
Italy	37	53	61	63	61	63
Swaziland	30	25	32	31	33	33
France	16	23	29	31	28	26
Cyprus	16	14	23	16	22	22
Australia	10	18	16	17	18	15
Japan	1	14	17	19	15	18
Finland	9	10	11	10	11	10
Other countries*	21	17	28	19	35	16

* Includes small production in about 20 other countries, in part estimated.

minerals fall into two general categories - chrysotile and amphibole. Because of the importance of chrysotile and of its relative abundance in areas of serpentine, it is the main subject of this report.

Chrysotile

Chrysotile, a hydrous magnesium silicate ($3MgO.2SiO_2.2H_2O$), is an essential mineral of serpentine and usually occurs in veinlets. Its fibers are strong and very flexible, making it the most valuable of the asbestos minerals. About 95 percent of the world's asbestos production comes from chrysotile, most of it from Canadian deposits. In the United States, chrysotile asbestos occurs in the serpentinized peridotites of Vermont, California, and Oregon; and in serpentinized dolomitic limestones of Arizona.

Chrysotile occurs most commonly as cross-fiber veins, ranging in thickness (fiber length) from microscopic size to 3/8 inch or more, with the parallel fibers approximately perpendicular to the vein walls. The mineral is gray to pale green in the rock, but separates into white fibers that form a a fluffy mass. The basic crystal structure of chrysotile is a cylindrical lattice. Its tubular character has been established by electron microscopy. Chrysotile fibers of good quality are silky, highly flexible, and have a tensile strength 10 times that of nylon. Some fibers are naturally harsh,

TABLE 2. Properties of Asbestos Minerals (modified after Rice [1957]).

	Chrysotile	Tremolite	Crocidolite	Amosite	Anthophyllite
Color	Green, greenish-yellow, gray, or white.	White, grayish-white, greenish-yellow, or bluish gray.	Lavender, blue, or greenish.	Ash-gray, greenish, or brown.	Grayish-white, brownish-gray, or green.
Texture	Soft to harsh, silky.	Generally harsh, some soft.	Soft to harsh.	Coarse, but somewhat pliable.	Harsh
Mineral Association	In serpentine, magnetite, antigorite, picrolite, etc.	In serpentine, Mg. limestones and various metamorphic rocks.	Iron-rich siliceous argillite in quartzose schists.	In crystalline schists, etc.	In crystalline schists, gneisses, or metaserpentine.
Veining and fiber length	Cross and slip fibers; short to long.	Slip or mass fiber; rarely cross fiber; short to long.	Cross fiber; short to long.	Cross fiber; mostly long.	Mass or slip fiber, rarely cross fiber; short.
Tensile strength lb/sq in.	80,000 to 100,000.	8,000 or less.	100,000 to 300,000.	16,000 to 90,000.	4,000 or less.
Flexibility	Very flexible.	Fairly flexible to brittle.	Flexible.	Flexible.	Mostly brittle.
Spinnability	Very good.	Generally poor; rarely spinnable.	Fair.	Fair.	Very poor.
Fusibility	Fusible at 6.	Fusible at 4.	Fusible at 3.	Fusible at 6.	Infusible or difficultly fusible.
Acid resistance	Poor.	Good.	Good.	Good.	Very good.

which reduces their flexibility and strength. A simple test for flexibility is to hold a bundle of fibers between the fingers and twist or rotate it. Weak fibers will break readily under this twisting; harsh fibers will tend to spring back when bent the first time. Fibers that lie approximately parallel to the vein are called slip-fiber veins. Such veins lie along faults or slip planes. This fiber, although longer, is weaker than most of the cross fiber.

A mineral sometimes mistaken for chrysotile is picrolite. This vein-like serpentine mineral commonly occurs near chrysotile veins. It is a splintery, semifibrous variety of serpentine that will not fluff when scratched with a knife. It is usually necessary to scratch a vein in order to tell chrysotile from picrolite.

Amphibole

The amphibole group of asbestos minerals includes tremolite, crocidolite, amosite, and anthophyllite (see Table 2). Tremolite and anthophyllite are the only amphibole asbestos minerals found in Oregon. Tremolite ($2CaO.5MgO.8SiO_2.H_2O$), the most common of the amphibole asbestos minerals, generally occurs in narrow veins in fault zones in or adjacent to serpentine. Actinolite, a variation of tremolite containing iron, is usually found with it. In comparison to chrysotile, the fibers of tremolite are coarser and weaker and are easily broken when flexed between the fingers. World production of tremolite is less than $\frac{1}{4}$ of 1 percent of the total asbestos production. Anthophyllite ($[Mg,Fe]SiO_2$) occurs in schists, gneisses, and metaserpentine. Its fibers have the lowest tensile strength and are the most brittle of asbestos minerals.

Crocidolite and amosite are important amphibole asbestos minerals, but no commercial deposits occur in North America. The principal source of crocidolite is South Africa, with lesser amounts coming from Australia and Bolivia. Amosite is produced only from South Africa.

Uses of Asbestos

Chrysotile can be separated by mechanical means into fibers which contribute desirable characteristics to industrial products. Some of these qualities are chemical inertness, resistance to corrosion, good thermal and electrical insulation, and good bonding with portland cement, in addition to high tensile strength. The long fibers (more than 3/8 inch) go into the making of fire-resistant textiles.

The medium-length fibers (ranging from 1/16 inch to 3/8 inch) are used in cement pipe, cement sheets, roofing paper, gaskets, molded brake bands, clutch facings, instrument panels, some molding compounds, and lagging. For industrial construction, asbestos cement products have been universally accepted; as a result, cement-length fibers are at present the main product of the asbestos industry.

In Europe today 60 percent of the pipe used in construction is made of asbestos cement. In Sydney, Australia, more than half of the houses are of asbestos-cement construction using sheets inside and out, and corrugated material on the roof.

In damp climates, such as the coastal areas of Oregon, construction with asbestos cement results in superior resistance to weathering and minimizes maintenance problems.

The shorter fibers, or lengths under 1/16 inch, are used in floor tile, paint, plastics, joint cement, asphaltic compounds, roofing shingles, road paving, and drilling mud.

Tremolite and anthophyllite asbestos have limited application because of the low strength of their fibers. They are, however, used as fillers in various products, welding rod coatings, and acid-resistant filters.

Origin of Chrysotile Asbestos

Serpentine minerals are formed from two general rock types: peridotites and dolomites or magnesia-bearing limestones. It is generally accepted that serpentinization is caused by hydrothermal solutions which alter these rocks, adding water and perhaps some magnesia, silica, and other elements.

Mineralogists Faust and Fahey (1962) in their study of serpentine group minerals recognize only three: namely, chrysotile, lizardite, and antigorite. Other serpentine minerals, such as deweylite, bastite, and picrolite are variations or combinations of these recognized minerals. Serpentine minerals have essentially the same chemical composition and differ only in internal structure and to some extent in outward physical appearance.

It is not well understood what causes abundant cross-fiber veinlets of chrysotile to form in serpentine and various theories have been advanced. Since good deposits of chrysotile are not common, it seems reasonable to assume that the environment in which they formed involved fairly critical physical and perhaps chemical conditions. Time could also be an important factor. In other words, it may be that the temperature, pressure, and chemical balance must be held within certain critical limits for a sufficient time to enable the chrysotile fibers (crystals) to grow.

Shearing stresses set up by folding and faulting are believed by some to be a contributing factor in localizing the deposition of chrysotile. Bateman (1954, p. 293) discusses the occurrence of horizontal layers of serpentine with horizontal cross-fiber chrysotile veins in dolomitic limestone in Arizona. He argues that neither fissure filling nor the force of growing crystals can explain the presence of chrysotile veins, because of the enormous weight of the overlying rocks and the fact that the beds above and below the serpentine layers are undisturbed. Bateman further states: "The most tenable explanation is that certain bands of limestone were converted to serpentine by circulatory solutions and that some slight change in the character of the solutions caused the serpentine to undergo molecular rearrangement into fibrous form. May not the same hypothesis apply to the peridotite occurrences...?"

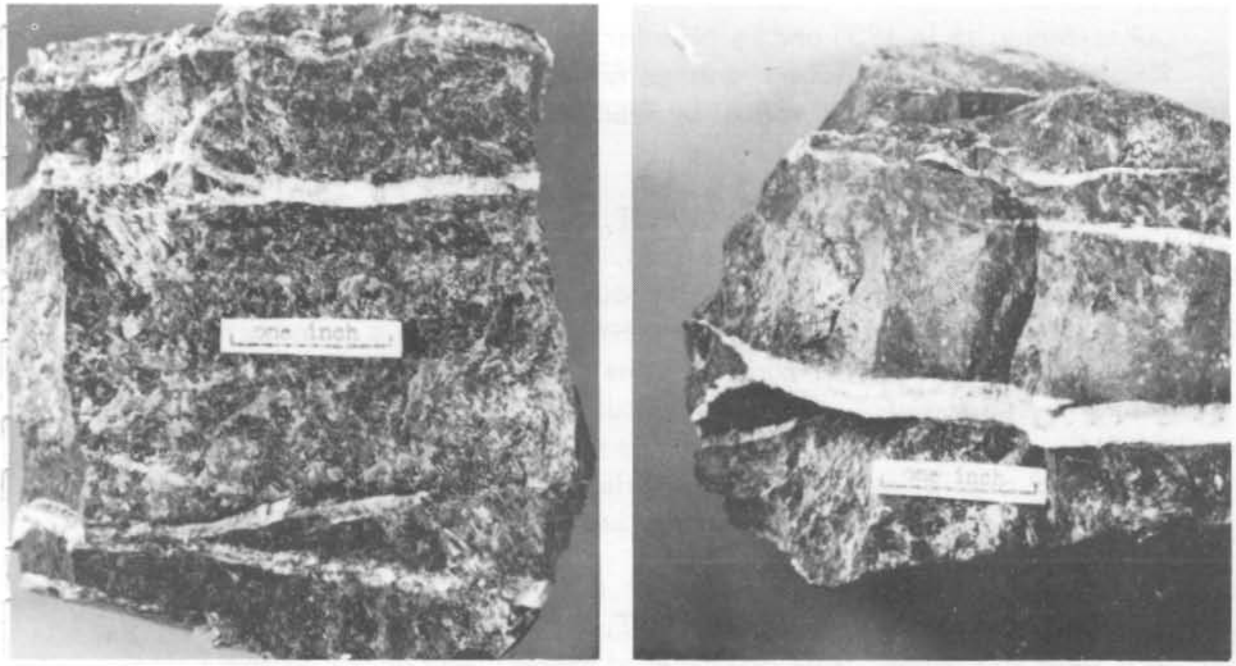
Asbestos Occurrences in Oregon

Southwestern and northeastern Oregon contain many scattered areas of peridotite and serpentine. The distribution of these "ultramafic rocks," as they are often called, is shown on the accompanying maps. The peridotite, an intrusive igneous rock composed largely of olivine and pyroxenes, has been partly (in some areas completely) altered to serpentine. In most outcrops peridotite and serpentine are intermixed. Chrysotile, being one of the serpentine minerals, is of course always present in serpentine. If it occurs in veins of sufficient size and abundance, it may constitute a rich ore body. Tremolite, an amphibole asbestos mineral, also occurs in areas of serpentine, generally in narrow, isolated veins.

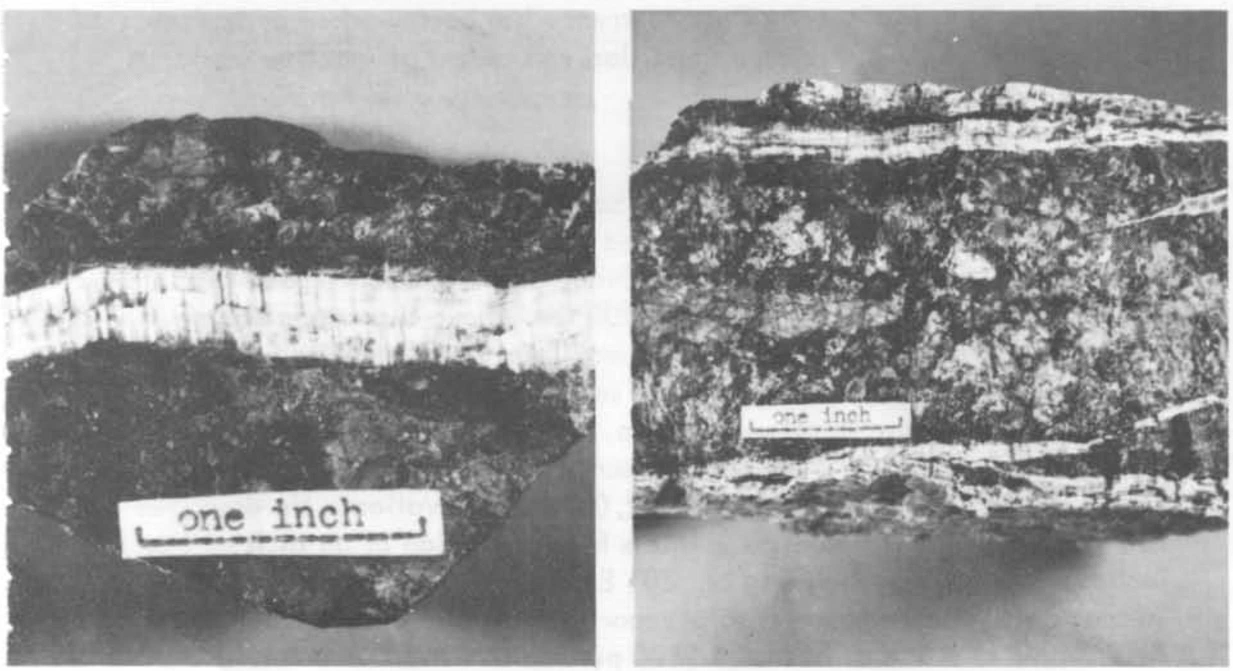
The known asbestos deposits in Oregon are small. Production to date has been limited to a few shipments of hand-sorted tremolite from the Liberty Asbestos in Jackson County and the L.E.J. occurrence in Josephine County; and 525 short tons of milled chrysotile from the Coast Asbestos Co. pilot plant near Mt. Vernon in Grant County (Wagner, 1963). The location of the asbestos mines and prospects is shown on the accompanying map. A brief description of each occurrence is given below.

Southwestern Oregon

C-1 Foster Asbestos (Bear placer): Secs. 35, 36, T. 38 S., R. 9 W., Josephine County. This is the best-known chrysotile occurrence in southwestern Oregon. It is situated on the west bank of Josephine Creek between Days and Fiddler Gulches. Chrysotile was discovered by George Foster while he was drift-placer mining along the surface of serpentine bedrock which underlies a cover of cemented Pleistocene bench gravel as much as 100 feet thick. Cross-fiber chrysotile veinlets are of good quality, but rarely exceed 3/8 inch thickness with partings and are more commonly about 1/8 inch thick. Fiber occurs in both the north and south placer drifts, which are about 900 feet apart. The deposit was explored and drilled by Canadian



Cross-fibre chrysotile veinlets in serpentine from the Foster asbestos deposit near Josephine Creek. Samples were selected from the dump of the southern adit.



Johns-Manville in 1953 and by Nicolet Asbestos Mines, Ltd. in 1960. Results indicated insufficient tonnage to justify further development. The placer is currently being worked by Fred Von Rohder.

A-1 L.E.J. Asbestos: Sec. 9, T. 37 S., R. 6 W., Josephine County. This tremolite claim, held by location, is situated at about 1,200 feet elevation on the southwest side of Bolt Mountain about 6 miles southwest of Grants Pass. Slip fiber of varying quality was found in a main northeast-trending fracture or sheer zone 4 inches to 2 feet thick in serpentine. The tremolite is associated with talc. About 3 tons of hand-sorted fiber was reportedly shipped in bags in 1952. The workings consist of an open cut and trench not over 35 feet deep. The wider fiber-bearing zone pinched down where mining stopped. No new work has been done.

A-2 Liberty Asbestos: Sec. 36, T. 32 S., R. 4 W., Jackson County. This tremolite deposit is on 640 acres of deeded land on the southern flank of Cedar Springs Mountain at 4,500 feet elevation. Treasher (Oregon Dept. of Geology and Mineral Ind., 1943) describes the occurrence as containing some good quality tremolite fiber in several parallel northeast-trending fractures in serpentine and associated altered volcanic rock. Most of the slip fiber is brittle, but where the fracture zones widen occasional "kidneys" of flexible fiber are found. The occurrence has been worked by both surface cuts and tunnels. Present condition and extent of inactive workings was not investigated.

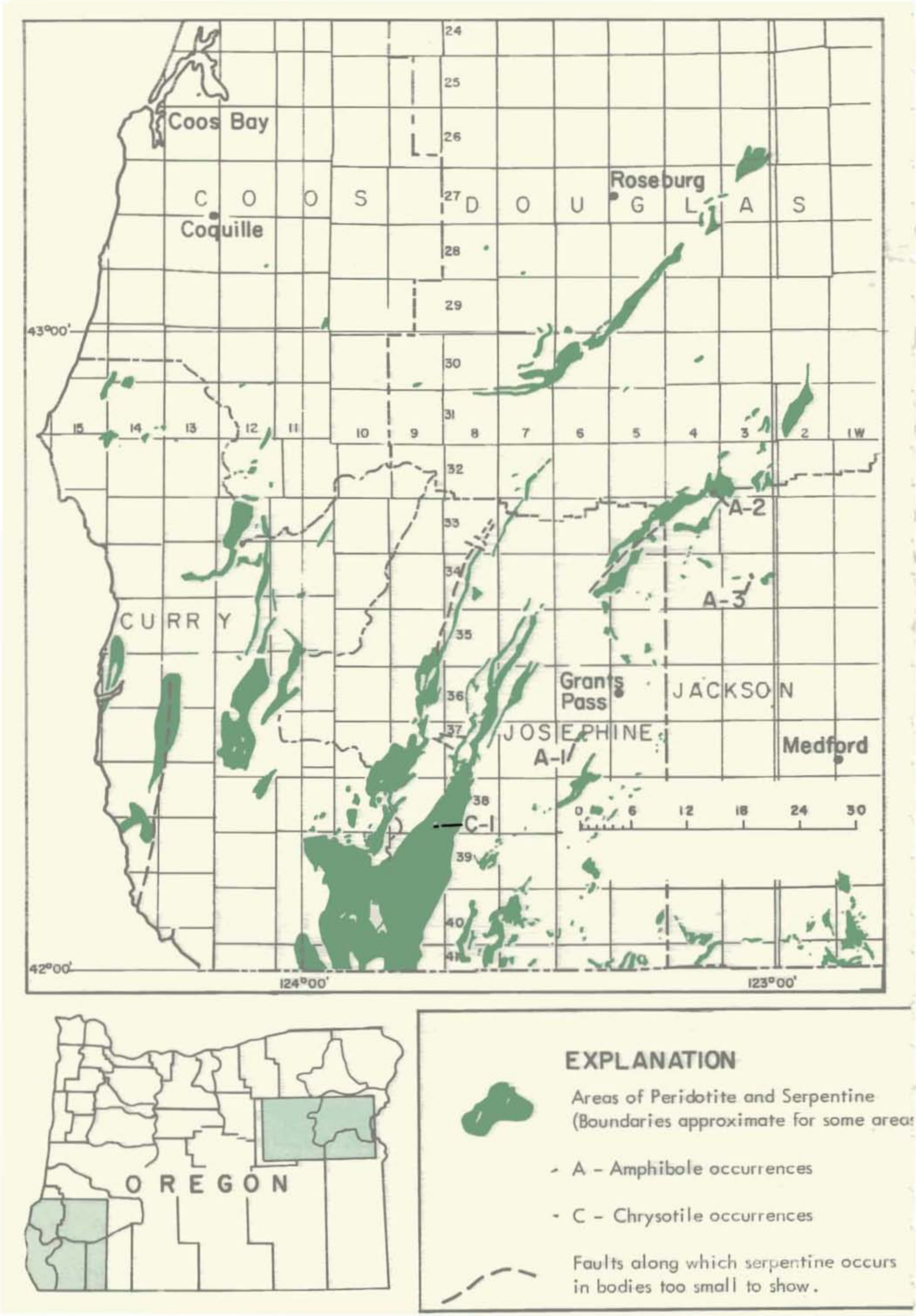
A-3 Raspberry Creek tremolite: Sec. 15, T. 34 S., R. 3 W., Jackson County. The occurrence is situated on the south side of Raspberry Creek about $\frac{1}{4}$ mile west of the west fork of Evans Creek at about 1,800 feet elevation. A small discovery cut about 100 feet above the creek exposes a narrow lens of matted tremolite. The maximum width appeared to be no more than 1 foot. The fiber occurs in serpentine near its contact with metavolcanic rocks of the Applegate Group. An unpublished Department file report, 1945, by E. A. Youngberg describes the main occurrence as being 700 feet north of Raspberry Creek at 2,000 feet elevation. He describes two shallow cuts with asbestos veinlets from a fraction of an inch to 4 or 5 inches wide in a zone striking N. 30° E. Width of the zone was undetermined due to poor exposures. The report also mentions about 600 pounds of fiber mined and sold at a rate of $600 per ton in 1943. In a recent visit to the area, only the southern cut was observed.

Northeastern Oregon

C-2 Mount Vernon deposit: Secs. 12, 13, 14, T. 13 S., R. 30 E., Grant County. The only chrysotile occurrence in the state that has had any production is located on Beech Creek beside U.S. Highway 395 about 3 miles northeast of Mount Vernon. The pilot mill operation of Coast Asbestos Co. was described by Wagner (1963). The deposit has also been examined by geologists of Asbestos Corp., Ltd. and Johns-Manville Co. The chrysotile fiber occurs in a narrow northeast-trending body of serpentine which intrudes Permian metavolcanics and sediments and is partly obscured by overlying Tertiary volcanics and Pleistocene to Recent alluvium. The deposit is reported to contain well-defined cross fiber chrysotile veinlets of good quality from which attractive specimens have been obtained, as well as considerable slip-fiber. The pilot plant recovery from pit-run ore is reported to average about 7 percent fiber so far. Details of the size of the deposit are not indicated in the available reports.

C-3 Spare Time claims: Secs. 7, 8, T. 14 S., R. 32 E., Grant County. These claims lie on the northern slope of Canyon Mountain at 4,500 feet elevation, adjacent to Little Pine Creek and 3 miles by unimproved road from Canyon City. The property consists of six unpatented lode claims located in 1960. The deposit is described in detail by N.S. Wagner (unpublished Department file report, 1961). Veinlets of cross-fiber chrysotile, most of them 1/16 inch or less in width, a few 3/16 inch, and rarely $\frac{1}{4}$ inch, are found in an area of serpentine near its northeast-trending contact with an olivine-rich peridotite. Veinlets strike both northeasternly and northwesterly. The better areas examined contained an estimated 5 percent fiber. Some of the serpentine area is obscured by alluvium in the valley of Little Pine Creek. Additional exploration would be needed to make a satisfactory evaluation of the occurrence.

C-4 Big Butte Creek asbestos: Secs. 17, 18, 19, 20, T. 11 S., R. 34 E., Grant County. The occurrence is about 2 miles northwest of Dixie Butte in the drainage of Big Butte Creek at about 4,400 feet elevation. The deposit is held by 5 unpatented claims located in 1950. It is described by N.S. Wagner (unpublished Department file report 1951, 1955, and 1962). Chrysotile veinlets of $\frac{1}{4}$ to $\frac{1}{2}$ inch widths, with semi-harsh fiber and partings, are common. Fiber lengths are mostly about 1/8 inch and rarely greater than $\frac{1}{4}$ inch. The fiber was originally found in a narrow zone thought to be 300 to 400 feet long, with a fiber content estimated at 10 percent or greater. The Asbestos Corp. of Canada examined the occurrence in November, 1951 and made about 1,000 feet of bulldozer trenches. In 1952-53,



Coos Bay
Coquille
C O O S
Roseburg
D O U G L A S
CURRY
Grants Pass
JOSEPHINE
JACKSON
Medford
A-1
A-2
A-3
C-1
43°00'
42°00'
124°00'
123°00'
24
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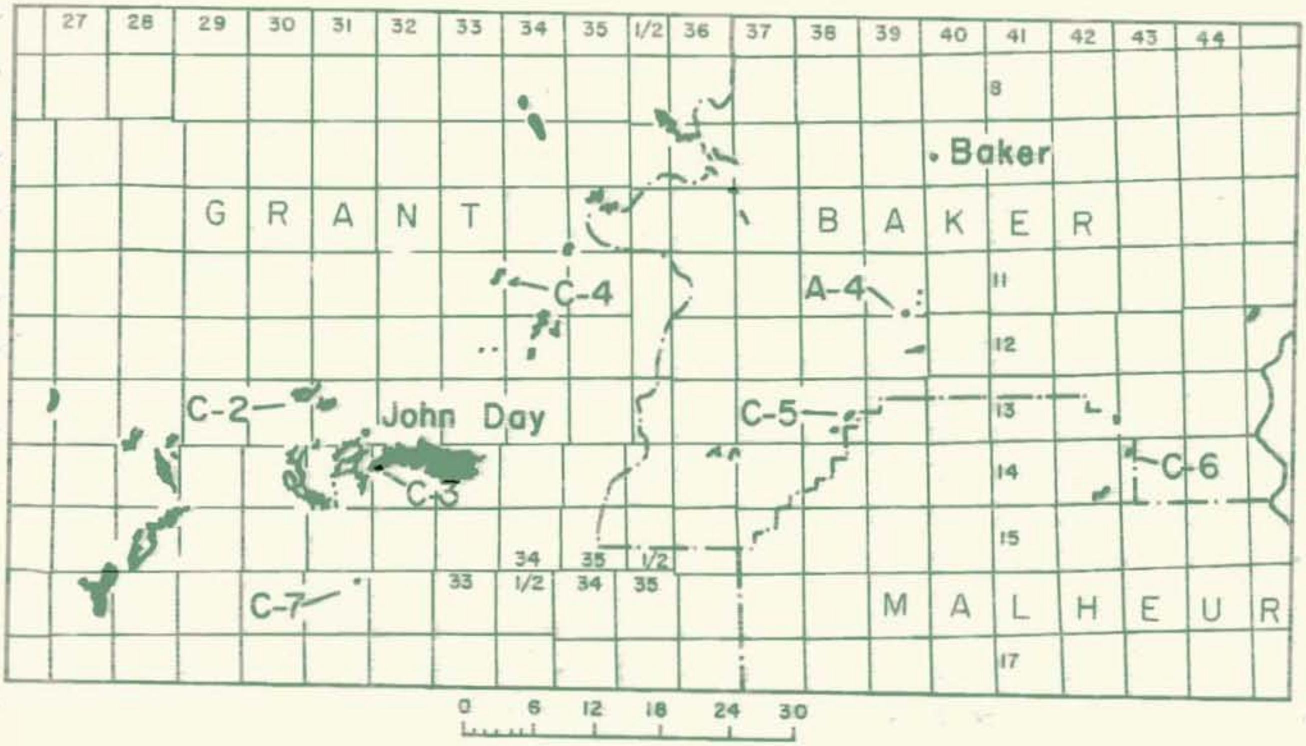
OREGON
EXPLANATION
Areas of Peridotite and Serpentine (Boundaries approximate for some areas
A - Amphibole occurrences
C - Chrysotile occurrences
Faults along which serpentine occurs in bodies too small to show.



ASBESTOS OCCURRENCES IN OREGON

Map No.	Name	Sec.	Location T.	R.	County	Reference
Chrysotile						
C-1	Foster Asbestos	35-36	38 S.	9 W.	Josephine	Dept. files
C-2	Mount Vernon	12-13-14	13 S.	30 E.	Grant	Wagner, 1963
C-3	Spare Time Claims	7-18	14 S.	32 E.	Grant	Dept. files
C-4	Big Butte Creek	17-18-19-20	11 S.	34 E.	Grant	Dept. files
C-5	Rock Creek Butte	22	13 S.	38 E.	Baker	Dept. files
C-6	Towell Claims	7	14 S.	43 E.	Malheur	Dept. files
C-7	Bear Valley	1-2-3, 11	16 S.	31 E.	Grant	Dept. files
Amphibole						
A-1	L.E.J. Asbestos	9	37 S.	6 W.	Josephine	Dept. files
A-2	Liberty Asbestos	36	32 S.	4 W.	Jackson	Dept. Bull. 14-C
A-3	Raspberry Creek	15	34 S.	3 W.	Jackson	Dept. files
A-4	Pine Creek Asbestos	34-35	11 S.	39 E.	Baker	Moore, 1937

Canadian Johns-Manville did additional trenching, geologic mapping, and about 1,000 feet of diamond core drilling. The later work indicated a fiber-bearing zone about 400 feet wide and 1,300 feet long trending N. 45° E. on the hillside west of Big Butte Creek. This zone occurs in serpentinized peridotite containing occasional inclusions of argillite and quartzite. Exploration revealed that the fiber occurs in disconnected patches separated by fairly large areas of barren rock.

C-5 Rock Creek Butte occurrence: Sec. 22, T. 13 S., R. 38 E., Baker County. This chrysotile occurrence is situated on the northeast flank of Rock Creek Butte at nearly 5,000 feet elevation, about 8 miles east of Unity and 5 miles south of Hereford. N. S. Wagner describes the deposit in an unpublished Department file report, 1950. The property is held by four unpatented lode claims located in July 1950. Fiber occurs in blocky, serpentinized peridotite over an area estimated to be about 400 feet long and 100 feet wide. The fiber appears to be of good quality in lengths up to ¼ inch. A few ½-inch veinlets have partings. The better areas contain 10-percent fiber. No development work had been done when the occurrence was last examined.

C-6 Towell claims: Sec. 7, T. 14 S., R. 43 E., Malheur County. The property is situated about half a mile west of the Baker-Malheur County line at an elevation of 4,000 to 4,500 feet. It is about 15 miles west of Huntington by an improved dirt road. The prospect was examined by Canadian Johns-Manville during 1956 and 1957, and a preliminary report was prepared (Sharratt and Todd, 1957), a copy of which was made available to the Department by the owner of the property. Development consisted of four bulldozer trenches. The fiber occurs in serpentinized peridotite and dunite in narrow zones 4 to 10 feet wide, striking north to N. 30° E. The fiber is mostly harsh and the veins commonly contain partings. Hot-spring activity has altered the serpentine and the chrysotile fibers in places. Picrolite is reported to be abundant.

C-7 Bear Valley occurrence: Secs. 1,2,3,11, T. 16 S., R. 31 E., Grant County. The deposit is about 4 miles east of U.S. Highway 395 between Canyon City and Burns, and is about 7 miles from the town of Seneca. Elevation of the area is about 4,900 feet. The property is held by placer claims totaling 480 acres. Information on the property is given in a Department letter by N. S. Wagner, September, 1954. Small areas of closely spaced chrysotile veinlets in serpentine are scattered over a fairly extensive area, but apparently separated by considerable subgrade to barren serpentine. Exposures of rock are poor and the report indicated that more exploration would be needed to expose larger areas of fiber-bearing serpentine before the occurrence could be considered to have commercial possibilities. Veinlets of apparently good quality chrysotile fiber were reported in the 1/8- to $\frac{1}{4}$-inch range, with $\frac{1}{2}$-inch widths very rare.

A-4 Pine Creek amphibole asbestos: Secs. 34, 35, T. 11 S., R. 39 E., Baker County. The deposits are described by Moore (1937). The area is near the divide between Cow Creek and Pine Creek and between 5,200 and 5,500 feet elevation on the southwest flank of Bald Mountain, 15 air miles south of Baker. The fiber is described as mainly anthophyllite, which occurs at various places in the area, associated with talc in narrow, lens-shaped bodies in crushed zones, fault contacts of greenstone, schist, and serpentine. The fiber is reported to vary in length from 1 to 16 inches. It is characteristically weak and brittle and occurs as both slip- and cross-fiber. The deposits were exposed by several shallow surface cuts when examined in 1931.

Prospecting and Development

There are undoubtedly portions of the Oregon ultramafic outcrops that have never been adequately prospected for asbestos. In the early days of Oregon prospecting, it was considered that only fibers in lengths exceeding $\frac{1}{2}$ inch were commercial. Consequently, the early-day prospectors paid no attention to outcrops that might have contained lengths of fiber that would now be considered commercial.

The usual percentage of fiber recovered from a commercial deposit ranges from 4 to 6 percent; occasionally this may vary if the deposit contains longer fibers. The most interesting fiber lengths from the economic point of view are from 1/8 inch to 3/8 inch. An ore body must contain some $\frac{1}{4}$-inch-plus length fiber to be minable at a profit.

The best manner of prospecting for asbestos is to examine the serpentine outcrops, preferably on a sunny day when the glossy fiber veins are more easily seen. A heavy rock hammer is needed to break lichen-covered rocks and a small knife to scratch likely looking veins. The fiber should fluff up readily when scratched with a knife. The fiber generally occurs in irregular veins scattered throughout the serpentine rock mass.

One cannot safely eliminate any variety of serpentine when prospecting for chrysotile. Even the highly sheared variety sometimes referred to as "slickentite" or "fishscale" should be examined. The new discoveries in Fresno and San Benito Counties northwest of Coalinga, California, occur as matted fiber in a unique type of highly sheared serpentine. The most favorable environment for occurrence of stockwork (crisscrossing) veinlets of

SUBDIVISION OF THE GROUPS OF CANADIAN CHRYSOTILE ASBESTOS

CRUDE ASBESTOS

Class	Standard Designation of Grade	Description
Group No. 1	Crude No. 1	Consists basically of crude ¾ inch staple and longer.
Group No. 2	Crude No. 2	Consists basically of crude ⅜ inch staple up to ¾ inch.
	Crude run-of-mine	Consists basically of unsorted crudes.
	Crudes sundry	Consists of crudes other than above specified.

MILLED ASBESTOS

Groups No. 3 to No. 9 Inclusive	Standard Designation of Grade	Guaranteed Minimum Shipping Test			
Group No. 3	3D	10.5	3.9	1.3	0.3
	3F	7.0	7.0	1.5	0.5
	3K	4.0	7.0	4.0	1.0
	3R	2.0	8.0	4.0	2.0
	3T	1.0	9.0	4.0	2.0
	3Z	0.0	8.0	6.0	2.0
Group No. 4	4D	0.0	7.0	6.0	3.0
	4H	0.0	5.0	8.0	3.0
	4J	0.0	5.0	7.0	4.0
	4K	0.0	4.0	9.0	3.0
	4M	0.0	4.0	8.0	4.0
	4R	0.0	3.0	9.0	4.0
	4T	0.0	2.0	10.0	4.0
	4Z	0.0	1.5	9.5	5.0
Group No. 5	5D	0.0	0.5	10.5	5.0
	5K	0.0	0.0	12.0	4.0
	5M	0.0	0.0	11.0	5.0
	5R	0.0	0.0	10.0	6.0
Group No. 6	6D	0.0	0.0	7.0	9.0
Group No. 7	7D	0.0	0.0	5.0	11.0
	7F	0.0	0.0	4.0	12.0
	7H	0.0	0.0	3.0	13.0
	7K	0.0	0.0	2.0	14.0
	7M	0.0	0.0	1.0	15.0
	7R	0.0	0.0	0.0	16.0
	7T	0.0	0.0	0.0	16.0
	7W	0.0	0.0	0.0	16.0
Group No. 8	8S	under fifty pounds per cubic foot loose measure			
	8T	under seventy-five pounds per cubic foot loose measure			
Group No. 9	9T	over seventy-five pounds per cubic foot loose measure			

cross-fiber chrysotile appears to be in the more blocky varieties of serpentine.

Jenkins (1949) reports that siliceous dikes or sills are often found close to high-grade chrysotile deposits; so the presence of such intrusives in serpentine can be considered a possible guide.

Magnetite is almost always associated with chrysotile that has formed by alteration of peridotite. It is a natural by-product of serpentinization and occurs as segregations along margins and in partings of chrysotile veinlets. This relationship has enabled use of magnetometers in prospecting for chrysotile. Their main value is in helping to determine the extent of known occurrences.

It is sometimes possible to log the surface outcrops by taking a visual reading of the fiber lengths over an exposed surface. Cross-fiber veins are generally recorded as multiples of a sixteenth of an inch over a five-foot length. The average width of irregular veins is estimated. Veins that are of a composite nature or that have kinks that will cause the fiber to break readily into shorter lengths should be recognized.

Field men in the industry have developed a method of mathematically reducing the visual face reading to a dollar value per ton of ore. It is always necessary to mill a portion of the rock in a small pilot mill and grade the fiber to be sure of the value.

Slip-fiber is often associated as a minor constituent in deposits made up mainly of cross-fiber, or slip-fiber can make up an entire ore body. Laboratory assistance is always necessary to evaluate slip-fiber.

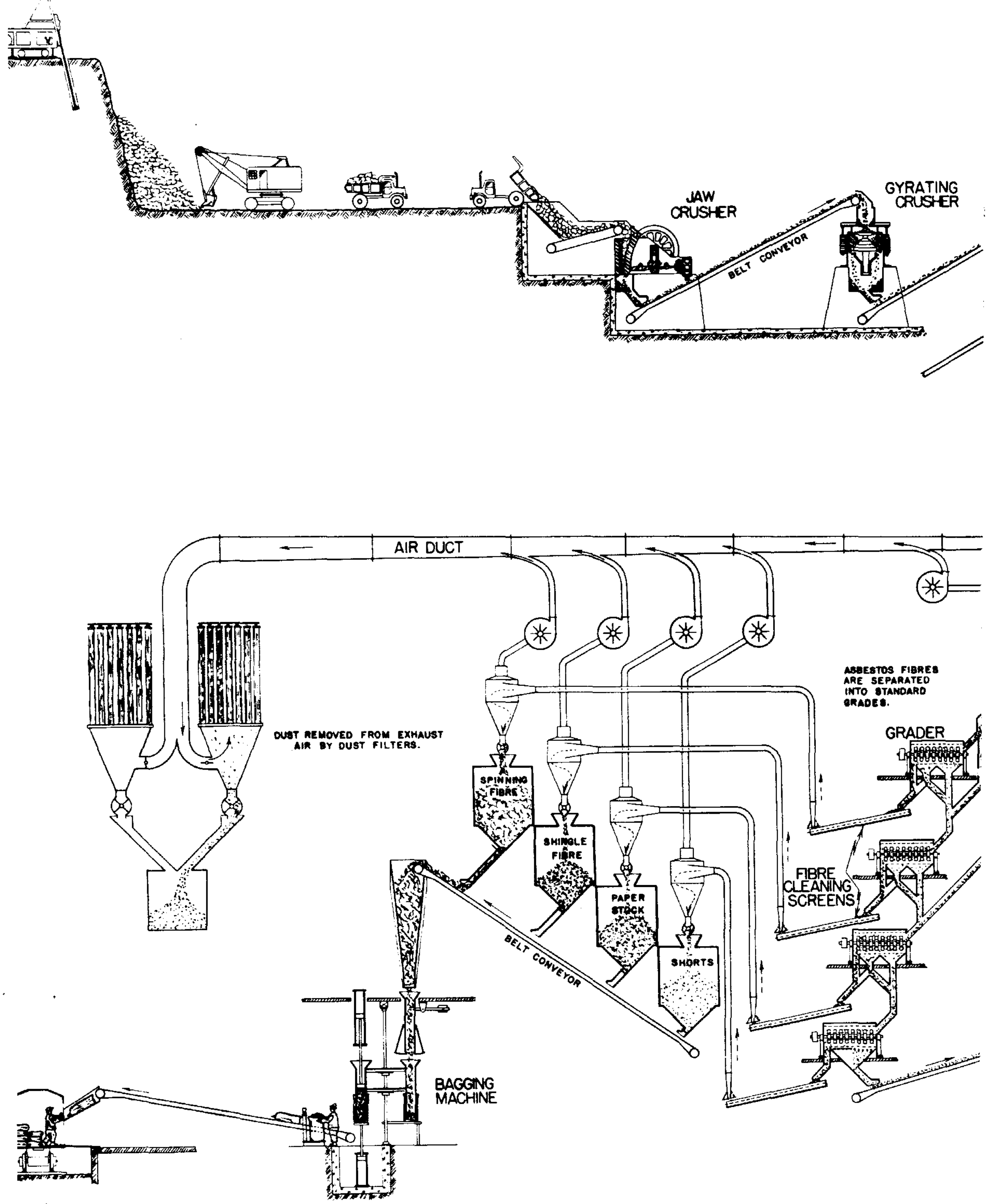
When a likely looking prospect has been found, it should be examined by an engineer or geologist experienced in asbestos. If the prospect warrants further work, the first step is to expose the fiber-bearing rock by trenching, where this is practical. The next step is diamond drilling to recover core from the deeper part of the ore zone, thereby exploring and developing an ore body. Portions of both the ore body and the core must be tested in a small pilot mill before the characteristics of the deposit can be known well enough to design a mill. If sufficient ore can be found by this process, the result could well be a producing asbestos mine. Such mines are usually huge open pits or large, underground block-caving operations.

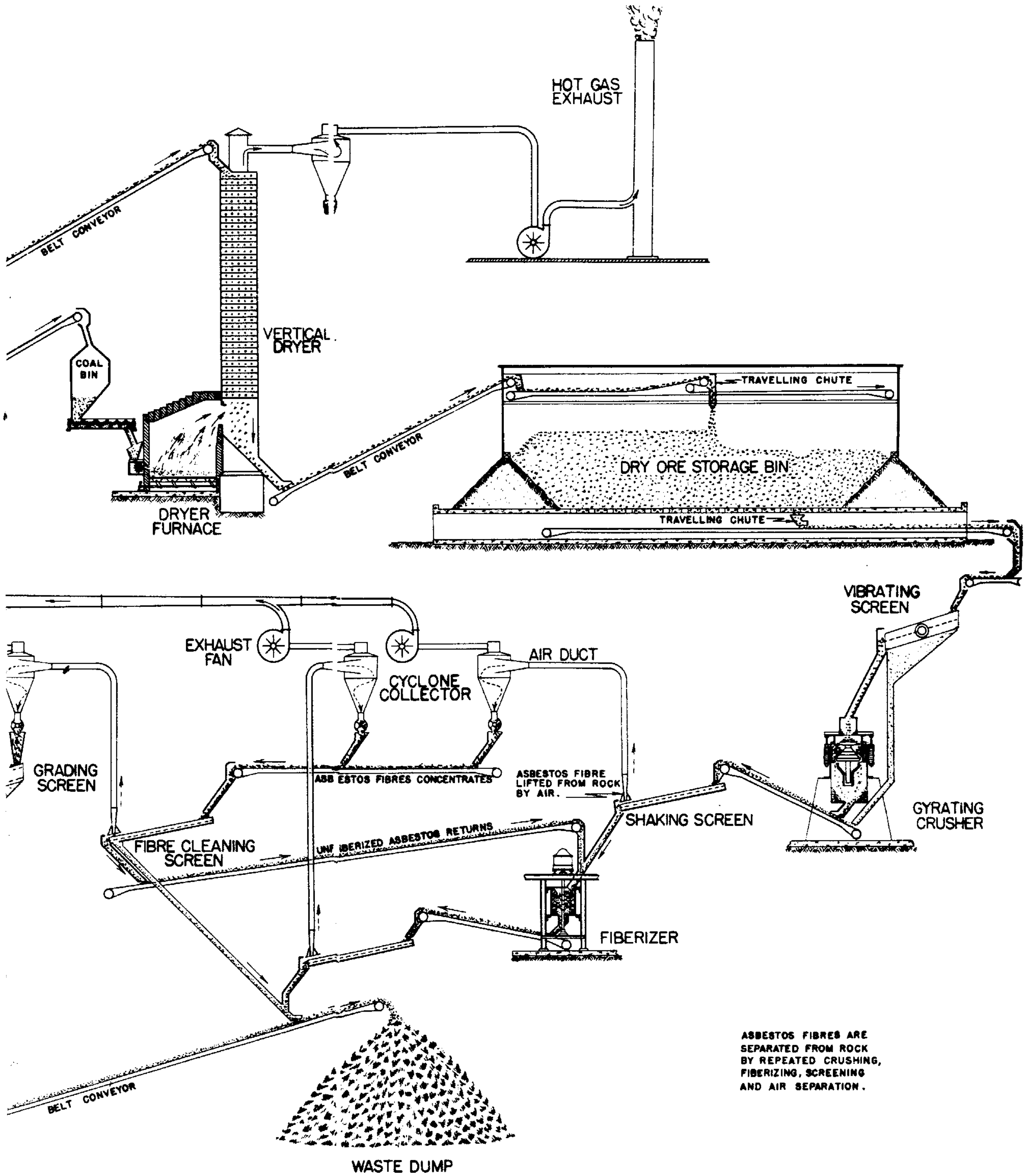
Grading and Processing the Ore

The milling process which removes the fibers from the rock and grades them for sale is fairly complicated and contributes quite a bit to the cost of the product. (See illustration of flow sheet.)

The grading and pricing of all asbestos is governed by the length of the fiber. The longer fibers (more than 3/8 inch) range in price from $345 to

ASBESTOS MILL FLOW SHEET




HOT GAS EXHAUST
BELT CONVEYOR
VERTICAL DRYER
COAL BIN
DRYER FURNACE
TRAVELLING CHUTE
DRY ORE STORAGE BIN
TRAVELLING CHUTE
VIBRATING SCREEN
EXHAUST FAN
AIR DUCT
CYCLONE COLLECTOR
GRADING SCREEN
ASBESTOS FIBRES CONCENTRATES
ASBESTOS FIBRE LIFTED FROM ROCK BY AIR.
SHAKING SCREEN
GYRATING CRUSHER
FIBRE CLEANING SCREEN
UNFIBERIZED ASBESTOS RETURNS
FIBERIZER
BELT CONVEYOR
WASTE DUMP
ASBESTOS FIBRES ARE SEPARATED FROM ROCK BY REPEATED CRUSHING, FIBERIZING, SCREENING AND AIR SEPARATION.

$1,400 per ton. A very small tonnage of the higher priced material is sold in a year. The medium-length fibers, ranging from 1/16 to 3/8 inch, sell for from $90 to $220 per ton. The shorter fibers, or lengths under 1/16th inch, sell for from $28 to $77 per ton.

One of the generally recognized methods of testing asbestos is the Quebec screen test. This test was developed by the Quebec Asbestos Mining Association and has set specifications for the various grades of fiber. The test is used as an ore-evaluation tool and as a production-control method which serves to grade fiber for sale.

The Quebec standard testing machine consists of three rectangular screens -- $\frac{1}{2}$-inch mesh, 4 mesh, 10 mesh -- and a box for the shortest material. The test consists of placing 16 ounces of clean fiber on the top screen and shaking the nest of screens horizontally at 327 rpm for 600 revolutions. The fiber grade is then determined on the basis of the number of ounces remaining on each of the screens and in the box. (See classification chart.)

As an example, if 2 ounces of the fiber remained on the $\frac{1}{2}$-inch screen, 8 ounces remained on the 4 mesh, 4 ounces on the 10 mesh, and 2 ounces in the pan, the fiber would be classed as 3R. The ounces of fiber in each case totals 16. These specifications are minimum tests. Fiber falling between the noted values is carried to the lower scale.

Asbestos milling consists essentially of coarse crushing, drying, and recrushing in stages, each step followed by screening and air separation of fiber from the rock. It is important to separate the fiber from the rock with a minimum of fiber breakage. The process also includes preparing fibers to conform to exacting specifications regarding grading and dust removal.

Mills of several thousand tons per day capacity are customarily built in the asbestos industry. Construction costs are $3,000 to $4,000 per ton of capacity, resulting in an investment of several million dollars in the mill to produce from each mine. It is essential that the mills have enough ore to allow them to operate for 20 or more years, thereby providing for the recovery of the initial investment.

Diligent effort on the part of asbestos prospectors and asbestos mining companies may very well result in one of these large mills being built in Oregon to produce fiber.

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McCOLLOCH REAPPOINTED TO GOVERNING BOARD

Frank C. McColloch, Portland attorney, was reappointed to the Department's Governing Board March 16, 1965, by Governor Mark O. Hatfield. McColloch has been chairman of the board since October 18, 1961. His term continues until March 15, 1969. Mining and water law have been McColloch's special interests during his many years of practice, and he has served on a number of state boards concerned with these problems. He is a member of the Koerner, Young, McColloch, and Dezendorf law firm.

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OREGON ACADEMY OF SCIENCE and NSA PROGRAM SCHEDULED

The joint meeting of the Oregon Academy of Science and the Northwest Scientific Association will be held in Portland April 9 and 10, 1965. The Geology-Geography section will hold its meetings at Portland State College and at the Sheraton Hotel. A field trip to the Columbia River Gorge has been scheduled for Friday, April 9, at 10 a.m. For reservations write to Dr. J. S. Lowther, Geology Department, University of Puget Sound, Tacoma, Washington, 98416. A symposium on the gorge will be held at the Sheraton Hotel on Saturday, April 10, at 9 a.m. Papers to be presented at the two-day program are listed on the following page.

Friday, April 9 (with Engineering Section of the NSA)

8:45 a.m. - Room 338 College Center, Portland State College; J. W. Crosby III and J. E. Sceva presiding.

1. Auger Center - a new approach to new problems; J. E. Allen, Portland State College.
2. Earthquake-induced landslides, Anchorage, Alaska; S. D. Wilson, Shannon & Wilson, Inc., Seattle-Portland.
3. Geologic hazards, what are they and what can be done about them; H. G. Schlicker, Oregon Dept. of Geology and Mineral Industries, Portland.
4. Investigation of a rock slide, site for a dam in the Cedar Creek watershed, Idaho; H.A. Allen and J.L. Holland, Soil Conservation Service.
5. The science of finding, quarrying, and using jetty stone; R.J. McReary, Ureka, Inc., Portland.
6. Geologic design for the foundations of weirs in river channels; G.R. Stephenson, Dept. of Agriculture Research Service, Boise.

1:00 p.m. - Room 338 College Center; W.H. Taubeneck and R.H. Russell presiding.

1. Geomechanics; D.L. Masson, Dept. of Mining, Washington State Univ., Pullman.
2. Potential application of nuclear explosives in water management; A.M. Piper, U.S. Geological Survey, Menlo Park.
3. Land subsidence due to water-level decline, and its engineering significance; J.F. Poland, U.S. Geological Survey, Sacramento.
4. Methods used in locating and testing a major ground-water resource in the Washakie Basin, southern Wyoming; G.A. Duell and W.M. Sahinin, Pacific Power & Light Co., Portland.
5. Use of artesian relief wells for a specific drainage problem; G.E. Neff, Bureau of Reclamation, Ephrata.
6. The role of geology in waste-disposal practice; W.A. Haney and D.J. Brown, Battelle-Northwest, Richland.

Saturday, April 10

9:00 a.m. - Room 71, State Hall, Portland State College; Dr. Ray Broderson and Dr. J.E. Allen presiding.

1. Indicators of Late Pleistocene paleoclimatology, east-central Idaho; Wakefield Dort, Jr., University of Kansas.
2. Glacial geology of the Stuart Range and Leavenworth area, Washington; W.A. Long, Washington State Dept. of Natural Resources, Ellensburg.
3. Late Cenozoic stratigraphic sequence in Oreana quadrangle, southwest Idaho; N. R. Anderson, Univ. of Puget Sound.
4. Palisades lava flow, Clear Fork of Cowlitz River, south-central Cascade Mountains, Wash., J.A. Ellingson, Pacific Lutheran University.
5. Natural gas storage, Marys Corner, Wash., and its effect upon water resources which overlie the structure; R.H. Russell, Wash. State Dept. of Conservation, Olympia.
6. Development of ridges in plastic layers; Z.F. Danes, University of Puget Sound.
7. Geochemical prospecting in the Darrington-Granite Falls area, northern Cascade Mountains, Wash.; Paul Eddy, University of Puget Sound.

1:30 p.m. - Room 71 State Hall; Dr. H.E. Wheeler presiding.

1. Problems associated with the extension of the stratigraphic units of south-central Washington: the late basalt flows, Ellensburg and Ringold Formations; R.E. Brown and D.J. Brown, Battelle-Northwest, Richland.
2. Problems associated with the extension of the stratigraphic units in south-central Washington: the post-basalt sediments; D.J. Brown and R.E. Brown, Battelle-Northwest.
3. The Touchet Beds; W.F. Scott, Washington State University.
4. Some fossil plants from the Naches Formation of central Washington; E.P. Klucking, Central Washington State College.

The ORE BIN
Volume 27, No. 4
April, 1965

THE WALLS OF PORTLAND

By Ralph S. Mason*

Much publicity has been given in recent years to new construction in the Portland area, particularly to those sections undergoing urban renewal. Very little mention has been made, however, of the role played by the mineral industry in the creation of attractive, long-lasting, economical, fireproof structures. Almost without exception, the recent advances in building construction have been concerned with improved techniques in the handling, fabrication, and erection of mineral industry products. Lift slabs, tilt-up walls, prestressed and post-tensioned structural members, and slip forms are but a few examples of these developments. Anybody who has watched a multi-silo grain elevator rising into the air in one long, continuous movement, or has seen a large, single-floor commercial building suddenly sprout walls overnight, has witnessed some of the more spectacular achievements made possible by the use of minerals in modern construction.

The most noticeable part of any building is usually its walls. Walls must be functional, giving support and protection to the building, but they can also be an ornament not only to the building but to the area as well. For the first time in history, the architect has no limitations as to length, width, or thickness of his materials. He has a wide choice of natural aggregates and cut stone, a great variety of ceramic and concrete pre-cast units, and numerous methods for incorporating them into a wall.

Brick Walls

Historically, the first use of a manufactured mineral product for the construction of a wall was the laying of one sun-dried clay brick upon another by a Persian bricklayer more than 5,000 years ago. Some time later, the art of brick making progressed to the firing of clay blocks in kilns and this has remained as standard practice.

Modern brick comes in many shapes, sizes, textures, and colors. The manner of laying up the brick ranges from the common staggered course to

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* Mining Engineer, Oregon Dept. of Geology and Mineral Industries.

stacked bond with numerous designs incorporated by indenting or extending individual brick. Treatment of mortar joints also adds variations to brick walls with flush, raked, and slump mortar in various colors currently being used.

Common red-fired brick laid up conventionally is still an attractive wall covering, as evidenced by the several stores using it in the Lloyd Center. The west wall of Meier & Frank's store is a good illustration of the proper use of brick for covering large, unbroken surfaces. The wall is attractive and interesting at close range and still retains these same qualities, only slightly subdued, when viewed from a block or more away. Slight differences in the shades of the brick help to accomplish this effect. Another brick-faced building, occupied by Blue Cross of Oregon, on S. W. 5th Avenue uses jet-black brick for the first-story and dark blue for the second-story walls, thus achieving, if this is ever possible, an architecturally subtle pun.

In recent years, used bricks, sometimes in rather a woebegone state of preservation, have been extensively employed for wall coverings. Properly applied, such brick add a certain charm, partly to their ties with the past and partly to their imperfections, and partly perhaps to the fact that used brick costs more than new brick.

Ceramic Tile Walls

Large wall areas of many downtown buildings, particularly in the upper stories, display ceramic tiles of various dimensions. These are applied in much the same manner as stone veneering. Almost without exception, the tiles are imported considerable distances from regions where high-quality clays are readily available. Large dimension tiles present a minimum of joints to the weather, and the glazed surface resists weathering to a high degree, making for low maintenance costs.

In the past few years a great number of buildings have been faced, at least in part, with one-inch-square tiles. The small unit size is well adapted to narrow areas between structural elements of the building and an infinite variety of design through selection and arrangement of colors is possible. The recently completed Pacific Northwest Bell Building in the urban renewal project on S.W. 4th Avenue uses wall panels covered with single-color tiles.

Two unusual applications of ceramic products to Portland walls have been produced by Bennett Welch of Pacific Stoneware. On the St. Helens Hall campus just west of Portland, the exteriors of the buildings are covered with hand-glazed tiles one-half-inch thick, wire-cut from standard green brick stock as they leave the pug mill. The tiles were made by

Equitable Savings & Loan Bldg., 1300 S.W. 6th Ave. Pre-cast wall panels of white concrete and quartz aggregate. Eight-window units one floor high were cast in one piece at Swan Island and trucked to the job. (Photo by W. H. Grand)

Portland Chamber of Commerce Bldg., 824 S.W. 5th Ave. (bottom). A complete renovation of the old building uses Cold Springs granite facings from Minnesota, and white concrete with white exposed aggregate pre-cast panels. (Photo by Ackroyd)

Willamina Clay Products' Tigard plant. The tile on the exterior walls are shades of brown; those on some of the interiors are of brighter colors. Welch also created the ceramic tiles above the Christian Supply Center at Lloyd's. Pounded clay was sculptured into vertical panels about three feet wide. They were cut into 12-inch-square tiles, then fired and glazed. Both of these treatments are unique and are not likely to come into general use, since unit costs would run much higher than those for any of the standard types of wall coverings now being employed.

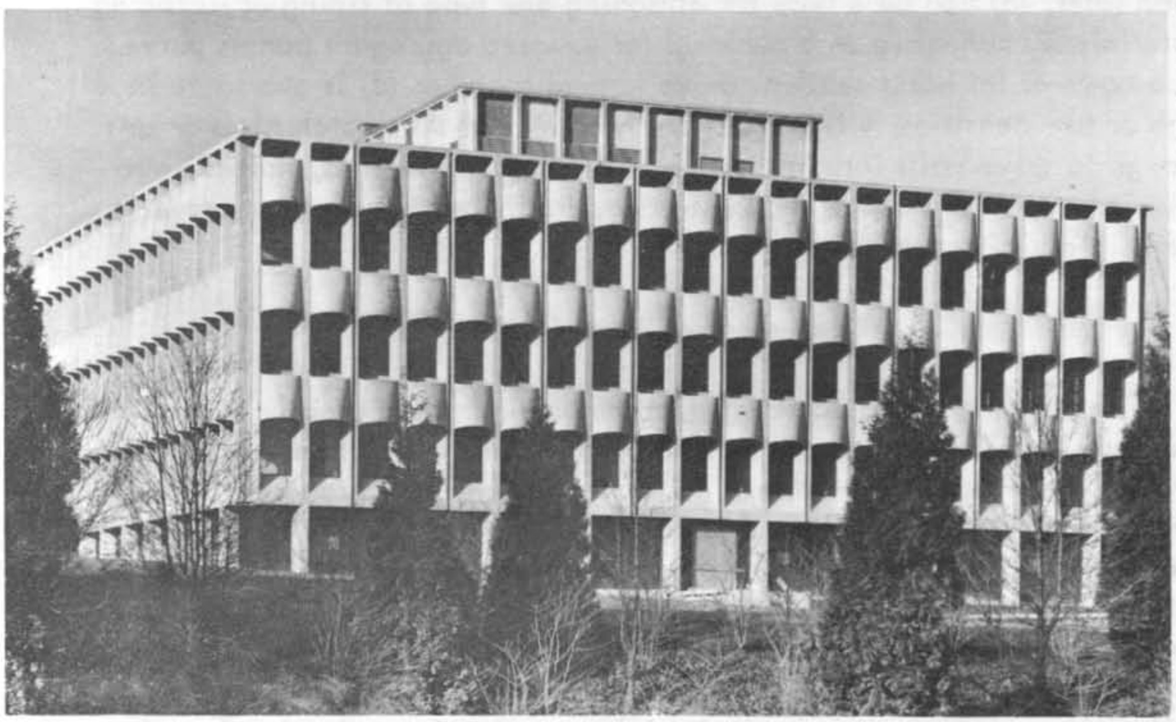
Concrete Walls

Concrete block has been used extensively in wall construction in the Portland area for many years. Both standard aggregate and lightweight blocks are available. Most of the lightweight blocks are fabricated from expanded shale produced locally. More than 100 shapes and styles of blocks are currently being utilized. One of the most interesting applications of block is in the creation of screen walls having a wide variety of designs. Although many of these blocks appear to be quite fragile, they possess considerable strength due to the manufacturing process, which uses vibration plus pressure to produce a sound block. Curing is improved by autoclaving in steam rooms. Careful mix control and the proper selection of aggregate also aid greatly in the making of high quality block. Several firms in the Portland area have completely automated block plants which operate without human assistance during the mixing, forming, stripping, and palleting stages.

The Lloyd Center has large quantities of concrete block in its basic construction, now hidden behind decorative coverings. A lacy screen wall of concrete block surrounds the ice-rink area. Similar walls are employed around town as sight screens for parking garages and other areas where adequate ventilation, attractiveness, and a visual barrier are required.

Concrete is a basic building material in modern commercial and industrial construction. Usually concrete forms the supporting element of a structure and its presence is often masked behind veneers of surfacing materials. Several recently completed buildings in Portland used concrete as a structural material, and also as the finished surface, without any attempt to dress it up with surface coverings. The IBM Building is an excellent example. Pre-cast wall panels 12 feet wide and 52 feet high provide, by means of a series of ingenious fairings, the exterior and interior wall, the window frames, and sunscreens. The wall units were manufactured in Tacoma, Washington, and were trucked to the site, where they were speedily placed into position and attached to the floors. Unlike similar wall panels, these units are actually load bearing, sharing the weight of the floors with the

Pioneer Broadcasting Bldg. (KGW-TV). Splayed poured-in-place concrete posts support the second floor, which features thin-shell concrete sunscreens. Uncompleted building is at 1500 S. W. Jefferson St. (Photo by Alan Hicks)



IBM Bldg., 2000 S. W. 1st Ave. (top). Thirty-eight smooth-surfaced concrete panels 12 feet wide and four floors high cover the structure and support the outer perimeter of the floors. Panels were cast in Tacoma and trucked to site. (Photo by W. H. Grand) central core structure to provide an uninterrupted floor space. Another example of concrete used in this manner is to be found in the new KGW Building on S.W. Jefferson St. Here the building is supported by branching posts of concrete and the walls are embellished with concrete sunshades which are extensions of the walls. Both the IBM and KGW buildings have a compactness and pleasingly functional appearance which has been enhanced by a single building material.

Modern concrete technology employs such relatively new developments as lightweight concretes, high-alloy reinforcing steel, prestressing, post-tensioning pozzolan replacement, pumping, slip-forms, air entraining additives, and over-all improvement in concrete aggregates and mixes. The net result of all these advances is to provide the architect and the builder with a material that is essentially limitless in its application to modern building construction. For the first time, builders have a product that: (1) is available in practically any size and shape; (2) can be formed on the job, brought to the job ready for final installation, or brought to the job in modular units and set in place in an endless variety of ways; (3) improves with age, is rot-, fire-, water-, and termite-proof; (4) has inherently great compressive strength and can be fabricated so as to have high tensile strength as well; (5) can be given a surface ranging from perfectly smooth to rough, plus either raised or incised designs created by pouring against prepared forms, in any color which can be added either to the mix or applied later; (6) can be a base for attaching any type of siding or surfacing material; (7) can serve as a back-up for exposed aggregate panels poured face down or for hand-seeded panels formed face up; (8) is available in high or low densities, with aggregate hard enough to scratch glass or soft enough to drive nails into; (9) can be sawed, split, drilled, nailed, and chiseled when hard or molded, extruded, trowelled, poured, or carved immediately after mixing.

Aggregate Panel Walls

The use of exposed aggregate panels has increased greatly in the past few years. This type of wall covering has several advantages, since relatively low-cost aggregate rather than more expensive, large-size stone veneers can be used. Construction of either tilt-up or plant-poured exposed aggregate panels is essentially a bulk-materials handling operation, with its relative saving in costs as compared to the hand-laid masonry or veneer wall. Current practice in making exposed aggregate panels employs a retarder which delays the setting up of the outer surface concrete while the base concrete gains its initial strength. Immediately after the panel has attained sufficient strength to be moved, it is upended and the retarded surface is either brushed, acid etched, or water sprayed to expose the aggregate. The choice of methods for exposing the surface depends upon the desired effect, which may range from flush through high relief. A recent example of exposed aggregate panels in Portland is to be found in the new Equitable Building, where 38-ton pre-cast units of white concrete faced with white quartz aggregate from Washington form the walls. A novel feature of this job was the incorporation of the air-conditioning ducts into the units just below the deeply embayed window openings. Other examples in the Portland area include the basalt river pebbles in the exposed aggregate on the Hilton Hotel base walls, the fronts of several Safeway stores which have brown quartzite cobbles obtained locally, and the University of Oregon Medical School Research Building, using white Washington quartz in through-the-wall panels measuring 7 feet high by 30 feet long and weighing approximately 20,000 pounds each.

Stone Veneer Walls

Sheets of stone veneer have been the standard wall coverings for commercial office buildings for many years, sharing the total field with brick and, to a much smaller extent, with dimension stone. Most of the veneers used locally are imported from considerable distances, and, although they are expensive on a first-cost basis, the upkeep is low and the stones normally have a long service period. The Oregonian Building is veneered with Cold Springs granite from Minnesota around the base course and topped with buff Indiana limestone. The same Cold Springs granite also appears on the lower portions of the State Office Building, the upper floors of which are covered with cream-colored ceramic tiles. The Interior (Bonneville) Building is covered with Georgia marble, as is the Executive Building. The remodeling of the Chamber of Commerce Building entails the use of Cold Springs granite and white-on-white precast exposed aggregate panelling for the upper floor. The lower portions of the Meier & Frank Co. store in the Lloyd Center are covered with slabs of a blue larvikite from near Larvik, Norway. The shimmering blue color is imparted by the feldspar anorthoclase, which often occurs as twinned crystals. Numerous buildings in Portland are faced with sheets of buff travertine. This banded stone, characteristically pitted with irregular small openings, comes from large quarries near Rome that have been in production for more than 2,000 years.

Natural Stone Walls

The day of the building constructed with walls of solid blocks of stone has practically gone, with the exceptions of federal structures in National

Parks where materials at hand are employed to enhance the scene. This type of construction is still in use for retaining walls, however, and an interesting example can be seen at the Standard Plaza Building on S. W. 5th Avenue, where rough blocks of Cold Springs granite have been laid up to form massive retaining walls that are part of the lower floors of the building.

In Portland quite a few walls have been erected with chunks of rubble. Most of these walls are of the tilt-up variety. This system uses a form, the thickness of the wall, which is laid flat on a concrete surface. In the form a bed of dry sand is spread to a depth of several inches then the rubble pieces are placed on it. Grout is next applied around the rubble, and then concrete is poured to fill the form. Structural steel, conduits, window and door frames, and any other necessary accessories can be incorporated in the panel before pouring. Once the panel has set, it is tilted up and locked into position; the outer surface is then cleaned to reveal the rubble. Standard stone masonry techniques have also been used for laying up rubble-faced walls. The Thunderbird Restaurant has walls studded with large chunks of silicified rhyolite rubble from the Warm Springs Indian Reservation near Mt. Hood, and the Americana Motel on S.W. 5th Avenue has portions of both interior and exterior walls composed of white magnesite rubble from near Chewelah, Wash. Several small commercial buildings in Portland have recently used an angular, elongated volcanic rock from southern Washington to produce a rustic, textured wall.

For quite a number of years long narrow strips of sandstone veneer have been laid up brick fashion to form wall coverings. Most of this type of stone is imported from Arizona, with smaller quantities coming from other states or originating in Oregon. Three Oregon quarries, the Rainbow Tuff quarry near Pine Grove in Wasco County, the Willowdale quarry in northern Deschutes County, and the Idanha quarry in Marion County, have been producing small amounts of veneer strips and ashlar. The Rainbow quarry is noted for brightly colored tuff with pronounced bands of color, the Willowdale stone is darker and the banding is less accented. The Idanha tuff resembles the Rainbow but the banding shows less contrast.

Walls of Lloyd Center

The most interesting collection of walls in Portland is to be found at the Lloyd Shopping Center. Here in gay profusion are excellent and imaginative applications of mineral-industry products to more than 100 shops. One of the problems in designing the walls of the Center was the necessity of providing distinctively different store fronts while making them all into a cohesive assemblage that would be both pleasing and practical. The decision to use mineral products proved to be a happy one, since it gave the widest possible choice of materials and combinations of compatible materials.

An international flavor is imparted to the Center with the use of marble, travertine, and verde antique from Italy and of granite from Norway and Peru. Neighboring and distant states also supplied some of the materials, with quartzite and dolomite from Washington, sandstone from Arizona, granite from Minnesota, rose quartz from Nevada, brick from California, and slate from Vermont.

Ceramic products include clay brick and tile and one-inch-square glass tiles, many of which were imported from Italy. Several stores use specially crafted tiles with either fired or raised designs. A wide variety of effects has been achieved, however, with standard shapes and colors which are available in an almost unlimited selection. Natural stone has been used as a veneer, as rubble, as ashlar, in precast and poured-in-place units, and as exposed aggregate.

Again, far-away places account for many of the stones used. One interesting effect is obtained by utilizing sliced river pebbles of white marble from Italy in pre-cast units, another is obtained by using polished slices of Cold Spring Rainbow granite from Minnesota 4 inches square set in pre-cast units 24 inches square. Slate, which is normally thought of as a floor covering, also appears in the Center on several walls as a veneer, and common glass marbles used by children the world over form a hob-nailed surface for entire walls of one of the larger stores. Glass, incidentally, occupies a large proportion of the Lloyd Center walls. Glass is at its best when it is nearly invisible, and equally invisible to the lay public is the fact that glass is made from mineral products of very great purity.

EXAMPLES OF MINERAL MATERIALS USED IN LLOYD CENTER WALLS

BRICK (used, clinker, red, white, rug):
Manning's, Pancake Corner, Armishaw's, Hippopotamus Restaurant, Safeway, Meier & Frank's, J.C. Penney, Tradewell, U.S. National Bank.

MARBLE:
Best's, Dean Witter & Co., Meier & Frank.

SANDSTONE:
Title & Trust Co., Hol'n One Donut, Mario's.

SLATE:
Goldberg's Restaurant, Alpine Hut, McCall Oil.

CERAMIC TILE:
House of Nine, Van Duyn's, Pay 'N Save, First National Bank, Alpine Hut, Toyland.

GRANITE:
Meier & Frank, Fahey Brockman, J.J. Newberry.

TRAVERTINE:
Rosenblatt's, Stevens & Son.

GLASS MARBLES:
Nordstrom's.

RIVER COBBLES:
Chandler's.

EXPOSED AGGREGATE:
J.C. Penney, Woolworth's, Lerner's, main stairwell.

Conclusions

From the foregoing it is quite clear that modern commercial buildings rely heavily upon the mineral industry for materials with which to wall their structures. Architectural styles in commercial buildings change from time to time. Currently there is a swing away from buildings walled almost completely with glass toward structures employing larger areas of solid walls. Mineral materials are ideally suited for this service. They are fireproof, durable, distinctive, and range in price from the low-cost, plain concrete wall to the high-cost specialty masonry job. The local demand for wall coverings attracts stone facings from distant lands and other products from many of the western states. Oregon has many attractive building stones, but very little use is made of them in the state.

Whether it is visible or not, every modern commercial building has considerable quantities of concrete in it. An essential part of concrete is the sand and gravel aggregate. Sand and gravel are low-cost commodities and a growing community needs large quantities of them close at hand if it is to remain competitive. Building stone commands a higher unit price and can be transported for greater distances than sand and gravel. Building stone sources as well as deposits of other industrial minerals must be kept available until they can be put to the best possible use.

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U. S. MERCURY REPORTS PUBLISHED

The U.S. Bureau of Mines has recently published "Mercury potential of the United States," as Information Circular 8252. The 376-page book provides information on all of the known mercury deposits of the country and gives an estimate of the domestic resources of mercury producible at various price ranges. Information Circular 8252 is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The price is $1.75.

The U.S. Geological Survey has issued "Mercury -- its occurrence and economic trends," by E.H. Bailey and R.M. Smith, as Circular 496. The 11-page booklet discusses the cause of the recent price spiral and the probable future of the mercury industry, and presents information on recent trends in price, production, and consumption of mercury. Circular 496 is free on application to the U.S. Geological Survey, Washington, D.C., 20242.

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TEKTITES AND OREGON'S VOLCANIC GLASSES

By Erwin F. Lange*

Small pieces of glassy materials that have been naturally etched by chemical action, eroded by wind-driven sand, or tumbled by running water are to be found in various localities in Oregon. These particles have been variously referred to as obsidianites, Apache tears, marekanites, and obsidian bombs. Often they resemble tektites and are sometimes mistaken for them. Since there is at the present time a great deal of interest in matter from space and in space research generally, and since the possibility exists that tektites are a form of space matter, a comparison of Oregon's volcanic glasses and tektites warrants careful consideration. The possibility also exists that tektites might be found in Oregon, although none have been reported to date. A general awareness of tektite properties is helpful in their identification.

Tektites are small, naturally occurring glassy objects that have been found in a few somewhat restricted geographical areas throughout the world. They are generally characterized by peculiar shapes such as tear-drop, dumbbell, spherical, and disc, forms which indicate a rapid cooling from a molten state. The word tektite is derived from the Greek word for molten. Tektites are usually named after the geographical area in which they are found. The main localities and tektite names are as follows:

Southern Australia - australites
Philippine Islands - rizalites or philippinites
Island of Billiton in Java Sea - billitonites
Czechoslovakia - moldavites after Moldau River
Indochina and Malayan Area - indochinites

In the United States tektites have been found in Texas (bediasites), Georgia, and a single specimen in Massachusetts (Martha's Vinyard). They have also been found along the Ivory Coast of West Africa.

The origin of tektites is unknown. In the early literature they were looked upon as a special kind of volcanic glass or as remnants of prehistoric glass makers. Some have suggested that they were fulgurites produced by

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Surface features of tektite from Thailand.

Surface features of obsidian pebble from Lake County, Oregon.

the fusing of sand or soil by lightning. Later they were regarded as glassy meteorites. In recent years, the formation of tektites has been considered to be associated with meteoritic, comet, or asteroid impact. One group looks upon the impact as occurring on the earth (Barnes, 1961), the other on the moon (O'Keefe, 1964). In either case, it is postulated that high temperatures and pressures produced by impact and explosion of large meteorites would splash materials outward and would form glassy objects shaped like tektites. Considerable support to the impact theory has developed by the discovery of nickel-iron spherules in a Philippine tektite by E.C.T. Chao of the U.S. Geological Survey and the more recent announcement* by Louis Walter of the National Aeronautics and Space Administration (NASA) of the discovery of coesite in tektites from Thailand. Coesite, a high-temperature, high-pressure form of quartz (SiO_2), is found in the great meteorite craters, and its presence is considered to be a criterion in the identification of craters formed by meteorite impact. Laboratory tests have shown that pressures and temperatures associated with volcanic activity are not sufficient to produce coesite.

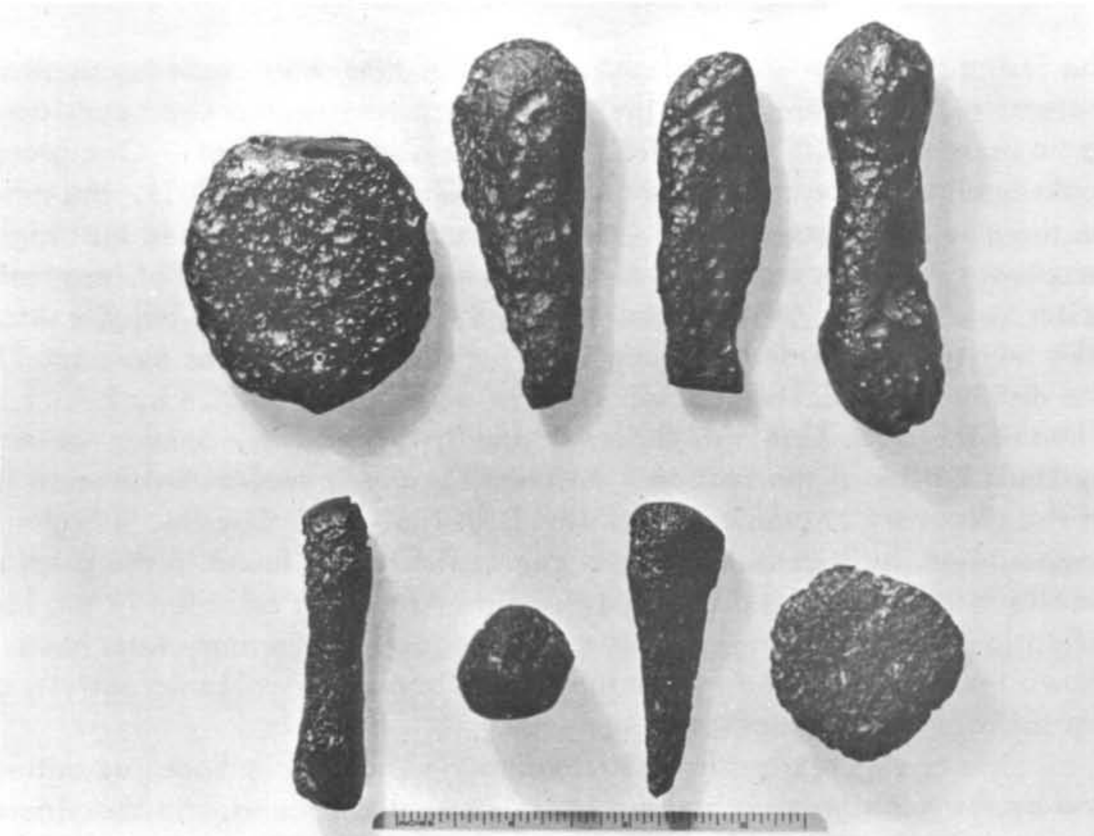
The age of tektites has been determined both by radioactive dating and by the geological formations in which they are found. Studies indicate the Texas bediasites belong to the Eocene (45,000,000 years), while the australites are the youngest group of about 5,000 years. All tektites from any particular group are of the same age.

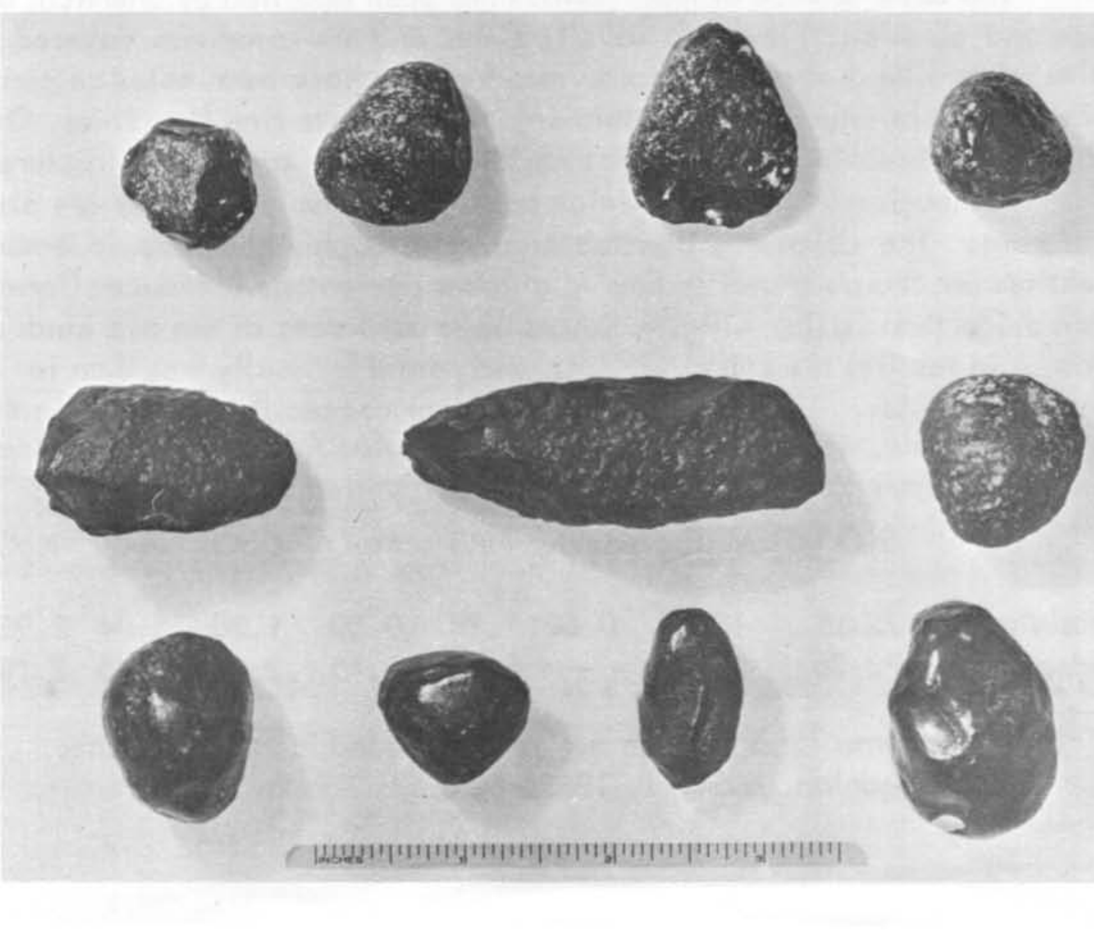
The outer surface of most tektites has been modified by chemical action and abrasion. They are usually pitted and are sometimes covered with worm-like grooves. Similar surface features have been noted on pieces of western obsidian. Unlike obsidian, tektites have fine flow lines. On chipping or breaking tektites, like obsidian, exhibit conchoidal fracture.

Although tektites and obsidian are similar chemically, they are also different. The silica and alumina content is roughly the same in each. Tektites are characterized by having a higher percentage of reduced (ferrous) iron oxide than ferric, while obsidians have but traces of the two kinds of iron. In tektites the content of soda and potash is usually less than in volcanic glasses. The difference in chemical composition is shown in the following table, which lists an analysis for obsidian from Newberry Volcano and the analysis of an indochinite tektite as reported by Barnes (1940):

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O
Obsidian	72.35	13.98	0.60	1.78	0.30	1.30	5.04	3.92
Indochinite	72.26	13.18	- - -	5.32	2.15	2.42	1.43	2.15

* New tests show lunar surface may resemble sand found on beaches. The Oregonian, March 1, 1965, p. 6.





Internally tektites exhibit strain patterns and often have glassy inclusions. Volcanic glasses have opaque inclusions which are rarely found in tektites.

A pronounced difference between tektites and volcanic glasses occurs on heating. In the laboratories of the Oregon Department of Geology and Mineral Industries, a number of tektites and a variety of obsidian glasses were heated to 2,000°F (1,100°C) for five minutes in a muffle furnace. All samples of obsidian exploded or expanded. One variety became a white, frothy mass similar to styrofoam. Tektite fragments of similar size from Thailand, Viet Nam, and Australia under the same conditions retained their original shape and form but became coated with a bright metallic luster. Further studies of tektites and volcanic glasses will be made as different kinds of materials become available. The writer would appreciate receiving samples of unusual tektite-like glassy objects found in the West.

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Explanation of photographs on opposite page.

Upper photograph:
Top row: Tektites from Thailand.
Bottom row: Tektites from Dalat, Viet Nam.

Note: All tektites from collection of Portland State College.

Bottom photograph:
Top row: Obsidian pebbles from Orval Butler ranch, Crooked River, Crook County, Oregon.
Middle row: Obsidian pebbles from Thorn Lake, Lake County, Oregon.
Bottom row: Apache tears from Wasco County, Oregon.

TEKTITES ON EXHIBIT

Tektites from Thailand, Australia, and Viet Nam are now on display in the Department's Portland office. All of the tektites are from the Portland State College collection and were loaned by Dr. Erwin Lange, author of the above article. The exhibit includes obsidian pebbles from central Oregon that look like tektites and also furnace-treated specimens.

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WILD RIVERS BILL WOULD AFFECT ROGUE RIVER

S. 1446, a bill to establish a National Wild Rivers System, has been introduced into the U.S. Senate by Church (Idaho) and 28 others. The bill defines a "wild river area" as a stream or section of a stream, tributary, or river -- and the related land area -- that should be left in its free-flowing condition, or that should be restored to such condition, in order to promote the public use and enjoyment of the scenic, fish, wildlife, and outdoor recreation values.

Oregon's Rogue River from Grants Pass to the Pacific Ocean is designated as a "wild river area." Other rivers thus named in the bill are segments of the Salmon River in Idaho, the Clearwater in Idaho, the Rio Grande in New Mexico, the Green River in Wyoming, and all of the Suwannee River in Georgia and Florida. Additions to this system are also recommended in the bill.

The bill would provide, among other things, that "Nothing in the Act shall affect the applicability of the United States mining and mineral leasing laws within the National Wild Rivers System, except that all prospecting, all mining operations, and all other activities on a mining claim perfected after the date of this Act, either before or after the issuance of patent, and all mining operations and other activities under a mineral lease, license, or permit hereafter issued, shall be subject to such regulations as the Secretary of the Interior, or the Secretary of Agriculture in the case of national forest lands, may prescribe to effectuate the purposes of this Act. Any patent so issued shall recite this limitation. All such regulations shall provide among other things for safeguards against pollution of the river. Any portion of a wild river area that is within the national wilderness preservation system shall be subject to the mining and mineral leasing provisions of both the Wilderness Act and this Act, and in case of conflict the more restrictive provisions shall apply."

The Senate Interior and Insular Affairs Committee scheduled hearings for April 22 and 23; Interior Secretary Stewart L. Udall and Agriculture Secretary Orville L. Freeman were expected to testify on the proposal.

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The ORE BIN
Volume 27, No. 5
May, 1965

GEOLOGY OF LAKE OWYHEE STATE PARK AND VICINITY, MALHEUR COUNTY, OREGON

By R. E. Corcoran*

Introduction

One of the most scenic areas in Oregon surrounds the Owyhee Dam and Reservoir in Malheur County of southeast Oregon (figure 1). This region has been well known to sportsmen for many years, because of the abundance of game in the hills and the excellent fishing in the lake. "Rockhounds" from all over the United States have been attracted to the Owyhee country by the many varieties of agate for which the region is famous. In April 1958, the State Highway Department established this area as one of its parks, in order to develop the recreational facilities of the Owyhee Reservoir and make it more accessible to the general public. Since that time a paved road has been constructed from the mouth of Owyhee Canyon into the newly developed park areas on Lake Owyhee. In addition to the state picnic and overnight camp grounds and the boat-launching ramps, there is a private motel and restaurant on the lake shore just beyond the park (figure 2).

Owyhee Dam was built in 1932 to develop a water-storage reservoir for irrigating the low alluvial lands along the Oregon side of the Snake River Plains (figure 3). The dam is 405 feet from foundation to crest, 835 feet long, and forms a reservoir 52 miles in length - the longest lake in Oregon. At the time it was built, Owyhee Dam was considered to be the highest in the world. In addition to the construction of the dam, approximately 15 miles of tunnel were driven eastward through the Owyhee Ridge to carry the water from the reservoir to the main irrigation system along the Snake River and Malheur River valleys.

According to McArthur (1952), the name "Owyhee" is derived from the old way of spelling "Hawaii." During the early part of the 19th

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* Stratigrapher, Oregon State Dept. of Geology and Mineral Industries.

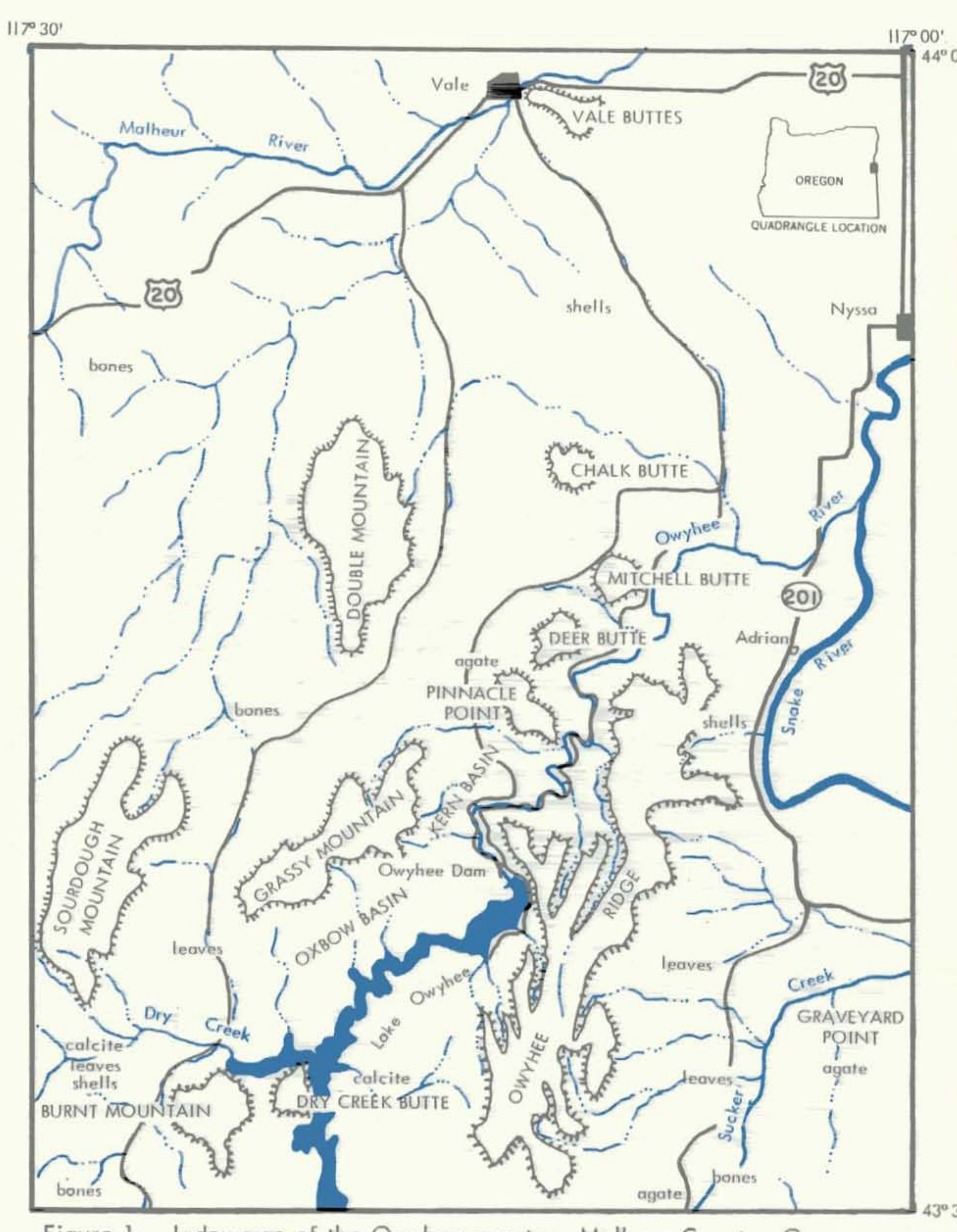


Figure 1. Index map of the Owyhee country, Malheur County, Oregon, showing the main geographic features and the location of some of the fossils and minerals.

century, natives from the Hawaiian (Sandwich) Islands were brought to the Pacific Northwest to work as laborers for the Hudson's Bay Company and the North West Company. Hawaiians were also used as boatmen to transport the fur traders into the interior parts of what are now the States of Oregon, Washington, and Idaho. Peter Skene Ogden, chief fur trader for the merged Hudson's Bay and North West Companies, was the first to make note of this fact in the report on his second expedition into the Snake River region. On Saturday, February 18, 1826, he "reached Sandwich Island River, so called, owing to 2 of them murdered by Snake Indians in 1819." McArthur states, "There seems to be no doubt that the Owyhee River was named for these Hawaiians, for on June 15 of the same year Ogden uses the word 'Owyhee'."

Geologists first visited this part of Oregon almost 100 years ago, when Clarence King led a geological exploration of the fortieth parallel for the U.S. Government (King, 1878). Since that time, additional studies have uncovered considerable information regarding the age and stratigraphy of the Tertiary volcanics and continental sediments that underlie this region (Bryan, 1929; Corcoran and others, 1962; Kittleman, 1962). The excellent surface exposures of the rocks in the vicinity of Lake Owyhee State Park make it an ideal "outdoor laboratory" for all those interested in the study of the earth's crust. This report briefly describes the rocks of the area around the state park and summarizes the geological history.

Physiography and Climate

The Lake Owyhee State Park is situated within the physiographic province called the "Owyhee Upland," which lies in southeastern Oregon, almost entirely within Malheur County (Dicken, 1959). It is characterized by a moderately to highly dissected upland surface with few perennial streams. In the vicinity of the state park, the Owyhee River has cut a deep canyon which, together with its tributaries, has produced an area of high relief. Hole-in-the-Ground is the name given to the part of the canyon immediately above the dam. The crest of Owyhee Ridge which borders the eastern edge of the reservoir has a maximum elevation of almost 5,000 feet. The surface of the lake is approximately 2,600 feet above sea level.

The Owyhee River rises in Nevada and flows northerly and northwesterly through Idaho and Oregon, and then east to its junction with the Snake River four miles north of Adrian, Oregon. Because the Owyhee River passes through an area of deficient rainfall, it possesses only three perennial tributaries.

The entire area lies within the high desert climatic belt of eastern Oregon. The leading characteristics of the high-desert climate in these northerly latitudes are: wide daily temperature range; small precipitation; generally cloudless skies; hot, dry summers; and moderately cold winters during which there is some rain and snow. The average annual temperature is about 52° F and the total annual rainfall is usually less than 10 inches.

Stratigraphic Geology

The Lake Owyhee region is underlain by a thick series of continental lake and stream beds, the deposition of which was interrupted from time to time by volcanic activity, as outlined in the stratigraphic column given below. The oldest sediments now exposed at the surface were laid down about 16 million years ago during the late Tertiary period (upper Miocene). The Miocene strata have been tilted by movements of the earth's crust, whereas beds of Pliocene age are in most places only slightly disturbed (Corcoran, 1954).

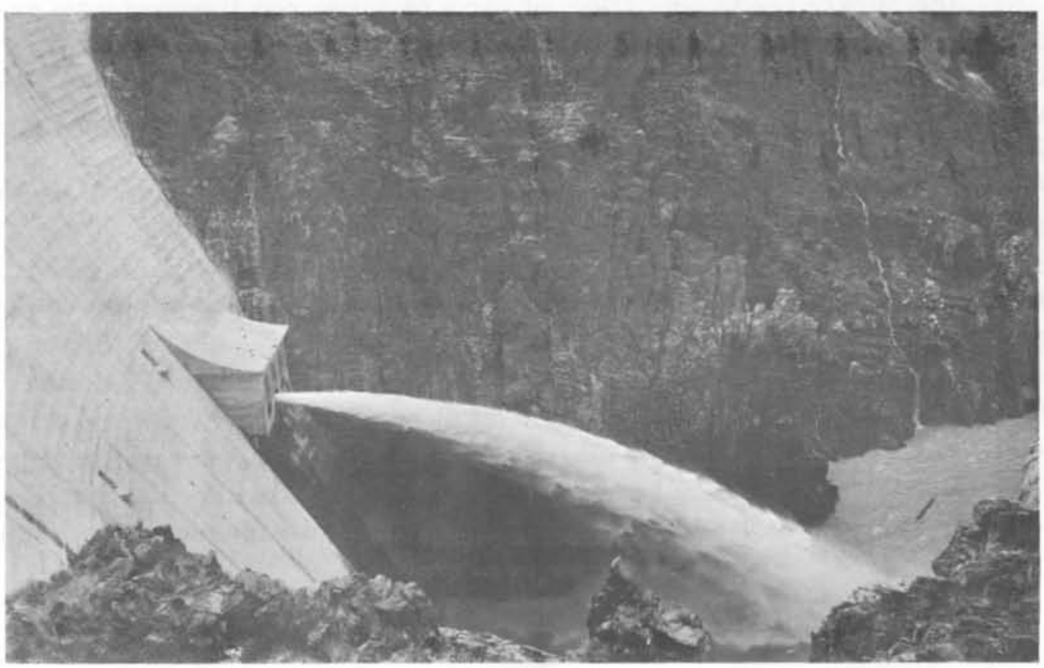
The sequence of sediments and volcanics that crop out in this part of the state have been subdivided into several "formations," based on distinguishing rock characteristics, in order to facilitate their identification in other areas and to aid in correlating the Tertiary stratigraphy of southeastern Oregon. The formational name is usually derived from the geographic

Stratigraphic Column for the Lake Owyhee Region.

Age		Formation	Description
Middle Pliocene	Idaho Group	Chalk Butte Formation:	Mostly fluviatile deposits with a few intercalated basalt flows.
Lower Pliocene	Idaho Group	Grassy Mountain Basalt:	Olivine basalt flows with interbedded tuffaceous sediments.
Lower Pliocene	Idaho Group	Kern Basin Formation:	Tuffs, tuff breccias, and tuffaceous sediments.
Upper Miocene		Deer Butte Formation:	Tuffaceous sediments in lower part with intercalated lavas grading upward into coarser arkosic sandstones and rhyolite-granite conglomerates.
Upper Miocene		Owyhee Basalt:	Massive to thin-layered plateau basalts with interbeds of tuffs and ash deposits.
Upper Miocene		Sucker Creek Formation:	Fine-grained tuffaceous sediments with basaltic lavas in the lower part and rhyolitic lavas in the upper.

Figure 2. Aerial view of Lake Owyhee State Park in September 1960. Privately owned Cherry Creek-Owyhee Resort can be seen at right of photograph. State park area in center of photograph is situated on the Sucker Creek Formation. Water level of lake is approximately 50 feet below normal. Usual level is indicated by vegetation line.

Figure 3. Owyhee Dam, constructed in 1932 for irrigation purposes. The dam is situated on a rhyolite vent which served as a feeder for the massive Sucker Creek flows that crop out beneath the Owyhee Basalt. Note the well-developed vertical jointing in the wall of the canyon. (Photographs courtesy Oregon State Highway Department.)



locality where the unit best shows its distinguishing lithologic character. In discussing the geology of the Lake Owyhee area in this report, the oldest rocks are described first, followed by progressively younger units. These are, in order: Sucker Creek Formation, Owyhee Basalt, Deer Butte Formation, Kern Basin Formation, Grassy Mountain Basalt, and Chalk Butte Formation. Within each formation there may be one or more major rock types which have some form of similarity compared to the stratigraphic units above and below. Formations may be separated on the basis of "unconformities" which represent old erosion surfaces, but this is not a necessary requirement for subdivision.

The generalized geologic map accompanying this report (p. 90-91) shows the areal distribution of the rock formations which underlie Lake Owyhee State Park and vicinity. It should be pointed out that there is considerable variation in the nature of the continental sediments in any one formation. The climate in southeastern Oregon in the late Tertiary period was more humid than now, and during any particular interval of time, streams or rivers were depositing medium to coarse sands in some areas while lakes were slowly filling with fine mud and silts in adjacent basins. Basalt or rhyolite lavas may have poured down a broad valley in one direction and left an adjacent valley completely undisturbed. The lateral variation in rock types caused by differences in sedimentary environments has complicated the problem of formational identity, and in some places the correlation of one series of rocks with another is based partly on time equivalency of the fossils found within them.

Sucker Creek Formation (Tsc)

The Sucker Creek Formation of upper Miocene age is named from exposures along Sucker Creek, approximately eight miles southeast of Lake Owyhee State Park (figure 4). The formation is also exposed in the Owyhee Canyon near the dam, but the lake has now covered most of it. Before the dam was built, Renick (1930) measured a 500-foot section between the floor of the canyon and the base of the overlying Owyhee Basalt. The camp and picnic grounds at the state park are situated on the sediments of the Sucker Creek Formation. The rocks are varicolored volcanic tuffs and tuffaceous lake bed deposits that are characterized by their high ash content and lack of induration. In other areas platy shales, massive volcanic agglomerates, and siltstones predominate. Thin beds of air-laid ash are fairly widespread, but make up only a small proportion of the entire section.

Because of its relatively unstable volcanic content, most of the original material in these beds has been altered to bentonite clay (montmorillonite). This has resulted in a characteristic type of weathered surface that

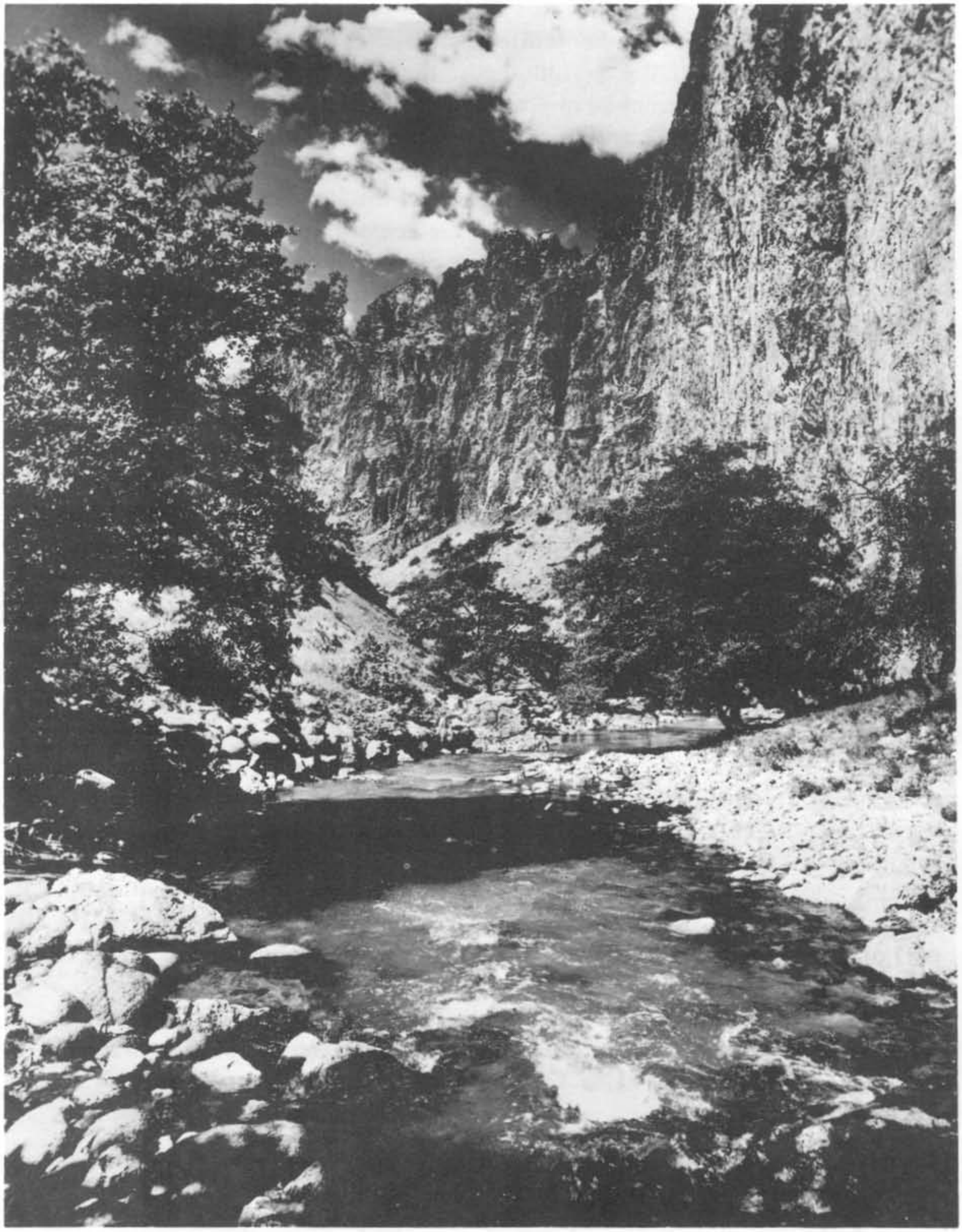


Figure 4. Sucker Creek canyon southeast of Lake Owyhee State Park. The stream has cut a deep canyon through resistant volcanic tuffs of the Sucker Creek Formation. Agates, thundereggs, and fossil leaves are found in this area. (Photograph courtesy of Oregon State Highway Department.)

can be seen at many outcrops in this area. When saturated with moisture during the rainy season, the bentonite absorbs excess water and swells considerably. Subsequent dry periods cause the clay to shrink, giving the weathered outcrop a cracked or "expanded" aspect. Plates of selenite (gypsum) are also quite common as a product of surface weathering of the bentonites.

Rhyolite flows occur in the upper part of the Sucker Creek Formation. The rhyolite (Tsr) is best exposed along the eastern scarp of the Owyhee Ridge east of the dam and along the sides of the Owyhee River canyon in the reservoir area. The dam itself was constructed on an old rhyolite vent which appears to have been the source of the flows that spread westward from this point (see figure 3). The vent shows well-developed flow banding which is nearly vertical and has a general northeasterly trend. The rock, however, is locally contorted, and small-scale folds and crenulations are prominent below the dam. The flow structure in the vent is noticeable even at a distance because of the well-developed jointing and fracturing which tend to parallel the banding. The agate deposits in the Graveyard Point area near the Idaho border are found within the Sucker Creek Formation and probably originated from high-silica solutions emanating from some of the acid magmas associated with the rhyolitic volcanic activity.

The fossilized leaves and bones that have been found in the Sucker Creek Formation portray well the environment that prevailed during deposition of this series. The over-all climate was warm to cool temperate, with an average annual rainfall of more than 20 inches. An upland forested region is indicated, with oaks as the dominant form on the slopes and lakes or swamps occupying the intervening lowlands. Ancestors of the modern horse, deer, camel, and pronghorn were abundant during this period and suggest that there were probably extensive grasslands as well as forested areas. Along the swampy lowlands beaver were common. Elephant and rhinoceros remains in beds of the Sucker Creek Formation show that this part of Oregon may have resembled the present African plateau.

After the period of rhyolitic activity interspersed with lake and stream sedimentation, a lowering of base level or general uplift of the area ushered in a time of erosion that stripped the sedimentary cover from some of the acid flows of the Sucker Creek Formation and produced a surface of fairly rugged relief.

Owyhee Basalt (Tob)

Following the erosional interval described above, there was a resumption of volcanic activity and great thicknesses of basalt were laid down on the existing land surface. Valleys quickly became filled, and the region soon took on the aspect of a featureless volcanic plateau. Large sections of what are now eastern Oregon and Washington and southwestern Idaho became covered to depths of several thousand feet by this series of lavas. Later erosion of the plateau removed much of the volcanic surface, but remnants of this thick sheet of upper Miocene lavas are well displayed in such areas as the Columbia River Gorge, Picture Gorge, Abert Rim, Steens Mountain, and the Owyhee Plateau.

The main mass of the Owyhee Basalt crops out in the canyon walls of the Owyhee River from the general vicinity of the state park to a point just south of Mitchell Butte, where the river leaves the canyon. The flows form the upland surface that constitutes the main portion of the Owyhee Ridge east of the park area. In the Hole-in-the-Ground where the dam is located, the basalts are at least 1,300 feet thick. The original thickness was probably much greater before erosion removed some of the overlying sediments and the upper layers of basalt.

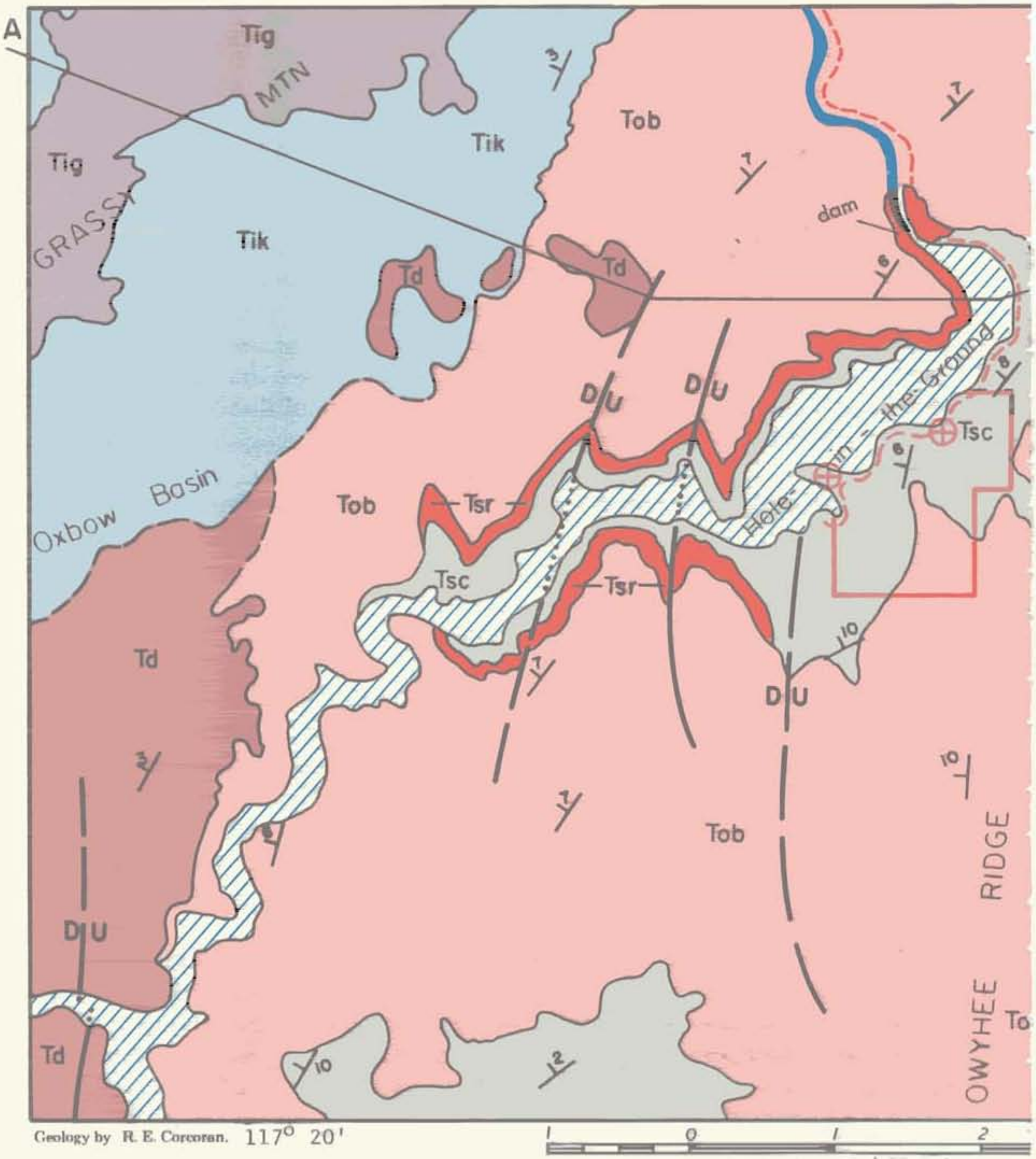
Interbedded tuff and ash deposits, representing explosive phases of volcanic activity, are common throughout the Owyhee Basalt section. In some outcrops these layers, as much as 10 or 15 feet thick, appear to make up at least half of the total section, but a lack of consolidation causes them to weather down readily and they usually are hidden beneath the basalt rubble of the overlying flows.

In hand specimen the basalt is generally fine grained, dark gray to black, and ranges from very dense to highly vesicular. Most of the vesicular zones occur in the upper part of the flows, where rising bubbles of gas in the hot liquid portion were trapped in the colder surface crust. The minerals commonly present in the basalts are plagioclase feldspars (in the groundmass and as phenocrysts), augite, hypersthene, olivine, magnetite, and minor amounts of glass, chlorite, iddingsite, and calcite. Zeolites fill the vesicles of many of the less dense flows.

Numerous feeder dikes are visible on the canyon wall that makes up the east face of the Hole-in-the-Ground (figure 5). Most of these are no more than a few feet wide where they cut through the underlying Sucker Creek beds, and probably represent fissure fillings along fractures that once provided channelways for the basaltic magmas. They are of the same mineralogic composition as the flows but are generally denser, more finely crystalline, and non-porphyritic.

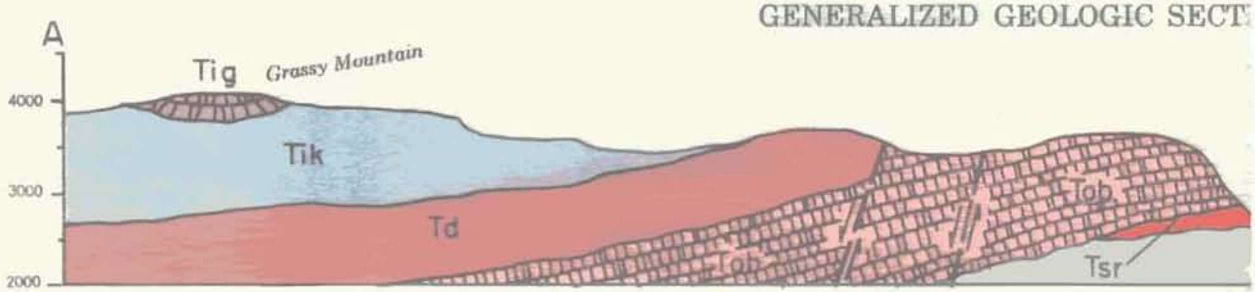
After the period of volcanism in which numerous flows of Owyhee Basalt were poured out, the area was gently upwarped and once more subjected to erosion. To the south, where the lavas appear to have been thinner, the entire volcanic layer was stripped and a surface of fairly rugged topography was developed on the underlying Sucker Creek Formation.

Geologic Map of the Lake Owyhee State Park



Geology by R. E. Corcoran.

GENERALIZED GEOLOGIC SECT



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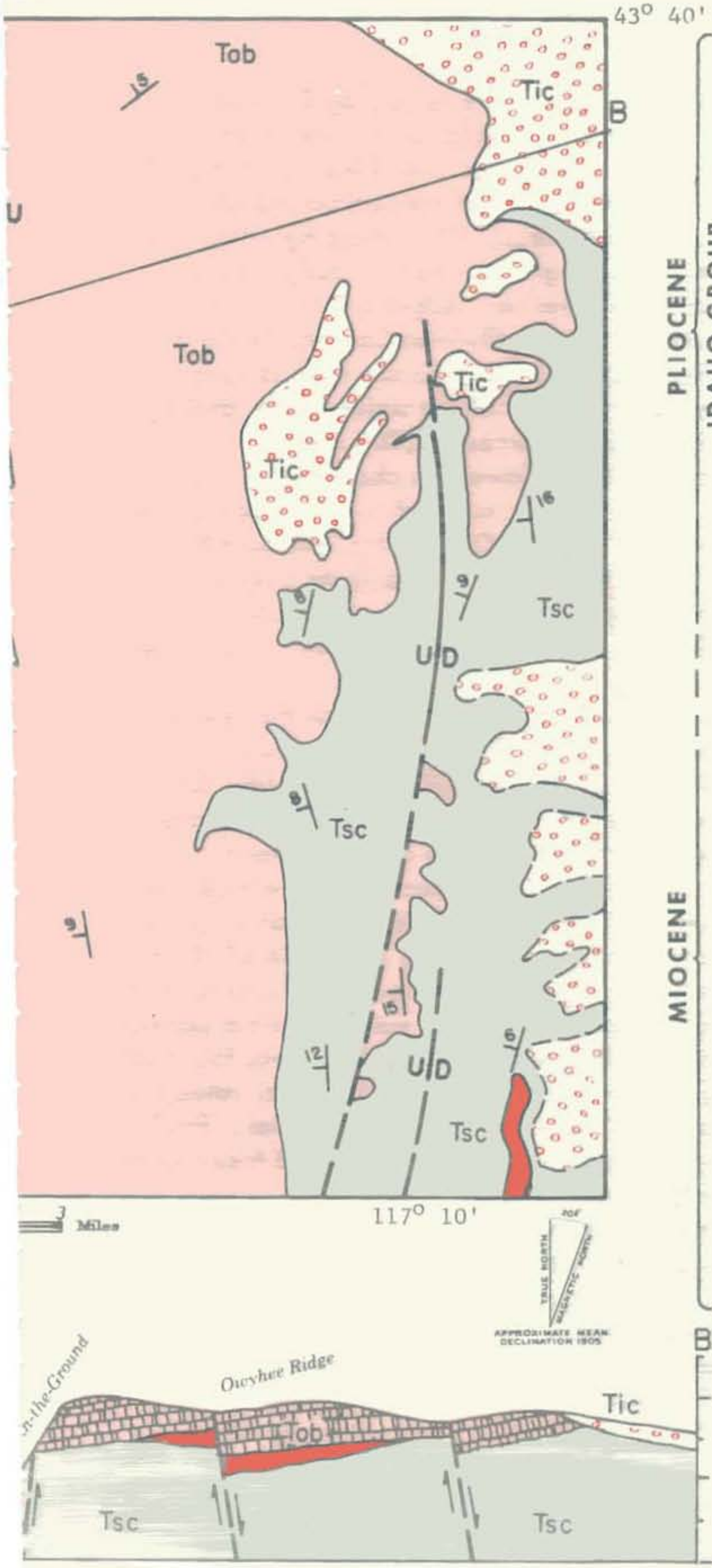


PLIOCENE

MIOCENE

IDAHO GROUP

EXPLANATION

Tic

Chalk Butte Formation

Loosely consolidated tuffaceous conglomerate, sandstone and siltstone of lacustrine or fluviatile origin with lesser amounts of ash and fresh-water limestone, Tic.

UNCONFORMITY

Tig

Grassy Mountain Basalt

Thin flows of normal olivine basalt, Tig; includes interflow sediments.

DISCONFORMITY

Tik

Kern Basin Formation

Tuffaceous sandstone and siltstone with bedded tuffs, ash deposits and massive tuff breccias. Conglomerate beds common in basal part of section.

UNCONFORMITY

Td

Deer Butte Formation

Soft tuffaceous siltstones and shales grading upward into interbedded tuffaceous siltstones, massive silicified arkosic sandstones and rhyolite-granite conglomerates, Td.

UNCONFORMITY

Tob

Owyhee Basalt

Massive and scoriaceous basalt flows with tuffs and ash deposits.

UNCONFORMITY

Tsc Tsr

Sucker Creek Formation

Predominantly bedded and massive varicolored tuffs and tuffaceous shales with minor siltstone and sandstone, Tsc; includes massive flows and intrusions of rhyolite, in upper part, Tsr.

Lake Owyhee

Lake Owyhee State Park

⊕ Developed areas of park

Access road

Deer Butte Formation (Td)

Near the end of the Miocene epoch, the region again became a basin of deposition. The first sediments to be laid down were chiefly fine-grained tuffaceous rocks with a few intercalated lava flows. Later on, the source area became more varied and the nature of the sediments changed to coarser grained sandstones and conglomerates. Silica-bearing waters permeated the coarser beds, firmly cementing them into very resistant arkoses that today stand out conspicuously as prominent ledges and high buttes.

Deer Butte, near the north end of the Owyhee Canyon, is the type locality for which the formation is named. This resistant knob is composed of the coarser and more highly cemented part of the series. The total thickness of the Deer Butte Formation probably exceeds 2,000 feet.

The well-cemented arkoses and conglomerates characteristic of the upper part of the section are responsible for many of the more prominent hills surrounding the state park, including Dry Creek Butte, Pinnacle Point, and Mitchell Butte (figure 6). In several places these knobs crop out as isolated steptoes separated from the main body of the formation by younger sediments and lavas. The Vale Buttes, just south of the town of Vale, are a good example of this type of erosional feature.

In the area around Dry Creek, near the south edge of the geologic map, the tuffaceous shales, siltstones, and claystones are particularly widespread. These deposits are quite similar in appearance to the older Sucker Creek Formation, and the two sedimentary units are difficult to distinguish in the field in areas where the intervening Owyhee Basalt is missing.

An interesting feature of the fine-grained sediments in the lower part of the Deer Butte Formation near Dry Creek is the occurrence of numerous veins of calcite. Some of these veins are as much as 25 feet in width and half a mile long. The deposits were investigated by the Department several years ago to determine whether crystals of sufficient size for optical purposes could be extracted from the veins. Unfortunately, no method was found for removing clear crystals in big enough pieces to be of commercial value, but rockhounds can still obtain large rhombs of good quality material. Fossil collectors can also find well-preserved specimens of leaves and fresh-water snails in the sediments that surround the calcite veins.

The cobbles which make up the conglomerates in the Deer Butte Formation are as much as 6 or 8 inches across and are composed predominantly of granites, rhyolites, quartzites, and quartz. The amount of basaltic material in these beds is quite low, which is rather surprising in view of the fact that this formation rests on the erosion surface of the underlying Owyhee Basalt. The source area for these rocks is not definitely known, but it appears to be in the vicinity of Silver City, Idaho, approximately 50 miles southeast of the state park. A mineralized Mesozoic granite stock about 10 miles wide by 25 miles long has been unroofed in this mountainous region by erosion of the overlying Tertiary rhyolites, tuffs, and basalts.

The environmental conditions that prevailed during Deer Butte time seem to have been similar to those which existed a few million years earlier when the Sucker Creek Formation was being deposited. Vertebrate remains collected from Deer Butte beds or formational equivalents farther to the west suggest a semihumid or perhaps a forest environment. Among the larger animals living in the area were grazing horses, camels, and antelopes. Rodents were abundant and included the tree and ground squirrels, rabbits, and so-called mountain beaver.

The depositional period marked by the Deer Butte Formation was interrupted for a short time, during which the basins were uplifted and faulted and a surface of relatively high relief developed on the older rocks.

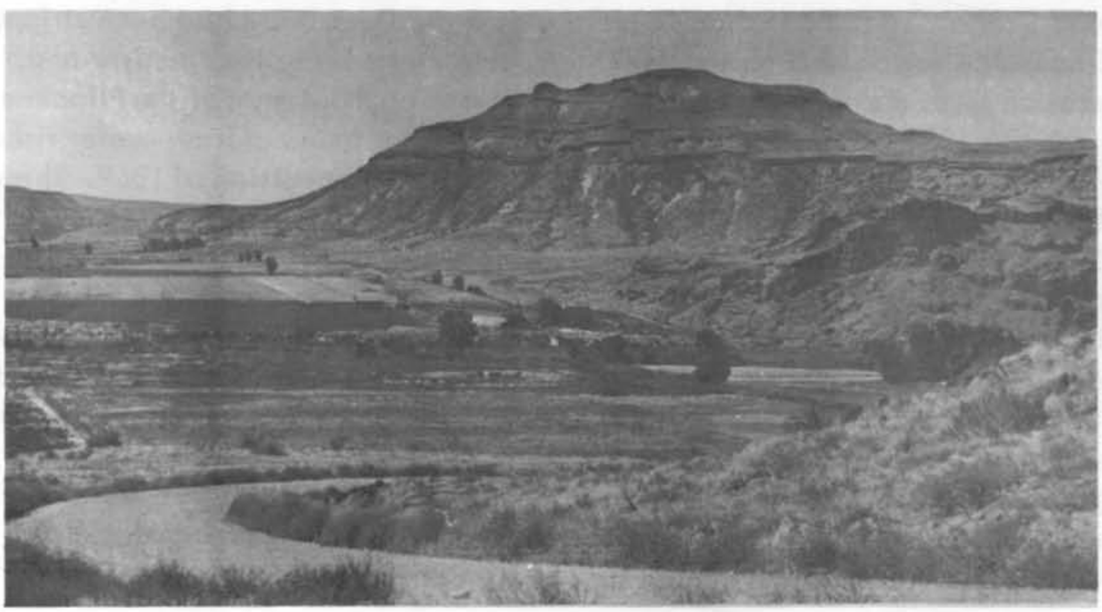
Idaho Group

At the beginning of the Pliocene epoch about 12 million years ago, a major structural basin, which was developed in part by block faulting, began to form in the area along the present Idaho-Oregon border. Lake and stream sediments derived from the surrounding uplands were widely distributed over the basin, known as the Snake River plains, from the general vicinity of Hagerman, Idaho to Huntington, Oregon. Because the formations dip generally toward the center of the plains, this region is sometimes called the Snake River downwarp. Along the margins of this downwarp in the Lake Owyhee region, fine- to coarse-grained sediments were deposited on the eroded surface of the Deer Butte Formation or on the Owyhee Basalt and Sucker Creek Formation in areas where the Deer Butte had been stripped. Sedimentation, although locally interrupted by periods of volcanism and erosion, was on the whole fairly continuous throughout most of the Pliocene.

In 1883, E.D.Cope described an extensive fauna of fresh-water fishes from fossil collections made by the Clarence King expedition of 1869. These fossils came from the banks of Castle and Sinker Creeks, tributaries to the Snake River in southwestern Idaho. On the basis of his studies, Cope proposed the name "Idaho Formation" for the sediments and assigned them a Pliocene age. More recent geological studies have shown that sedimentary and volcanic rocks in southwestern Idaho and southeastern Oregon included in the Idaho Formation are quite diverse in lithologies and source areas and are difficult to trace from one basin to another. For this reason it has been proposed to elevate the formation to a group so that distinctive lithologic units which are characteristic of various areas in and bordering the Snake River plains, but which cannot be closely correlated, can be adequately

Figure 5. Basaltic feeder dike in right foreground cuts through tuffaceous rocks of Sucker Creek Formation near Lake Owyhee State Park. Flows of Owyhee Basalt can be seen on both sides of the dam in background. (Photograph courtesy Oregon State Highway Department.)

Figure 6. Deer Butte Formation exposed in Mitchell Butte near Adrian. Resistant benches are well-cemented sandstones and conglomerates typical of the upper part of the section.



described. In the Lake Owyhee region the Idaho Group has been subdivided into three units: the Kern Basin Formation (lower Pliocene), Grassy Mountain Basalt (lower Pliocene?), and Chalk Butte Formation (middle Pliocene).

Kern Basin Formation (Tik)

Good exposures of the Kern Basin Formation can be seen in Oxbow, Sourdough, and Kern Basins (figure 7) where the sediments form steep bluffs from 100 to more than 600 feet in height capped by Grassy Mountain Basalt. The beds vary in color from white to green with occasional dark bands. Most of the beds are loosely consolidated and tend to weather into pinnacled or "hoodoo" forms. They include tuff, tuffaceous siltstone and sandstone, low-rank graywacke, and conglomerates, deposited under conditions that fluctuated from stream environments to broad, shallow lakes.

Grassy Mountain Basalt (Tig)

Overlying the Kern Basin Formation is the series of flows referred to by Kirk Bryan (1929) as the "Grassy Mountain Basalt." The basalts cap the hills northwest of the state park, and flows of similar stratigraphic position and composition can be traced for several miles westward. The formation contains several sedimentary interbeds, the number and thickness of which vary considerably. The basalts are massive, but usually no more than three or four separate flows can be observed at any one locality. Individual flows range in thickness from a few feet to about 100 feet.

In the hand specimen, the basalt is brownish-gray to olive-black in color, fine-grained with phenocrysts of plagioclase and olivine. Vesicles in the lava may be lined or filled with secondary zeolites and calcite. One of the distinguishing mineralogic characteristics of the flows in this unit is the presence of olivine, readily visible in hand specimens, as straw-yellow crystals as much as 2mm in diameter scattered through a fine-grained matrix. In some flows the olivine has altered to the secondary mineral iddingsite, which gives it a red, speckled appearance.

Chalk Butte Formation (Tic)

The Chalk Butte Formation is the most widely distributed sedimentary unit north and east of Lake Owyhee State Park in the region of the Snake River downwarp. The formation consists of unconsolidated to semi-consolidated clay, silt, sand, volcanic ash, diatomite, fresh-water limestone, and conglomerate. The road south from Vale towards the mouth of

Figure 7. Light-colored tuffaceous sedimentary rocks of the Kern Basin Formation at the type locality. Note fluted weathering of the beds.

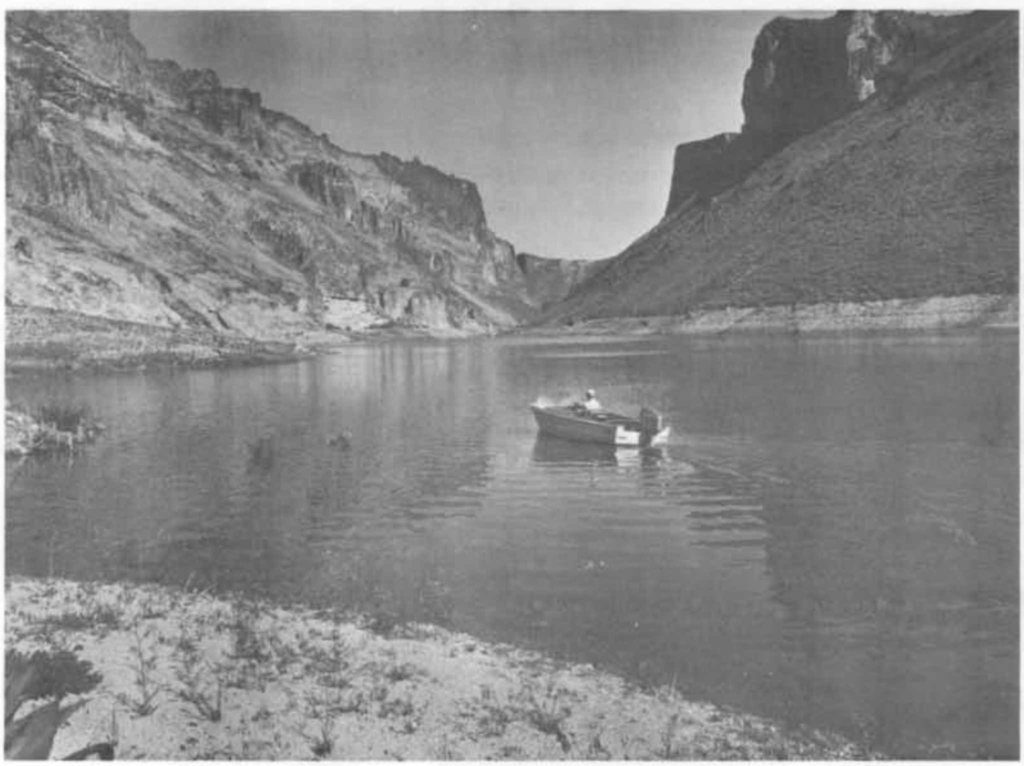


Figure 8. Massive varicolored tuffs of the Sucker Creek Formation form the canyon walls near the upper end of Lake Owyhee. This scenic region is easily accessible by boat from the state park. (Photograph courtesy Oregon State Highway Department.)

Owyhee Canyon crosses a low, hilly region composed of continental lake and stream deposits of this formation. Thin remnants of Chalk Butte sediments visible on some of the higher parts of Owyhee Ridge indicate that these deposits covered much of the area through which the Owyhee River and its tributaries now flow. Stream erosion, begun after the region was uplifted, has stripped most of the sedimentary cover from the older rocks.

The formation appears to have been deposited chiefly by streams and rivers, with the diatomite, limestone, silt, and clay representing local lake basins. The younger beds of the Chalk Butte Formation are coarser grained, particularly on the Idaho side of the Snake River plain, and are apparently derived from weathering and erosion of the Idaho batholith to the east. A study of the oil and gas exploratory well logs drilled in the central portion of the plains shows that the Chalk Butte beds or their correlatives may be as much as 4,000 to 5,000 feet thick (Newton and Corcoran, 1963).

Conclusions

Some of Oregon's most scenic and geologically interesting areas are to be found in the dry eastern parts of the state. A region that is becoming better known is that in the vicinity of Lake Owyhee in central Malheur County. There is something here for everyone who enjoys the outdoor life, whether it be hunting, fishing, "rockhounding," fossil collecting, or just plain camping. The colorful and varied rock formations, unobscured by vegetation, are a delight to the amateur photographer. A good paved road gives easy access to the camp areas above the dam. Those who wish to explore the upper reaches of the lake can do so easily by boat (figure 8) and in this way see some of the otherwise inaccessible scenic areas of the Owyhee country.

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TUALATIN VALLEY GEOLOGY PUBLISHED

"Geology and Ground Water of the Tualatin Valley, Oregon," by D. H. Hart and R. C. Newcomb, has been published by the U.S. Geological Survey as Water Supply Paper 1697. The 172-page report includes well records, geologic maps, and cross sections. It may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 for $3.00.

* * * * *

AN OLD MINE? -- GOOD LUCK!

What is cold and dark, has hidden pitfalls, treacherous floors, walls, and ceilings, bad air, poisonous water, wild animals and reptiles, loose sticks of dynamite, no house number or street address, and attracts hundreds of people every year? Answer: OLD MINES.

The rapidly growing interest in rockhounding, prospecting, and geology unfortunately also creates a lot of interest in old mines. This is easy to understand, since there is bound to be a lot of curiosity about where all the gold, in some cases millions of dollars worth, came from in an old mine. Crystal hunters also are interested in old workings and there are those who "just want to look around underground." In addition to mine tunnels, there are also glory holes, vertical shafts and open pits, to watch out for in "mining country." All of them pose some real hazards not well appreciated by the general public.

Here are a few rules to keep in mind when you are out in the hills and come across an old mine: (1) If you can't resist the urge to enter, go in with extreme caution; (2) watch for rotten timbers and flooring over shafts, loose rock, rusty nails in timbers, abandoned dynamite and caps, foul air, poisonous water, short-tempered wild animals and reptiles, and confusing cross tunnels; (3) leave somebody outside to go for help; (4) wear a hard hat, heavy shoes, and warm clothing; (5) take a carbide lamp, canteen, matches, and a rabbit's foot. Better yet, stay on the outside and just peer inside.

* * * * *

THE TACOMA EARTHQUAKE OF APRIL 29, 1965

By
E. F. Chiburis, Peter Dehlinger, and W. S. French*

About the time Seattle and Tacoma people were going to work on the morning of April 29, 1965, the Pacific Northwest states were shaken by their largest earthquake in decades. The shock was as large, or larger, than the famous Tacoma shock of April 13, 1949. The recent quake was felt over Washington, Oregon, Idaho, and British Columbia, and as far away as Coos Bay, Oregon. Considerable damage occurred in the Tacoma-Seattle area, where at least three persons were killed. The shock was so strong that recordings at most seismograph stations in the Northwest went off scale, and subsequently recorded vibrations were so large that the different waves could not be identified. Consequently, the magnitude of the shock could be determined only at distant stations, where recorded amplitudes were smaller.

The magnitude of the shock was reported to be $6\frac{1}{2}$ (Richter scale)** by the Seismological Laboratory in Pasadena, California, and 7 by the Seismographic Stations in Berkeley, California. The maximum intensity was estimated to be VIII (Modified-Mercalli scale)** in the Tacoma-Seattle re-region, decreasing to intensities of VII at Longview, Washington; IV at Corvallis, Oregon; and III at Coos Bay, Oregon. By comparison, the Portland earthquake of November 5, 1962, had an estimated magnitude of 4-3/4, with intensities of VI in Portland and III in Corvallis.

The epicenter was located in the northeast part of Tacoma, at latitude 47° 16.8'N, longitude 122° 29.7'W, very near the epicenter of the 1949 quake (see map on next page). The origin time was calculated to be 08:28:41.9 PDT (15:28:41.9 GCT). The depth of focus, for an assumed average velocity of 7.0 km/sec to Seattle and Longmire, was 80 km, and for an assumed average velocity of 6.3 km/sec, it was 66 km.

The quake was relatively deep for the Pacific Northwest region, although it would be classed as shallow to intermediate in depth (shallow shocks are 0-60 km deep; intermediate 60-300 km; deep 300-700 km). By contrast, the depth of the Portland shock of November, 1962, is estimated to have been 10-15 km. Had the Tacoma shock been only 10 km deep, extensive damage indeed would have occurred throughout the city and adjacent regions. The actual damage corresponds to that from the shocks at epicentral distances of 70 km or more.

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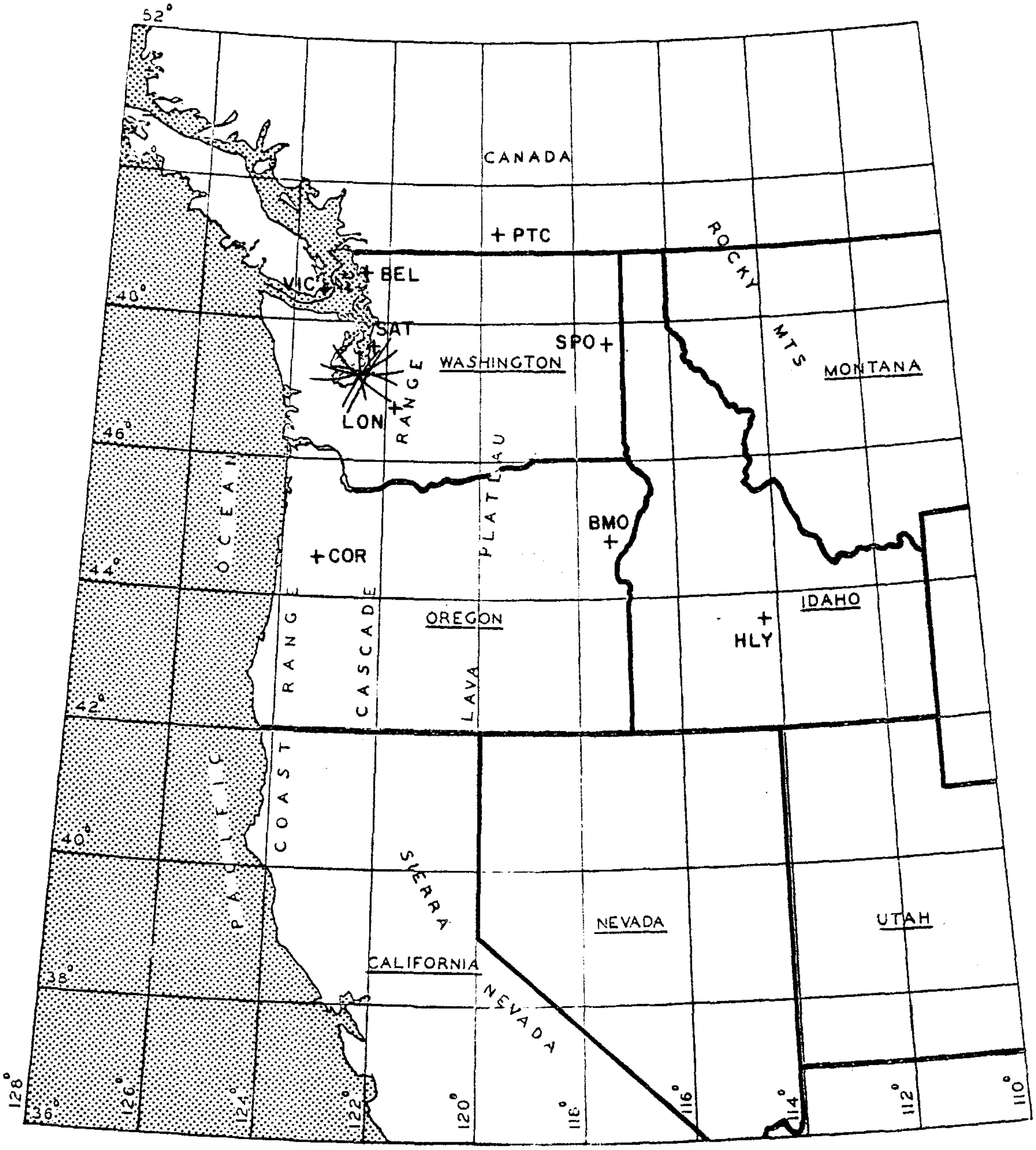
* Geophysical Research Group, Department of Oceanography, Oregon State University, Corvallis.

** Richter scale is the instrumentation measurement as determined by a seismograph; Modified-Mercalli scale is a subjective measurement of the intensity by people who feel the quake.



The above map shows the epicentral location of the earthquake as determined by arc intersections from the following seismic stations:

Seismic Stations	Arrival times	Epicentral distance (km)	Travel time (sec)
Seattle, Wash. (SAT)	08:28:54.5 PDT	45	
Longmire, Wash. (LON)	08:28:58.4	77	
Victoria, B. C. (VIC)	08:29:05.9	152	24.5
Bellingham, Wash. (BEL)	08:29:08.5	162	25.9
Corvallis, Oregon (COR)	08:29:26.4	303	44.2
Penticton, B. C. (PTC)	08:29:27.4	311	45.2
Spokane, Wash. (SPO)	08:29:35.8	388	55.3
Blue Mtn. Obs., Oregon (BMO)	08:29:48.8	476	66.4
Hailey, Idaho (HLY)	08:30:22.0	755	101.4

The ORE BIN
Volume 27, No. 6
June, 1965

PRELIMINARY DATA ON COMPOSITIONAL VARIATIONS OF TERTIARY VOLCANIC ROCKS IN THE CENTRAL PART OF THE OREGON COAST RANGE*

By

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Basalt flows and breccias of early to middle Eocene, late Eocene to early Oligocene, and middle Miocene ages are important stratigraphic units within the sequence of Tertiary marine sedimentary rocks of the Coast Ranges of Oregon and Washington. Studies currently being conducted on samples from these three volcanic units (plate 1) in the central part of the Oregon Coast Range indicate that each unit has distinctive petrographic and chemical characteristics.

The purpose of this report, which briefly summarizes preliminary petrochemical data on these volcanic rocks, is to call to the attention of petroleum geologists a stratigraphic tool that may prove useful in determining the ages of volcanic units encountered in exploration drilling, particularly on the continental shelf off western Oregon. The writers are aware, however, of limitations attendant to correlation of volcanic rocks solely by petrochemical characteristics, since altered or highly zeolitized basalts and fragmental rocks provide little useful data. Also, differentiation in shallow magma chambers has produced small amounts of basaltic rocks of early middle Eocene age that are similar in composition to those of late Eocene age. Caution, therefore, must be exercised in utilizing petrochemical data alone to assign an individual basalt sample to a particular volcanic sequence.

The petrographic and chemical data in this report were determined for more than 100 samples of volcanic rocks collected in the central part of the Oregon Coast Range. A much smaller number of samples from Tertiary extrusive rocks in other parts of western Oregon and Washington has been studied. The available data indicate that volcanic rocks of corresponding

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* Publication authorized by Director, U.S. Geological Survey.
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ages throughout the Coast Ranges of western Oregon and Washington have similar petrochemical characteristics. These Coast Range volcanic rocks have a close affinity to the oceanic province, since they contain a high (2 to 3 percent) TiO_2 content (Chayes, 1964; Chayes and Metais, 1964).

Lower to Middle Eocene Volcanic Rocks

The oldest rocks exposed in the Coast Ranges of Oregon and Washington consist of a eugeosynclinal accumulation of basaltic pillow lavas and breccias with interbedded marine tuffaceous sedimentary rocks. In the central part of the Oregon Coast Range (pl. 1) this predominantly volcanic sequence was named the Siletz River Volcanic Series by Snavely and Baldwin (1948).

Based upon present knowledge, the Siletz River Volcanic Series is divided into two major petrochemical units: a lower Eocene tholeiitic suite, which is principally submarine in origin and forms the bulk of the series, and a lower middle Eocene alkalic suite, which apparently forms a thin veneer on the older unit and is both submarine and subaerial in origin. The relation of the tholeiitic and alkalic basalts * in the Siletz River Volcanic Series is similar to that described in the Hawaiian Islands by Powers (1935), Tilley (1950), and Macdonald and Katsura (1964) and in the northeast Pacific Ocean by Engel and Engel (1963; 1964), because in those areas thick shields of tholeiitic basalts are capped with alkalic basalt.

Lower unit

The lower unit consists of more than 6,000 feet of alternating sheets of basaltic pillow lava and breccia with thin interbeds of marine tuffaceous siltstone. These lower Eocene tholeiitic basalts form lenticular masses that are probably thickest, as much as 20,000 feet (Snavely and Wagner, 1964), along the former axis of the Tertiary eugeosyncline. This unit is interpreted as representing a shield-forming stage of early Eocene volcanism which was

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* As used in this report, tholeiitic basalt is a rock saturated in silica and containing normative quartz and(or) hypersthene; alkalic basalt is an undersaturated rock with abundant alkalis, and with nepheline in the norm

> Editor's Note: The Siletz River Volcanic Series was named prior to the 1961 Code of Stratigraphic Nomenclature, which recommends that "Series" be confined to time-stratigraphic use.

characterized by voluminous submarine eruption of basaltic magma along north-trending fissures. Broad submarine ridges constructed on the sea floor probably did not rise above sea level because the rate of subsidence kept pace with the rate of volcanism.

The lower unit consists predominantly of submarine lava which is composed of closely packed ellipsoidal pillows that are 3 to 4 feet in diameter and radially columnar-jointed. The pillows contain a chilled selvage up to half an inch thick which originally was a basaltic glass, but has altered to waxy, greenish-black clay minerals. Massive to rudely columnar-jointed basalt sills and flows(?) up to 50 feet thick occur locally in the pillow sequence. In places glassy tuff-breccias that contain broken pillows or small isolated pillows are interbedded with or grade laterally into pillow flows. The predominant rock type is an amygdaloidal dark greenish-gray aphanitic to fine-grained basalt. Zeolites and calcite commonly form the cementing material in breccias, fill interstices between pillows, and occur as amygdules in the basalt.

Microscopically, the basalt is holocrystalline to hypocrystalline. Some rocks are porphyritic to seriate, but more commonly they are equigranular. The most common texture is intersertal to subophitic or intergranular. Unaltered rims of pillows and basalt fragments in the breccia are vitrophyric. In the outer rims of some pillows the basalt is variolitic and amygdaloidal.

Plagioclase and clinopyroxene are the most abundant minerals; they occur in nearly equal proportions (clinopyroxene most commonly predominates) and form as much as 80 to 90 percent of the more crystalline rocks. Plagioclase phenocrysts, as well as crystals in the groundmass, are progressively zoned and range from calcic labradorite (An_{70}) in their cores to andesine (An_{40}) at their rims. The average composition of the zoned crystals is labradorite (An_{60}). The plagioclase is commonly altered in part to clay minerals. The clinopyroxene is augite with 2V ranging from 47° to 55° and refractive index (Ny) ranging from 1.689 to 1.707. Some augite has a pinkish cast and probably is titaniferous. Scattered phenocrysts in a few thin sections are much more calcic and somewhat more magnesian than coexisting augite in the groundmass. Olivine (Fo_{80}) or its alteration products is found in about half of the samples and composes as much as 10 percent of some rocks; it is commonly altered to yellowish-brown to green pleochroic montmorillonitic clay minerals, hematite, and magnetite. Euhedral to subhedral crystals of magnetite and less common elongate crystals of ilmenite form as much as 10 percent of the basalt. The mesostasis of the hypocrystalline basalt commonly consists of dark-brown glass which characteristically is devitrified to a green or brown, fibrous-appearing, montmorillonitic clay mineral. This clay mineral, which is probably nontronite, forms as much as 90 percent of some samples and is present in all the thin sections studied. Some samples contain a variolitic residuum consisting of radiating sheaves of augite and plagioclase. Small amounts (1 to 5 percent) of chlorophaeite or its alteration products are commonly associated with glass in the matrix. Amygdules, cavity fillings, and veinlets in the basalt consist most commonly of zeolitic minerals and calcite, and less commonly of clay minerals.

Upper unit

In a few areas, such as in the vicinity of Ball Mountain (pl. 1), volcanic activity continued into earliest middle Eocene time, and a part of the basalt was extruded on land. This late stage of volcanism was sporadic and moderately explosive and is characterized by a differentiated alkalic suite consisting of flows of alkalic basalt, porphyritic augite basalt, feldsparphyric basalt, and picrite-basalt interbedded with tuffs and breccias. A few flows and numerous sills of tholeiitic basalt also occur in this part of the sequence. Massive beds of water-laid basaltic fragmental debris as much as 100 feet thick, and thick- to thin-bedded fine to lapilli tuff and tuffaceous siltstone are common in the upper unit. In places the beds of lapilli tuff contain abundant euhedral crystals of augite up to three-fourths of an inch in width.

The petrography and chemistry of the rocks in the differentiated upper part of the Siletz River Volcanic Series are rather complex, and more than a capsule discussion is beyond the scope of this report. The following discussion will serve only to call attention to the presence of rock types that doubtless are much less widely distributed in the geosyncline than the tholeiites in the lower unit of the Siletz River Volcanic Series.

Alkalic basalt occurs as pillow flows and breccia and as rudely jointed masses that form the lower parts of lava pods similar to those described from Unalaska Island, Alaska by Snyder and Fraser (1963). In the field the alkalic basalt cannot be distinguished from the tholeiitic basalt, except that individual pillows in the alkalic basalt are commonly peanut shaped or more elongate than pillows in the tholeiitic lavas. The alkalic basalt is dark greenish gray, is aphanitic to finely crystalline, and is generally amygdaloidal in the pillow flows.

Petrographically the alkalic basalt has a pilotaxitic texture with laths of plagioclase (andesine) and titaniferous augite (Ny 1.710, 2V = 48°) set in an altered finely crystalline to cryptocrystalline matrix.

Porphyritic augite basalt is found in pillow flows and in the upper parts of some lava pods. In the lava pods the alkalic basalt at the base grades upward into porphyritic augite basalt within a single cooling unit. In hand sample, black equant phenocrysts of augite as much as 1 inch in width are conspicuous. In many samples the augite phenocrysts compose 15 to 25 percent of the rock, but make up as much as 40 percent of some specimens.

The large pyroxene phenocrysts in pillow flows are calcic augite to salite (Ny = 1.694 to 1.697, 2V = 58 to 60); in a lava lens, however, the phenocrysts are more iron rich (Ny = 1.707, 2V = 58), have a pinkish cast, and are titaniferous. The groundmass augite of both pillows and lenses is titaniferous.

Olivine phenocrysts probably composed 5 to 15 percent of many of these rocks, but have been completely replaced by clay minerals or calcite. Outlines of plagioclase laths in the groundmass are discernible, but the laths are now almost entirely altered to clay minerals. The remainder of the groundmass consists of clay and zeolite minerals and calcite.

Feldspar-phyric basalt occurs as massive subaerial flows and amygdaloidal submarine flows. Pillow structures have been found in only one outcrop, where a wedge-shaped pillow unit of feldspar-phyric basalt is intrusive into tuffaceous siltstone. This basalt is characterized by abundant light-gray stubby phenocrysts of plagioclase up to half an inch in length and averaging somewhat less than one-fourth of an inch in width.

The feldspar-phyric basalt has intergranular to subophitic textures with bytownite (An_{80}-An_{87}) phenocrysts composing 20 to 50 percent of the rock. Sodic labradorite (about An_{50}) makes up 35 to 60 percent of the groundmass; calcic, iron-rich augite (Ny = 1.705, 2V = 53) makes up 30 to 50 percent of the groundmass and in some specimens occurs as scattered phenocrysts. Olivine, which probably formed less than 1 percent of the basalt, has been entirely replaced by clay minerals. Opaque minerals make up an average of 7 percent of the rock. Basaltic glass that originally composed 2 to 20 percent of the rock has been completely altered.

Picrite-basalt is known only from one place in the Ball Mountain area where it occurs in pillow lavas and subaerial flows or sills. In fresh samples the picrite-basalt is a dark greenish-gray dense rock with conspicuous, water-clear, yellowish-green phenocrysts of olivine one-eighth to three-eighths of an inch in length.

A modal analysis of a typical thin section indicates that phenocrysts of olivine (Fo_{87}, Ny = 1.678) form 40 percent of the rock. The groundmass is extremely fine grained and is composed of abundant feather-shaped crystallites (predominantly pyroxene with lesser amounts of plagioclase) as well as opaques and olivine.

Tholeiitic basalt sills and dikes and a few pillow flows are associated with the flows and tuffs of the upper unit. The composition of this tholeiitic basalt is similar to that of the lower unit. The sills range in thickness from a few feet to more than 100 feet, are rudely columnar jointed, and have the appearance of massive subaerial flows. In hand sample the intrusive rocks are dark gray to black, are fine to medium grained, and have a sugary texture.

Microscopic textures range from intersertal to intergranular or subophitic. Commonly the basalt contains a few scattered plagioclase phenocrysts or glomerophenocrysts. Andesine (An_{40}) to labradorite (An_{65}) laths comprise 40 to 50 percent of a typical sample and commonly are partly altered to clay minerals. Augite ($Ny = 1.70$, $2V = 50$) makes up about 30 to 40 percent, is very light brown, and in places shows uralitic overgrowths. Olivine or its alteration products are present in more than half of the specimens studied. Opaque minerals compose about 5 percent, and apatite less than 1 percent. Chlorophaeite is abundant in some samples, where it makes up as much as 5 percent of the rock. Very light brown to yellowish-brown glass, commonly altered, occurs with the chlorophaeite in interstitial areas and contains abundant crystallites of apatite, opaque minerals, and feldspar.

Chemical data

The flows that compose the lower unit of the Siletz River Volcanic Series are predominantly tholeiitic basalt which is saturated to oversaturated with respect to silica. Tholeiitic-olivine basalt flows are less common and contain both modal and normative olivine and normative hypersthene. The average composition of the lower unit, based on 10 widely distributed representative samples from the outcrop belt west of Corvallis, is shown in table 1, column 1. This composition is similar to both the correlative Crescent Formation of southwestern Washington (table 1, col. 2) and the tholeiitic basalts of the Hawaiian Islands (Macdonald and Katsura, 1964, p. 124, table 9).

The upper unit of the Siletz River Volcanic Series is composed of such diverse rock types that an average chemical composition would be of little significance. However, the composition of the alkalic basalt of the upper unit is given (table 1, col. 3) in order to demonstrate the chemical similarity between these alkali basalts and basalt of late Eocene to early Oligocene age.

Upper Eocene to Lower Oligocene Volcanic Rocks

A sequence of basalt flows, flow breccias, and massive to thick-bedded

TABLE 1. Average chemical analyses of Tertiary volcanic rocks in the central part of the Oregon Coast Range (recalculated to water-free basis).

	Lower to middle Eocene			Upper Eocene to lower Oligocene	Middle Miocene	
	1	2	3	4	5	6
SiO_2	48.5	49.1	49.6	50.3	55.8	51.8
Al_2O_3	14.4	14.9	17.5	17.2	14.1	13.9
Fe_2O_3	4.4	4.4	3.6	4.4	2.2	3.5
FeO	8.2	7.7	7.2	6.7	9.9	11.0
MgO	7.1	7.0	4.3	4.2	3.6	3.9
CaO	12.0	11.4	6.1	9.1	7.1	7.9
Na_2O	2.5	2.6	5.7	3.5	3.3	3.1
K_2O	0.20	0.22	2.0	1.0	1.3	1.0
TiO_2	2.2	2.1	3.0	2.9	2.0	3.0
P_2O_5	0.22	0.26	0.81	0.54	0.36	0.69
MnO	0.23	0.21	0.22	0.18	0.21	0.23
Number of analyses	10	10	4	19	8	11

Forty-four analyses used in the above averages were done by methods described in U.S. Geological Survey Bull. 1144-A by analysts Paul Elmore, Ivan Barlow, Samuel Botts, Gillison Chloe, Lowell Artis, and H. Smith, U.S. Geological Survey; 16 analyses were standard rock analyses by Dorothy Powers, June Goldsmith, Elaine Munson, and Christel Parker, U.S. Geological Survey; and 2 analyses were done using a combination of X-ray fluorescence and chemical methods by Leoniece Beatty and Albert Bettiga, U. S. Geological Survey.

1. Tholeiitic basalt; lower unit of Siletz River Volcanic Series, central part of Oregon Coast Range.
2. Tholeiitic basalt; Crescent Formation, southwest Washington.
3. Alkali basalt; upper unit of Siletz River Volcanic Series, central part of Oregon Coast Range.
4. Basalt; upper Eocene to lower Oligocene volcanic rocks, central part of Oregon Coast Range.
5. Tholeiitic basalt; lower unit of Miocene volcanic rocks, central part of Oregon Coast Range.
6. Tholeiitic basalt; upper unit of Miocene volcanic rocks, central part of Oregon Coast Range.

water-laid palagonitic lapilli tuffs forms precipitous sea cliffs between Heceta Head and Yachats and at Cascade Head along the central Oregon coast (pl. 1). These volcanic rocks intertongue with marine tuffaceous strata of late Eocene and early Oligocene age. Although these volcanic rocks originally extended into the central part of the Coast Range, erosion has removed them except on the west flank of the uplift in the central part of the range. The upper Eocene to lower Oligocene basaltic rocks attain a maximum thickness of 1,500 to 2,000 feet near former centers of volcanism, but thin rapidly away from these centers.

The flows are chiefly of subaerial origin and were erupted from numerous vents. However, in places basalt was extruded onto the sea floor, and the attendant rapid chilling of the magma by sea water produced glassy fragmental debris (commonly lapilli size) in which a few small pillows are enclosed locally. Much of the glass has been hydrated to palagonite, which later altered to clay minerals. The basalt flows are thin, averaging 10 to 20 feet thick, and in a few outcrops have a platy parting or well-developed columnar jointing. The upper parts of flows are commonly oxidized and contain brick-red scoriaceous fragments. Numerous basalt dikes, 1 to 8 feet in width, cut the volcanic sequence.

The basalt is dark gray to grayish black and is typically porphyritic. Tabular phenocrysts of plagioclase up to three-fourths of an inch long are easily recognized in hand samples and commonly make up 10 to 15 percent of the rock; fragmental basaltic debris usually contains many broken plagioclase crystals.

Microscopically the basalt is holocrystalline to hypocrystalline, porphyritic, or glomeroporphyritic; the groundmass texture is intergranular or pilotaxitic and vitrophyric where less crystalline. Phenocrysts of oscillatory zoned calcic labradorite (range An_{60}-An_{70}) generally compose 10 to 15 percent of the rock. Calcic andesine to sodic labradorite (An_{45}-An_{55}) in the groundmass makes up as much as 50 percent of the more crystalline samples. Sparse phenocrysts of calcic augite to ferroaugite (2V = 50° to 58°, Ny = 1.705 to 1.715) are found in about half of the samples. Granules of calcic augite to calcic ferroaugite (2V = 50° to 55°, Ny 1.70 to 1.71) in the groundmass average about 25 but form as much as 35 percent of the basalt. Olivine (Fo_{80}), both as phenocrysts and grains in the groundmass, is present in about half of the samples studied, and forms as much as 10 percent in a few sections. Opaque minerals, chiefly magnetite, compose 1 to 15 percent of the basalt. Interstitial areas between crystals consist of volcanic glass that is altered mainly to montmorillonite (nontronite[?]). Amygdules of montmorillonite (nontronite[?]) are common, but a few consist of calcite, apophyllite, and zeolite minerals.

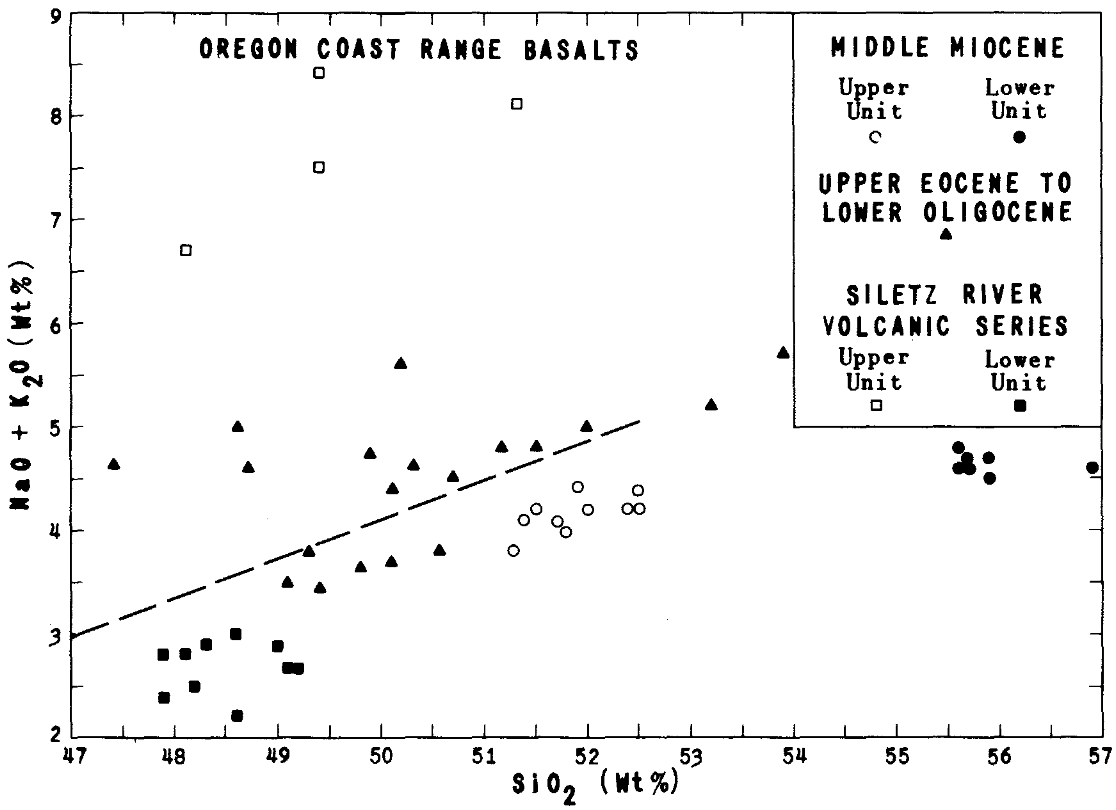


Figure 1. Alkali-silica diagram of Oregon Coast Range basaltic rocks. Analyses plotted are those used in averages given in table 1. Dashed line is boundary between tholeiitic and alkalic fields of Macdonald and Katsura (1964, p. 87).

Chemical data

Chemical analyses of upper Eocene to lower Oligocene basalts indicate that this suite is intermediate in character between the alkalic and tholeiitic suites, since most of the basalts are over-saturated with respect to silica (tholeiitic affinity) but contain a total alkali content that averages 4.5 percent (alkalic affinity). These volcanic rocks typically have a rather high alumina and high total alkali content (table 1, col. 4) and are similar in total chemistry to the alkalic basalt of the upper unit of the Siletz River Volcanic Series (table 1, col. 3). They also have chemical affinities to typical andesites (Nockolds, 1954, p. 1019), but lack the characteristic mineralogy (hypersthene and/or hornblende and more sodic plagioclase) of the calc-alkaline andesites. The upper Eocene to lower Oligocene basalts have a rather wide range of silica content (47 to 54 percent) with a differentiation trend toward rocks of andesitic composition; the total alkali content increases as silica increases (fig. 1).

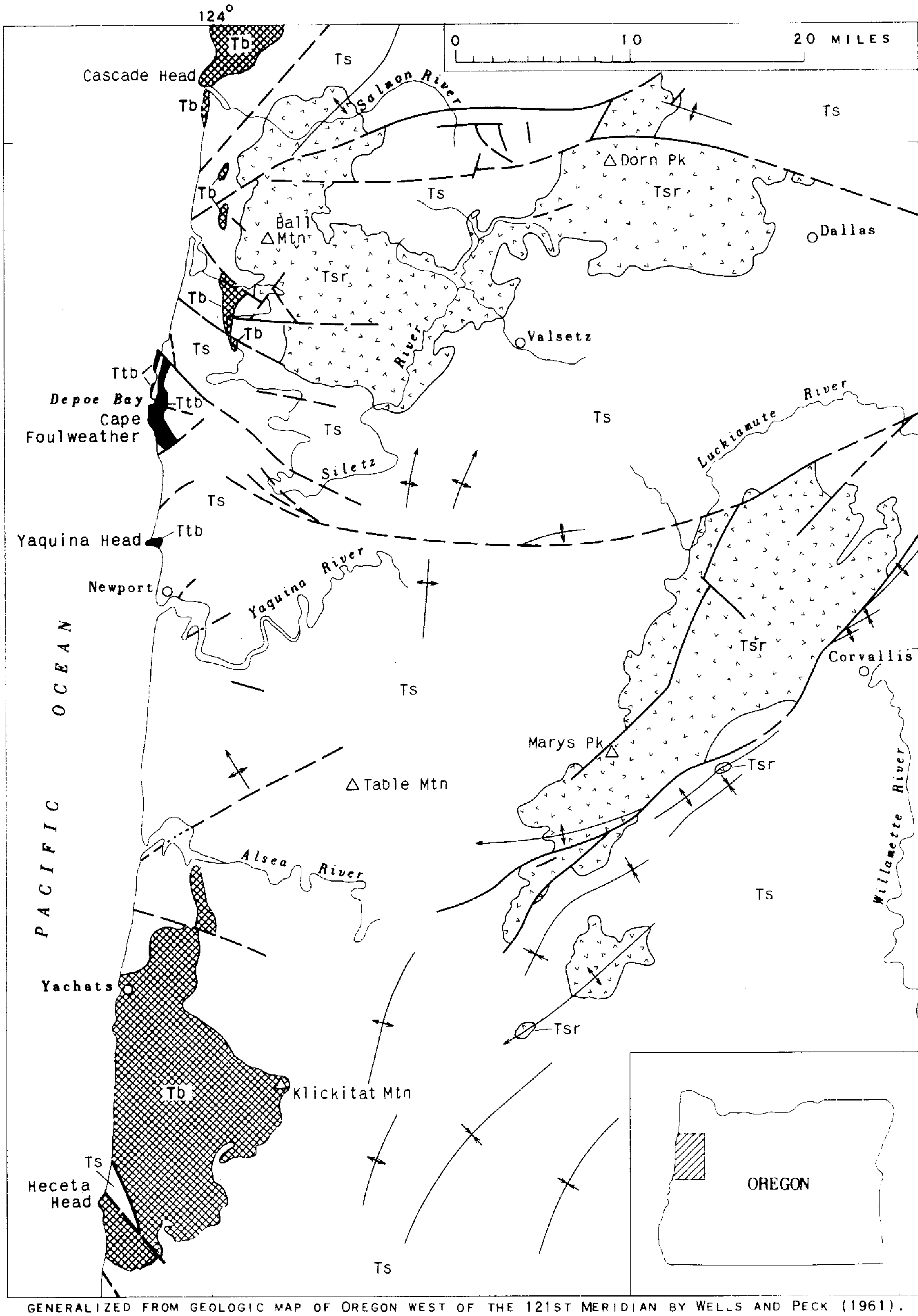


Plate 1. Generalized geologic map showing the distribution of Tertiary volcanic se
Oregon Coast Range.

MAP EXPLANATION

SEDIMENTARY ROCKS

Eocene to Miocene

Ts

Marine sedimentary rocks

Includes some Quaternary deposits

VOLCANIC ROCKS

Middle Miocene

Ttb

Tholeiitic basalts and breccia

Upper Eocene

Tb

Basalt flows and breccia

Lower to middle Eocene

Tsr

Siletz River Volcanic Series

TERTIARY

Geologic contact

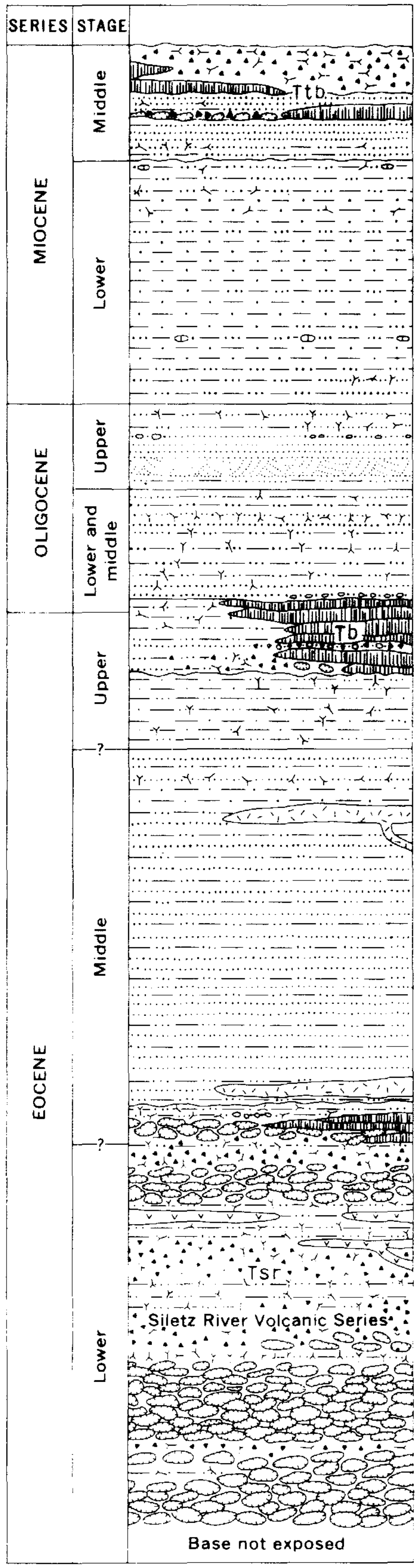
Fault

Dashed where approximately located

Anticline

Arrow indicates direction of plunge

Syncline



COMPOSITE SECTION EXPLANATION

Mudstone

Siltstone (in part concretionary)

Tuffaceous siltstone

Sandstone

Crossbedded sandstone

Conglomerate

Tuff

Water-laid fragmental basaltic debris

Flow breccia

Submarine basaltic pillow lavas

Subaerial basalt flows

Feeder sills or dikes of basalt

Granophyric gabbro intrusives

ces, and composite section showing their stratigraphic positions, central part of

Middle Miocene Volcanic Rocks

Basalt flows, pillow lavas, and water-laid fragmental debris of middle Miocene age form precipitous headlands at Cape Foulweather and Yaquina Head in the map area (pl. 1) and farther north at Cape Lookout, Cape Meares, and Tillamook Head. These volcanic rocks were extruded from local centers near a middle Miocene strand and are of both subaerial and submarine origin.

Along coastal Oregon these basalts compose two mappable and petrochemically distinctive units, an older unit consisting of a subaerial flow and subaqueous palagonitic pillow lavas and breccias, and a younger unit consisting of subaerial basalt flows and subaqueous water-laid fragmental basaltic debris. These volcanic units are separated by nearshore to brackish water arkosic sandstone in the vicinity of Depoe Bay (Snavely and Vokes, 1949). Unconformities, in places marked by fossil soil zones, occur at the base of each unit; the upper unit overlaps the lower unit at Cape Foulweather and rests on older strata.

Lower unit

The lower unit is well exposed at Depoe Bay where pillow flows and palagonitic tuff-breccias 75 feet thick form the north-trending east shoreline of the outer bay. Immediately south of Depoe Bay these pillow lavas grade laterally into a rudely columnar-jointed subaerial flow approximately 50 feet thick.

The basalt in the lower unit is medium to dark gray, is aphanitic, and commonly contains patches of apple-green (on fresh breaks) to brownish-black chlorophaeite. In the complex of pillow lava and tuff breccia at Depoe Bay, ellipsoidal pillows are enclosed by a light-brown palagonite matrix in which fragments of black, glassy basalt occur in abundance.

Petrographically the basalt is hypocrystalline and equigranular with intersertal to intergranular or subophitic textures. The glassy breccias and chilled margins on pillows exhibit vitrophyric to hyalo-ophitic textures. Calcic andesine to sodic labradorite (An_{40}-An_{60}) forms 5 to 50 percent of the sections studied. Augite to subcalcic augite (2V = 27 to 45, Ny 1.704 to 1.711) and pigeonite form 5 to 40 percent. Opaque minerals, largely magnetite, average about 2 percent but range from less than 1 to nearly 10 percent of the rock; apatite is present only in the most crystalline rocks, where it composes 1 percent or less. Dark- to light-brown basaltic glass forms 5 to 90 percent of the rock. In the fragmental rocks and in the outer-most rims of pillows, the most common basaltic glass is a clear pale-brown variety with refractive index greater than balsam (sideromelane); interior to the outer rims of pillows and as occasional fragments in the breccias, the glass is a dark-brown to nearly opaque variety that is minutely dusted with opaque minerals (tachylyte). The glass is generally fresh, but the outer rims of some fragments are altered to yellow palagonite which has a refractive index less than balsam. Chlorophaeite, commonly olive green to orange brown with index less than balsam, makes up as much as 10 percent of some samples. A glassy silicic residuum occurs in the more crystalline samples; cryptocrystalline quartz and calcite occur in amygdules, in veinlets, and as the cementing material of some breccias.

Upper unit

The upper unit of the middle Miocene volcanic sequence is typically exposed in sea cliffs at Yaquina Head and Cape Foulweather. The volcanic sequence in these headlands is cut by swarms of feeder dikes and volcanic necks, thus indicating that these basalts were erupted from numerous vents and fissures located near the present coast. The upper unit consists predominantly of basalt breccias and water-laid fragmental debris with lesser amounts of massive flows and pillow lavas. Much of the basaltic magma was extruded onto the ocean floor, and rapid chilling by sea water caused this extensive fragmentation.

In hand sample, yellowish phenocrysts of plagioclase, as much as three-fourths of an inch in length, serve to distinguish this sparsely porphyritic younger unit from the nonporphyritic basalt of the older unit.

Thin-section studies show that the basalt is hypocrystalline with intersertal to subophitic textures the most common. The less crystalline samples have vitrophyric to hyalo-ophitic textures. Sparse phenocrysts (less than 1 percent) of calcic labradorite (An_{63}-An_{65}) and laths of sodic labradorite (An_{55}) form 5 to 40 (commonly 20) percent of the basalt. Augite ($2V = 42$ to 50, $Ny = 1.699$ to 1.709) and pigeonite (less common) comprise 1 to 25 percent; olivine, which is generally altered, forms 1 to 5 percent; opaque minerals make up 1 to 10 percent of the samples studied. Basaltic glass is present as both sideromelane and tachylyte and composes up to 95 percent of individual fragments in the breccias; sideromelane is commonly partially palagonitized. In the more crystalline basalt a glassy silicic residuum ($N < 1.54$) makes up about 20 percent of the rock. Chlorophaeite is common and forms as much as 10 percent of some samples. Analcite, calcite, apophyllite, cryptocrystalline quartz, and celadonite occur in amygdules and veinlets.

Chemical data

Both the lower and upper volcanic units of middle Miocene age in coastal Oregon are tholeiitic basalts that are over-saturated with respect to silica. These Coast Range Miocene basalts bear a marked similarity to the Yakima Basalt of the Columbia River Group of Waters (1961, p. 607). The lower unit (table 1, col. 5) is remarkably close chemically to the Yakima petrographic type (Waters, 1961, p. 593); the upper unit (table 1, col. 6) is strikingly similar to the Late Yakima type of the Columbia River Basalt (Waters, 1961, p. 594). The lower unit is characterized by a higher silica and lower TiO_2 and P_2O_5 content than the upper unit.

Summary

The three basalt sequences that comprise the Oregon Coast Range petrographic province generally can be distinguished from one another on the basis of either their petrographic or chemical characteristics. The principal

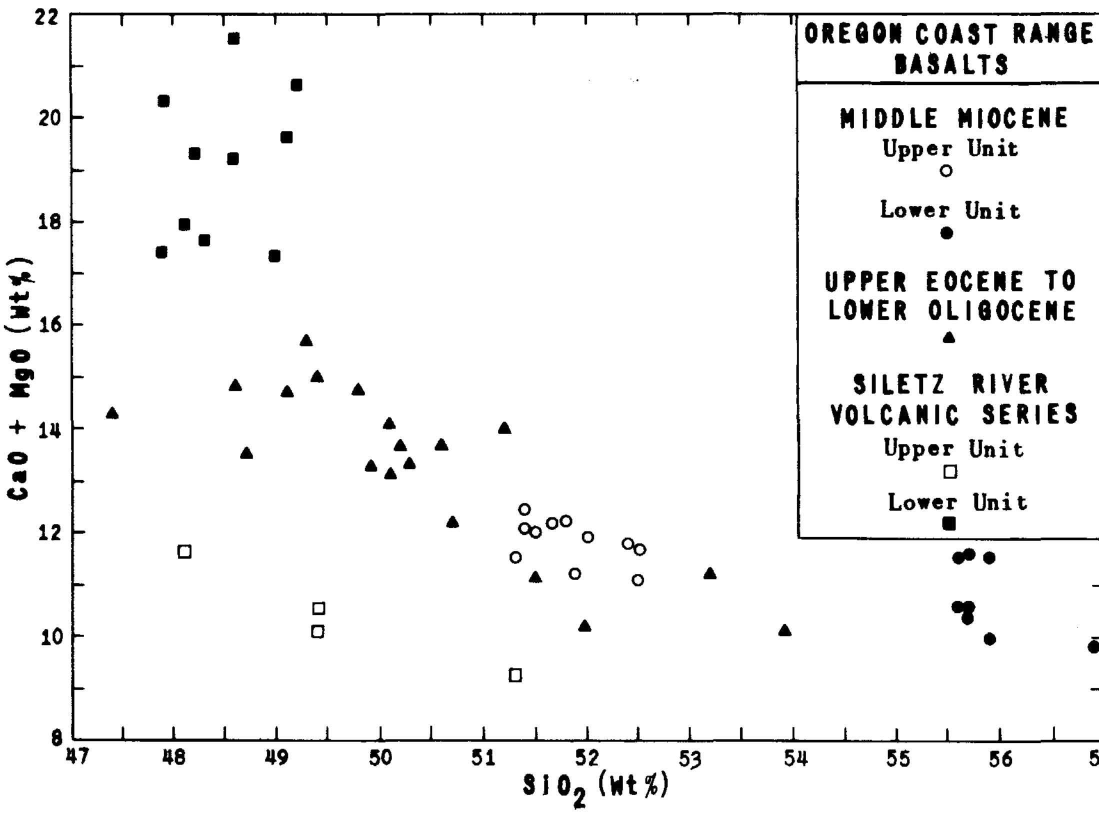


Figure 2. Diagram showing the relation of CaO+MgO to SiO_2 in Oregon Coast Range basaltic rocks. Analyses plotted are those used in averages given in table 1.

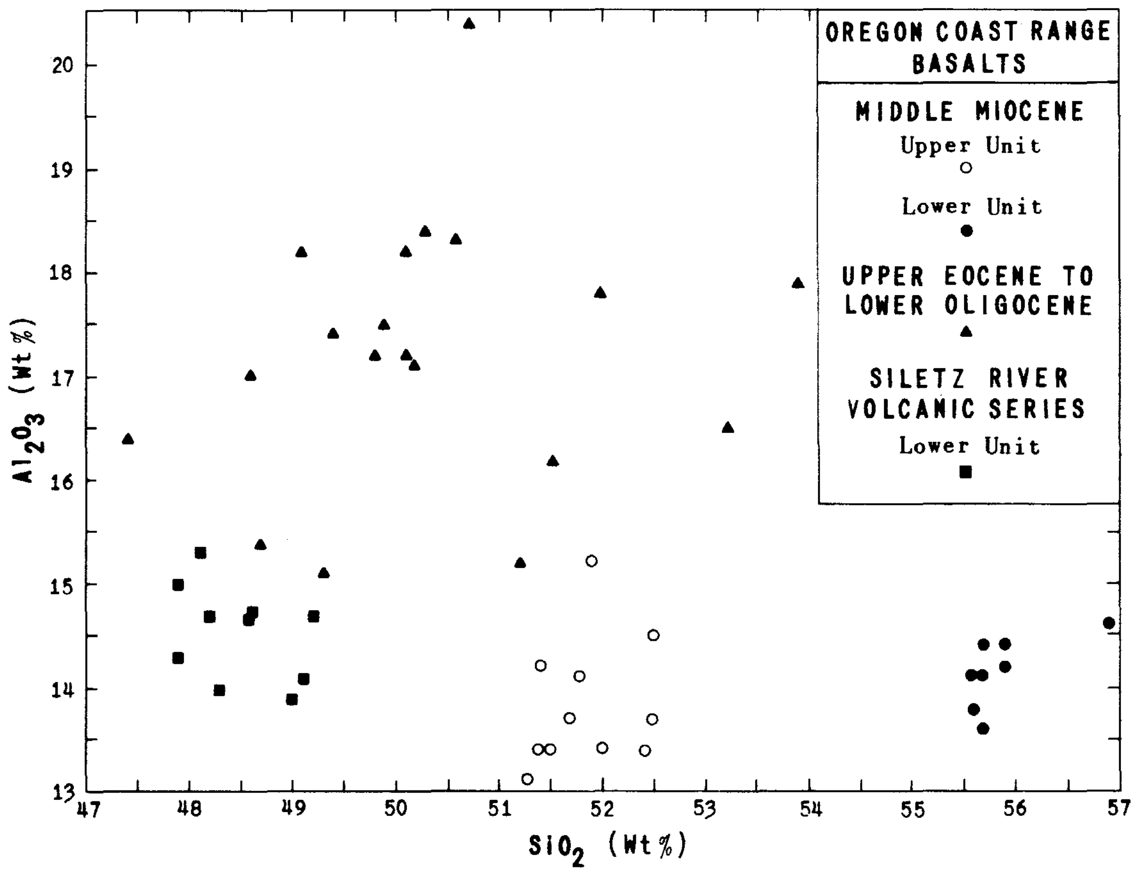


Figure 3. Alumina-silica diagram of Oregon Coast Range basaltic rocks. Analyses plotted are those used in averages given in table 1.

characteristics are:

1. The widespread tholeiitic basalt in the lower unit of the Siletz River Volcanic Series has a lower silica content, a lower content of total alkalis, and a higher content of CaO and MgO than is present in either the upper Eocene to lower Oligocene basalt or the Miocene basalts (figs. 1 and 2). The original basaltic glass in the Siletz River Volcanic Series is typically altered to montmorillonitic clay minerals.
2. The upper Eocene to lower Oligocene basalt has a higher alumina content than most of the other volcanic units (fig. 3), with the exception of the alkalic and feldspar-phyric basalts in the upper unit of the Siletz River Volcanic Series. However,
   a. the upper Eocene to lower Oligocene basalt has a lower content of total alkalis (fig. 1) and a higher content of CaO plus MgO for a given silica content (fig. 2) than is present in the alkalic basalt of the upper unit of the

Siletz River; also,

b. the pyroxenes of the upper Eocene to lower Oligocene basalt are typically more iron-rich (higher Ny) than those of the alkalic basalt; and

c. the upper Eocene to lower Oligocene basalt can generally be distinguished from the feldspar-phyric basalt (upper unit, Siletz River Volcanic Series) on the basis of plagioclase composition, since the plagioclase phenocrysts are considerably more calcic in the feldspar-phyric basalt.

3. The middle Miocene tholeiitic basalts have lower contents of CaO and MgO than most older lavas (fig. 2). Also,

a. the lower unit of Miocene age is richer in silica than other volcanics in this area (approaching an andesite in composition);

b. the upper unit of Miocene age can be distinguished from the lower unit of Miocene age by its higher contents of TiO_2 and P_2O_5 and lower content of silica (table 1); and

c. the upper unit commonly contains a few plagioclase phenocrysts and olivine grains in the groundmass, whereas the lower unit contains neither.

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OIL RECORDS RELEASED

The Department released records of the E. M. Warren "Coos County 1-7" well on June 5, 1965, after holding them in confidential file for the two-year period prescribed by law. The drilling was located in the SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 7, T. 27 S., R. 13 W., Coos County, 7 miles south of Coos Bay. Total depth of the Warren well was 6,337 feet. No volcanic rocks were logged in the drilling, as contrasted with the Phillips Petroleum Co. "Dobbyns 1" 4 miles to the north, which encountered volcanic rocks between 2,300 and 5,700 feet.

* * * * *

MINERS TO LOSE RIGHTS ON 57 PARCELS OF LAND

The latest in a long and continuing series of proposed withdrawals of public lands from mineral entry has been announced by the U.S. Bureau of Land Management. Total acreage involved in the current withdrawals amounts to nearly 4,800 acres, scattered widely over the state. Most of the withdrawals are designed to provide or protect recreation areas. One area involves 440 acres on Sugarloaf Mountain near Myrtle Point in Coos County, where the Bureau wishes to withdraw a hardrock deposit from application by individuals. The quarry site is adjacent to Oregon State Highway 42 and not far from the Myrtle Point-Powers road. Both of these roads were damaged in the winter high water, and large quantities of crushed rock are needed for their rebuilding and repair.

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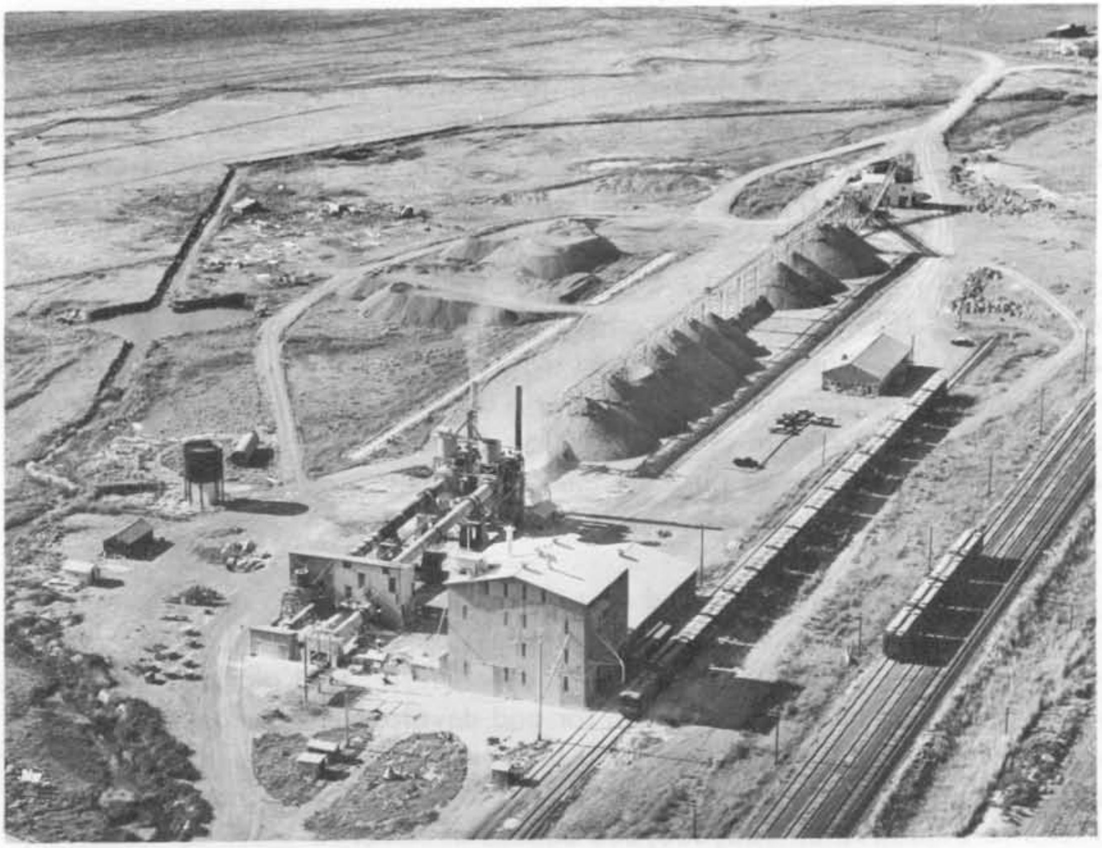
Chemical Lime Co. quarry on Baboon Creek, Baker County.

Road from Marble Creek over the summit of Elkhorn Ridge.



Chemical Lime Co. Processing Plant

What a resource-based industry does for the welfare of the Baker community is evident in the facts about Chemical Lime Co., Baker County, Oregon.

Chemical Lime operates a quarry just over the "hump" of Elkhorn Ridge west of Baker on Baboon Creek, sec. 20, T. 9 S., R. 38 E. By an access road developed by the company, raw lime rock is trucked to a plant at Wing Siding, where gas-fired kilns and other equipment convert the quality limestone into lime of chemical grade for the industries of the Pacific Northwest (see photograph above).

Chemical Lime Co. employs full or part time from 35 to 40 men. The annual payroll is from $257,000 to $300,000. The operation generates 700 to 750 rail cars of freight, shipping to all points in the Northwest, entailing freight costs in excess of $200,000. Lime and limestone shipped are valued at $850,000 to $950,000 annually.

Natural gas consumed and supplies purchased locally exceed $400,000 annually. Construction of plant, building of the road, and completion of the power line provided major additional employment. In the haul between the quarry and the plant, four trucks of Reed's Truck firm operate two shifts six days a week for approximately six months a year. Chemical Lime's general manager is Ned Thomas. The auditor is Leo Case, the quarry foreman Bert Farrar, and the chemist Raymond Fenn.

(All photographs courtesy of Chemical Lime Co.)

MINING CONCERNS WESTERN GOVERNORS

The Western Governors' Conference held its three-day session at the Hilton Hotel in Portland June 10-13, 1965, with Governor Mark O. Hatfield as chairman. A number of resolutions dealing with the mining industry were recommended, as follows:

Gold: It was resolved that the Western Governors' Conference endorse in principle S. 1377 for direct incentive payments to our domestic gold producers or similar legislation designed to reactivate our gold mines and increase our domestic gold production; recommend adoption of tax incentives to encourage greater domestic gold production; and urge the Federal Government in evaluating solutions of the balance of payments problem to study the desirability of multilateral revaluation of gold.

Silver: The Conference resolved that Congress be urged to reject moves to eliminate silver from our coinage and that it provide for retention of silver in reduced amounts in all coins now made of silver; that affirmative programs be adopted to increase exploration for and development of domestic silver supplies, and that silver be permitted to seek its own price in the market place; and that the Administration be commended for its action in setting a national stockpile objective of 165,000,000 ounces of silver to meet our security requirements, a move which the Conference has urged for many years.

Public lands: It was resolved by the Conference that all actions proposed by the Bureau of Land Management which substantially affect the administration of the public lands be openly and publicly considered with representatives of the localities affected prior to implementation.

Mineral taxation: It was resolved that the Conference urge that adequate depletion allowances for minerals be provided and that mining exploration expenditures be made fully deductible on a basis comparable to the research expenditures of other businesses.

Import controls: It was resolved that the Conference recommend the imposition of import controls, where necessary, with provision for adjustments to assure the maintenance of sound and vital domestic natural resource industries.

Oil shale: It was resolved that the Governors of the western states urge prompt action to establish and implement a leasing policy with private enterprise to develop western oil shale deposits.

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The ORE BIN
Volume 27, No. 7
July, 1965

RECENT VOLCANISM BETWEEN THREE FINGERED JACK AND NORTH SISTER OREGON CASCADE RANGE

Part I: History of Volcanic Activity*

By Edward M. Taylor**

Introduction

On the crest of the Oregon Cascade Range, between the Pleistocene volcanoes known as Three Fingered Jack and North Sister, an impressive array of cinder cones stands in the midst of Recent basaltic lava fields whose total area exceeds 85 square miles (fig. 1). Although each major field is closely approached by a highway, several lava flows and many cones, vents, and other volcanic features have not been described in print. In this paper, the history of each eruptive center first will be interpreted from the standpoint of field observations, and then will be reviewed in an integrated outline of recent volcanism. The volcanic history and geologic maps presented here have been abstracted from a general survey of petrology in the High Cascades of Oregon which the writer has followed for several years and which has progressed from Bachelor Butte to Three Fingered Jack.

North and south geographic limits of the present study are placed along straight east-west lines through Three Fingered Jack and North Sister, respectively; east and west boundaries are drawn coincident with the east and west borders of the High Cascades as outlined by Williams (1957). The temporal range of geologic events extends from the end of the last major glacial episode to the present. It is believed that all exposed eruptive units within these boundaries of space and time are included in this report. Several unofficial, but suitable, geographic names are introduced where reasonable discussion demands them. For background information, the reader is referred to the appended Glossary of Selected Terms and to Williams (1944).

Cones and Flows of Questionable Recent Age

The maps presented in this paper differ slightly from earlier reconnaissance geologic maps (Williams, 1944, 1957) in their definition of Recent basaltic cones and flows. Discrepancies arise with respect to: (1) identification of landforms, (2) recognition of cones and flows which have been glaciated, and (3) recognition of possible pre-Recent cones and flows which have not been glaciated. Included in the first group are the following land forms not previously identified: a glaciated dome of rhyolite and obsidian at the southeast base of Condon Butte, a knob of glaciated bedrock near the terminus of the northwest lava flow from Collier Cone, a nearly flat glaciated

* Part II, Petrographic studies and chemical analyses, to be published at later date.
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surface between Collier and Four-in-One lavas, two glaciated steptoes which rise through Little Belknap lava near McKenzie Pass, a glaciated hill $1\frac{1}{2}$ miles northwest of Yapoah Cone, and a glaciated steptoe at the west end of the Belknap lava field. Landforms of the second group are located on figure 1 by the symbol "X". The third group includes four lava flows which do not appear on the older maps, Scott Mountain, Two Butte, a feature known as the "Cinder Pit," and two cinder cones on the northeast slope of Black Crater. This group is described as follows:

Lava flows, so old that deep forests now hide them from view, issued from four separate vents close to the western boundary of the High Cascades. Their individual histories are relatively unknown. Included here are the Park Creek flow, the flows on the west slope of Maxwell Butte, and the Anderson Creek flow (fig. 1). No cinder cones have been recognized in association with these lavas.

The Park Creek flow is composed of blocks which have been somewhat rounded by weathering. Crustal features and the outlines of lava tongues can be seen only where ancient fires have limited the forest cover. The flow originated near a small hill at the north lava margin, moved south for two miles, and forced Park Creek to undercut a high cliff of sedimentary rocks.

Equally vague is the eruptive history of flow rocks on the side of Maxwell Butte. Two source vents approximately 2.3 miles west of the Maxwell summit are indicated by the distribution of lava, but neither has been located precisely nor has it been possible to trace contacts between flow units. Here too, old forest fires have exposed slaggy crusts and numerous pressure ridges. Where the North Santiam Highway cuts through the flows, their thin, vesicular character can be seen in cross section. Farther west, about two miles from their source, they are found adjacent to the Park Creek flow; relative age has not been determined.

To trace the Anderson Creek flow one must learn to "feel" it beneath the forest floor; indeed, the very existence of fresh lava would be difficult to prove if logging operations had not disclosed striking examples of lava levees and vesicular flow tops. The advanced age of this flow is inferred from the condition of its forest cover in comparison with the cover found on other flows which lie at similar elevations to the north and south. Lava issued from a subdued spur 2.3 miles west of Scott Mountain summit and poured as a cascade into the valley of Anderson Creek. A north lobe appears to have advanced, then stagnated, three miles from the source. Another lobe was channeled west by an intervening hill, and then was deflected northward, where it lies in contact with the northernmost lobe. This western lobe eventually spread into the valley of Olallie Creek. Its terminal lava front, six miles from the source, can be seen beside the Clear Lake Highway.

Scott Mountain is a glaciated shield volcano, located southwest of the Belknap lava field (fig. 1). Upon the summit of Scott Mountain is a small cinder cone of recent appearance. Layered deposits of ash and scoria are abundant near the top, where only an indistinct remnant of the crater rim has survived erosion. The flanks are composed of coarse red scoria and perfectly shaped spindle bombs. Black lava spread over the west and southwest lip of the crater but did not move beyond the cone.

Two Butte is a double cinder cone located 3.4 miles south of Scott Mountain (fig. 1). The cones are 400 feet high, are aligned north-south, and have lost their craters by erosion. Red scoria and spatter are exposed near their summits, but their flanks are mantled in dense forest. Except to the south, where small flows can be traced to the edge of the Lost Creek glacial trough, surrounding terrain bears the

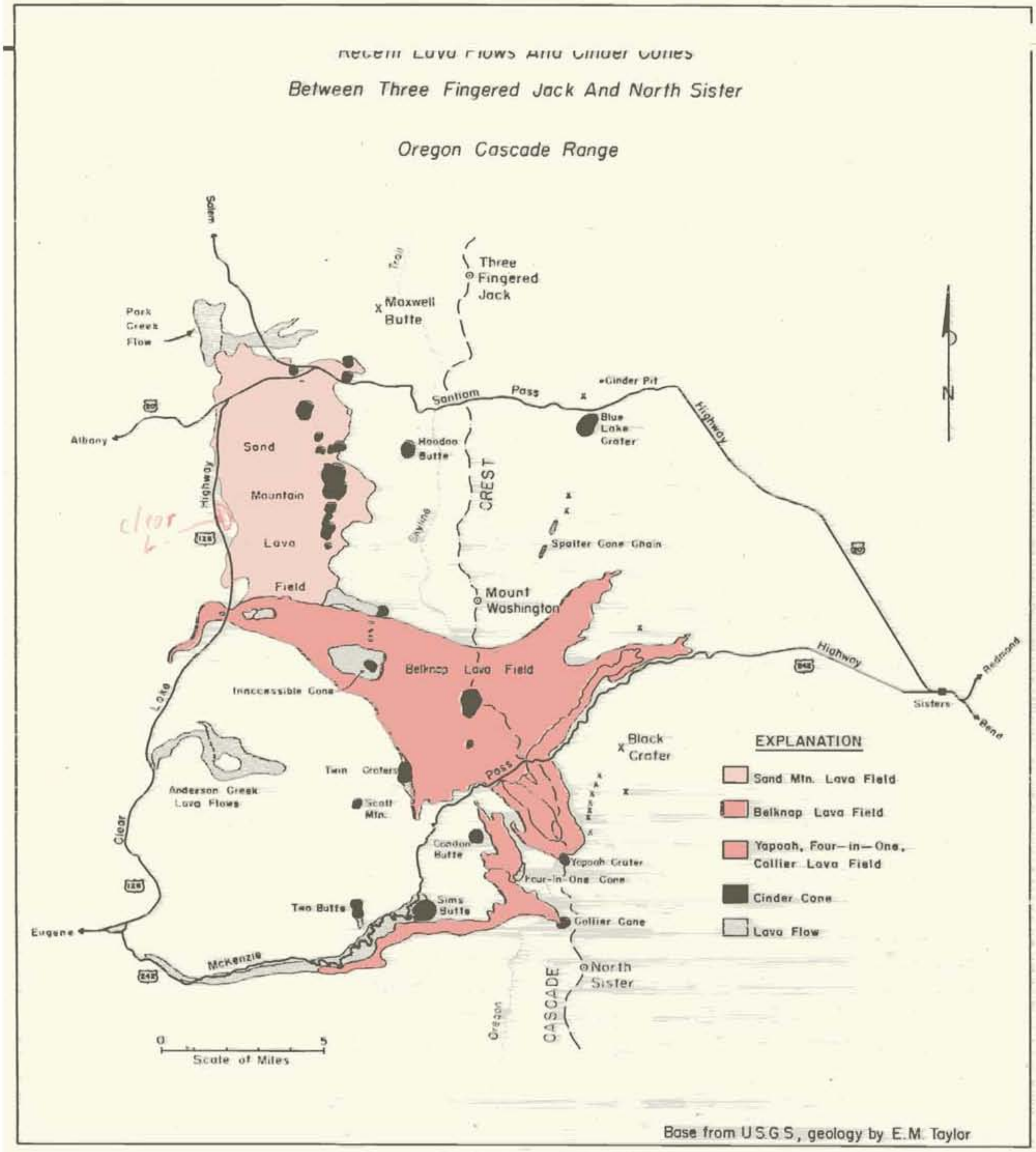


FIGURE I. INDEX MAP

imprint of profound glaciation.

One and one-half miles north of Blue Lake Crater (fig. 1), a diminutive cinder cone has been excavated for road metal. As a result, the conduit - now occupied by a plug of basalt - has been laid bare within a shallow, cinder-covered pit. The designation "Cinder Pit," which appears on the Three Fingered Jack topographic map (U.S. Geological Survey, 1959, 15-minute), will be adopted here. A narrow stream of lava moved only a few hundred feet east from the conduit. The lava rests upon glacial deposits which, as exposed in the pit, have been oxidized by volcanic emanations.

Two other cinder cones with well-preserved summit craters stand 250 and 350 feet above the north and northeast flanks of Black Crater. No glacial deposits nor striae occur upon these cones, but the coarse, weathered scoria on their slopes strongly resembles ejecta from other cones north and south of Black Crater which have been glaciated.

A Recent age for the above cones and flows is open to question, even though they rest upon older glaciated bedrock surfaces or glacial deposits. The last (latest Wisconsin?) major advance of glacial ice between Three Fingered Jack and North Sister is recorded by a variety of features which include lateral and terminal moraines, bedrock striations, vegetation patterns, and glacially transported erratic lithologies. Glaciers, as interpreted from these records, did not cover the Anderson Creek nor west Maxwell lavas during Late Wisconsin time, but may have obliterated their source cones. It is clear that such glaciers reached neither the Park Creek flow nor the Cinder Pit. Similarly, glaciers did not affect Two Butte, but they might have destroyed Two Butte lavas in the adjacent glacial trough. Glacial ice, as outlined by morainal patterns, probably moved between the two cones on Black Crater without disrupting them, and might not have significantly eroded the Scott Mountain cone because of its high-standing position.

Volcanic History of the Sand Mountain Lava Field

Within the High Cascades there are many examples of volcanic mountains arranged in nearly perfect linear or arcuate patterns. Few are as easily recognized as the chain of 22 cinder cones and 41 distinct vents referred to here as the Sand Mountain alignment (fig. 2). An elongate zone of weakness probably developed in the rocks beneath the cones along which magmatic gases and liquids were conducted from the depths to the surface. In detail, this zone diverges northward into two distinct branches. Sand Mountain Cones are the largest volcanoes on the alignment and rise above the intersection of the branches. The principal landforms are geographically as follows: Little Nash Crater and the Lost Lake Group on the north, Nash Crater and the Central Group farther south, Sand Mountain Cones, and the South Group (see fig. 2).

Over a long span of time, the numerous and closely spaced eruptive centers of the Sand Mountain alignment discharged about three-quarters of a cubic mile of lava and a large but unknown volume of ash. The result was an intricate accumulation of overlapping cones, flows, and sheets of ejecta, whose volcanic history is set forth in approximate chronological sequence below.

The oldest volcano exposed on the alignment probably is a small, 150-foot cinder cone located between Nash Crater and the junction of North and South Santiam Highways. Erosion has destroyed all trace of a summit crater, and the lower forested slopes are covered with ash from younger cones. Another denuded cinder cone, approximately 400 feet high, lies one mile southwest of Lost Lake, and has retained only a vestige of its crater rim. Any lava which may have issued from these cones is now lost to view beneath younger flows from later vents.

The Central Group is a tight cluster of five cinder cones, three of which overlap to form an east-west volcanic ridge, half a mile long and 200 feet high. The west end of the ridge contains a small symmetrical crater, but the east end has been breached at its northern base by a great outpouring of lava. The central part of the ridge is occupied by two craters, one nested within the other. Lava issued also from the west base of the ridge, undermining a small satellite cone. In the lava field a short distance west and northwest stand two 100-foot cones with well-preserved craters. Two additional cones at the northwest base of North Sand Mountain strongly resemble those of the Central Group. One is 200 feet high and breached on the west; the other is only 50 feet high but contains a small summit crater.

Lava from the Central Group spread widely to the west, northwest, and north. Much of the west lava now is covered by a younger flow from Nash Crater. To the north, however, lavas poured from the Central Group onto the floor of a broad, glaciated valley, moved over the region now occupied by Santiam Junction, and probably reached the ancestral upper McKenzie River. Several long, isolated ridges and gutters are seen in these lavas just south of the junction, where they trend westward and pass beneath a flow from Little Nash Crater. The ridges often are capped by lava crust, and their sides have been vertically striated by the foundering of adjacent blocks. These features are evidence that the Santiam Junction area was at one time a lake of lava which drained out to the west, probably from beneath a congealed crust.

A short alignment of four cinder cones forms a great ridge across the glaciated valley of Lost Lake Creek, two miles east of Santiam Junction. The lava-dammed lake nearby gives to these cones the collective name "Lost Lake Group." The smallest cone lies against the north valley wall, 700 feet above the lake. On the south, it overlaps the rim of a lower, but much larger cone. Consequently, both cones share a common rim which separates an elongate, shallow crater on the north from a symmetrical, deep crater on the south. A low saddle lies between these northern cones and a centrally located third cone on which there remains only an indistinct crater. The rim of the southernmost cone rises 320 feet above the adjacent Santiam Highway, though the bottom of its crater extends to highway level.

Lava issued from the east base of the north cone and spread eastward, as did a much larger flow from the saddle. Irregular slabs of jagged crust can be seen protruding through a thick overburden of ash along the west shore of Lost Lake. Lava from the saddle also moved west as far as Santiam Junction, where it is deeply buried beneath ash from Little Nash crater, and therefore is exposed best in road cuts.

A large volume of lava was discharged from the base of the north Sand Mountain cone, building a broad ridge which extended 2,000 feet to the west. The ridge was capped by a lava gutter whose walls were breached at frequent intervals. A collapsed lava tube descends the western extremity of the ridge. This lava, which moved far to the west, may be seen on the north shore of Clear Lake. The northern contact with Central Group lava is obscured by ash deposits, but the southern limit of exposure is traced easily against a younger flow from a vent southwest of Sand Mountain.

The South Group consists of four principal cinder cones, all of which probably were associated with extensive lavas, now buried beneath younger flows. The northernmost cone is 1,000 feet south of Sand Mountain, rises 300 feet in height, and contains a deep crater. Next south is a smaller cinder cone which was built adjacent to an elongate southwest-trending ridge of spatter and bombs. Lava issued from the west base of this cone. The largest cinder cone of the south group stands south of the spatter ridge and is 400 feet high. A large central crater is attended by a smaller counterpart on the north flank of the cone, and by a great bocca near the southwest base. Lava from the bocca spread south, surrounding a small breached cone, and southwest to form an extensive flow. The McKenzie River pours over this lava at Koosah Falls. The lava is obscured on the south by flows from Belknap Crater; to the east and north the lava is overlain by later flows from Sand Mountain.

Nash Crater is a cinder cone which was built 500 feet above a lateral moraine. The summit contains a north-south trench-like crater 1,000 feet long with a smaller symmetrical crater set into its west rim. A narrow ridge of spatter extends from the south base of Nash Crater, and is surmounted by six vertical conduits which range from 30 to 5 feet in diameter and from 40 to 30 feet in depth. These conduits lead to a lava tube which has collapsed at the south end of the ridge. Lava from this vent moved west, damming Hackleman Creek to form Fish Lake, and for this reason is called the Fish Lake Flow.

At the northwest base of Nash Crater is a broad depression rimmed with spatter. Approximately 100 feet northwest, a 5-foot spatter cone surrounds a vertical conduit which is 25 feet deep. Both vents probably lie above a lava tube and mark the source of the extensive flow now crossed by South Santiam Highway. Sawyer's Cave, adjacent to the highway, is a lava tube far removed from the source of the flow. Lava from the northwest vent of Nash Crater dammed the ancestral McKenzie River (now called Park and Crescent Creeks) to form a swampy area known as Lava Lake. At this point, the flow turned abruptly southward, following the McKenzie drainage to Fish Lake. The Lava Lake Flow rests upon lava from the Central Group and is overlain by a flow from Little Nash Crater.

The most extensive lava flow exposed on the Sand Mountain alignment (referred to here as the Clear Lake Flow) was fed from a vent located half a mile southwest of Sand Mountain Cones, and dammed the lake for which it is named. A circular pit, 50 feet in diameter, displays several flow units in its walls and probably represents a collapse depression over the lava source. A smaller pit, 200 feet to the east, separates the collapse depression from an east-west spatter ridge 600 feet long. The west end of the ridge contains a shallow crater 30 feet in diameter. On the summit of the ridge are two vertical pipes, 3 and 6 feet in diameter, which are at least 40 feet deep. Lava from the collapse depression spread west to the McKenzie River, forming a dam from Sahalie Falls to Clear Lake. The upright trees which may be seen in the depths of the lake are well known. Wood from one of the submerged trees, drowned as the lake rose behind its lava dam, has been given a radiocarbon age of approximately 2,950 years B.P. (Benson, 1965), thus fixing the date of the eruption of the Clear Lake Flow at about 1,000 B.C.

The south flank of Sand Mountain is interrupted by a broad furrow which, at its base, leads to a bocca and a lava gutter. Lava from this vent moved chiefly eastward and then four miles to the south, where it now lies buried beneath younger flows from Belknap Crater. It should be noted that, although eruptions from the southwest

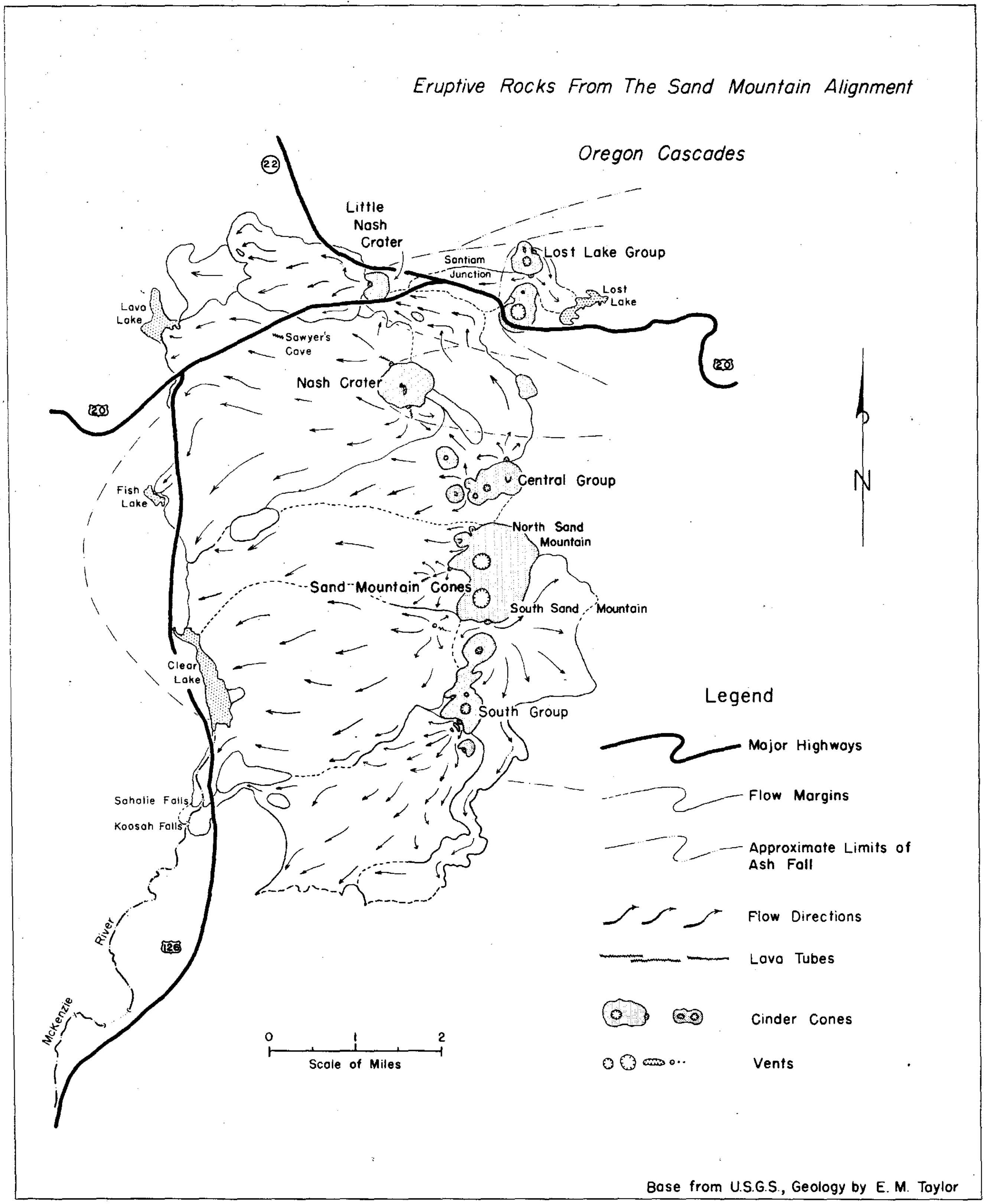

Eruptive Rocks From The Sand Mountain Alignment
Oregon Cascades
22
Little
Nash
Crater
Santiam
Junction
Lost Lake Group
Lost
Lake
Lava
Lake
Sawyer's
Cave
20
Nash Crater
20
Central Group
N
Fish
Lake
North Sand
Mountain
Sand Mountain Cones
South Sand Mountain
Clear
Lake
South Group
Legend
Major Highways
Flow Margins
Approximate Limits of
Ash Fall
Flow Directions
Lava Tubes
Cinder Cones
Vents
Sahalie Falls
Koosah Falls
River
126
McKenzie
0
2
Scale of Miles
Base from U.S.G.S., Geology by E. M. Taylor

FIGURE 2.

and south Sand Mountain vents probably occurred at about the same time, their common lava boundaries are obscured by ash deposits and their relative age is unknown. Consequently, the age of Clear Lake does not necessarily define a maximum age for Belknap lava.

Lavas from the cinder cone called Little Nash Crater probably are the youngest eruptive rocks on the Sand Mountain alignment. The cone has been quarried, exposing a complex internal stratification. A persistent structural discontinuity may be seen in the quarry faces, which suggests that the process of cone building was interrupted briefly by violent explosions which greatly enlarged the crater.

Road cuts north of the cone display weathered till overlain by a three-inch layer of fine black ash, which is attributed to eruptions from Nash Crater. Resting upon the ash layer is a 4- to 5-foot bed of coarse ejecta from Little Nash Crater. The lower part of this bed contains abundant accidental fragments derived from glacial deposits beneath the cone. Late in its history, Little Nash Crater was breached on the west by a flow whose volume is approximately nine million cubic yards.

Some cones of the Sand Mountain alignment, such as Little Nash Crater, were constructed and ceased to emit ash before a significant amount of lava appeared; others, such as Nash Crater and the Sand Mountain Cones, ejected ash throughout the course of lava extravasation. It is a significant fact that as one crosses westward over the lava field from Sand Mountain Cones (which were the greatest producers of ash), the average thickness of ash cover increases because older lava surfaces are encountered and more of the total ash fall is exposed. Most of the ash from Sand Mountain Cones drifted east and northeast, heavily blanketing an area of more than 100 square miles. This material has been so extensively reworked by surface water that it is difficult to reconstruct an original thickness distribution.

The modern appearance of Sand Mountain Cones is one of surprising freshness and perfection in view of the fact that most of the ash was expelled more than 3,500 years ago (see discussion of Blue Lake Crater). Some ejecta fell upon the 3,000-year-old Clear Lake flow, and it is possible that still later eruptions contributed to the form of the cones.

Eruptive Rocks from Inacessible Alignment and Twin Craters

Three and one-half miles southwest of Mount Washington, a short alignment of four cinder cones has been nearly buried by Belknap flows (fig. 1). The southernmost and largest cone, here named Inaccessible Cone, now lies five miles from the nearest road and is surrounded by a wide barrier of jagged lava. The cone contains a symmetrical crater and is encircled by flows which issued from numerous boccas at its base. The Belknap flows partly obscure three smaller cones which lie one mile to the north. An unnamed cone, offset near the north end of the Inaccessible alignment, is 300 feet high and has been breached on the west and southwest by a flow of gray basalt, charged with bombs. The flow has been traced westward beneath the Sand Mountain and Belknap lava fields, and thus is older than both of them. In outward appearance, the lava from this cone closely resembles the glaciated and nearly ubiquitous, pale gray bedrock which is so abundant in older parts of the High Cascades. It is probable that additional vents and a small field of lava associated with the alignment have been lost to view.

Twin Craters is a cinder cone located at the margin of the Belknap field, three miles southwest of the Belknap summit (fig. 1). The cone is 300 feet high and the north and south craters are about 200 feet deep. A small pit, 30 feet in diameter, is set into the east rim of the north crater. The final ejecta from the north vent consisted of fine scoria and ash which accumulated in stratified deposits on the crater rim. The south crater emitted clots of spatter which, as they fell upon the rim, split apart and disgorged tiny streams of lava. Scoria and bombs litter the glaciated landscape to the west. North of the cone, several mounds of red cinders are imperfectly exposed along the margin of Belknap lava; whether they represent separate cones or scoria-covered flow ridges is not known. Boccas exist on all sides of the Twin Craters cone, but most of them are clustered upon the north and south flanks. Lava from these vents must have been very fluid, for some flows are only three feet thick and their upper surface is coated with minute, glassy spines. An extensive lava field may have spread into the broad glaciated valley which then existed to the north; if so, it is deeply buried beneath the Belknap volcano.

Hoodoo Butte

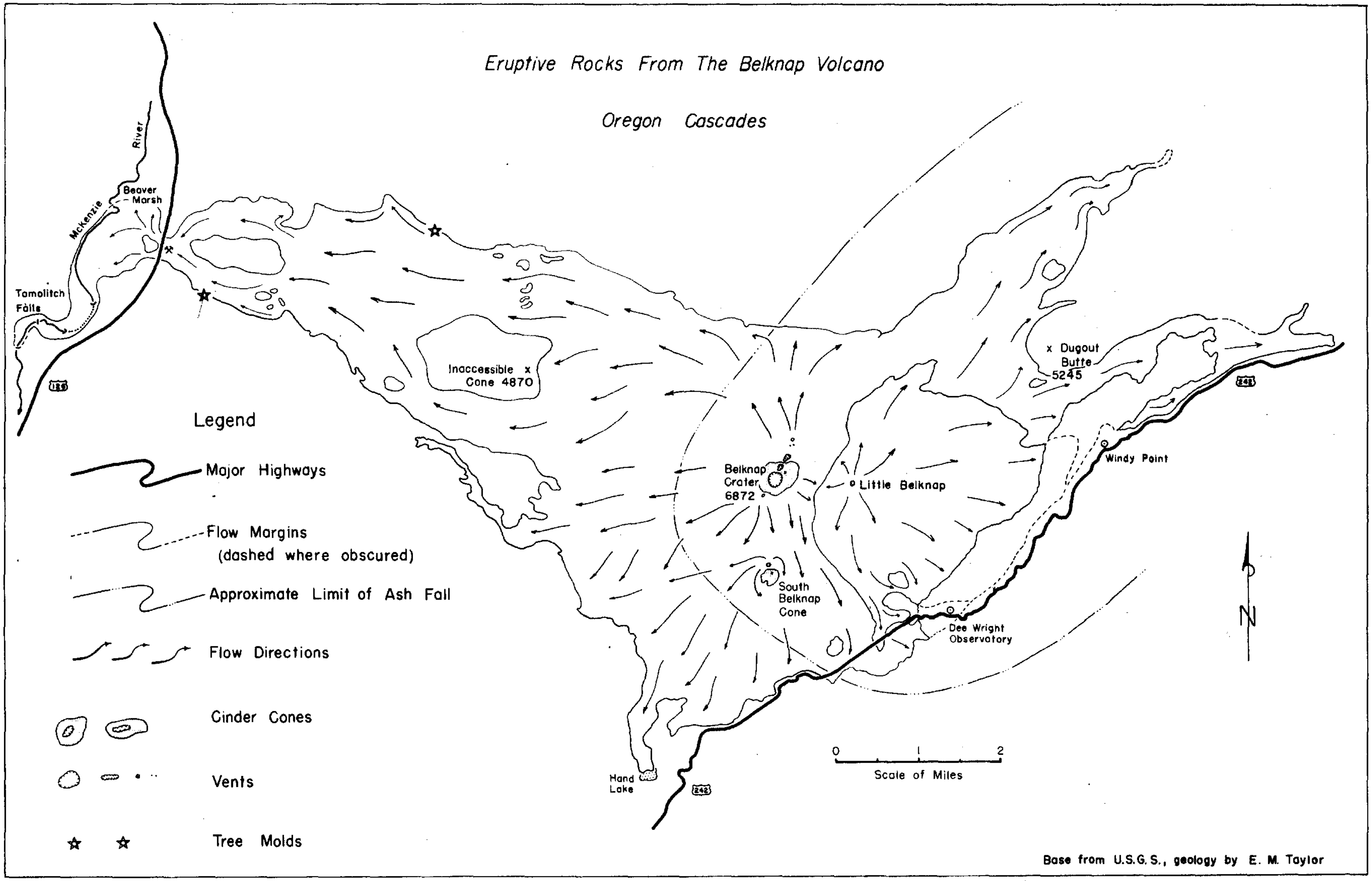
Hoodoo Butte is an isolated cinder cone which rises 500 feet above the eastern edge of a glaciated platform, midway between Sand Mountain Cones and Santiam Pass (fig. 1). The small summit crater is open to the east, but could not have been breached by lava because none has been found in association with this cone. Instead, the incomplete appearance of the crater rim is a result of the very irregular topography on which the cone was built; much of the ejecta simply fell over the east edge of the platform. Although Hoodoo Butte stood in the path of fallout from Sand Mountain Cones, most of this ash has been washed onto the surrounding lowlands. A thick deposit of Sand Mountain ash still survives on the crater floor.

History of the Belknap Volcano

Of the volcanic centers discussed in this paper, none poured forth a greater volume of lava than the shield volcano which is surmounted by Belknap Crater, Little Belknap, and related vents (fig. 3). Williams (1944) has provided a lucid description of the Belknap shield; only its salient features are outlined here. The surface of the mountain is covered largely by lava which poured repeatedly from vents marginal to a composite summit cone. This lava was relatively fluid and eventually inundated an area of more than 37 square miles. It did not move in long, continuous streams. Instead, short channels branched and crossed one another, resulting in thin lobes with complex drainage patterns. Accurate reconstruction of the surface on which the volcano rests is precluded by the great thickness and widespread distribution of lava. Consequently, 1 1/3 cubic miles is regarded as only a rough estimate of the volume of Belknap rocks.

The oldest exposed lavas of the Belknap shield occur on its eastern flanks. They were erupted from vents now poorly defined, which may have been subsequently buried as the summit cone reached final development. These lavas moved principally northeastward, diverging into two lobes on either side of a ridge called Dugout Butte. Both lobes descended to an elevation of 4,150 feet, seven miles from their source.

The summit cone of the Belknap volcano rises 400 feet above its basal shield. Two deep craters at the top of the cone emitted ashes and coarse cinders, which accumulated as high mounds of stratified lapilli-tuff on their east rims. In the walls of



Eruptive Rocks From The Belknap Volcano
Oregon Cascades
Legend
Major Highways
Flow Margins
(dashed where obscured)
Approximate Limit of Ash Fall
Flow Directions
Cinder Cones
Vents
Tree Molds
McKenzie River
Beaver Marsh
Tamolitch Falls
Inaccessible Cone 4870
Belknap Crater 6872
Little Belknap
South Belknap Cone
Dugout Butte 5245
Windy Point
Dee Wright Observatory
Hand Lake
242
126
Scale of Miles
0
1
2
N
Base from U.S.G.S., geology by E. M. Taylor

FIGURE 3.

the southern crater, which is about 250 feet deep and more than 1,000 feet wide at the rim, thick flow rocks are exposed. Some lava poured over the southwest lip of this crater and is now partly obscured by spatter. Well-formed spindle bombs, up to three feet in length, are common along the west rim of the north crater. A broad pit 200 feet long was blasted through a bocca at the north base of the cone. Two small spatter cones appeared at a late stage about 1,000 feet still farther north.

The distribution of ash and cinders on the rim of Belknap Crater, as described above, was caused by strong and prevailing wind transport to the east. Thin deposits of scoria are found on lava immediately west of the cone, but as the eastern slopes are approached the lavas become mantled in black ashes and fine cinders. A wide area from Dry Creek on the north to Black Crater on the south was heavily blanketed. Deposits have been recognized eight miles to the east.

During a late stage in the development of the Belknap summit cone, vast quantities of lava issued from boccas on the south, west, and north and poured west toward the McKenzie River. Ropy surfaces and lava squeeze-ups between large rafted platforms of broken crust are common here. Lava from the south vent poured across older lava from Twin Craters; three miles from the Belknap summit, the western streams overran lava and cinder cones of the Inaccessible alignment. Farther west, the Belknap lavas poured over flows from the south vent of Sand Mountain and from the south group of the Sand Mountain alignment, before finally plunging in a steep cascade into the McKenzie Canyon.

The McKenzie River was altered profoundly by the lava which spread across its path. A broad, swampy area known as Beaver Marsh formed upstream from the point where the river now flows onto the Belknap rocks. Where it once flowed freely through its open canyon, the river is now gradually absorbed into the buried talus along the canyon margins and into permeable zones between lava units, reappearing at Tamolitch Falls. Downstream from the falls, the flow has been reduced by erosion to a lateral terrace, perched on the west canyon wall 30 feet above the level of the river.

Tree molds were formed along the margins of the west Belknap flows. They are displayed best at the westernmost locality shown in Figure 3. Here, several dozen molds range from 1 to 5 feet in diameter and from 6 to 15 feet in depth. Most of them are vertical and widen downward. Hemicylindrical trenches as much as 35 feet long occur where trees fell onto the pasty lava. In most areas tree molds are rare because lava must be sufficiently fluid to conform to the shape of a tree, yet must not flow or be deformed after the tree has been consumed. In the present instance, the Belknap flow spilled into a protected recession in a steep, north-facing slope which presumably was, at the time of the eruption, as moist and deeply forested as it is today. The level surface of the resulting pond is an indication of the fluidity of the lava at the time of its isolation from the active stream. From the buried soil at the base of one of the molds, the writer excavated a radial system of large roots which had been deeply charred. Radiocarbon analysis of this material indicates that trees were burned by the west Belknap flows about A.D. 360 $\pm$ 160 years (WSU-292). This date is based upon a C-14 half-life of 5,570 years.

One mile south of the Belknap summit is a small volcano referred to here as the South Belknap Cone. This cone was breached on the southwest by lavas which then spread over the south base of the Belknap shield. A later flow, from a vent 300 feet to the northwest, surrounded the cone and inundated the early lavas. The later flow overlapped the west Belknap lava and, at its farthest extension, poured south through a narrow gap into Lake Valley, where it now forms the north shore of Hand Lake.

The latest addition to the Belknap volcano took the form of quiet discharge of lava from a vent called Little Belknap, one mile east of the summit craters. So much lava issued from this one point that a subsidiary shield was formed. It is surmounted by a chaotic heap of cinders and blocks from which collapsed lava tubes diverge radially. One of the western tubes can be followed to its confluence with a vertical conduit which is approximately 20 feet in diameter, and which remains choked with snow, even in late summer. Lava from Little Belknap spread east to within one mile of Windy Point and southeast to McKenzie Pass. It rests upon the ash from Belknap Crater and is overlain by younger flows from Yapoah Cone.

A peculiar, and general, feature of the flow rocks from Little Belknap is seen along the Skyline Trail half a mile northwest of the McKenzie Pass Highway, where the lava stream diverged after passing between two prominent steptoes. As it cooled, the contracting surface warped upward to lift part of the crust, together with its still-plastic substratum, and peel it back upon itself. Thick overturned slabs may be found which are as much as 10 feet wide and 50 feet long, usually parallel to the direction of flow. Except for distortion due to contraction and fragmentation, each slab matches perfectly the adjacent counterpart surface from which it was pulled. Such features will be referred to as lava curls.

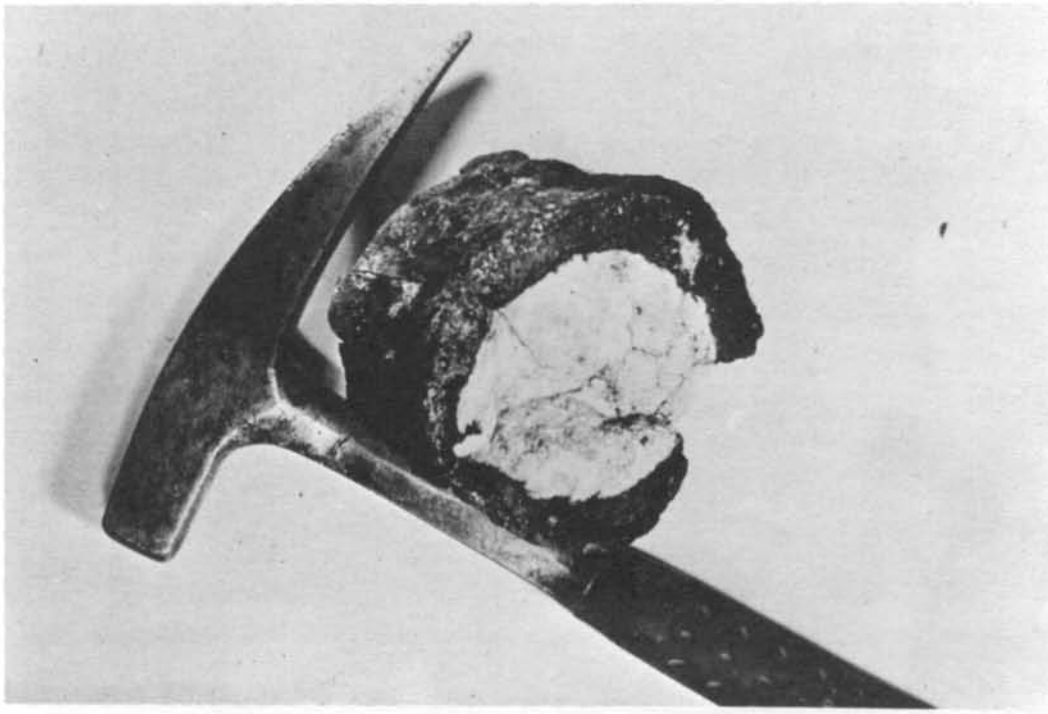
Blue Lake Crater

Blue Lake, as seen from the Santiam Pass Highway, is $3\frac{1}{2}$ miles east of the Cascade crest (fig. 1). It is 0.5 mile long and 0.2 mile wide, and set in a deep pit formed by Recent volcanic explosions of great violence. The Blue Lake eruptions resulted in at least three overlapping craters which are aligned approximately N.25°E., and which fall within a geographic trend common to Belknap Crater and the Spatter Cone Chain to the south, and the "Cinder Pit" to the north. The first (and only?) published suggestion that Blue Lake might occupy a volcanic crater appeared in 1903 (Langille and others).

The southern half of Blue Lake is rimmed by a crescentic ridge which, in places, stands 300 feet above the water and 150 feet above the adjacent topography. The outer slopes are covered with basaltic cinders, bombs (some of which are six feet long), and accidental fragments of older, underlying lavas. Inner slopes of the rim generally lead to cliffs which disappear into azure depths. If one may compare Blue Lake crater to other Cascade craters of similar diameter, the lake is probably in excess of 300 feet deep.

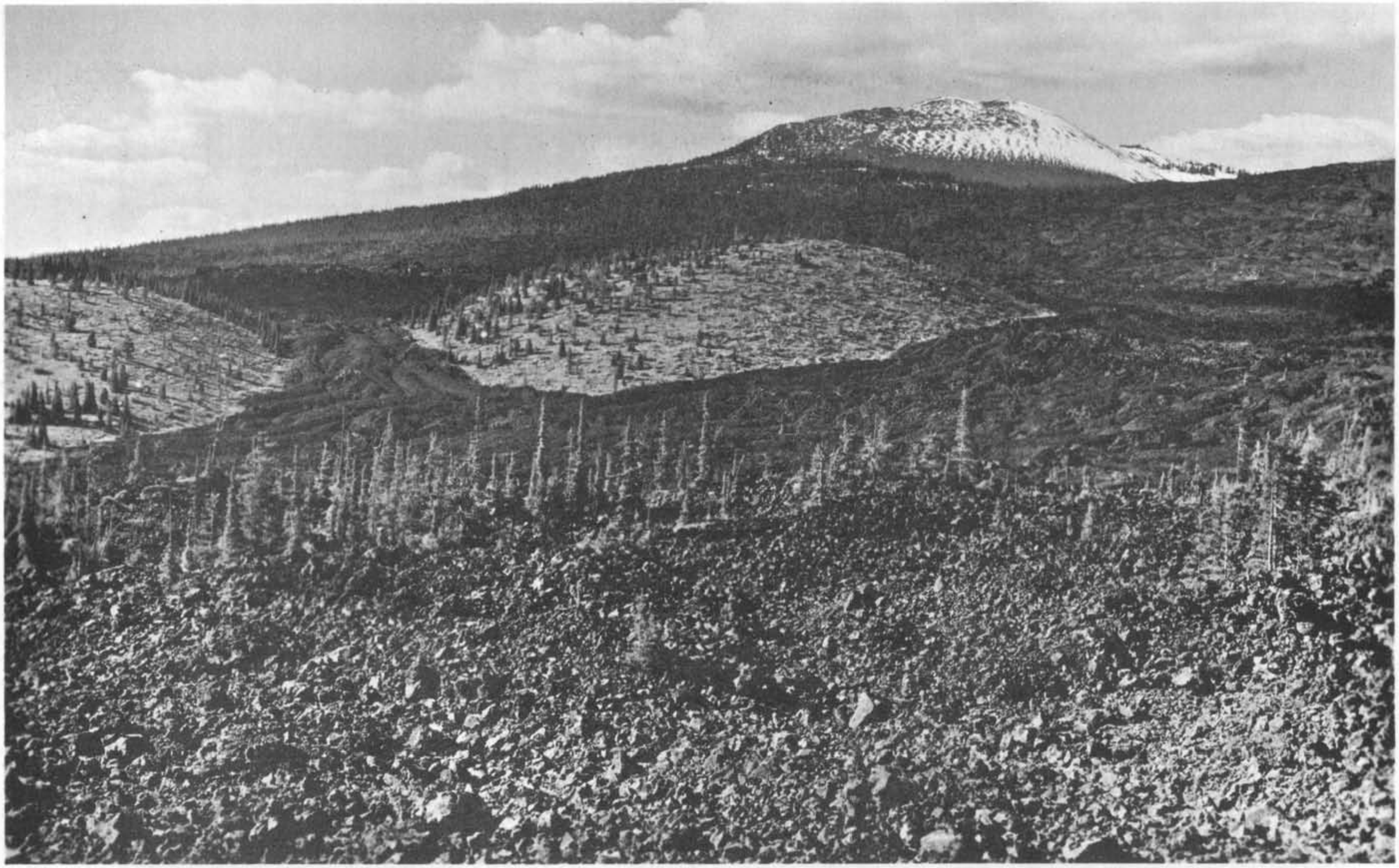
Some of the lakeshore cliffs may have been formed by the collapse of over-steepened crater walls, but no prominent dislocations of a concentric type have been found. The north crater wall, now largely submerged, was blasted through pre-existing bedrock, fragments of which are found scattered over the nearby landscape. Consequently, it appears that Blue Lake crater was the result of upward explosions rather than interior subsidence. Above lake level, the southern crater walls are composed of crudely stratified cinders and bombs with intermixed bedrock blocks. No Recent lava flows have been recognized in the Blue Lake area.

Bombs and blocks were ejected in all directions from the crater, but most of the fine scoria and ashes drifted east and southeast. A typical section taken through these deposits contains, at its base, weathered till overlain by 2 to 3 feet of fine black ash attributed to eruptions of the Sand Mountain alignment. Capping the black ash is a



Pumice-cored volanic bomb with basaltic rind from Four-in-One Cone.

Lava gutter west of Collier Cone provides pathway for Skyline Trail.



Belknap Crater seen from Dee Wright Observatory: Belknap Crater (snow-covered skyline) is impressive in stature, but is only a pile of cinders on the summit of a vast shield of recent lava. Forests in background grow upon old Belknap lavas; trees in foreground stand upon young lava from Yapoah Cone. Lava of intermediate age and position surrounds "islands" and issued from a subsidiary vent called Little Belknap. (Oregon State Highway Department Photograph No. 423)

Lava from Little Belknap: Desolate fields of blocky lava (foreground) from Yapoah Cone, and hummocky lava (background) from Little Belknap, lie between Dee Wright Observatory and the volcanic plug of Mount Washington. The jagged features of these lava surfaces were formed less than 1,500 years ago. (Oregon State Highway Department Photograph No. 427)

Lava flows from Collier Cone: Collier Cone (upper left) and lava streams which spread from its crater down the west slope of the Cascade Range (foreground), are probably the most recent manifestation of millions of years of Oregon vulcanism. Left of the cone is the Ahalapam Cinder Field; lava gutters lead west and northwest to lava lobes which are marked by levees and pressure ridges. Large volcanoes behind the cone are North Sister (left) and Middle Sister (right). Collier Glacier (center) has receded from the cone to its present position in only 40 years. In the background are Broken Top (left) and South Sister (right). Four-in-One Cone and lavas are visible at lower left. (Delano Aerial Oblique No. 631234) thick accumulation of scoria which may be traced directly to Blue Lake. Charred wood from the limb of a conifer has been excavated from the sharp interface between the scoria and ash. The radiocarbon age of this material is 3,440 ± 250 years B.P. (WSU-291), assuming a C-14 half-life of 5,570 years. The eruption of Blue Lake Crater commenced therefore, at about 1,500 B.C. This date, when compared with the age of Clear Lake (about 1,000 B.C.), suggests that most of the ash from the Sand Mountain alignment was deposited in the Blue Lake area 500 years before the final eruptions of Sand Mountain lava.

The Spatter Cone Chain

A chain of spatter cones, one mile long, trends N.23° E. across the valley of Cache Creek between Blue Lake Crater and Mount Washington (fig. 1). Volcanic features are restricted to north and south segments, but several trench-like depressions aligned parallel to the midsection of the chain outline a strong subsurface continuity. The northernmost vent is a circular crater, 10 feet deep, which appears to have emitted only gas. About 200 feet south is the first of four spatter cones, with craters 30 to 40 feet deep, which surmount a narrow ridge of spatter and scoria. Still farther south, a series of discontinuous grabens, averaging 10 feet in width and 3 feet in depth, leads to a southern line of vents. Deposits of ejecta occur intermittently along the grabens. Fractured bedrock is exposed where the trend of this chain intersects Cache Creek, but no displacements have been recognized. There are seven southern vents, as follows: Three small craters to the north are separated by a short graben from three large craters located on a spatter ridge to the south; the central crater on this ridge contains a small crater in its north rim. A shallow graben extends about 150 feet south from the ridge. Volcanic rocks of the Spatter Cone Chain overlie ash deposits that are correlative with the deposits of fine ash near Blue Lake Crater.

Sims and Condon Buttes

The western third of McKenzie Pass Highway follows a Recent lava flow, $9\frac{1}{2}$ miles from source to terminus. The source cone is Sims Butte, located $6\frac{1}{2}$ miles south of the Belknap volcano (fig. 1). The cone is 650 feet high and is broadly indented on the west side by a shallow crater, located 400 feet below the summit. Ejecta are coarse and are confined largely about the vent within a circular area of one-mile radius. The limited extent and symmetrical distribution of ejecta suggest that the asymmetry of the cone is a result of lava breaching rather than prevailing wind direction.

Short flows emerged from the north base of the cone, but most of the lava issued from a west bocca, 200 feet below the shallow crater. Collapsed lava tubes may be traced downstream from this bocca for several hundred yards. At one point, where the flows are steeply inclined, a 70-foot lava tube descends beneath the crust. Two "skylights" penetrate the thin roof, and collapse depressions define an inaccessible western continuation of the tube.

The extensive lava flows from Sims Butte spread onto a topographic shelf west of the cone, then poured into the Lost Creek glacial trough. They covered the floor of the trough and moved westward to within a quarter of a mile of Limberlost Forest Camp. White Branch, Obsidian, Linton, and Proxy Creeks all disappear beneath this blanket of lava before reappearing in a series of large springs at the head of Lost

Creek. It has not been possible to trace single flow units from Sims Butte for long distances because of the overlying Collier lavas and the heavy forest cover, and because the Sims lava advanced as thin, overlapping sheets of limited extent. Lava tongues, only one foot thick, cover several acres along some parts of the flow margins. The best cross-sectional exposures of Sims lava are seen along the switchbacks of the McKenzie Pass Highway, where five or more separate flows can be counted in one 15-foot embankment. A typical flow is 3 to 5 feet thick with a thin, dense crust resting upon a base of unconsolidated rubble.

Condon Butte is three miles northeast of Sims Butte and is considered here to be genetically related to it. The cones are about the same size, equally forested, and their ejected material is, for all practical purposes, identical. Condon Butte, however, did not emit a great volume of lava and as a consequence the cone is symmetrical. In the summit are two nested craters from which short, stubby flows moved down the southwest flanks.

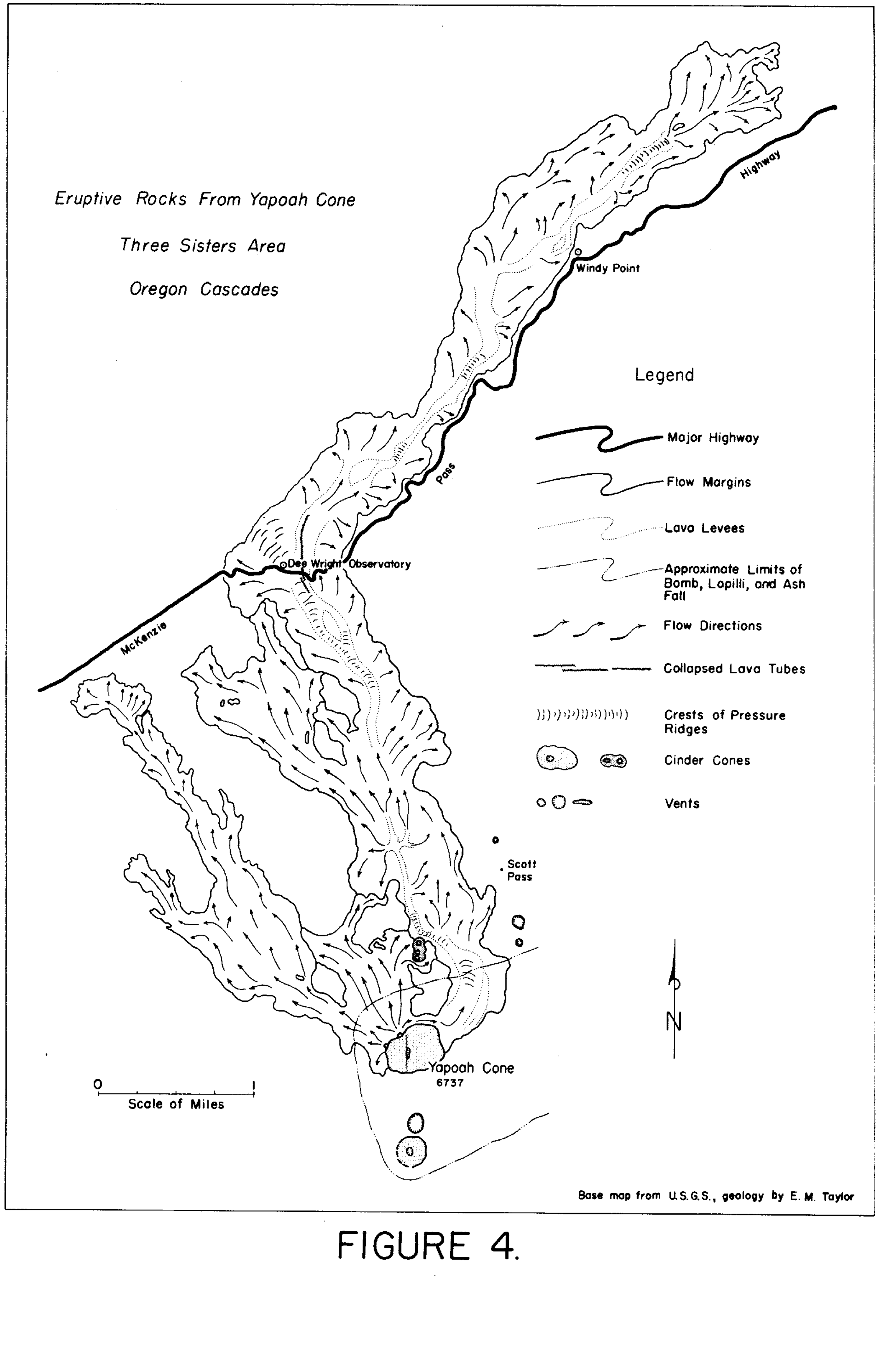
Volcanic History of Yapoah Cone and Related Vents

Between McKenzie Pass Highway and the North Sister, the Skyline Trail (fig. 1) leads across an alignment of six cinder cones and gas vents which is 1.4 miles long and trends S.4°W. At the midpoint of the alignment stands Yapoah Cone, and from its base several lava streams extend northward, covering 6 square miles (fig. 4). Lava from Yapoah Cone rests upon Little Belknap lava and is overlain by ashes and fine scoria from Four-in-One Cone.

Prior to Recent time, an unusual type of flow rock was erupted from a set of fissures along the Cascade crest between Black Crater and North Sister (fig. 1). Bombs and lava were discharged simultaneously and spread down the western slopes in what might be described as an agglutinate flow. A typical unit is 30 feet thick with a 10-foot crust of red bombs and spatter which passes gradationally into an underlying dense lava choked with bombs. Yapoah Cone and related vents, together with Collier Cone and the Ahalapam Cinder Field (fig. 5), rests upon the glaciated agglutinate flow rocks. Some of these Recent and older-than-Recent eruptive features are not easily distinguished along the crest; consequently, an interpretation of the volcanic history of this area may be subject to a wide variety of opinion.

Hodge (1925) named the Ahalapam Cinder Field and described it as "two rows of volcanoes having the appearance of morainal topography." Williams (1944) suggested that "ejecta from Collier and Yapoah cones had accumulated on morainic mounds," but noted the presence of "many large bombs, several more than four feet across and a few even eight feet across, scattered among the fine scoria." The bombs were cited as evidence of eruption from local vents and most of the crest in this area was mapped as a field of Recent eruptive activity (Williams, 1957). In the opinion of the writer, however, the Ahalapam Cinder Field is a mantle of scoria and ash ejected from the Collier vent and deposited upon glacially dissected agglutinate flows. Recent eruptions between McKenzie Pass and North Sister have occurred only adjacent to Scott Pass and along the Four-in-One and Yapoah-Collier alignments, as described below.

Yapoah Cone rises 500 feet above its surroundings except on the south side, where it abuts against a glaciated ridge of agglutinate flows. The summit crater is about 300 feet long in a north-south direction, 100 feet wide, and mantled with red cinders. Stratified deposits of yellow lapilli-tuff occur on the east rim, but outer


Eruptive Rocks From Yapoah Cone
Three Sisters Area
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Flow Directions
Collapsed Lava Tubes
Crests of Pressure Ridges
Cinder Cones
Vents
Highway
Windy Point
Pass
Dee Wright Observatory
McKenzie
Scott Pass
N
Yapoah Cone
6737
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Scale of Miles
Base map from U.S.G.S., geology by E. M. Taylor

FIGURE 4.

slopes of the cone are covered with black cinders. The remarkable symmetry of Yapoah Cone may be due to persistence of explosive activity until a late stage; all lavas adjacent to the cone are partly obscured by ashes and scoria. Pyroclastic deposits resulting from Yapoah eruptions, however, are neither as thick nor as widely distributed as similar material from nearby Collier and Four-in-One Cones.

Half a mile north of Yapoah Cone, a linear cluster of three small spatter cones was nearly engulfed by Yapoah lava. Rocks from these vents are identical to ejecta of the Yapoah type, and probably came into existence during the same eruptive episode.

Other Recent volcanic activity near Yapoah Cone may antedate the Yapoah eruptions. A gas vent was blasted through the agglutinate flows 0.3 mile south of Yapoah Cone, leaving a circular depression 300 feet in diameter (fig. 4). Immediately south of the gas vent a small, asymmetrical cinder cone was built on the margin of a precipitous ridge. The west flank of this cone rises 350 feet above nearby lowlands, while its eastern rim stands only 30 feet above the ridge top. Near Scott Pass, one mile to the northeast, a deep, round pit, 400 feet in diameter, interrupts a glacially striated surface cut on red agglutinate flow rocks. Other poorly defined gas vents exist to the north and south of Scott Pass and are located along the system of agglutinate flow fissures mentioned previously. These vents may be assigned on a provisional basis to a Recent, but pre-Yapoah, eruptive episode. The activity was confined largely to the incipient Yapoah alignment, but also reached the surface through conduits along the older agglutinate flow fissures.

Lava units from Yapoah Cone are composed of porous crustal blocks which become increasingly coherent downward, grading into a thin, dense base. A cross-section of this structure is exposed in highway cuts east of Dee Wright Observatory on McKenzie Pass.

Yapoah lava was discharged first from a bocca on the north, then from a bocca on the northwest side of the cone. The first lobe, here referred to as the <u>Observatory Lobe</u>, was channeled northward until it reached that part of the Cascade crest now traversed by McKenzie Pass Highway. At this point it encountered the Little Belknap shield volcano and was deflected down the east slope of the range, eventually reaching a total length of 8 1/3 miles.

For a distance of $1\frac{1}{2}$ miles downstream from Yapoah Cone the final lavas of the Observatory Lobe moved in a narrow channel perched on the lobe crest, and confined by lava levees. At intervals the levees were breached, releasing dendritic cascades which poured laterally down their flanks. At its terminal end, the channel split into three principal branches. The central and eastern branches fed the main lobe; the west branch produced a subsidiary lobe only two miles long. The remaining length of the Observatory Lobe is surmounted by a system of lava gutters which are, in some places, narrowly confined between lava levees. Upstream from such constrictions, transverse pressure ridges were formed; downstream, the lava frequently drained from beneath a congealed crust. In this way lava tubes were produced and long narrow trenches occur where their ceilings have collapsed. An excellent example of a collapsed tube is to be seen just east of the Dee Wright Observatory on both sides of McKenzie Pass Highway.

A later lobe issued from a bocca approximately 100 feet above the northwest base of Yapoah Cone. Initially, the lava spread northward, plunged down a steep slope, and chilled to a standstill at the head of a large steptoe called "The Island." Succeeding lava flows by-passed this lobe on the west and formed an extensive ribbon which ceased to move only after it had reached the base of the Belknap volcano three miles distant. The northwest bocca now is represented by a gutter leading to an open tube, which descends 20 feet into the flanks of the cone before it pinches out above a fill of jagged lava.

Volcanic History of Four-in-One Cone and Related Vents

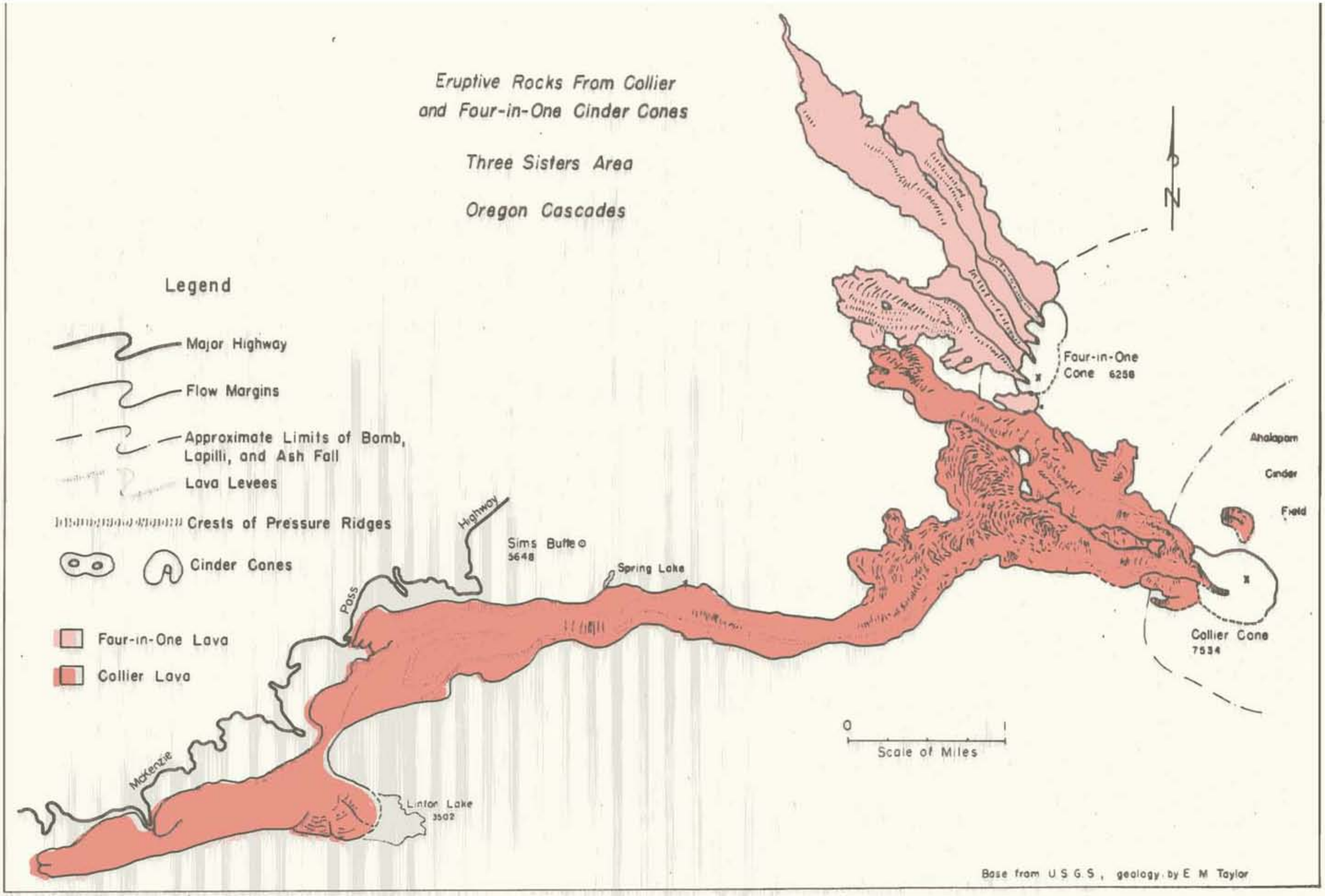
A series of 19 visible vents forms a short volcanic alignment about $1\frac{1}{2}$ miles southwest of Yapoah Cone. The northern end of this alignment is marked by an elongate ridge of four coalescing cinder cones, appropriately named Four-in-One (fig. 5). At its southern end the alignment was inundated by lavas from Collier Cone. Between Four-in-One Cone and the margin of Collier lava, three small vents can be seen. One is slightly offset to the east and covered with scoria; two others are half-obscured by the Collier lobe, and emitted pasty clots of black spatter and accidental fragments of underlying rocks. In the Collier midstream, the summits of four cinder cones are exposed, each with a well-defined crater. The northern cone of this group was breached on its southwest flank by a lava flow which now is covered by the Collier lobe. Only the source area of the lava and its terminal extremity, one mile to the northwest, are exposed.

The eruptive history of Four-in-One Cone is not known in detail, but several major events can be outlined. Activity developed first along a half-mile fissure, and probably was soon concentrated at four conduits separated by a uniform interval of about 700 feet. Concurrent eruption of bombs and coarse cinders resulted in the construction of four overlapping cones which attained a height of 200 feet. Lava escaped from the southern base of the south cone, covering several acres with a thin veneer of black vitreous rock, crowded with tiny vesicles. During the height of the eruption the cone was enveloped in black spatter, while scoria and ashes, composed chiefly of turbid brown glass, drifted east to the Cascade crest. Near the vents, the resulting deposits are more than 50 feet thick. Southward, they pass beneath Collier lavas; to the north they rest upon flow rocks from Yapoah Cone.

Following the more violent stages of activity, four deep gashes were excavated in the west slope of the cone by streams of lava which eventually covered 1.4 square miles and reached a point 2 3/4 miles to the northwest. Counting from the north vent, the flow from the second was obscured by a subsequent flow from the third, which seems to have issued at about the same time as flows from the first and fourth vents. Because the lavas moved northwest and the ash was blown eastward, they do not in general overlap. The breaching of the cone, however, clearly involved both its reddish core and its black covering of spatter.

Surfaces on Four-in-One lava resemble those found on the Yapoah lobes, except for the prevalence of red scoria (quarried from the cone) and the lack of long, continuous channels bordered by lava levees. The Four-in-One flows tend to branch repeatedly over short distances. This suggests that as the lava moved forward, it congealed quickly and succeeding lava was obliged to take a new course. Marginal lava curls were developed near the source vents.

Finally, it should be noted that fragments of white rhyolitic pumice were expelled with the basaltic ejecta. The pumice is most abundant as fine ash, but large samples occur on the cone, chiefly about the north vent. Occasionally pumice is found encased within the black rind of a spindle-shaped basaltic bomb.


Eruptive Rocks From Collier
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Cinder Cones
Four-in-One Lava
Collier Lava
N
Four-in-One Cone 6258
Cinder
Field
Collier Cone 7534
Sims Butte 5648
Spring Lake
Highway
Pass
McKenzie
Linton Lake 3502
0
1
Scale of Miles
Base from U S G S , geology by E M Taylor

FIGURE 5.

Volcanic History of Collier Cone

Collier Cone lies at the north-by-northwest base of the North Sister and probably is, of the features described, the most recently active volcano. Stratified cinders and bombs are exposed in the crater walls. Black, fragmented bombs as much as one foot in diameter are abundant on the cone and may be found as distant as half a mile west and a quarter of a mile east of the vent. Fine-grained ejecta were driven eastward by the wind to form a square mile of alpine desolation, known as the Ahalapam Cinder Field. Vitrophyric pumice, often mixed intimately with basaltic glass, is common in deposits of Collier ash and scoria.

Collier flow rocks afford an unusually clear record of eruptive history. An estimated 0.04 cubic mile of lava issued from the cone, producing a west lobe $8\frac{1}{2}$ miles long and a northwest lobe 3 miles long (fig. 5). The lavas advanced in several distinct surges, each different in composition from its predecessor. Outward appearances of these flows, however, are remarkably uniform.

The initial lobe moved westward down the valley of White Branch Creek, blocking the drainage of a large spring to form Spring Lake at the base of Sims Butte. It then plunged into the Lost Creek glacial trough, damming Linton Creek to form Linton Lake. Relief of this west lobe, from source to terminus, is 4,160 feet.

The midsection of the lava stream, especially where it is steeply inclined, is occupied by long, multiple lava gutters. Several surges of lava must have poured down gutters formed previously, because two pairs of lava levees are nearly constant features of the early lobes and three pairs are fairly common.

A final surge of lava filled and overtopped the crater of Collier Cone, mantling its western slopes in a shroud of thin lava tongues. The northwest part of the cone was breached at this time and a large sector was rafted a quarter of a mile by the rising flood. As the breach widened the lava drained away, leaving a smooth coating on portions of the crater walls. The new lavas poured westward, narrowly confined between high levees. This last addition to the west lobe has been traced as far as Linton Lake but its furthest extent has not been recognized.

Several short, broad, subsidiary lobes were formed as lava spilled out of the gutters along the upper third of the west lobe - probably because the narrow channel could not accommodate the large volume of lava discharged into it. Perhaps for this reason, lava burst through an opening north of the breached area to form the northwest lobe. As activity shifted to the northwest, the supply of fresh lava to the west lobe diminished, and the blocky crust was folded into transverse, arcuate pressure ridges which now occur upstream from constrictions in its course. Final motion of the west lobe consisted of draining from the steeply inclined flow near the source vent. The deep gutter thus formed is now the most accessible route to the crater floor, and is occupied by the Skyline Trail. Before the northwest lobe chilled to its present form, a minor extension moved approximately 200 feet into the upper reaches of this gutter.

A few small lava tongues emerged at the north base of Collier Cone from a vent now buried beneath scoria and ashes. The position of these flow rocks in the eruptive history of the cone is uncertain.

At intervals throughout its length, the west lobe has been dissected by White Branch Creek. In the walls of these stream channels, the lobe is seen to be a mass of tumbled blocks and scoria. Close to the source, however, the blocky crust is underlain by dense glassy lava cut by deep transverse fractures.

During the past century, Collier Cone blocked the "Little Ice Age" advance of Collier Glacier. An early photograph (Campbell, 1924) shows Collier ice high on the flanks of the cone. When the ice attained a thickness of 200 feet at its terminus, meltwater was discharged into the crater, much of the floor was covered with outwash, and stream gravels were deposited for more than one mile down the west gutter. As the stream deposits near the cone are discontinuous and without interconnecting channels, the meltwater must have traversed snowfields and probably was active for only a brief time.

Continuity in the Volcanic Record

In the preceding descriptions, reference was made to more than 125 separate vents which have emitted various combinations of lava, ejecta, and gas. A number of genetic interpretations of the resulting landforms and deposits were offered. The shape of cinder cones, for example, depends upon such diverse factors as vent configuration, underlying topography, erosion, lava-breaching, explosive violence, and prevailing wind direction. The thickness of flow rocks and their surface features, aerial distribution, and sequence of superposition are determined by available topographic channels, viscosity and volume of lava, eruptive chronology, and the nature of the volcanic "plumbing" in the subsurface. The interdependence which exists between some of these factors is critical to petrologic interpretations.

Persistent linear vent patterns suggest that systems of faults or fractures must underlie the volcanoes. The most obvious alignments are those of the Sand Mountain groups, Inaccessible Cone, Four-in-One cones, and the Yapoah-Collier vents. While caution must be exercised in tracing vent alignments over long distances, the trend displayed by the Belknap craters, the Spatter Cone Chain, and Blue Lake Crater probably represents a similar continuous connection at depth. Close study of the eruptive centers, however, reveals several interesting irregularities. Some alignments (Four-in-One, for example) are linear over short segments but arcuate over their full length. Nearly all vent patterns except Belknap - Spatter Cone - Blue Lake and Four-in-One, trend individually north-south even where the composite alignment is differently oriented (Nash Crater, for example).

With few exceptions, each cinder cone is associated with a swarm of subparallel, north-south vegetation lineaments which are seen best on stereographic pairs of aerial photographs. These lineaments are composed of trees which stand 10 to 30 feet above the surrounding forest. Several lineaments are visible from mountain tops, but only one, on the west flank of Bachelor Butte, has been traced directly on the ground. They are not observed, of course, above timberline or in deforested areas. As seen on a photo scale of 1:50,000, some of the lineaments are only 30 to 50 feet wide, are as much as five miles long, and are nearly straight when plotted on a planimetric base.

The origin of such lineaments is not well known. None transect the most recent of the forested flows, but older lava fields display them in profusion. They occur with greatest frequency upon High Cascade glaciated bedrock which is overlain by thin deposits of ash or ground moraine. While the lineaments are not restricted to areas of Recent volcanic outbreak, they are concentrated near cones and usually a vent pattern coincides perfectly with a lineament. The following interpretation is offered on a provisional basis: Linear patterns of accelerated forest growth reflect irregularities in the supply of ground water which are, in turn, influenced by a bedrock joint set. Because the forest cover generally is scanty on glaciated bedrock surfaces, it is difficult to correlate lineaments on the map with joints in the rocks. If such a joint set exists, it is parallel to the length of the High Cascades and, for the most part, predates Recent volcanism. Volcanic conduits, rising above a broad, magmatic alignment were influenced by the joints. Consequently, the vent patterns generally trend north-south even if the alignment of which they are a part does not. Lineaments of the lava fields are commonly arcuate and concave toward the source cones, and may represent fracture systems above a subsiding magma column.

If the above interpretation is correct, it is likely that vents of a single eruptive center, coincident with a vegetation lineament, were active at about the same time. To what extent can this principle be applied to a whole alignment of eruptive craters? The answer is contained in the statement of lava chronology given in Table I below.

The central column in Table I is an eruptive sequence based upon radiocarbon age determinations, glacial records, and direct superposition of lava flows and ash deposits. Whether or not the approximate correlations in the third column are accepted, it will be seen that strict, detailed interpretation of an alignment as

TABLE I. Lava Chronology

Dates	Eruptive Sequence		Approximate Correlations
Older than 400 years	Collier		
	Four-in-One		
	Yapoah		
	Little Belknap		
	South Belknap flows		
360 A.D. ± 160 (WSU-292)	West Belknap flows		
1000 B.C. ± 220	Clear Lake flow	..?..	S. vent Sand Mtn.; Twin Craters; Sims; Condon; Little Nash
1500 B.C. ± 250 (WSU-291)	Blue Lake Crater	..?..	Latest flow, South Group; Fish Lake, Lava Lake flows; Spatter Cone Chain.
	Central Group and earliest flows from Nash, Sand, South Group; most of the ash from Sand Mtn. Alignment	..?..	Lost Lake Group
	Cone and flow of N. Inaccessible; two old cones of N. Sand Mtn. Alignment; Hoodoo	..?..	S. cones and flows of Inaccessible Alignment
Older than 10,000 years?	Flows and cones of quest. Recent age.		

consisting of coeval rocks is hazardous. The over-all eruptive sequence, however, is clearly related to geographic position; the eruptive history progressed from northwest to southeast. Exceptions to this rule are few and represent a comparatively modest volume of lava.

Several physical characteristics of lava flows in the area of study can be correlated with this eruptive sequence. For example, early lavas were relatively fluid and for this reason formed voluminous shields and extensive lava fields of thin flows with complex, discontinuous drainage patterns. Later lavas were more viscous, and were erupted in lesser volume; they formed thick flow units with high-standing margins and developed pressure ridge and lava gutter systems which are continuous for miles. In Part II of this paper, to be published at a later date, the results of petrographic studies and more than 200 partial chemical analyses will be placed within this framework of volcanic stratigraphy, and it will be shown that textural, mineralogical, and chemical characteristics of the lavas change in a regular way through the eruptive sequence.

Many details of the Recent volcanic history of this interesting region remain unknown. In particular, correlations must be extended over a larger area and additional radiometric dates must be obtained. The evidence at hand suggests that an elongate zone of volcanic activity cuts obliquely across north-south lineaments of the High Cascades in the vicinity of the Three Sisters. It may be continuous with a similar volcanic trend between the Three Sisters and Newberry Caldera to the southeast. For more than 10,000 years intermittent eruptions of basalt have occurred over the northwest extension of this zone, and during the last 4,000 years volcanic activity has shifted from northwest to southeast. The duration, recency, and continuity of such a record all suggest that future eruptions are possible in spite of the brief period of quiescence during historic time.

Acknowledgment

Radiocarbon dates were financed through a Northwest Scientific Association Grant-in-Aid. The writer is indebted to Dr. R. M. Chatters of the Washington State University Radiocarbon Laboratory for his help and advice, and to Roald Fryxell for many fruitful discussions concerning Recent geochronology of Oregon and Washington.

Glossary of Selected Terms

Accidental fragments. Rock particles erupted from a volcanic vent which are foreign to the magma associated with the vent.

Agglomerate. An accumulation of volcanic ejecta, usually near a vent, in which most of the particles are larger than scoria.

Agglutinate. A deposit of mixed bombs and spatter, more or less consolidated.

Ashes. Unconsolidated particles of volcanic ejecta, smaller than scoria.

Blocks. Angular fragments of volcanic ejecta, larger than scoria. Also applied to crustal fragments of lava flows.

Bocca. An Italian term meaning vent. English usage generally refers to a lava vent at the base of a cinder cone.

Bombs. Volcanic ejecta of any size which have assumed a rounded, aerodynamic shape during flight and have retained a recognizable vestige of this shape after impact.

Composite volcano. A volcanic mountain, generally large, in which lava is as abundant as ejecta. Opposed to cinder cone, generally small, in which ejecta predominate.

Lapilli. A class of volcanic ejecta which includes scoria and accidental fragments of scoria size.

Lapilli-tuff. A deposit of consolidated lapilli and ash.

Lava fields, flows, lobes, and tongues. A lava field is a wide and complex expanse of lava flows from separate, but related, vents. A flow is made up of lava from a single vent or from a small source area of closely related vents. Lobes are separate and distinct lava streams belonging to a single flow. A lava tongue is, as the name implies, a small, tongue-like offshoot from a flow.

Lava gutters and lava levees. If the supply of lava to an established channel rapidly diminishes, and if the flow gradient and fluidity is sufficiently great, the medial portion may drain away leaving a long deep gutter. Lava gutters are often bordered by high-standing margins called lava levees.

Pressure ridge. Broad ridges of lava, transverse to the direction of flow. Generally arcuate in plan, concave upstream, and thought to result from differential movement between a stagnant crust and a mobile interior.

Recent. A feature is considered to be of Recent geologic age if it came into existence since the last major glacial episode (here estimated to be 10,000 - 12,000 years ago).

Scoria. Particles of volcanic ejecta having coarse vesicular habit, irregular form, generally basaltic composition, and variable BB-shot (4mm) to walnut (32mm) dimensions.

Shield volcano. A large, broad volcanic mountain with gentle slopes of constructional rather than destructional origin.

Spatter. Irregular clots of ejecta, larger than scoria, but not highly vesicular; similar to bombs in origin but not in shape.

Squeeze-ups. Protrusions of lava extruded through rifts in a solid crust.

Steptoe. An elevated point of land surrounded by lava flows.

Vesicles. Rounded gas-bubble cavities in lava rocks.

Vitrophyric. The texture displayed by predominantly glassy lava which contains abundant megascopic crystals.

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* * * * *

NOTABLES TO ATTEND INTERNATIONAL LUNAR CONFERENCE

Nearly 100 scientists from 12 foreign countries and the United States will participate in the International Lunar Geological Field Conference in Bend, Oregon, August 22-28. The scientists are authorities in astronomy, geology, astrophysics, and related fields. Included in the roster of those attending are such names as Dr. Shotaro Miyamoto, Kyoto University, Japan; Dr. Harouin Tazieff, University of Brussels, Belgium; Dr. Aleksandr Mikhailov, Main Astronomical Observatory, Soviet Union; Dr. Nikolay Kozyrev, Physico-Mathematical Sciences, Leningrad; and Dr. Gerard Kuiper, Lunar and Planetary Observatory, University of Arizona.

The Conference is being co-sponsored by the New York Academy of Sciences and the University of Oregon, and is intended to advance investigation into the nature of the lunar surface. At least 10 papers will be presented and discussed by the participants, and five days will be spent on field trips in the area around Bend.

Dr. Jack Green, New York Academy of Sciences, and Dr. Lloyd Staples, Department of Geology, University of Oregon, are co-chairmen of the conference. Other members of the general committee are Lawrence A. Dinneen, Oregon Division of Planning and Development, Hollis M. Dole, State Geologist; and Marion Cady, Lunar Base Research Facilities, Inc., Bend.

KGW-TV, Portland, plans a program on the Conference August 22 at 11:30 a.m.

* * * * *

CENTER FOR VOLCANOLOGY

Dr. A. S. Flemming, President of the University of Oregon, has announced the establishment of a Center for Volcanology in the Department of Geology. Named as Director of the Center is Dr. A. R. McBirney, who will come to the University of Oregon from the University of California, San Diego, at LaJolla. He has done extensive work in volcanic regions in Central America, and is the author of many papers on volcanic activity.

The decision to establish a Center for Volcanology at the University of Oregon was based on the fact that the State of Oregon contains areas of volcanism, ancient and recent, unsurpassed in variety and scientific interest. More than half of the State is underlain or covered by volcanic rock, much of it extruded during Tertiary and Quaternary times. The Recent cones, flows, and pyroclastic deposits have changed very little since they were formed and are excellent laboratories for field studies.

The early planning of the Center was done by a committee consisting of Dr. A.C. Waters, University of California, Santa Barbara; Dr. Howel Williams, University of California, Berkeley; Dr. Gordon Macdonald, University of Hawaii; Mr. P. D. Snavely, U.S. Geological Survey, and Dr. L. W. Staples, University of Oregon. Dr. Staples, who is Head of the University of Oregon Department of Geology, announced that one of the first activities of the Center for Volcanology will be the co-sponsoring with the New York Academy of Sciences of an International Lunar Geological Field Conference in Bend August 22 to 28. About 17 lunar geologists from abroad and 32 from the United States have indicated their intention of attending the conference. Many scientists will read papers and all will participate in five days of field trips to volcanic features similar in appearance to lunar topography shown by the pictures taken by Rangers 7, 8, and 9.

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The ORE BIN
Volume 27, No. 8
August, 1965

NATURAL GAS AND PETROLEUM PRODUCTS PIPELINES IN THE NORTHWEST

By Vernon C. Newton, Jr.*

Introduction

Petroleum supplies the largest portion of energy used in the United States at the present time. Fuel consumption figures for 1962 show that oil provided 43 percent of our energy, natural gas 29 percent, coal 24 percent, and electricity 4 percent (Oil and Gas Journal, 1963). Natural gas consumption is climbing rapidly and some economists predict that gas will continue to provide nearly one-third of the United States' energy through 1980.

In 1957 Oregon and Washington received supplies of natural gas upon completion of the Pacific Northwest Pipe Line Corp. system. The firm was acquired by the El Paso Natural Gas Co. in 1959. Gas is transmitted through this pipeline from the southwestern states and is imported from western Canada on the northern end of the system. Completion of the Pacific Gas Transmission Co. pipeline from Alberta to northern California in 1961 provided the Northwest with three sources: British Columbia, Alberta, and the southwestern states. Domestic and industrial consumption of natural gas in Oregon in 1964 amounted to 49.3 MMMCF (Paul, 1965). [MCF is the abbreviation for 1,000 cubic feet of gas. Each M is equal to multiplying by 1,000.]

Pipelines carrying refined petroleum have not been used as extensively in Oregon and Washington as in some of the other states because of fewer areas of dense population; however, the demand for petroleum products is increasing in these two states. The Salt Lake Pipe Line Co. has supplied the inland area of the Northwest through its 8-inch pipeline since 1950. Refineries in northern Utah supply the Salt Lake system pipeline. Industrial growth throughout the Willamette Valley prompted the building of a products pipeline from Portland to Eugene in 1962 by Southern Pacific Pipe Line Co., a subsidiary of Southern Pacific Railroad. Construction is now under way on the Olympic Pipe Line Co. system between Portland and Seattle to supply those cities with products from refineries in northern Washington. The

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Yellowstone Pipe Line transports oil from refineries near Billings, Mont., to the Spokane area of eastern Washington.

Gas Transmission Companies

El Paso Natural Gas Co.

The El Paso Northwest system provides gas for industry and households in portions of Oregon, Washington, and Idaho (see figure 1). Its executive and operating offices are in El Paso, Tex. Gas is collected into the southern end of the pipeline from fields in the San Juan Basin, N. Mex.; Paradox and Uinta Basins, Utah; Piceance Basin, Colo.; and the Green River Basin, Wyo. Gas from the Peace River fields of British Columbia and Alberta is piped to northwestern Washington, where about 300 MMCF per day is put into the north end of the El Paso system. This gas is purchased from West Coast Transmission Co., a Canadian firm, at the international border near Sumas, Wash. El Paso also purchases 151 MMCF per day from Pacific Gas Transmission Co. at Spokane, Wash. for its customers in eastern Washington and northwestern Idaho. Since El Paso is the licensed transmission company for the northwestern states, any gas taken from the PGT pipeline for use in Oregon, Washington, or Idaho must be transmitted through El Paso's facilities (Paul, 1965).

El Paso delivered an estimated 140 MMMCF of gas to distributing firms in Idaho, Oregon, and Washington in 1964. Considering the purchase price at the wellhead by El Paso, the cost to the distributing companies, and the ultimate cost to the consumer, the value of the gas used in the Northwest in 1964 amounted to approximately $160 million.

In April 1964 the United States Supreme Court ordered El Paso Natural Gas Co. to divest itself of its interests in the Northwest system. El Paso merged with Pacific Northwest Pipe Line Corp. in 1959, following acquisition in 1957 of the latter company's stock. A complete new company will be organized under a divestiture plan approved June 24, 1965, by Judge Ritter for the Federal District Court at Salt Lake City, Utah. The new company will be known as Northwest Pipeline Corp. and will be headed by Glenn W. Clark, former president of the Mississippi River Fuel Corp. The new company will start operations following the transfer of the stock and the liquidation of the El Paso holdings (Paul, 1965).

The new firm will assume control of $243 million in assets of the Northwest system, which includes 2,633 miles of pipelines, 95,220 proven acres of gas leases, and 511 producing gas wells. Reserves are estimated to be 1.7 trillion cubic feet of gas, an approximate 27-year "life index" for the system (Brumbelow, 1965).

NATURAL GAS TRANSMISSION PIPELINES

Figure 1

Pacific Gas Transmission Co.

Pacific Gas Transmission Co. is only one portion of a project sponsored by Pacific Gas & Electric Co. to import natural gas from Alberta, Canada, to its distribution systems in central and northern California. The PG&E project encompasses a 36-inch pipeline 1,400 miles long with an initial delivery capacity of 414 MMCF and an optimum delivery capacity of 800 MMCF per day at Antioch, Calif.

PGT receives its gas supply from Alberta Natural Gas Co. at the international border near Kingsgate, B.C. The gas is then transported 614 miles across the states of Idaho, Washington, and Oregon, where it is delivered toPG&E at the California-Oregon border near Klamath Falls (see figure 1). The pipeline was completed and placed in operation in December 1961. The line was constructed primarily to supply gas to the San Francisco Bay region. However, a portion of the facility's capacity is reserved for the northwestern states.

No significant changes were made in the Pacific Gas Transmission Co. pipeline in 1964. Meter taps were made by El Paso Natural Gas Co. in the 36-inch pipe at Beaver Marsh and Gilchrist to allow service to those central Oregon communities. A tap will soon be made for Chemult. Daily deliveries through the PGT system in 1964 average as follows: California, 425 MMCF per day; Washington, 116.3 MMCF per day; Montana, 30.1 MMCF per day; Oregon, 2.7 MMCF per day; and Idaho, 0.3 MMCF per day for a total of 574.4 MMCF per day (Nabors, 1965).

Hearings were scheduled to begin in July 1965 to consider the application of PGT filed January 12, 1965 with the Federal Power Commission to increase its daily deliveries to PG&E to 600 MMCF per day. If approved, the company would increase its deliveries by 50 percent, or 200 MMCF per day, by 1968 (Paul, 1965). New compressors will be installed in the system, which will increase present transmission by 52,000 horsepower. Cost of the added compressors will amount to $14 million. Oregon will receive $9.2 million of the new installations, or 34,000 of the added horsepower. Compressor stations are planned at Ione, Madras, and Bonanza in central Oregon (Nabors, 1965).

Gas Distributing Companies

Six gas distributing companies, described below, buy gas from El Paso Gas Co. and pipe it to areas in Washington and Oregon (see figure 2). Table 1 gives sales statistics on gas sold in Washington in 1963 and in Oregon in 1964. Sale and distribution of gas is regulated by the Washington Utilities and Transportation Commission and by the Oregon Public Utility Commissioner.

TABLE 1. Sales Statistics.

Sales Statistics – Washington (1963)
(Washington Utilities and Transportation Commission)

Company	Number of therms sold	Revenue	Est. cu. ft. sold (MMMCF)*
Cascade Natural Gas Corp.	301,654,377	$14,806,802	28.0
Columbia Gas Co.	2,433,236	232,455	0.2
Northwest Natural Gas Co.	108,797,901	4,555,634	10.0
Washington Natural Gas Co.	390,143,621	28,473,505	36.4
Washington Water Power Co.	124,529,983	8,431,395	11.6
Totals	927,559,118	$56,499,791	86.2

Sales Statistics – Oregon (1964)
(Oregon Public Utility Commissioner)

Company	Number of therms sold	Estimated Revenue**	Est. cu. ft. sold (MMMCF)*
California Pacific Utilities Co.	50,631,134	$ 3,310,000	4.7
Cascade Natural Gas Corp.	63,464,849	4,150,000	5.9
Northwest Natural Gas Co.	417,300,942	27,340,000	38.7
Totals	531,396,925	$34,800,000	49.3

* Estimates based on 1 cu. ft. = 1,075 Btu.

** Estimated on average 6.51 cents per therm revenue.

California-Pacific Utilities

The Cal-Pac system was organized as an independent company in 1938 with its head offices in San Francisco, Calif., for the distribution of gas and electricity in southern and eastern Oregon and northern California. The company now provides electricity, gas, water, and telephone service in Oregon, California. Nevada, Arizona, Idaho, Utah, and Wyoming. Prior to the advent of natural gas, the company served liquified petroleum-air gas in La Grande in eastern Oregon and in Ashland, Grants Pass, Klamath Falls, Medford, Phoenix, Roseburg, and Talent in southern Oregon. When natural gas became available, the systems were converted: La Grande in September, 1956, Klamath Falls on April 3, 1962, and the other southern Oregon communities in October and November, 1963.

The company has expanded service to the following additional communities: Gold Hill, Central Point, Jacksonville, Winston, Elgin, Sutherlin, Imbler, Rogue River, Canyonville, Myrtle Creek, Dillard, Island City, Yoncalla, and Beaver Marsh.

The construction budget for 1965 was set at $2.4 million. During 1964, the company sold 4.7 MMMCF (Paul, 1965, and Lyman, 1965).

Cascade Natural Gas Corp.

Cascade Natural Gas Corp. was incorporated as an independent company on January 2, 1953. On December 21, 1964, the company provided service in 64 communities, of which 49 were in Washington and 15 in Oregon.

During 1964, Cascade sold about 5.9 MMCF of gas in the following Oregon cities: Madras, Bend, Crescent, Hermiston, Pilot Rock, Athena, Baker, Nyssa, Redmond, Gilchrist, Umatilla, Pendleton, Milton-Freewater, Weston, and Ontario.

The company has three service areas in western Washington: north of Seattle to the Canadian border; west of Puget Sound to Hoquiam on the coast; and the industrialized communities between Castle Rock and Woodland. East of the Cascade Mountains the firm supplies natural gas to 12 communities in the Yakima Valley and 9 other communities in and around Pasco, Moses Lake, and Walla Walla. Construction is under way on facilities to furnish natural gas to the city of La Conner in Skagit County, Wash., late in 1965 (Camp, 1965; Paul, 1965; and Timm, 1965).

Columbia Gas Co.

The Columbia Gas Co. began selling natural gas to residents of Ritzville, Wash., in 1957. Since that time the communities of Endicott, Goldendale, Warden, and Stevenson have been added to the company's service

GENERAL DISTRIBUTION AREAS FOR NATURAL GAS IN THE NORTHWEST

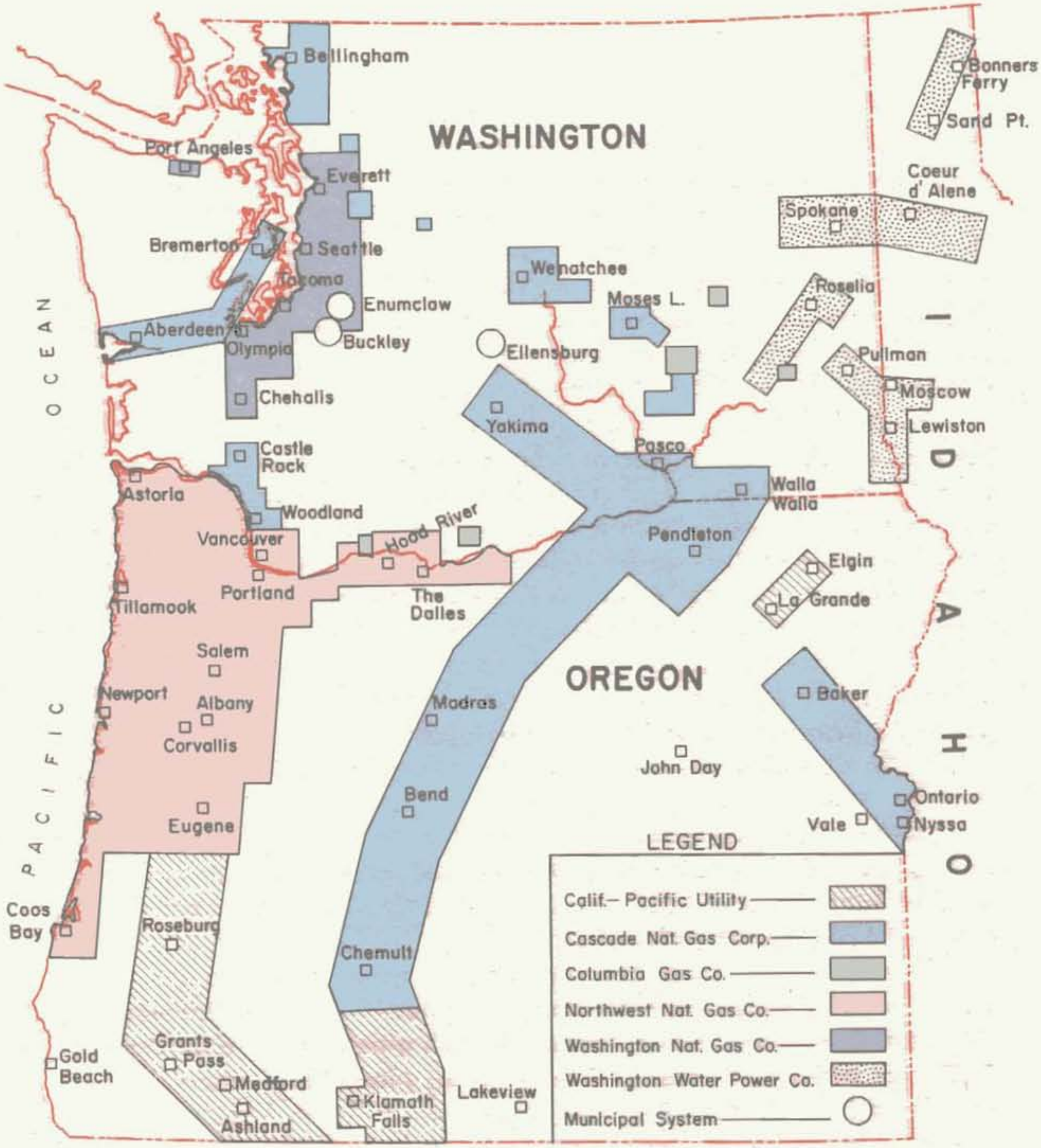

Figure 2

area. Present headquarters of Columbia Gas Co. are at Great Falls, Mont. The firm is a subsidiary of the Hardrock Oil Co. of Montana. It was formerly the Eastern Washington Natural Gas Co. of Ritzville, Wash. The company has no immediate plans for expanding its distribution system in eastern Washington (Lowry, 1965, and Timm, 1965).

Northwest Natural Gas Co.

Northwest Natural Gas Co. is the largest natural gas distributing firm in Oregon, its system encompassing in excess of 4,000 miles of main ranging from one inch to 32 inches in diameter. The firm first began operations by distributing gas made from coal, under the firm name of Leonard & Green Co. In 1913, under the then corporate name of Portland Gas & Coke Co., the company's operation was converted to the use of oil for the production of gas. From October to November 1956, the company again converted its system -- this time to natural gas. On July 1, 1958, the corporate name was changed to Northwest Natural Gas Co.

Since the advent of natural gas in 1956, the company has greatly expanded its operations. At that time it was serving the Willamette Valley from Portland to Albany and the Tualatin Valley to Forest Grove, in Oregon, and Vancouver in Washington. During the past eight years, the company has acquired the liquified petroleum distribution systems serving Camas and Washougal, in Washington, and The Dalles, Eugene, Springfield, Cottage Grove, and Coos Bay in Oregon. All these systems, with the exception of the Coos Bay system, have been converted to natural gas. It is planned to convert Coos Bay about 1967. The company now serves natural gas in 63 incorporated and about 83 unincorporated communities in Oregon. It has also extended its system to White Salmon, Ridgefield, and Battle Ground, Wash.

In March, the company announced plans to construct three transmission lines to extend its system to the Oregon coast during the next three years, at an estimated cost of $16.7 million. Construction of the transmission lines alone will require 300 miles of pipe.

Phase I of the planned program includes extension of the company's system from St. Helens to Astoria and Seaside. The project included the stringing of more than 3,800 feet of 16-inch pipe across the Columbia River near Deer Island by El Paso in March 1965. Northwest Natural Gas has completed the construction of that portion of its line to Wauna, where it is now serving the Crown-Zellerbach plant, and construction is continuing on the rest of the line. The completed line will be 16 inches in diameter to Clatskanie, 12 inches in diameter to a point west of Wauna, where it is reduced to 10 inches to Astoria. A 6-inch line will then extend the system into Seaside. (See photograph page 162.)

Phase II of the expansion involves building a pipeline from Mt. Angel to Newport and Toledo by way of Otis. The 10-inch section of the line from Mt. Angel to Perrydale was completed in 1964. The project from Perrydale to Toledo will be either 10 or 12 inches in diameter, and is scheduled for completion by November 15, 1965. At Boyer an 8-inch lateral will be laid to Hebo, where the line will be reduced to 6-inch to Tillamook and Garibaldi. The transmission line alone for this project will cost about $5 million.

Phase III includes laying a 12-inch pipeline between Cottage Grove and Reedsport, then south to Coos Bay. The south coast pipeline will cost an estimated $6 million. This transmission line is scheduled for completion some time in 1968. Termini of the three coastal laterals are strategically located with respect to offshore oil leases now being explored by several large oil companies. Should gas production be found, it would seem to be an easy matter to utilize the new resource (Paul, 1965, and Gould, 1965).

Washington Natural Gas Co.

Prior to 1956, Washington Natural Gas Co. sold manufactured gas to its customers. In the period 1956 to 1964, it increased its plant investments $3\frac{1}{2}$ times following conversion to natural gas. The company serves 45 communities along a 125-mile route reaching from Marysville in the north to Chehalis in the south. Franchises and applications are pending on the Washington towns of North Bend, Snoqualmie, Winlock, and Toledo. Delivery to these communities is expected by late 1965. Main offices of the company are located in Seattle. The Washington Natural Gas Co. is an independent company (Rockey, 1965).

Washington Water Power Co.

The company supplies natural gas to areas of eastern Washington and northwestern Idaho. The Washington Water Power Co. is an independent organization with its main offices in Spokane. Gas is obtained from the El Paso Northwest pipeline and distributed to communities in the two states in the Lewiston-Clarkston area and in the Spokane and Coeur d'Alene districts. Washington Water Power plans to add to the east end of its service area by constructing a pipeline to Wallace, Idaho; gas will reach mining towns in that area by 1966 (Cannon, 1965).

Washington Water Power Co., Washington Natural Gas Co., and El Paso Natural Gas Co. initiated an underground storage project near Chehalis in May 1963. Gas has been injected into a small structure located by the Pleasant Valley Oil & Gas Co. in 1958. A total of 13 wells has been drilled to date. Of these drillings, two are injection wells, six are observation wells, and five are water withdrawal wells (Deacon, 1964).

Municipal gas companies

The cities of Enumclaw, Buckley, and Ellensburg, Wash., have their own departments for distributing natural gas. Consumption figures have not been included in this report.

Petroleum Products Pipelines

Olympic Pipe Line Co.

Work began on the Olympic Pipe Line Co. products system in mid-summer of 1964 and completion of the project is scheduled by late this year (see figure 3). A crossing of the Columbia River was made near Sauvie Island in October 1964. Olympic will be a common carrier of refined oils from the Shell Oil Co. and Texaco, Inc., refineries near Anacortes, Wash., and from the Socony-Mobil refinery at Ferndale, Wash. Gasoline, jet, diesel, and heating fuels will be shipped through the pipeline from the refineries to Portland. The 269-mile pipeline is designed to carry a maximum of 135,000 barrels of products daily. The line will be 16 inches as far as Renton, Wash., and 14 inches from Renton to Portland. Spurs totalling 40 miles will also deliver products to marketing facilities in Seattle, Tacoma, and Olympia. Socony-Mobile Oil Co., Shell Oil Co., and Texaco, Inc., share holdings in the pipeline company and they will be the main users of the system. However, other companies will utilize the pipeline also. Head office of the company is located at Bellevue, Wash. (McCarthy, 1965).

Salt Lake Pipe Line Co.

The Salt Lake Pipe Line Co., a wholly owned subsidiary of Standard Oil Co. of California, serves parts of eastern Oregon and Washington (see figure 3). Main offices are located in Salt Lake City, Utah.

The products pipeline between Boise, Idaho, and Pasco, Wash., was completed in 1950. Three years later the pipeline was extended to Spokane. The Boise-Pasco section is designed to carry a maximum of 32,000 barrels per day and Pasco-Spokane section to carry 14,000.

Tank storage for the pipeline fluids is located at marketing centers along the pipeline, as follows: Baker, Oreg., 35,000 barrels; Adams, Oreg., 78,300 barrels; Pasco, Wash., 1,370,260 barrels*; and Spokane, Wash.,

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* 28,000 barrels is transported by barge.

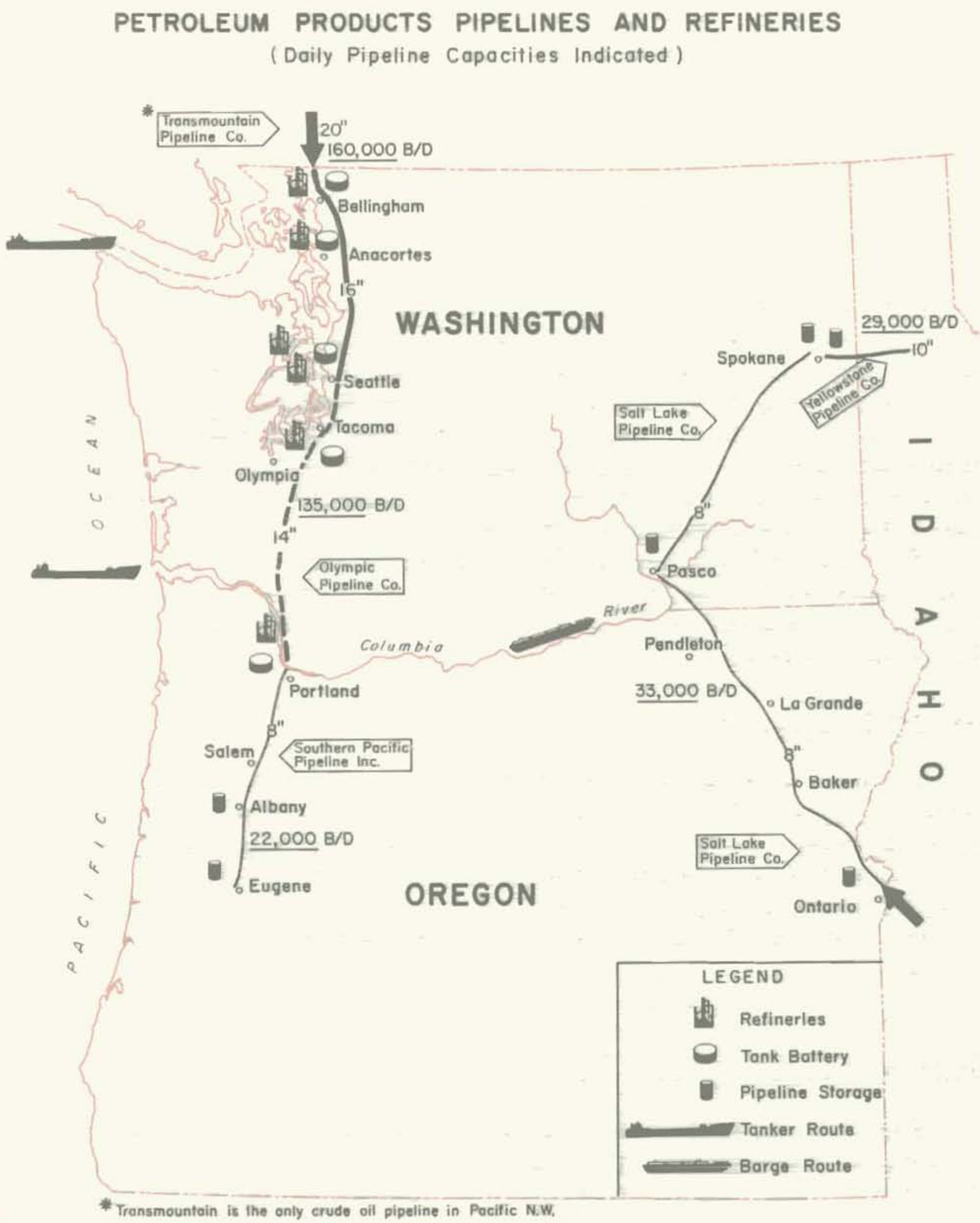
PETROLEUM PRODUCTS PIPELINES AND REFINERIES
(Daily Pipeline Capacities Indicated)
* Transmountain Pipeline Co.
20"
160,000 B/D
Bellingham
Anacortes
16"
WASHINGTON
Seattle
Tacoma
Olympia
135,000 B/D
14"
Olympic Pipeline Co.
PACIFIC OCEAN
Columbia River
Portland
8"
Salem
Southern Pacific Pipeline Inc.
Albany
22,000 B/D
Eugene
OREGON
Spokane
29,000 B/D
10"
Yellowstone Pipeline Co.
Salt Lake Pipeline Co.
8"
Pasco
Pendleton
33,000 B/D
La Grande
8"
Baker
Salt Lake Pipeline Co.
Ontario
IDAHO
LEGEND
Refineries
Tank Battery
Pipeline Storage
Tanker Route
Barge Route
* Transmountain is the only crude oil pipeline in Pacific N.W.

Figure 3

1,091,000 barrels*. Pasco is the terminus for barge traffic up the Columbia River. Because of its location on rail and water transportation, it is the central distribution point for marketing to the inland area of eastern Washington and Oregon and western Idaho (Baxter, 1965).

Southern Pacific Pipe Lines, Inc.

An 8-inch pipeline owned by Southern Pacific Pipe Lines, Inc., San Francisco, Calif., connects cities in the Willamette Valley of western Oregon with supplies of petroleum brought to Portland by ocean tankers (see figure 3). The 113-mile pipeline was constructed at a cost of $7 million. Gathering lines totalling 12 miles in length collect products from oil company storage along the Columbia River in northwest Portland.

A plant consisting of 15 tanks capable of storing 120,000 barrels of oils is located at Albany. A second and larger facility comprising 30 tanks is situated at the end of the pipeline near Eugene. Capacity of the Eugene tank battery is approximately 300,000 barrels.

The Southern Pacific pipeline is used by all the major oil companies which market in the area. Refined oils are shipped intermittently through the pipeline, depending on demand. Capacity of the pipeline is 22,000 barrels per day (Morgan, 1965).

Yellowstone Pipe Line Co.

Petroleum products gathered and refined near Billings, Mont., are shipped through a 10-inch line owned by the Yellowstone Pipe Line Co. to Spokane, Wash. (see figure 3). Yellowstone is owned and operated by the Continental Oil Co. Capacity of the system is rated at 29,000 barrels per day. Offices of the pipeline company are located at Ponca City, Okla. (Wright, 1965, and Governors' Special Study Committee, 1964).

Crude-oil Pipelines

Trans Mountain Oil Pipe Line Co.

Only one crude-oil pipeline has been constructed to the Pacific Northwest thus far (see figure 3). This is a Canadian system operated by the Trans Mountain Oil Pipe Line Co. (U.S. subsidiary named Trans Mountain Oil Pipe Line Corp.). Offices of the firm are located in Vancouver, B. C. Crude oil is transported through a 24-inch line from fields near Edmonton,

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* A portion of the storage serves the Yellowstone pipeline.

Alberta, to the company's tank farms at Burnaby, B.C., and Sumas, Wash. The capacity of the system is 250,000 barrels per day. Addition of two sections of 30-inch line and pumping stations will increase the capacity to 300,000 barrels per day.

A 20-inch extension was constructed in 1954 from the international boundary to refineries in northern Washington. Average daily deliveries of crude in 1964 were approximately as follows (Sheasby, 1965):

Vancouver, B.C.	72,324 barrels per day
Ferndale, Wash.	33,000
Anacortes, Wash.	94,115
Edmonds, Wash.	3,760
Seattle, Wash.	3,000
Tacoma, Wash.	11,740
	217,939 barrels per day

Refineries in the Pacific Northwest

The U.S. Bureau of Mines reports the following capacities for refineries in the Pacific Northwest in 1964:

Mobil Oil Co.	Ferndale, Wash.	39,000 barrels
Shell Oil Co.	Anacortes, Wash.	63,500
Texaco, Inc.	Anacortes, Wash.	50,000
Union Oil Co.	Edmonds, Wash.	4,000
U.S. Oil & Ref. Co.	Tacoma, Wash.	12,500
American Bitumels & Asphalt Co.	Portland, Oreg.	7,000

Petroleum Supply and Demand

The marketing of petroleum fuels in the Northwest has developed into a very sophisticated business involving huge pipeline facilities, ocean transport, and river barging. Each new facility has extra capacity designed in it for growth, indicating that oil companies expect the area to prosper. The major portion of the refined petroleum entering the Northwest comes by ocean freighter from California. More than two million barrels of foreign crude oil from the Persian Gulf and Venezuela were unloaded from supertankers at Anacortes in 1963.

Construction on 16-inch gas line near Rainier, Oregon, 1965 (Photo courtesy of Northwest Natural Gas Co.).

Petroleum products comprised 50 percent of the shipping at Portland docks in 1964 and approximately 55 percent at the Port of Seattle. A total of 6.5 million tons of petroleum reached the Port of Portland by ocean tanker in 1964, and 4.9 million tons were unloaded at Seattle (tonnage includes asphalts and nonclassified petroleum products). About 75 percent of the shipments received at Seattle were rerouted and 1 percent of the petroleum shipments received at Portland were reshipped. A brief review of marketing reports (table 2) gives a general idea of the petroleum supply-demand organization in Oregon and Washington.

Given below are figures for the amount of petroleum used in these two states in 1962 and net receipts of petroleum in 1963. Although data available are for different years, the total amounts are in fairly close agreement.

Amount of petroleum used*, 1962 (from "Petroleum Facts and Figures," American Petroleum Inst., 1963):

Oregon	35,348,000 barrels
Washington	56,169,000 barrels
Total	91,517,000 barrels

Total net receipts of petroleum*, 1963 (from figures supplied in this report):

Domestic crude: freighter	2,800,000 barrels
Foreign crude: pipeline	46,000,000 barrels
freighter	2,300,000 barrels
Refined products: Salt Lake Pipe Line	5,000,000 barrels
Yellowstone Pipe Line	4,000,000 barrels**
Refined products:	
Coastwise freighter	32,343,000 barrels
Foreign freighter	374,000 barrels
Total	92,817,000 barrels

* Excluding road materials

** Estimated

Approximately 8.5 percent of the petroleum received at the Portland docks is barged up the Columbia River to inland markets (table 3). Many of the river barges are constructed with oil tanks in the lower hull and grain hoppers above. Upriver hauls are made with petroleum and downriver hauls consist of grains. Pasco, Wash., is the main upriver destination of products.

TABLE 2. Ocean shipments of petroleum commodities, Washington-Oregon, 1963*.

Ocean Shipments into Puget Sound, Washington[1]
(Short Tons)

Commodity	Foreign Imports	Foreign Exports	Domestic Receipts	Domestic Shipments
Gasoline	9,633	8,466	1,148,620	1,876,368
Gas-oil, distillate fuel oil	-	140	1,310,363	765,229
Crude oil	385,659	-	220,095	-
Jet fuel	23,159	-	194,330	276,605
Kerosene	-	-	-	16,477
Residual fuel oil	44,825	17,235	878,204	231,594
Aliphatic naphtha	-	-	14,537	87,154
Lubricating oil, grease	-	737	66,988	5,029
Totals	463,276	26,578	3,833,137	3,258,456

Ocean Shipments into the Columbia River and Pacific Ports, Oregon[2]
(Short Tons)

Commodity	Foreign Imports	Foreign Exports	Domestic Receipts	Domestic Shipments
Gasoline	-	-	2,453,514	14,795
Gas-oil, distillate fuel oil	-	-	1,879,415	36,008
Crude oil	179	-	245,893	-
Jet fuel	-	-	86,742	-
Kerosene	-	-	357	-
Residual fuel oil	17,296	-	890,118	765
Aliphatic naphtha	-	-	21,236	12
Lubricating oil, grease	51	6,083	110,634	9
Totals	17,526	6,083	5,687,909	51,589

* Original data obtained from Waterborne Commerce of the U.S., 1963: U. S. Corps of Engineers, District Office, Portland, Oreg.

1 Includes ports of Seattle, Grays Harbor, Tacoma, Everett, Anacortes, Bellingham, Port Angeles, and Olympia.

2 Includes ports of Portland, Yaquina, Astoria, and Coos Bay, Oreg., and Vancouver and Longview, Wash.

TABLE 3. Barge shipments on the Columbia River for the calendar year 1964*

Commodity	Unit	Through Bonneville Dam		Through The Dalles Dam	
		Upstream	Downstream	Upstream	Downstream
Gasoline	Gals	43,746,424	1,941,559	40,417,243	1,941,559
	Bbls	1,040,000	46,400	962,000	46,400
Stove oil	Gals	11,295,833	255,000	10,765,925	255,000
	Bbls	267,500	6,014	256,000	6,014
Diesel oil	Gals	31,769,565	212,473	28,586,418	212,473
	Bbls	756,000	5,010	680,000	5,010
Misc. petroleum products	Gals	31,469,061		31,558,536	
	Bbls	748,000		753,000	
Totals	Bbls	2,811,500	57,424	2,651,000	57,424

* Waterborne Commerce of the U.S., Part 4, 1964; U.S. Army Engineers District Office, Portland, Oregon, Commercial Statistics Section. Preliminary figures, subject to revision, obtained from Lockmaster's Reports. Amounts shown in barrels were calculated from gallonage figures.

Acknowledgments: The author is very grateful to W. A. Paul, Director of Utilities, office of Oregon Public Utility Commissioner, and to R. D. Timm, Secretary of Washington Utilities and Transportation Commission for offering many helpful suggestions and for supplying much factual material for this report.

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THE RECOGNITION OF METEORITES

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After a meteorite has fallen to the surface of the earth, it becomes an object of concern to geologists, rockhounds, and even farmers and gardeners. In fact, the entire science of meteoritics is dependent on the alertness of many groups, both professional and lay, for the recovery of either old or newly fallen specimens. The writer, as well as the Oregon State Department of Geology and Mineral Industries, has received for identification from many well-meaning individuals a variety of rocks assumed to be different and meteoritic. Neither the Department nor the writer has yet found one meteorite among these rocks. However, it is hoped that, as more people become familiar with meteoritic characteristics, new meteorites of the Pacific Northwest will be made known.

The identification and subsequent recovery of meteorites is particularly difficult in this area because of the presence of so many volcanic rocks. While some meteorites resemble terrestrial volcanic rocks, they also have properties which are quite different.

In general, meteorites fall into one of three broad classes: (1) the irons, which are made up of a nickel-iron alloy; (2) the stones, which may have a gray to brown silicate groundmass through which small nickel-iron particles are distributed; and (3) the stony irons, which form an intermediate class. Of the stony irons, the Pallasites are best known, being formed of a metallic network in which the cavities are usually filled with crystals of the mineral olivine.

There is no single criterion by which all meteorites can be identified. The following points are useful in assessing an unusual specimen to determine if it is a meteorite:

1. Meteorites are heavier than ordinary rocks. The specific gravity ranges from about 3.0 for some stony varieties to about 8.0 for the iron, while most terrestrial rocks have a specific gravity well below 3.0. They are not porous or hollow, nor do they resemble cinders. The stony meteorites resemble terrestrial rocks and are often mistaken for them.

2. Meteorites are magnetic. The irons and stony irons are strongly attracted; the stony variety is only slightly attracted by a strong magnet.

3. Newly fallen meteorites usually have a black fusion coat and have shallow pits resembling thumb prints. Meteorites which have been exposed long to the weather may be brown or covered with rust, depending on the length of exposure.

4. On grinding a meteoritic specimen with an emery wheel, bright, shiny nickel-iron alloy becomes visible. The nickel-iron ranges from tiny specks in stony meteorites to the entire mass in the irons.

5. Meteorites are irregular in form and may be almost any shape. A number of known meteorites are cone shaped, but none are as round as a ball.

6. All meteorites contain the element nickel. A test for nickel is usually best done by a scientist.

7. When the polished surface of an iron meteorite is treated or etched with dilute nitric acid, characteristic patterns known as Widmanstatten figures are formed. Terrestrial alloys do not form Widmanstatten figures. Etching is usually best done by a scientist.

Meteorites, particularly those that are newly fallen, are of value as objects of scientific study and research. They are, however, of little value in the hands of an untrained individual. While there is a great similarity among all meteorites of any one class, there are also differences which are of concern to specialists. Therefore, every new meteorite is of interest to science, since it may possess properties that are somewhat unique.

If, on the basis of the above criteria, a reader feels that a known specimen is a meteorite, a small sample should be cut off without mutilating the main mass and should be sent to the State Department of Geology and Mineral Industries or to the writer for more exhaustive examination. In the case of a small meteorite, the entire specimen may be sent. The examination and evaluation of the specimen is done free of charge and the piece will be promptly returned. If the specimen proves to be meteoritic, an offer for purchase can usually be arranged.

Since it is impossible that a scientist always be present at the site of a new discovery, the addition of new meteorites for research depends largely on the ability of many lay people to recognize meteorites when they see them and on their willingness to submit specimens for scientific examination and recording in the literature.

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WATER RESOURCE PUBLICATIONS AVAILABLE

Two water-supply papers of interest, one concerned with ground water in the east Portland area and the other a non-technical report on lakes and rivers in Oregon, have been published by the U.S. Geological Survey and may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402. Water-Supply Paper 1793, "Ground water in the east Portland area, Oregon," by G. M. Hogenson and B. L. Foxworthy, is $1.00. Water-Supply Paper 1649, "Water in Oregon," by K. N. Phillips, R. C. Newcomb, H. A. Swenson, and L. B. Laird, is 60 cents.

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The ORE BIN
Volume 27, No. 9
September, 1965

WHAT PRICE GOLD?

By Pierre R. Hines*

"Miniver scorned the gold he sought,
But more annoyed was he without it;
Miniver thought, and thought, and thought,
And thought about it."
E. A. Robinson (Miniver Cheevy)

This review of monetary affairs is written for the gold-mining industry in the United States. It is in four parts, as follows:

Part I. Proposed plans for the improvement of the international monetary system.
Part II. The official policy of the United States Treasury upon international monetary systems.
Part III. The relief given to foreign gold mines by their governments.
Part IV. The unique economics of gold. What price gold? **

Introduction

Since 1958 the United States' deficits in international payments have grown to such a size that they now endanger the soundness of the U. S. dollar. Two investigations and studies for an international payments system have been made by separate U.S. commissions (one official and the other semi-official). Two committees of the International Monetary Fund have been working on the subject; and a number of books and pamphlets have been published recently by well-known economists proposing plans for improving

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** Parts I and II are in this issue of The ORE BIN. Parts III and IV will be published at a later date.

the international payments system. These plans affect the gold-mining industry either directly or indirectly. The ones most likely to be followed offer no assistance and let the gold-mining industry get along in the best way it can. Because the Third Gold and Money Session* will not be held until the spring of 1967, an interim review in 1965, as here presented, may be useful in preserving continuity between the 1963 and 1967 sessions. This review is addressed especially to the American gold-mining industry.

What is causing all of these plans for improvement?

The gold-exchange standard** imposes no controls upon either the debtor or creditor countries, so undesirable deficits and surpluses result. Further, key currency nations can run up large deficits, since their financial integrity is the only regulatory instrument.

Since the restoration of international currencies' convertibility and the removal of the restrictions upon capital movement, large capital flows of "hot" money, short-term funds, speculative money, and American foreign investments have upset the international balance of payments used to settle trade balances.

All of this has raised the question as to whether the gold reserves are ample for present and future world trade and whether they give sufficient time to correct international trade imbalances. Stated in the usual way: Has the world adequate "liquidity"? Liquidity is the main subject of most of the plans, and also the greatest differences of opinion exist about it.

The United States' deficits have grown and its gold reserves have diminished to a point where there is a danger of the collapse of the free-world payments system. Europe has all of the dollar exchange it wants and may demand future payments all in gold.

Plans for the management of the dollar, mutual assistance among central banks, and centralization of monetary reserves are already in operation and have been valuable during recent crises in the pound sterling and the lira. However, they do not solve the fundamental troubles with present international payments.

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* Pacific Northwest Metals & Minerals Conference.

** Gold-Exchange Standard: The gold-exchange standard is a compromise frequently made in the hope that the gold-coin standard will be adopted later. The reserves of the governmental or central bank may be largely in foreign exchange or notes of gold-standard countries. The unit of account is not directly convertible into gold, but instead into the currency of a country having a gold standard. This standard economizes in the use of gold. The reserves may be gold deposited abroad as a working balance or exchange in terms of a currency based on gold, or interest-bearing short-time assets readily convertible into gold, such as short-term obligations of the United States Treasury.

PART I.

Proposed plans for the improvement of the international monetary system.

Fritz Machlup, Director of the International Finance Section of the Department of Economics, Princeton University, has collected the various plans for the reform of the international monetary system and has published them (Machlup, 1964). He has systematically analyzed them and has classified them as follows:

A. Extension of the gold-exchange standard
   (1) With continuing increase of dollar and sterling reserves;
   (2) With adoption of additional key currencies.
B. Mutual assistance among central banks
   (1) With safeguards against expansive credit and fiscal policy;
   (2) With extension of domestic credit and expenditures.
C. Centralization of monetary reserves and reserve creation
   (1) With overdraft facilities available to deficit countries;
   (2) With autonomous reserve creation by the world central bank;
   (3) With finance of aid to underdeveloped countries.
D. Increase in the price of gold
   (1) With gold-exchange standard continued;
   (2) With gold-exchange standard abolished.
E. Freely flexible exchange rates
   (1) In order to make internal monetary policies more independent;
   (2) Because internal monetary policies are too independent.

Class A - Extension of the Gold-exchange Standard

(1) With continuing increase of dollar and sterling reserves.

The present international monetary system which has been followed since World War II is in Class A(1). It has many supporters among economists, bankers, officials, and politicians who believe that it is only a matter of time until our balance of payments will be adjusted to a satisfactory point, that our gold supply is ample for present and future needs, that our credit is so high our dollar obligations will be acceptable to other countries for gold-exchange reserves, and that our competitive position in world trade is improving while Europe's is deteriorating due to trouble with inflation, wage increases, higher cost of living, and rising prices.

(2) With adoption of additional key currencies.

In 1962 Robert V. Roosa (Aliber, 1964), then Under Secretary of the U.S. Treasury for International Finance, together with the Federal Reserve System made a series of agreements with other central banks and governments which add other currencies to the previous key currency reserves of the dollar and pound sterling. The United States now holds a number of foreign currencies in its reserves which were obtained in exchange for dollars. The other countries are also holding these dollars in their reserves. These arrangements are called "currency swaps." They have certain advantages in the management of the dollar in international finance and in the easing of the demand upon our gold reserves. They do not reduce the deficit in the United States' international payments.

Class B - Mutual Assistance among Central Banks

Under this heading come the "stand-by swaps" (Aliber, 1964) of currencies between the United States and foreign governments or central banks (these include the sales of U.S. Treasury obligations to foreign governments and central banks which are payable in the purchaser's own currency, are tax exempt, and are not marketable but serve in the place of gold); the mutual support by the free world's central banks, the U.S. Treasury, Federal Reserve System, and the International Monetary Fund in times of crisis; and the gold pool.

The "stand-by swaps" are agreements to exchange credits on demand but are not executed until an emergency arises. The sale abroad of U. S. securities gives the United States reserves of foreign currencies to have on hand in emergencies. These measures are designed to meet the sudden shifts of short-term "hot" money from one financial center to another. They replace the transfer of gold and extend the gold-exchange system. R. Z. Aliber's "The Management of the Dollar in International Finance" (1964) explains fully how, by intervening in the market, this protects the U. S. reserves of gold. The Group of Ten, namely the United States, the United Kingdom, Canada, Japan, Germany, France, Italy, the Netherlands, Belgium, Sweden, and by special arrangement, Austria and the Bank for International Settlements have a mutual support agreement for short-time credit which was used in the sterling crises of 1961, 1962, and 1964 and also during the run on the Italian lira in 1964.

These plans are now in effect and it has been proposed to put them on a permanent basis under the management of the International Monetary Fund.

Class C - Centralization of Monetary Reserves and Reserve Creation

Professor Machlup lists 11 plans in this classification, which he defines as follows:

> "What all these plans, beginning with the Keynes plan (Machlup, 1964, p. 41; Triffin, 1960, p. 90-93) and including all other prototypes and variants, have in common is that an international financial institution is charged with the function of creating - through the acquisition of claims or other assets (or fictitious assets) - additional deposit liabilities that would be accepted by central banks as part of their monetary reserves."

Keynes (Machlup, 1964, p. 41) proposed a new international monetary unit called "Bancor" for which national obligations, notes, etc., were security. Bancor would be used in place of gold to pay countries having a surplus. A Central Clearing Union would handle the international payments. This plan would create additional reserves. The Triffin plan (Triffin, 1960, p. 102; Harris, ed., 1961, p. 223-306; Machlup, 1964, p. 39-61) follows a similar line of reasoning and was until recently the most discussed plan of this type. It modified Keynes' plans in accordance with the experience acquired since the end of World War II. Robert Triffin explains his plan fully in "Gold and the Dollar Crisis" (1960); it is thoroughly discussed by Triffin and Altman in "The Dollar in Crisis" (Harris, ed., 1961).

The "Group of Ten," at the Tokyo meeting of the International Monetary Fund in September 1964, did recognize the possibility of the creation of a "new form of reserve asset" in the future. The International Monetary Fund's charter was the work of Lord Keynes and Harry Dexter White of the U.S. Treasury at Bretton Woods in 1945. Many of Lord Keynes' ideas were too novel and were not included at that time, but he is responsible for much of IMF's success. The study of these plans is not a waste of time, because they give a thorough understanding of the international payments problem.

So much has been written on Class C that it is reviewed only briefly here. Many of the tables of data are factual or based on good sources and are well worth studying; it is only in their interpretation that differences of opinion exist. The most important papers and publications are given in the references for those who wish to study them fully.

Class D - Increase in the Price of Gold

(1) With the gold-exchange standard continued
(2) With the gold-exchange standard abolished

The plans which would continue to accept the United States' and the United Kingdom's currencies, obligations, and liabilities as reserves for foreign government treasuries and central banks' reserves as a supplement to gold are placed in Class D (1), while those which would abolish these currencies and deficits in dollars and sterling as reserve assets are put in Class D (2), which actually makes them a return to the gold standard for international payments.

Professor Machlup distinguishes between the plans which would raise the price of gold for both newly mined gold and accumulated gold reserves, and the plans which would raise the price of newly mined gold alone. The increased value of the gold in the gold reserves of the latter plans would be neutralized to prevent realization of the "capital gain" and its misuse for issuing more money and consequent inflation. The raising of the price of newly mined gold is more important to the gold-mining industry than increasing the value of the gold reserves. Many monetary authorities believe you cannot raise the price of newly mined gold without increasing the monetary value of the gold reserves and creating loss of confidence in the stability of the currencies and international exchanges. The U.S. Treasury has resisted stubbornly any change in the price of gold for monetary reasons. Others, who say that world trade needs more liquidity, would secure it by raising the price of gold and increasing the value of the gold reserves correspondingly. So to keep these various purposes separate and distinct, Professor Machlup's Class D plans were reclassified in accordance with the gold-mining industry's needs. Also, some of Professor Machlup's Class D plans reduce the price of gold rather than increase it, so hardly come under his classification.

Plans concerned principally with gold price as advocated by those who would:

(1) Return to the gold standard
  (a) Raise the price of gold: Jacques Rueff (1961), Michael Heilperin (1962), Charles Rist (1961), Philip Cortney (1960, p. 34-38), Ian Shannon (1962), W.J. Busschau (1963, p. 11-18), Henry Hazlitt (1963, p. 7-10), John Davenport*, Donald H. McLaughlin (1963, p. 26-29).

* With reservations, see "The U.S. Economy," p. 160-163.

(b) Maintain the price of gold at $35.00: J. W. Bell and W. E. Spahr (1960), F. A. Bladford, the late D. E. Kemmerer, F. R. Niehaus, R. T. Patterson, C. W. Phelps, G. C. Wiegand (all in Bell and Spahr, 1960).
(c) Raise the price of new gold but neutralize the accumulated gold reserves: Fritz Machlup (1964, p. 73 and 88).

(2) Continue the gold-exchange standard, using gold as a supplement, and raise the price for greater liquidity: Sir Roy F. Harrod (Harris, ed., 1961, p. 46-62).
(3) Reduce the price of gold: L. A. Hahn, A. O Dahlberg, and Fritz Machlup (in Machlup, 1964, p. 69-71).
(4) Gradually increase the price of gold: Kiyojo Miyata, Paul Wonnacott (in Machlup, 1964, p. 72-73).

Plans concerned principally with gold:

(1) This includes those who would return to the true gold standard. They are further subdivided into three groups:
(a) Members of this group would raise the price of gold, because they believe it is essential to the successful operation of the gold standard by providing the necessary liquidity for international payments today. Their plans cover only the international payments system. They are mainly foreign economists, some of whose economic policies directed the recovery of post-war Europe. Very few American economists have come out openly for raising the price of gold.
(b) The second group would not change the price of gold, but would return the U.S. domestic monetary system to the old gold standard. "A Proper Monetary and Banking System for the United States" (Ronald Press Co., New York), edited by J. W. Bell and W. E. Spahr, states their plan and their arguments.
(c) Professor Fritz Machlup says he "...can reassure the friends of gold that he himself has been an old and faithful advocate of the orthodox gold standard...." He also approves Miyata's and Wonnacott's plans (in Machlup, 1964, p. 88), which would raise the gold price by a small percentage yearly.

(2) Sir Roy F. Harrod has several plans, but his first choice has always been to raise the price of gold to increase international liquidity. He would supplement this further by a plan on the order of the Triffin plan or a

modification of it. His main argument is "that the great benefit of revaluation would not be the immediate benefit from the act of revaluation, but from the greater flow of trade throughout the free world that would be its lasting consequence." Harrod is a tutor and reader at Oxford University and is one of the few economists who is familiar with the problems of the gold-mining industry; therefore, his writings and theories are of particular value to it.

(3) These plans would reduce the price of gold. Their object is to curb the speculation in gold, which has grown since the removal of many of the post-war restraints upon the movements of capital and funds and the convertibility of exchange. Three plans have been offered. The first would reduce the price only to private individuals; the second would reduce the price at the rate of 2 percent annually; the third would reduce the price gradually and periodically at a rate of three-quarters of 1 percent every three months. These plans would, according to their proponents' theory, recover a large amount of hoarded gold and put it back into the gold reserves. Such plans are like cutting down a tree to harvest the fruit.

(4) This type of plan would raise the price of gold by a small percentage (about 2 percent) annually. It would remove any uncertainty about the future price of gold and the advance would not be sufficient to hold gold for the prospective profit. Professor Machlup thinks both Miyata's and Wonnacott's plans have merit. They certainly have far greater appeal to the gold-mining industry than those in Class 3.

Any monetary plan will affect the gold-mining industry - either by benefiting it or killing it by abolishing the use of gold for money, or further by keeping gold at $35.00 an ounce as the base and approaching a step nearer to an international central bank - all of which would leave gold just where it is in its present predicament.

The only way to find out the faults of these many plans is to read the claims of one of them which always corrects the weaknesses of the others. While the gold standard has in its favor strong evidence and persuasive argument, it is not perfect. The following quotations are worthwhile to keep in mind:

> "One mistake we must not make. We must not say that the system did not work, for in fact the gold standard ran along fairly smoothly - subject to crises - for a century before 1914 and indeed for a much longer period. Still from the fact that it worked, it does not follow that it worked in the manner described by the contemporary economists. It may have worked in a different manner." (Harrod, 1958, p. 21-22)
>
> "The English monetary system in the generation before the

First World War has sometimes been represented as unchanging, largely automatic, and as near perfection as can be expected of any human institution. This brief sketch should be enough to show that it was none of these things; the Bank (of England) always had to exercise discretion; it had to face many changes in environment and was often in difficulties; it frequently experimented with new techniques; and it was exposed to a running fire of criticism" (Feaveryear, 1963, p. 334).

"Although basically absurd, a drastic revaluation of current gold prices is by no means an unlikely solution to the world liquidity problem. It will become well-nigh unavoidable - and preferable indeed to the alternate solutions of world deflation or world restrictions - if international negotiation fails to develop in time other and more constructive solutions to the problem" (Triffin, 1960, p. 79).

Class E - Freely Flexible Exchange Rates

This last classification, also called "fluctuating exchange rates," if chosen would depress the gold-mining industry. It would reduce the need for international reserves and in turn the need for gold.

Fluctuating exchange rates depend upon the following principles in their operation: "A reduction in the value of a deficit country's currency reduces the prices of its exportable goods in foreign currencies, thereby encouraging foreign demand for them and raising their prices in its own currency. The rise in the domestic price reduces the domestic market for them, releasing more of existing supplies for export. It also raises the prices of imported goods in the national currency, discouraging their importation and shifting domestic demand toward domestically produced goods and services. Thus the competitive position of the deficit country can be improved rapidly without deflation. The reverse changes occur in the surplus countries without inflation" (Salant and others, 1963, p. 259).

It is not the purpose of this review to go into the merits and faults of flexible or fluctuating exchange rates compared to fixed rates, but rather to call attention to the theory. Professor Machlup has made an analysis of the various proposed systems and the reader is referred to this author. It is a persuasive theory - one well supported by authority. Professor Machlup refers to a partial list of 24 noted economists who have written in favor of this theory. They, of course, differ about the working details and the practical operations. The Brookings report, made at the request of President Kennedy's Council of Economic Advisers, chooses flexible rates as an alternate to their primary policy recommendations (Salant and others, 1963,

p. 258-262.

Professor Jacob Viner (1964, p. 32), in discussing "freely flexible versus fixed foreign exchange rates," says "I know of only two instances of full-fledged floating exchanges, the Canadian and the Peruvian, both now dead, but both deaths bemoaned by many economists."

The first four classes of plans - extension of the gold exchange standard, mutual assistance among central banks, centralization of reserves and reserve creation, and finally the increase in the price of gold - have for their purpose increasing international liquidity. The fifth plan - flexible exchange rates - does away with the regulation of international payments by central banks and the necessity for reserves to tide over deficits in international payments until the imbalance is corrected. Gold is reduced thereby to a minor role in international monetary arrangements.

While the subject of flexible payments may be distasteful to a gold producer, still Professor Machlup's presentation, which compares flexible rates with fixed rates, contains a sound criticism of the present system based on the International Monetary Fund and its short-comings. Certainly it is knowledge with which those interested in gold and money should be familiar. Where political decisions are supreme and action waits until a crisis has arrived, anything may happen. Professor Machlup's warning given in the next to last paragraph of his analysis of flexible exchange rates cannot be brushed aside as a false alarm. It is as follows:

> "These remarks may sound strange to ears used to continual whispers that the price of gold may be raised and to periodic shouts that it ought to be raised. Bankers inclined to regard as practical only what is not too much in contradiction with political interests, may find it ridiculous to have gold referred to as a potential non-valeur. Whether it will ever come to the demonetization of gold depends on which ideology will win. In a world in which the discipline of the gold standard is felt chiefly as a nuisance, and monetary management is regarded primarily as an instrument of national growth and employment policy, not even the most inventive representatives of vested interest will be able to maintain the myth that the demonetization of gold is 'impractical' "* (Machlup, 1964, p. 88).

* "Perhaps the present author (Professor Machlup [Ed.]) can reassure the friends of gold that he himself has been an old and faithful advocate of the orthodox gold standard in the purity described by the most obsolete textbook. He would still vote for a 100 percent pure gold standard, where gold is really a 'standard' and not merely a price-supported commodity." (Machlup, 1964, p. 88)

Professor Machlup's classification and analysis of the foregoing plans are helpful in understanding the problems of the international payments system and his special paper is recommended reading. While these plans revolve around the subject of "liquidity" principally, they do not agree upon how much liquidity is needed to carry on world trade or how to determine it. Consequently, when authorities cannot agree upon premises - in this case liquidity - only confusion results.

PART II.

The official position of the U.S. Treasury upon international monetary systems.

Official Actions and Declarations

The future of American gold mining lies in the hands of either the U.S. Congress or the finance ministers and central bankers of the free world, or both.

Plans for the reform of the international payments system are being studied by several agencies. Just what will be agreed upon, it is now too early to say. Advance statements made by officials reject certain definite elements and principles. They give little hope for anything favorable to gold production or anything which would demonetize gold. They are worth examining in detail.

The report of the Commission on Money and Credit, 1961, is primarily upon domestic monetary policy, but because it makes recommendations upon gold and international monetary policy its conclusions are given here (Commission on Money and Credit, 1961). Its recommendations are that the price of gold be kept at $35.00 an ounce, that the 25 percent gold reserve back of the Federal Reserve System's bank notes and deposits be abolished, and that a more easily adjusted exchange rate be established. Its viewpoint upon the price of gold is the following:

> "The Commission believes that the arguments against an increase in the world gold price counsel against such a step at this time. At some future date, if alternative methods of meeting the needs for increased reserves be unsatisfactory, the revaluation of gold

may be advisable, but it should be under IMF sponsorship."

Because of the official origin of this report, it has been referred to here. The Eisenhower administration desired such a report but could not agree upon the persons to make it. Accordingly, the Committee for Economic Development sponsored it and appointed the Commission on Money and Credit (Commission on Money and Credit, 1961). The authority of the report is weakened by the number of distinguished persons connected with it in one way or another. Seventy-one are listed. The healthy condition of France's and Germany's finances are largely, in each case, the work of one mind. Possibly no such mind exists in the United States and could not be found?

The Brookings report (Salant and others, 1963), "The United States Balance of Payments in 1968," is official, since it was commissioned by the President's Council of Economic Advisers and paid for by the Government. Published in 1963, its title may be misleading on first glance. The high points of this report for gold mining are:

(1) It rejects the devaluation of the dollar or raising of the price of gold.

(2) It would abolish the Federal Reserve System's gold reserves for its notes and bank deposits.

(3) It recommends a plan which comes under Professor Machlup's "C" classification which is stated as follows: "Institutional arrangements should be proposed that will permit the liquid claims of surplus countries and liabilities of deficit countries to be denominated in an international unit of account, either with the IMF or with a new international payments union associated with it."

The report states that present reserves are inadequate; that as United States liabilities are paid off it will reduce the gold dollar exchange and cause a further loss in liquidity. It believes the United States' payments deficits will adjust themselves by 1968 with normal measures, and that fixed rates of exchange contribute to the development of world trade. It gives warnings and cautions against interfering with certain national objectives. On the whole, a lot can be learned from this report.

The most disturbing recommendation in the Brookings report is the alternative to the main recommendations, given in the last chapter, which approves of flexible exchange rates, as follows: "The best alternative to a system of fixed rates with provision for increasing liquidity, in our view, would be a modified system of flexible exchange rates consisting of a dollar-sterling bloc and an EEC (European Economic Council) bloc. There would be relatively fixed rates within each bloc and flexible rates between them.

Adoption of this system would imply cutting the tie between gold and the dollar."

The United States Treasury policy on the price of gold has been clear for the past five years. Former Secretary Anderson stated it long ago: "The assured interchangeability of dollars and gold at $35.00 an ounce...is a basic element of strength in the international financial structure." Former Secretary Dillon confirmed this repeatedly.

Under-Secretary Roosa, who recently retired, had this to say while still in office (Roosa, 1963, p. 107-122):

> "Yet in our present complex of economic relations among nations, it is difficult to imagine any gold standard at work without being rather extensively managed. And if managed, it would be little different from the procedures of today, except that a gigantic devaluation would have intervened and confidence in the dollar or any other currency as a supplementary part of the management process would, as a consequence, have been largely destroyed. It would seem difficult to build a system that depends on periodic repudiation of a government's firm undertaking to maintain the fixed price of gold."

Further on he takes up liquidity:

> "The concept or meaning of international liquidity needs clarification. For there are three different meanings and much unnecessary and unintentional disputation arises from confusion among them. One meaning is related to the needs of the trade; it refers to the availability of credit facilities for the financing of a growing volume of transactions among growing economies. In this sense, there clearly is not now, and it is not likely to be over any foreseeable future period, a shortage of international liquidity."

And this is followed by more discussion, and he continues:

> "But underlying the flows of trade and capital are the national reserves of each country - reserves that must be drawn upon if seasonal or cyclical or accidental or structural and sustained factors bring about a cumulative total of outpayments that exceeds the total of inpayments received by the country as a whole. And these resources for settling the residual balances among countries represent two other kinds of liquidity - the stock of actual reserves and the availability of borrowed reserves."

Distinctions between different types of liquidity are not usually made and are lumped together. In this writer's opinion, Mr. Roosa is right in making these distinctions. Countries vary in their requirements for reserves according to their resources, and what would be sufficient liquidity for one nation would not be for another.

Mr. Roosa also gave his position on the many plans for the reform of the international payments system. In order to discuss them, he divided them into three types, as follows:

(1) "They would return to a 'full' gold standard by doubling or tripling the price of gold and then removing dollar or sterling or other foreign exchange from the world's monetary reserves. Proposals of this presume a fixed price for gold after a one-time drastic change has been made in that price.

(2) "Giving up a fixed price of gold entirely and providing that each currency fluctuate in price against others. With a country free to allow its exchange rate to drop whenever it might lose reserves, proponents argue that there would be an economizing of reserves and the world would presumably no longer need to be as concerned over the composition or the total of the monetary reserves themselves.

(3) "This third approach would include in reserves a more flexible and larger volume of foreign exchange or internationalized credit than is used today, superimposing this upon the slow accretion of gold that reaches the world's monetary reserves. In most cases, proposals of this character would continue the present settled gold price of $35.00 per ounce."

And he concludes:

> "The first is discussed somewhat further in the next section; variable exchange rates, briefly, in the section following; but for reasons which will then appear, the United States considers only the third to be a promising avenue for constructive advance in the future."

On international liquidity, around which so much of the discussion for reform takes place, Mr. Roosa's position is:

> "The United States must, of course, re-establish balance of payments equilibrium to maintain confidence in the strength of the dollar. Yet it is quite possible, once the flow of new dollars into monetary reserves ceases, the present excess of dollars will be quickly absorbed and that the prospects of an imminent shortage of international liquidity will appear."

The U. S. Treasury's position agrees with that of the Group of Ten of the International Monetary Fund as far as the Group has made it known.

The U.S. Treasury has made few statements of policy in the last five years and when it has done so they were short, crisp answers to questions. Mr. Roosa's lengthy paper in "Foreign Affairs," from which the preceding quotations were taken, is one of the rare official policy statements. It is official because Mr. Roosa was Under Secretary of the Treasury for International Finance. It will probably continue to be the policy because during President Kennedy's term the present Under Secretary, Frederick Deming, was selected to take Mr. Roosa's place in case he was unable to perform his duties, the basis for the selection being that Mr. Deming had the same convictions regarding policy as Mr. Roosa.

This seems to be the right place to quote from the official Brookings Institution report (Salant and others, 1963, p. 261):

> "One objection sometimes made to a flexible exchange rate for the dollar is that the maintenance of the present gold parity and the present exchange rates between the dollar and other currencies are essential to U. S. national power or prestige. We think this view mistaken. The power and prestige of the United States derive in large degree from its economic strength and vigor, which in turn depend upon its high productive potential and its success in using that potential."

The world price for gold can be settled only by international agreement. The International Monetary Fund is the established agency through which nations value their currencies in either gold or dollars and secure stable exchange rates. It has had two committees studying and making "a thorough examination of the outlook for the functioning of the international monetary system and of its probable needs for liquidity" (Internat. Monetary Fund, 1964, p. 25). Some preliminary conclusions by the Group of Ten have been reached and reported at the last meeting in Tokyo in September 1964; several of them concern the future of gold. While not formally ratified, they undoubtedly will be.

The Group of Ten is the principal committee, composed of 10 nation members, as noted in Part I. The Fund itself has intensified its studies of international liquidity and related questions. Following are some of its preliminary conclusions (Internat. Monetary Fund, 1964, p. 25-33):

> "It appeared to be generally agreed that international liquidity was adequate."
>
> "Since the end of the war, the international financial system - based on reserves in the form of gold and reserve currencies supported by the International Monetary Fund as well as certain other

credit arrangements - has permitted a signal expansion of the world economy and of international trade. It has made it possible to restore the convertibility of the main currencies and to cope with a number of difficult situations which affected certain currencies. These results have been obtained while a relatively high level of employment was maintained in the world."

"It will be wise, therefore, to supplement and improve the system where changes are indicated, rather than to look for a replacement of the system by a totally different one."

"The supply of gold for monetary purposes is dependent upon such factors as changes in the conditions governing gold mining, as well as on the confidence factors that influence private gold hoarding."

"It must be assumed that payments deficits of the United States will not contribute to formation of reserves in future on the same scale as in recent years. It therefore seems safe to forecast that in the future greater reliance than over the past decade will have to be placed on the provision of international liquidity as needed by other means. The Fund could make an essential contribution in this connection."

The First National City Bank's monthly economic letter of September 15, 1964 (p. 104-107) discusses thoroughly previous decisions arrived at in the beginning, in 1963, by the International Monetary Fund's Group of Ten. They are:

"Of the bewildering array of reform proposals, the Ten discarded two ideas at the very outset of the inquiry. No change is contemplated in the established price of gold because, by spreading turmoil and creating distrust, it would do irremediable damage to the incentive to currencies as reserves, which is an essential part of the system as it operates today."

"Gold will continue to be 'the ultimate international reserve asset. However, while more gold is now being added from current output to official reserves than at any other time during the postwar period' we cannot prudently expect new gold production to meet all liquidity needs in the future."

Mr. Henry H. Fowler, who succeeded Douglas Dillon as Secretary of the Treasury this year, served as an Under Secretary from 1961 until April 1964. According to news reports, he will give his attention to the Government's part in promoting the nation's economy and leave the technical and operating divisions to his staff. It is too early to say whether Mr. Fowler will change the Treasury's past policies towards giving aid to the gold-mining industry.

For the past six years the Treasury has defeated the gold-mining industry's every effort to obtain help from Congress. The third part of this review, which will appear in an early issue, will show that the Treasury official's testimony before Congress has been purely opinion and cannot be supported by facts.

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UNION PACIFIC PURCHASES BUFFALO MINE

The Union Pacific Railroad Co. Friday (Sept. 10) exercised the option held on the Buffalo Mine since June 11 and purchased the property for a price reported to be in excess of $100,000. The gold and silver mine, owned and operated by Mr. and Mrs. James P. Jackson, is located about 21 miles north and west of Sumpter in Grant County, and is one of the very few active gold mines in the Northwest.

A Union Pacific spokesman said today that the Jacksons will continue to operate the mine which normally has a crew of 6 to 10 men. Expansion of the mine is expected under the new ownership with a "substantial" amount to be spent on opening the existing ore veins, according to the U.P. spokesman. The working crew will probably be doubled, he said. The Jacksons retained a royalty interest in the mine reported by the spokesman to be 5 percent of smelter output.

The purchase of the gold and silver mine is the first known venture for Union Pacific in the gold mining business. "The purchase is unusual for the U.P. in the past but not for the future. The U.P. Natural Resources Division has the authority to acquire properties for development for profit," the spokesman said. The company contracted test drilling and examination work during the summer to the Boyles Bros. Drilling Co. A geologist for Union Pacific, Keith Jones, was at the mine during the summer. (Democrat-Herald, Baker, Oregon, Sept. 11, 1965.)

[Editor's note: The geology of the Buffalo Mine is described in the Department's Bulletin 49, "Lode mines of the central part of the Granite Mining District, Grant County, Oregon."]

* * * * *

THE WILLAMETTE AND OTHER LARGE METEORITES

By Erwin F. Lange
Professor of General Science, Portland State College, Portland, Oregon

Occasionally an old, unpublished photograph of the Willamette meteorite comes to light, as is the case with the accompanying picture. The Willamette meteorite, found near Willamette (West Linn), Oregon in 1902 remains to this day the largest meteorite discovered on the American continent north of the Mexican border. Today it is on display in the Hayden Planetarium, a part of the American Museum of Natural History, New York City. The 15½-ton Willamette iron focuses attention on other large meteorites of the world.

Of the approximately 1,600 known meteoritic specimens in the world, there are 30 irons which weigh from one to 60 tons. Eight were found in Mexico and four in the United States west of the Rocky Mountains. The largest single individual yet discovered is the 60-ton Hoba West, and it remains where it was found near Grootfontein, South Africa, in 1920. The world's second most massive meteorite is the Ahnighto, the largest of the Cape York, Greenland, irons brought to the United States in 1897 by the famed Arctic explorer, Robert E. Peary. The Ahnighto, weighing 36½ tons, is also the property of the American Museum of Natural History. The next three largest meteorites remain where they were found. They are the Bacubirito, Sinola, Mexico; the Mbosi, Tanganyika, Africa; and the Armanty, China. Their weights are estimated at 27, 27, and 26 tons, respectively.

The Willamette is the world's sixth largest meteorite and the most massive one ever found in the United States. The second largest United States meteorite is the Navajo, found in 1922 in Apache County, Arizona. It weighs 4,814 pounds and is the largest meteorite in the collection of the Chicago Museum of Natural History. The third largest iron in this country is the Quinn Canyon, which was found in 1908 in Nevada and is now also in Chicago. It weighs 3,190 pounds. In 1938, deer hunters discovered the Goose Lake meteorite in the Modoc National Forest, California, less than a mile from the Oregon border. It weighs 2,573 pounds and is the largest meteorite in the collection of the U.S. National Museum (Smithsonian Institution) in Washington, D. C. [Photograph courtesy of Richard G. Bowen.]

LUNAR FIELD CONFERENCE GUIDE BOOK

"Lunar Geological Field Conference Guide Book," prepared by N. V. Peterson and E. A. Groh, editors, C. J. Newhouse, cartographer, and the editorial staff of the Department, has been published as Bulletin 57. The guidebook was designed for the international Lunar Geological Field Conference held at Bend, Oregon, August 22-29, 1965, and sponsored by the University of Oregon Department of Geology and The New York Academy of Science. It describes and illustrates recent volcanic features that can be seen in five field-trip areas in the High Cascades and Bend region. The areas were selected for their diversity of volcanic expression and for their accessibility, in the belief that analysis of such lunar-like geology is prerequisite to a manned base station on the moon.

The guidebook will be useful to anyone interested in the study of volcanology, and will serve as a basis for more detailed research in this field. The 56-page publication is abundantly illustrated with colored geologic and topographic maps, aerial views, sketches, and photographs.

NOTE: Between the time the above announcement was prepared as a press release and the publication of this issue of The ORE BIN, there has been an unprecedented demand for the guidebook. The supply is exhausted, but arrangements are under way for the reprinting of this bulletin.

* * * * *

ARTICLES ON RECENT VOLCANISM IN OREGON REPRINTED

A collection of seven papers on recent volcanism, originally published in The ORE BIN between October 1961 and July 1965, has been issued by the Department as Miscellaneous Paper 10. These articles have been very popular and the issues of The ORE BIN in which they appeared have, in most instances, been exhausted. The reprinted papers include: "Hole-in-the-Ground," "Recent volcanic landforms in central Oregon," "Maars of south-central Oregon," "Diamond Craters, Oregon," and "Crack-in-the-Ground, Lake County, Oregon," all by N. V. Peterson and E. A. Groh; "Age of Clear Lake, Oregon," by G. T. Benson; and "Recent volcanism between Three Fingered Jack and North Sister, Oregon Cascade Range," by E. M. Taylor. In addition, there is a brief description of Lavacicle Cave. The articles, illustrated by maps and photographs, depict some of the unique volcanic features in Oregon that had never been described in detail before. The collection is enclosed in a 7½-inch by 10½-inch envelope for convenience in storing and mailing.

Miscellaneous Paper 10 is available from the Department's offices in Portland, Baker, and Grants Pass. The price is $1.00.

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The ORE BIN
Volume 27, No. 10
October, 1965

THUNDEREGG*: OREGON'S STATE ROCK

The thunder egg, an agate-filled nodule characteristic of certain parts of central and eastern Oregon, became the official state rock on March 29, 1965. On that day Senate Joint Resolution 18 (see page 191 for text of resolution) was passed, whereupon the "thunderegg" joined the other nature symbols of Oregon, namely: the state animal (beaver), the state flower (Oregon grape), the state bird (western meadowlark), the state tree (Douglas fir), and the state fish (Chinook salmon).

Senator Glen M. Stadler, Lane County, who co-sponsored the resolution with Rep. Gerald Detering, Linn County, tells how it all came about in a letter to State Geologist Hollis M. Dole.

"The man who started the ball (excuse me, 'rock') rolling was Harold M. Dunn, of Lane County. About three years ago he was a Federation Director of the American Federation of Mineralogical Societies, and an officer of the Springfield Rock and Gem Club.

"He had read a story in the Federation's publication about a girl in South Dakota who had written the editor, asking for a list of state rocks. The editor's reply was that there was no such list.

"Mr. Dunn told the story to the Springfield Club which instructed him to 'do something about it' for Oregon. He contacted me as a newly elected State Senator. While I had a Senate Bill drawn, he sent letters to some four dozen rock and gem clubs in Oregon, asking their preference for a State Rock. The Thunderegg won the most votes.

"Then, OMSI held an 'election,' asking visitors their preference. It was 'Thunderegg, two to one.' By that time it was getting a bit late in the 1963 session. In fact, the deadline for bills had passed. However, I submitted the measure to the Senate Rules Committee, after getting a number of signatures, and the co-sponsorship of State Representative Gerald Detering of Linn County, whose late brother had been a longtime ardent 'rockhound.' Gerry and I 'politicked' for the bill, but the Senate Rules Committee did not have time to pass it out.

"Then, when the 1965 session convened, Gerry and I again submitted the measure. SJR 18 was passed in the Senate, 23 to 2, and in the House, 48 to 5. Because it was a Joint Resolution, it did not have to be signed by the Governor, and became the 'law of the land,' in effect, by the signatures of President Boivin and Speaker Montgomery on March 29, 1965.

"There were those who thought the measure was 'frivolous' and joshed us about it, but it now appears that the publicity being given the storied and romantic 'Thunderegg' is resulting in quite an economic factor in our increasing tourist industry.

"Thus ends, for the historical record, the answer to the Thunderegg-as-the-State-Rock question of 'Who-Dunn-it'."

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*Note: "Thunderegg" as one word was adopted by the Oregon Legislature for the name of the state rock and, therefore, is the correct spelling when referring to the state rock; however, in describing the geology and mineralogy of thunder eggs, the two-word spelling has priority, because of its use in the literature.

A pen set made from the new state rock in the outline of the State of Oregon was presented on March 29 to Governor Mark O. Hatfield. This was the pen that was used by Senate President Harry Boivin and House Speaker F. F. Montgomery to sign the resolution. On the Governor's desk are a number of other thunder eggs, some sawed open and others uncut. Standing behind Governor Hatfield from left to right are: Rep. Sam Johnson, Sen. Harry Boivin, Rep. William Gallagher (hidden), Sen. R. R. Raymond, Rep. L. B. Day, Rep. G.W. Detering, Sen. Ed Ahrens, Sen. Glen Stadler, Mr. Ed Nichols, Sen. Gordon McKay, Mr. Marion Cady, and Mr. Al Keen. (Photograph by Joseph V. Tompkins)

Senate Joint Resolution 18

Introduced by Senator STADLER, Representative DETERING, Senators AHRENS, VERNON COOK, WARD COOK, CORBETT, ELFSTROM, HUSTON, IRELAND, MONAGHAN, POTTS, RAYMOND, THIEL, WILLNER, YTURRI, Representatives BESSONETTE, DAY, GALLAGHER, SAM JOHNSON, LANG, McKINNIS and read February 19, 1965

Whereas the great and sovereign State of Oregon has a state flag, a state animal (the beaver), a state flower (the Oregon grape), a state bird (the western meadow lark), a state seal, a state tree (Douglas fir) and a state fish (the Chinook salmon); and

Whereas the State of Oregon, being of unbounded international importance as a "rockhound's paradise"; and

Whereas the State of Oregon needs a designated state rock; and

Whereas a number of rock and gem clubs representing all areas of Oregon and the Oregon Museum of Science and Industry have conducted a popular vote to select a state rock; and

Whereas this vote favored the thunderegg two to one; and

Whereas the thunderegg is described as a "remarkable and colorful agate-filled spherical mass of silicified claystone, and rhyolite found throughout the State of Oregon" ranging in size up to four feet in diameter; and

Whereas an old legend of the Warm Springs Indians tells us that these spherical masses were once hurled from the craters of Mt. Hood and Mt. Jefferson when the "spirits of the mountains" were angry and that the "thunder spirits" who lived in the craters hurled the nodules to the accompaniment of much lightning and thunder and therefore the agate-filled nodules became known as "thundereggs"; now, therefore,

Be It Resolved by the Legislative Assembly of the State of Oregon:

That this ancient symbol of geological significance and absorbing native legend, the thunderegg, be acclaimed the Oregon state rock.

What Is A Thunder Egg?

Thunder eggs are spherical masses of rock that range in size from less than an inch to 4 feet in diameter. Most are about the size of a baseball. They have a knobby rind of drab, siliceous rock and a cavity filled with agate. From the outside they appear nondescript, but when sawed open and polished they may reveal the most exquisite and colorful designs ranging from five-pointed stars to miniature gardens. Consequently, they are highly prized by rockhounds, who come from every state in the Union to hunt for them. Thunder eggs make handsome jewelry, book ends, paper weights, pen stands, and many other decorative objects. Each year they contribute thousands of dollars to the state's million-dollar semiprecious gem-stone industry.

How Did Thunder Eggs Form?

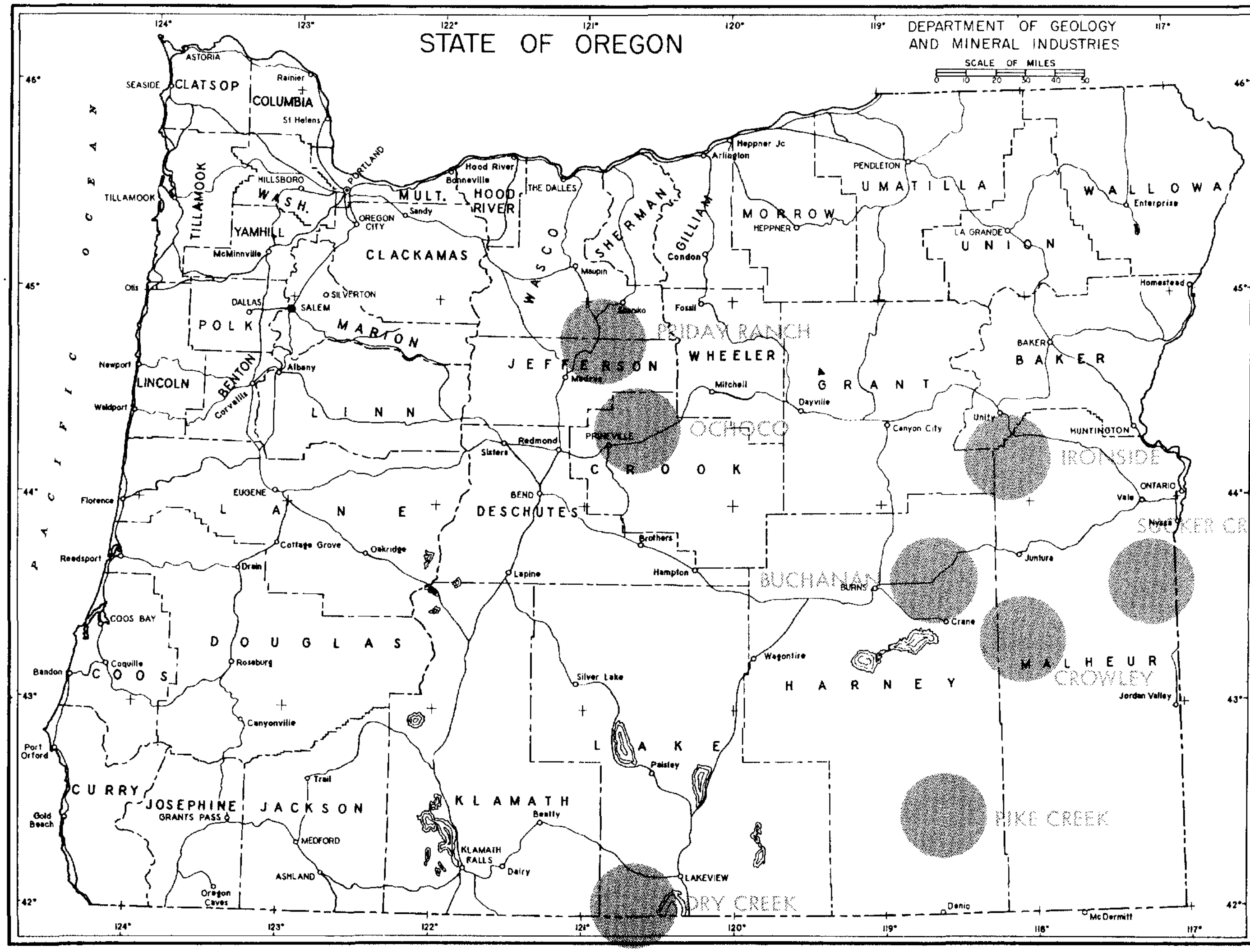
Thunder eggs are always associated with silicic volcanic rocks such as welded tuffs and rhyolite flows. Millions of years ago, fiery avalanches of this type of molten rock poured out of volcanoes and flowed over the land. In central and southeastern Oregon there are wide areas in which rocks of this type are well exposed.

Although the host rock in which thunder eggs occur is known, the development of these spherical objects in the parent material is not completely understood and various theories have been advanced to explain the complex process. One of the persons who has been particularly interested in these enigmatic structures is Dr. Lloyd W. Staples, Head of the Department of Geology at the University of Oregon. By studying thin, transparent sections of these rocks under a microscope, Dr. Staples has come up with some new ideas on their growth. His paper, which follows this introductory section, sums up all the known information and theories on thunder eggs, presents his own observations, and suggests areas in chemistry, mineralogy, and field geology where further research might clarify many of the least understood processes in the formation of thunder eggs.

Where Can Thunder Eggs Be Found?

In the early days of rockhounding, thunder eggs were gathered from on top of the ground where they had weathered out of the enclosing rock and remained as a surface residue after the less resistant matrix had been eroded. Now most of the surface specimens are gone, and so one must dig in the soil and talus slopes in order to find these agate-filled treasures.

The best-known thunder-egg localities in Oregon occur in the John Day Formation of late Oligocene to early Miocene age. Two of the better localities in the state occur in high-silica rhyolite flows or welded tuffs of this formation, namely the Priday Ranch northeast of Madras and the Ochoco Mountains east of Prineville (see accompanying map). Owners of the Priday Ranch charge a nominal fee for digging on their private lands, but in the Prineville area the city has staked out a number of good agate localities which are open to the public. Detailed information on the exact location of the Ochoco deposits can be obtained by writing to the Prineville Chamber of Commerce. Thunder eggs are also known to occur in John Day tuffs on the Warm Springs Indian Reservation where the name had its origin, but the reservation is closed to mineral collectors.



THUNDER EGG LOCALITIES IN OREGON

Six other localities are found in volcanics of similar or younger age in Lake, Harney, and Malheur Counties of southeastern Oregon (see map). The Buchanan deposits are associated with a rhyolite flow that crops out along the east edge of the Harney Basin near the town of Buchanan; the Crowley deposit, also associated with a rhyolitic lava, is near the old Crowley ranch east of State Highway 78, approximately 25 miles southeast of Burns; the Sucker Creek deposits are found near a thick welded tuff prominently exposed in the walls of Sucker Creek Canyon; the Ironside thunder eggs are found along a rhyolite dike near the east fork of Bridge Creek; the Pike Creek deposit is associated with rhyolite flows of the Pike Creek Formation at the base of Steens Mountain; the Dry Creek area lies along the west side of Goose Lake a few miles north of the California border.

Miocene and Pliocene rhyolitic flows and welded tuffs are exposed in a broad area extending from the Harper Valley near Vale westward through the Malheur River gorge as far as Buchanan, and from the vicinity of Creston near Juntura northward toward Ironside Mountain. Although no one has as yet publicly reported finding any thunder egg deposits within this part of southeastern Oregon, the presence of these silicic volcanics affords the proper geologic environment for their occurrence.

Thunder eggs are not limited to Oregon. Among some of the other reported localities in the West are Berkeley Hills and the Mojave region in California; Virgin Valley, Beatty, Coyote Springs, and Duckwater in Nevada; and Weiser, Twin Falls, and American Falls in Idaho. No thunder eggs have been reported from Washington.

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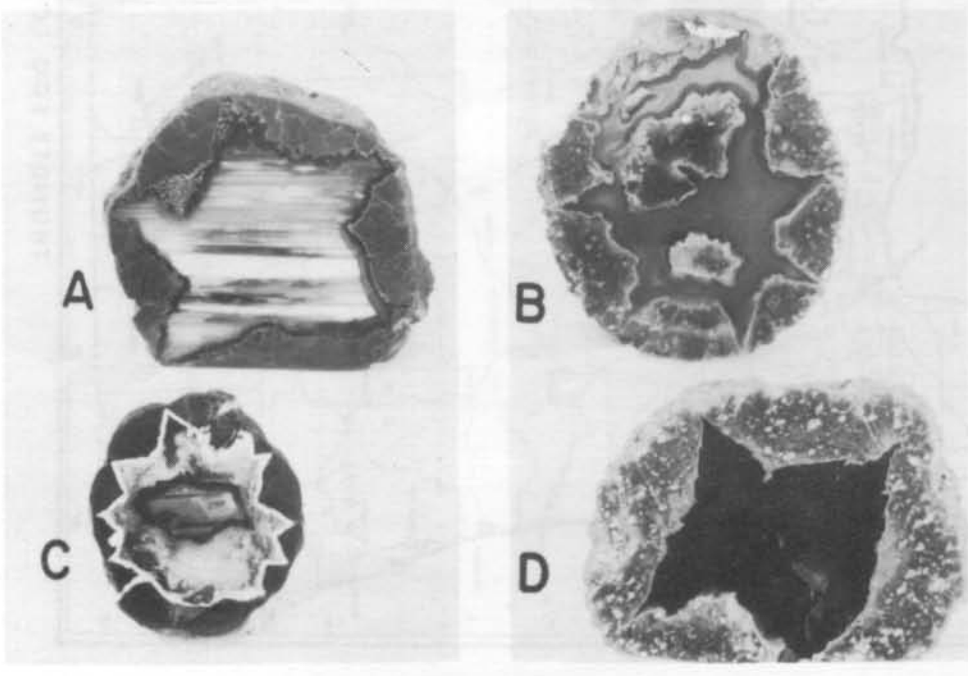

Figure 1. Cut and polished thunder eggs from four localities: (A) Priday Ranch, (B) Sucker Creek, (C) Buchanan, and (D) Ochoco. All are approximately ½ natural size. (Photograph by Leo F. Simon)

ORIGIN AND HISTORY OF THE THUNDER EGG

By

Lloyd W. Staples
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With the passage of Senate Joint Resolution 18 of the Oregon 53rd Legislative Assembly, the thunder egg became the Oregon state rock. Because no other rock material is more prized by the amateur collectors and lapidaries in Oregon, it is appropriate that if any one type of specimen was to be chosen, the thunder egg deserved that recognition. Although thunder eggs or similar specimens are known from many other areas, the Oregon material is unsurpassed for beauty, variety, and abundance, and in the minds of collectors the world over thunder eggs and the State of Oregon are closely related.

Considering the great interest in thunder eggs in Oregon, it is not surprising that many collectors have wondered about the origin of the fascinating structures observed in the specimens (figure 1, p. 194). However, it is surprising that very little careful scientific work has been done, by competent researchers with adequate scientific background, to explain the geologic history of the formation and development of thunder eggs. Because any careful study requires a combination of fieldwork and attentive experimentation in a well-equipped laboratory, the work can be expected to take considerable time. Some of these investigations are under way at the Center for Volcanology at the University of Oregon under the writer's supervision.

This paper is an attempt to bring together the known information on the origin and occurrence of thunder eggs with observations made by the writer in the field and laboratory. Much work remains to be done, and it is hoped that this work will aid in answering some of the unexplained observations presented in this paper.

History of The Name

The origin of the name "thunder egg" is difficult to determine with certainty. J. Lewis Renton probably deserves recognition for first putting it in print (Renton, 1936, p. 12) and giving credit to the Warm Springs Indians for "long ago" originating the name. He states (1936, p. 46), "Since the Indian appears to have prior preference in the matter of a name we will term the material 'Thunder Eggs' until such time when a specific scientific term is given to the specimens."

Renton (1951, p. 171-172) explains the origin of the name by citing an Indian legend, "... the two adjacent snow capped peaks -- Mt. Hood and Mt. Jefferson -- would at times become angry with one another. During these disputes, accompanied with thunder, Mt. Hood and Mt. Jefferson would hurl these spherical masses of rock at each other. Stray shots would land over in the Indian reservation, hence the Indian name of 'thunder eggs.'" Brown (1957, p. 329) adds, "The embattled gods presumably obtained these missiles by robbing the nests of thunderbirds." This idea is also held by Renton (written communication, 1965) who states, "I believe the Indians assumed that the egg shaped nodules were the egg of the thunder bird."

Dake (1938, p. 214) offers a slightly different version of the legend, which is that the thunder spirits who lived in the craters (of Mt. Hood and Mt. Jefferson) hurled the nodules to the accompaniment of much lightning and thunder, therefore the agate-filled nodules became known as thunder eggs. This account is less likely to be accurate than Renton's because, although it relates the name to thunder, it does not closely relate it to eggs. However, this version was used in connection with Senate Joint Resolution 18 which copied Dake's wording of the legend. An exception is the use of "thunderegg" as a single word, which usage was adopted by the authors of the Resolution, disregarding well-established priority of the name "thunder egg" as two words.

Definition of Thunder Egg

Unfortunately, popular names usually are not precise in definition and "thunder egg" is no exception. It will forever be impossible to determine the limitations on the term that might have been imposed by the Warm Springs Indians, if indeed they had in mind any limitation, which is very unlikely. Popular usage has clearly indicated the name for certain types of nodules, but it is difficult to limit the varieties which may be included. If names were defined by legislative action, then we would have a definition, but unfortunately the "legal" definition is incorrect. Senate Joint Resolution 18 uses the description from Dake (1938, p. 214), "a remarkable and colorful agate-filled spherical mass of silicified claystone and rhyolite found throughout the State of Oregon." It is now known that the thunder egg is a spherulitic nodule and is not related to silicified claystone.

It should be pointed out that, although the thunder egg has been designated as the state rock, it is not, strictly speaking, a rock. A rock is defined by the geologist as an aggregate of mineral matter constituting an essential and appreciable part of the earth's crust. Thunder eggs are structures found in a rock, the rock being the welded tuff or rhyolite enclosing them. However, both "rock" and "mineral" are words which are used loosely, and it is in this sense that the term "rock" is applied to thunder eggs in S.J.R. 18.

Renton (1951, p. 172) states that a thunder egg should be (1) spherical or nearly so, (2) have an exterior shell of varying thickness of rhyolite, (3) contain a core of agate, veins of agate, or an interior cavity partly filled or completely empty. Brown (1957, p. 329) defines thunder eggs as spherulitic geodes, restricted to the weathered outcrops of a prehistoric lava flow which is now a rhyolitic welded tuff in whose glassy matrix they originate. Peck (1964, p. D25) calls them "chalcedony-filled spherulites," and states that "The outer shell of each thunder egg is composed chiefly of shards, fine ash, and collapsed pumice lapilli, all of which are altered to radially oriented sheaves of fibrous cristobalite and alkalic feldspar."

The typical Oregon thunder egg (figures 1, 2, and 3) has the following features: (1) It is generally spherical or ellipsoidal in shape; (2) the surface is usually smooth or wart-like or cauliflower-like with ribs which encircle the specimen and intersect each other; (3) it has a shell of rhyolitic welded tuff or rhyolite which has devitrified to various degrees and in which spherulites or lithophysae have developed; (4) the center or core consists of chalcedony or quartz, which may be banded or contain

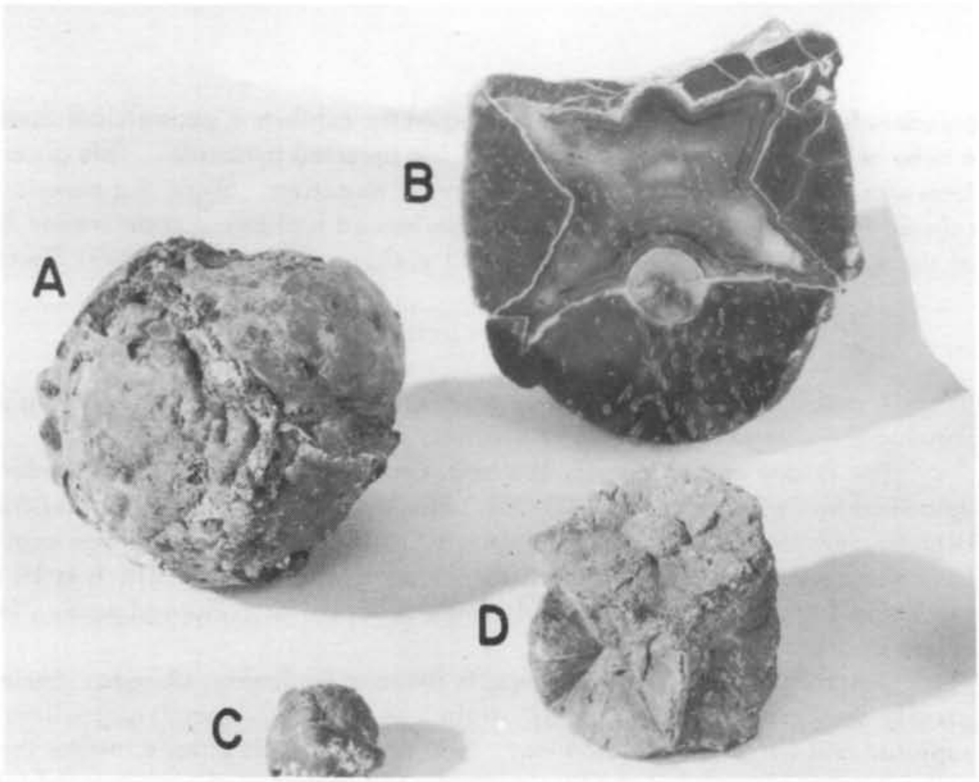

Figure 2. Group of four thunder eggs: (A and C) Exterior of Priday Ranch specimens, (B) sectioned thunder egg showing spherulite at bottom of filled cavity and corresponding hole at top [note Liesegang rings in chalcedony center], (D) chalcedony core of thunder egg weathered out of its shell [note "button" spherulite cast on top]. All are approximately 2/3 natural size. (Photograph by Leo F. Simon)

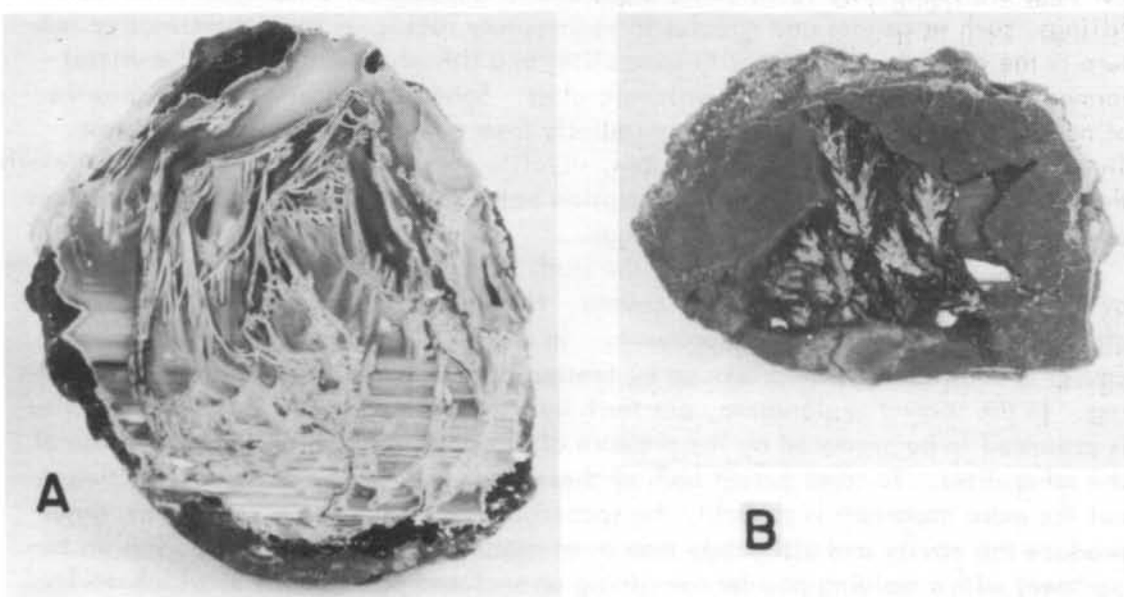

Figure 3. Two Priday Ranch thunder eggs: (A) Green moss agate, (B) red, yellow, and orange plume agate. All are approximately 2/3 natural size. (Photograph by Leo F. Simon)

pseudo-algal structures; (5) the core frequently exhibits a geometrical form, such as a cube or pyritohedron with the faces being inverted pyramids. This gives a star-like form when the specimen is cut in the correct direction. Since the exterior ribs are related to the apexes of the star, an experienced lapidary can determine from a study of the specimen which cutting plane will yield sections with the best figures.

Occurrences

A description of the places in which thunder eggs are found, along with a map showing the Oregon localities, is given on pages 192-194.

The Priday agate deposit, the best-known Oregon source for thunder eggs, is described by Peck (1964, p. D23-25). This deposit lies about six miles from U. S. Highway 97, and about 10 miles northwest of Ashwood. The thunder eggs occur chiefly in the lower few feet of a weakly welded rhyolite ash flow which is 10 to 20 feet thick and composed of black perlitic angular lapilli of collapsed pumice in a matrix of shards and ash.

An unusual type of thunder egg is found at Buchanan, Oregon. Some specimens clearly demonstrate the spherulitic origin where numerous small spherulites have been ruptured and filled with chalcedony. The occurrence is unique in that the chalcedony sometimes is colored red by cinnabar. The presence of cinnabar, which forms at temperatures below 344°C (Dickson and Tunell, 1955), the inversion point to metacinnabar, gives us some idea of the temperatures exising during the deposition of the cavity-filling material.

Origin of Thunder Eggs

There are still many unanswered questions concerning the details of the origin of thunder eggs, but the general processes involved are fairly well understood. Thunder eggs are found only in volcanic areas and in this respect differ from other cavity fillings, such as geodes and nodules in sedimentary rocks. A second distinctive feature is the close relationship with spherulites and lithophysae (hollow spherulites) formed during crystallization of volcanic glass. Spherulites are spheroidal growths of needlelike crystals which develop radially from one or more centers in a glass. These structures are common in obsidian, rhyolite, and vitric tuffs. One of the details that needs further study is the exact relation between the development of spherulites and the control of growth of thunder eggs.

An outstanding contribution to the study of spherulites and lithophysae was made by Wright (1915) on obsidian from Iceland. He discusses the two theories for the origin of hollow spherulites or lithophysae. In the first, advanced by Iddings, the cavity is considered to be produced by tension developed by the magma during cooling. In the second explanation, put forth by Von Richthofen and Zirkel, the cavity is presumed to be produced by the pressure of the gases set free on crystallization of the spherulites. To some extent both of these processes may be of some importance, but the more important is probably the second theory, which assumes that the gases produce the cavity and ultimately may even rupture it. Buddhue (1941) cites an experiment with a molding powder containing an enclosed pressure blister which resulted in a cavity similar to those found in thunder eggs. He concludes that this is laboratory proof that the star-shaped centers of thunder eggs are produced by expansion.

The tension or shrinkage origin is advanced by Dake (1954). Frondel (1962, p. 215) states, "In a highly viscous material expansion of the gas cavity by rupture may require less energy than spherical expansion, giving angular cavities which may be symmetrically developed." The evidence for expansion rather than shrinkage appears overwhelming to this writer.

Mansfield and Ross (1935, p. 320) state that the gas cavities are developed subsequent to complete welding of the tuff and the gas promotes devitrification and the formation of spherulites which sometimes act as a locus for the gas cavities. Wright (1915, p. 268) believes that the formation of the lithophysae or hollow spherulites take place at relatively high temperatures.

Frondel (1962, p. 215) states, "These chalcedony nodules generally contain or border on a spherulite aggregate of intergrown feldspar and cristobalite, the crystallization of which is believed to have initiated the release of gases dissolved in the rhyolitic glass."

Wright (1915) gives the first good description of the formation of the star-shaped cavities, explaining that they are due to rupture along cube diagonal planes. Ross (1941) expands on these studies and discusses the probable origin of the pentagonal shapes that are frequently encountered in Oregon thunder eggs. He describes the history of the development of thunder eggs as follows (1941, p. 732):

> "The following geologic history is, therefore, revealed by the Oregon 'thunder eggs.' Explosive volcanic activity produced finely divided glassy ash, which fell in a hot plastic condition that permitted its rewelding into a homogeneous material. While still hot, local centers of crystallization were set up, around which spherulitic masses of intergrown cristobalite and feldspar were formed. The formation of these anhydrous minerals released volatiles originally in solution in the glass. The gradual collection of volatiles exerted a pressure which, combined with the cooling shrinkage of the enclosing material, forced the walls of the cavity outward, expansion being by rupture along symmetrically arranged planes. The more perfect of these cavities had the geometrical symmetry of a modified pyritohedron bounded by 12 inward-projecting, 5-sided pyramids, formed by the shear along 30 triangular planes. The resultant cavity was later filled by chalcedony that was probably deposited during the alteration of the enclosing material to a clay."

The writer has studied many thin-sections of thunder eggs, and also transparent slabs projected on a screen. The sequence of formation, the manner of crystallization, and the order of deposition within the thunder egg are readily observed in this way. In most thunder eggs it can be seen that the glass shards, which are usually collapsed and well aligned, have a different orientation than the minerals produced during devitrification of the glass. These minerals, usually feldspar and cristobalite, are often radially arranged and produce the spherulites which cause the thunder egg's knobby or warty appearance. The spherulites under crossed nicols give a dark cross which simulates a positive uniaxial interference figure, the fibers being length slow. The phenocrysts of plagioclase (often oligoclase) in the welded tuff (figure 4) were fractured and somewhat corroded in the original rock. They remain fresh in their centers but are sometimes corroded during the growth of the spherulites.

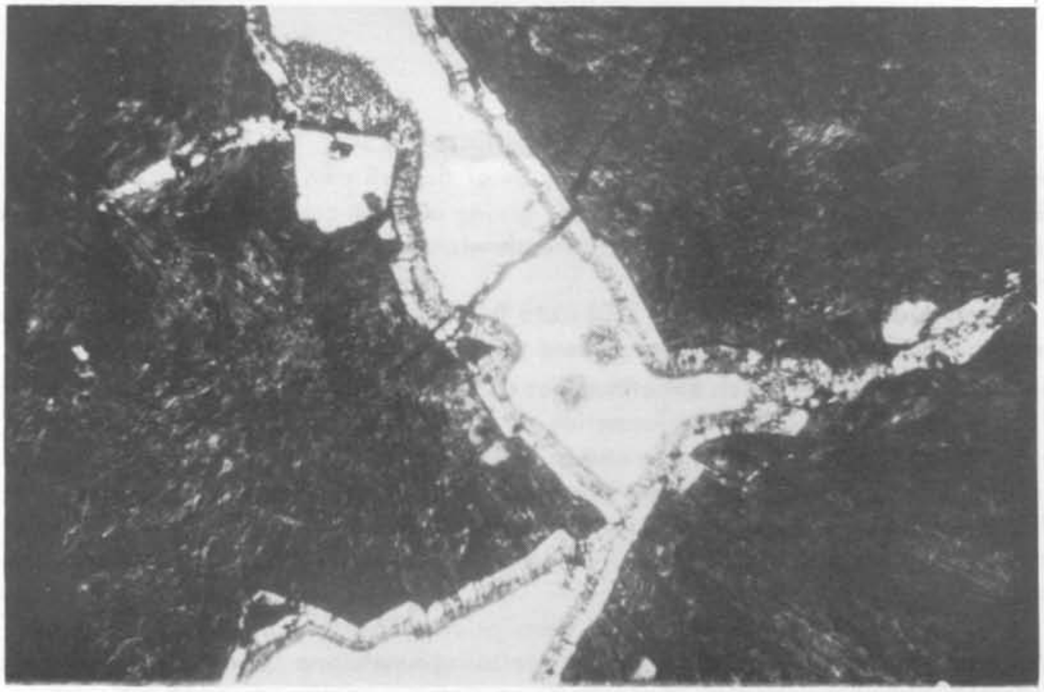

Figure 4. Photomicrograph of thin section of Priday thunder egg. Dark matrix is welded tuff showing glass shards. Central light channel is chalcedony. Zone at contact is composed of spherulites, both light and dark in color. Large crystal is feldspar phenocryst. Veinlet cutting across section is opal. Magnification 23 X, without crossed nicols.

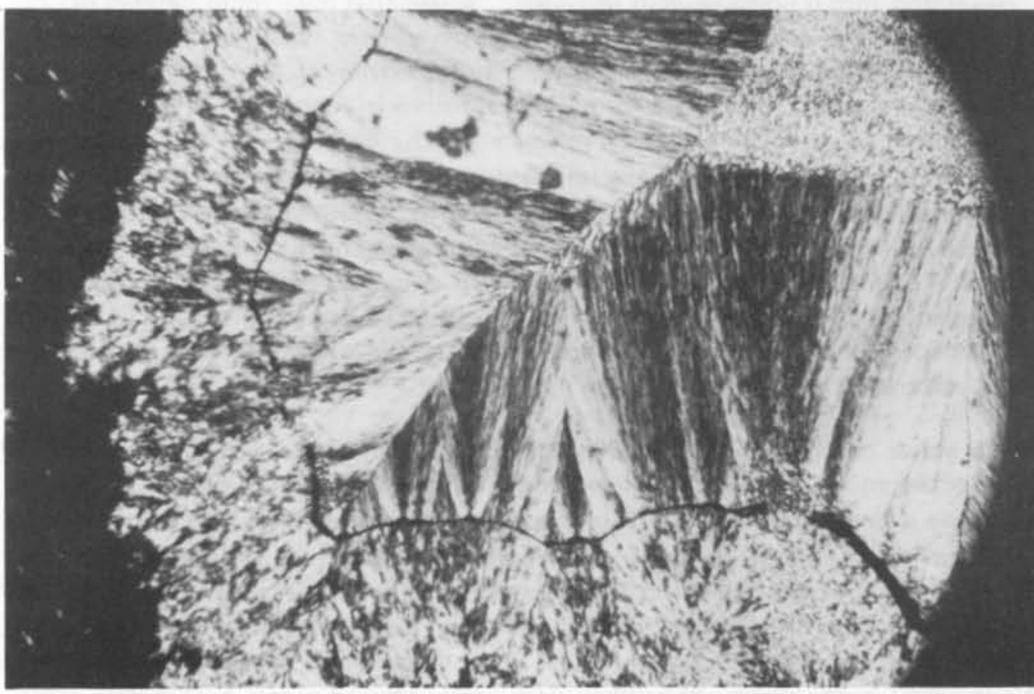

Figure 5. Photomicrograph of thin section of thunder egg from Mutton Mountains, Oregon. Chalcedony in filled cavity showing crystallization in sectors. Salt and pepper structure in upper right sector. Black Liesegang ring parallels contact with rhyolite matrix. Magnification 23 X, crossed nicols.

The centers of the thunder eggs contain chalcedony which is sometimes banded, forming agate (figure 1A). More rarely moss-like, plume, fern-like, or tubular inclusions are present giving rise to the name "moss agate" (figure 3, A and B). Brown (1957) describes the origin of these features showing that the filaments, derived from salts along the walls of the cavity, grew into the silica gel which filled the cavity. He states (p. 335), "These pseudoalgae shot up rapidly in pulses by chemical precipitation (probably as iron hydroxide and silicate), osmosis, and diffusion." It is evident that the inclusions are not organic as some people have concluded.

The chalcedony filling of the centers (figure 5) consists of fibers which for the most part are length fast, indicating that the c axis of the mineral is at right angles to the elongation. At the outer edges of the cavity adjacent to the host rock, the fibers radiate toward the cavity center and are normal to the boundary reflecting the shape of the cavity walls. On the other hand, toward the center of the cavity, the silica gel which filled it was crystallized in sectors with well-defined straight edges, possibly determined by the planes in the cubic or pyritohedral core. In addition to the fibrous or radiating structure of the chalcedony, it frequently shows the salt-and-pepper or aggregate structure. Superimposed on the fibrous chalcedony structure are Liesegang rings which are parallel to the cavity wall and perpendicular to the elongation of the fibers. Liesegang rings, named after their discoverer, are rings or curved bands formed by the rhythmic precipitation of salts in a gel. The structure produced may be easily confused with layers formed by deposition, but whereas depositional structures are primary, Liesegang rings are secondary due to diffusion. A simple method for making Liesegang rings is described by Cassirer (1936, p. 11, 12). Where there is incomplete filling, euhedral quartz often lines the cavity.

Excellent examples of weathered-out cores of chalcedony are found on Dry Creek, southeast of Lakeview in Lake County (figure 2D). These are casts of the cavity and each face has radial markings with a button at the center. The button is hemispheric on one face with a corresponding hollow on the opposite face. Because opposite sides of the cavity often would fit together if joined (figure 4B), it may be assumed that the sides were spread apart by fluid pressure, forming the cavity. This explains the positive and negative buttons seen on the weathered-out chalcedony cores and is further proof that the cavity formed after the development of the spherulites which produced the hemispherical buttons.

The zone of greatest difficulty to interpret is at the contact between the chalcedony core and the tuffaceous outer shell (figure 4). A complete understanding of the history of this zone of contact would clarify many of the least understood processes in the formation of thunder eggs. (The term "contact zone" used here refers only to location at the contact of the outer shell and matrix, and has no genetic significance as in ore deposits.) The rim of the cavity is often coated with colloform opal and this in turn may have a shell of spherulitic material on it. This spherulitic shell determines the form of the chalcedony bands which are composed of fibers lying normal to the shell, with Liesegang rings superimposed and paralleling the shell. In the contact area the spherulites can be recognized by their length slow habit as well as the radiating structure (figure 6).

In hand specimens there often appears a zone of chalcedony parallel to the cavity wall into which abut the paralleled bands of the agate. This zone seems, on cursory examination, to have been the first to form, as a cavity wall coating, and later to have been covered with banded agate as the cavity filled up. However,

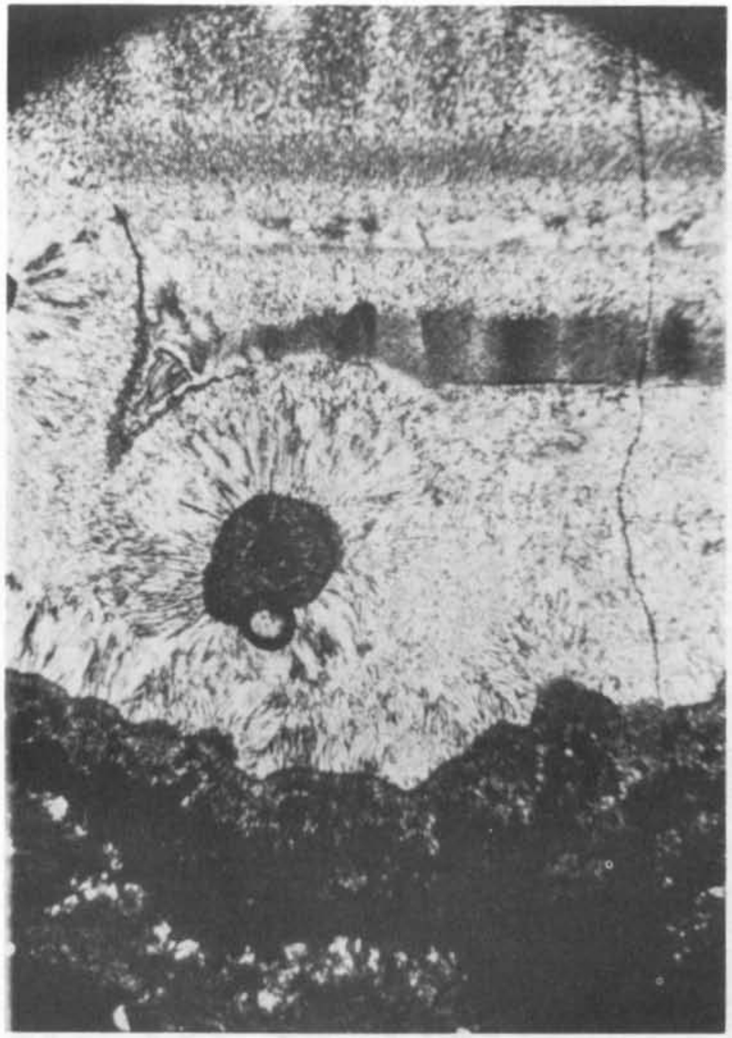

Figure 6. Photomicrograph of spherules surrounded by radiating chalcedony which has corroded earlier bands of agate. Contact zone of dark spherulites. Mag. 23 X, crossed nicols.

Figure 7. Moss agate showing Liesegang rings paralleling tubes and corroding earlier-formed horizontal bands of agate. Magnification 5 X.

careful observation of this zone, supported by thin-section studies (figure 6), shows the reverse sequence to be true. It appears that the cavity was filled with gel, layer on layer, which, due to slightly different compositions, produced banding. In some cases a tilting of the cavity during deposition resulted in an unconformity between the first set of bands and a later set. For reasons which are not now understood, the wall of the cavity often directs a Liesegang effect into the agate, eradicating the original structure. This is also seen where pseudoalgae or "moss" protrudes into the agate. The pseudoalgae are outlined by rings which cut across the agate bands, eradicating them (figure 7). The pseudoalgae or filaments, according to Brown, (p. 336), "...originated after and not before the cavity was filled with the gel."

The chemistry of the formation of the feldspar and cristobalite spherulites from rhyolitic glasses is not well enough understood to predict the amount and kind of material that would be liberated. Possibly some of the contact effects and growth of quartz crystals along the contact may be due to devitrification, but it seems unlikely that the large amount of silica which fills the central cavity could originate in this fashion. This silica which deposits as silica gel in the central cavity, and later crystallizes to chalcedony, and the quartz which lines or fills the remaining voids, undoubtedly entered the cavity through minute cracks or through the porous walls. The amount of secondary silica in veinlets, amygdules, and cavities in the rocks where thunder eggs are found is very great and there is little doubt that silica was transported and introduced from ground-water solutions.

Summary

The sequence of events in the formation of a thunder egg varies from specimen to specimen and some exhibit much greater complexity than others. The best examples are those which, when cut, exhibit four- (figure 1D) or five-pointed stars (figure 1A) and in which there is distinct banding. Possibly of greater beauty, but more difficult to explain are those which contain pseudoalgal structures (moss agate, plume agate [figure 3]), and those which have multiple-filled or very irregular cavities (figure 1C).

The development of thunder eggs has been discussed above. To summarize this briefly, they are rock structures formed in welded tuffs and rhyolites, of spherical or ellipsoidal shape, containing cores of chalcedony and sometimes quartz. The specimens consist of three concentric shells: an outer shell, usually brown in color with a ribbed, warty surface; a contact zone which borders the former cavity; and a core representing the cavity filling and consisting chiefly of chalcedony but sometimes containing quartz, opal, and pseudoalgal structures. The contact zone between the core and outer shell is sometimes only apparent microscopically. The most characteristic feature of thunder eggs is the devitrification of the rhyolitic glass by incipient crystallization forming spherulites. Although it has not been definitely proved, the devitrification probably releases gases which initiate spherulite growth and act as the force to open the central cavity, often between or around spherulites, but sometimes within them. The spherulitic growth produces the hardened outer shell, which becomes a residual structure in the surrounding rock as it alters to clay. Most specimens consist not of a single spherulite but rather of many of them intergrown, some of which may contain no cavities. The central filled cavity of many thunder eggs contains a hemispherical protuberance (button) on one side with a hole of a similar size on the opposite side (figure 2B), indicating that the cavity was formed around some spherulites and that the two sides were formerly joined. The cavities with regular shapes, yielding a four-sided or five-sided figure in section, have been explained by Wright (1915) and Ross (1941) as due to expansion and rupture along planes representing the faces of negative or inward-projecting four-sided and five-sided pyramids. Natural casts (figure 2D) of the cavities well illustrate these forms.

A careful study of thunder eggs raises nearly as many questions as it answers. Details concerning the types and pressures of fluids involved in forming and filling the cavities; the length of time required for devitrification, crystallization, and filling; the physical chemistry of development of spherulites; and the paragenesis of the minerals involved, including the temperatures of formation, all need to be given attention. In addition, further field work should be pursued in the hope that it would aid in solving some of the problems related to sources of the material which must be derived from outside of the thunder egg. Other field studies should consider the orientation and location of the thunder eggs in the flows or beds, the relations of spherulites and lithophysae, and the types of alteration involved.

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LUNAR GEOLOGICAL FIELD CONFERENCE

From all quarters, the first International Lunar Geological Conference, which was held in Oregon in the summer of 1965, has been judged a complete success.

During the week-long meeting at Bend, August 22 to 29, geologists, geophysicists, and astronomers from Australia, Belgium, Canada, Czechoslovakia, England, Iceland, Norway, South Africa, and West Germany joined with their counterparts from United States Universities, government agencies, and space industries to exchange information about the lunar surface.

Two State of Oregon Departments (Planning and Development, and Geology and Mineral Industries) staged the conference under the sponsorship of the University of Oregon and the New York Academy of Science. Dr. Lloyd Staples and Dr. Jack Green were the co-chairmen for the respective sponsors. The Lunar Base Research Committee and Chamber of Commerce committees of Bend proved to be extremely hospitable hosts. The State Highway Department contributed to the conference by demonstrating a vane sheer test at a pumice quarry near Bend.

Unlike typical conferences where most of the time is allotted to the lecture room for technical papers and discussions, this was designed with five days of field trips to show the visiting scientists the great variety of initial surfaces and volcanic landforms of central Oregon, and also to permit on-the-spot discussions of views concerning volcanic processes and the origin of the moon's surface.

Three Trailways buses were required for transportation of the 70 to 80 participants on the five separate field trips, which covered the central Oregon landscape from Bachelor Butte and the Three Sisters areas to Newberry Volcano, to Fort Rock and the Devils Garden, on to magnificent Crater Lake, and back to the McKenzie Pass lava field. The bus caravan never failed to negotiate the back roads that kept blocky obsidian flows, pumice flats, spatter cones, lava tubes, spiny lava fields, and large calderas within view the better part of every day. See pictures, pages 209-216.

The official guidebook for the five days of field trips was the Department's Bulletin 57 prepared especially for the conference. Its cover portrayed a photographically denuded central Oregon landscape as a fictitious lunar mare termed "Incognitum." Official photographer for the conference was Earl Roarig, 1735 E. 11th Street, Bend, Oregon, who shot a voluminous number of pictures with three cameras and took orders for prints.

During the conference week the Bend community used every available moment to entertain its distinguished guests. The opening event was a banquet at which Governor Mark O. Hatfield welcomed the conference members and noted that the key to Oregon's future lies in science and research. As proof of this, Dr. Arthur S. Flemming, President of the University of Oregon, announced the establishment of the Center of Volcanology at Eugene, to be headed by Dr. A. R. McBirney.

The Rim Rock Riders of Bend provided a buckaroo breakfast, and the Fort Rock Grange, with Reub Long in charge, put on an old-fashioned western barbecue lunch in the shadows of Fort Rock. And to top the week of hospitality, on Wednesday evening each visiting scientist was the personal guest in the home of a Bend family.

Many of the highlights of the conference were provided by the visiting scientists:

At East Lake within the Newberry Caldera, Dr. Haroun Tazieff, dynamic volcanologist from Paris and Brussels, demonstrated a portable gas analyzer used during actual eruptions to check the composition of emanating gases at erupting volcanic vents. The fumarolic gases bubbling to the surface at East Lake were found to be almost entirely carbon dioxide.

Deep within the enormous lava tube called "Lava River Cave," Dr. Gordon Macdonald, dean of Hawaiian volcanologists, vividly described the processes involved in its creation.

From the rim of sparkling blue Crater Lake, Dr. Howel Williams of the University of California described, as only he can, the building of mighty Mount Mazama, its eruption, and its collapse. The story was told from spectacular viewpoints where, in his own words, "The scene is one of overwhelming beauty."

Evening discussion groups at Pilot Butte Inn were led by Dr. Aaron Waters, Head of the Department of Geology at the University of California, Santa Barbara. One day of the week was devoted to presentation of technical papers with Dr. Jack Green as moderator. The papers are to be published by the Department.

On the last trip of the conference, into the vast McKenzie lava field, the conference delegates paused briefly to conduct their only official business meeting. Still unsolved was the answer to the main question of the lunar surface controversy: Are the craters volcanic or meteorite impact? Dr. Nicholas Short of the University of Houston presented resolutions for the members' approval that basically recommended the selection of a volcanic crater and an impact crater for intensive studies prior to manned landings on the moon. "Hole-in-the-Ground" near Fort Rock was mentioned as a possible volcanic crater and Oregon's new Center for Volcanology at the University of Oregon was urged to seek funds for a systematic study of the structure. Meteor Crater, Arizona, was chosen as the crater to be studied for impact phenomena. The resolutions were left with an "ad hoc" committee for final editing and circulation to conference delegates for signing.

As stated before, the conference has been judged by nearly everyone as an unqualified success, and if the only purpose had been to enhance Oregon's scientific image, it did. If it was to show space-oriented industries that Oregon has adequate research facilities and the terrain on which to experiment, it did. If it was to further publicize Oregon's volcanic scenery, it did. If it was to encourage the new Center for Volcanology at the University of Oregon, it did.

When asked for comments on the achievements of a meeting such as this, one of the participants replied as follows: "Besides getting to know the people of what is surely one of the finest States in the Union, and getting to understand its volcanic terrain, we had an exchange of views. It is the discussions which go on during such conferences between scientists of widely differing experience and from distant parts of the world that are the most important aspect."

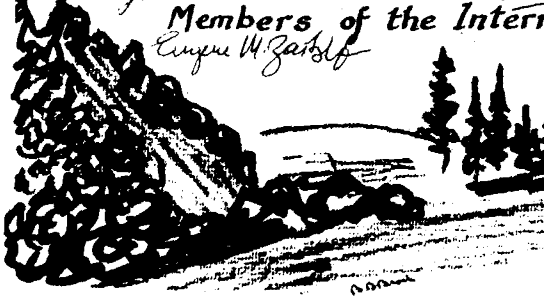
The scroll reproduced on the opposite page was sketched by Dr. B. B. Brock of the Union of South Africa during the field trip to Crater Lake; it was signed later by members of the conference. On the last day of the conference, at a noon luncheon in Bend, Dr. Fred M. Bullard, Texas volcanologist, made the formal presentation of the scroll to Oregon's State Geologist, Hollis M. Dole, who accepted it for the Lunar Conference Committee. →

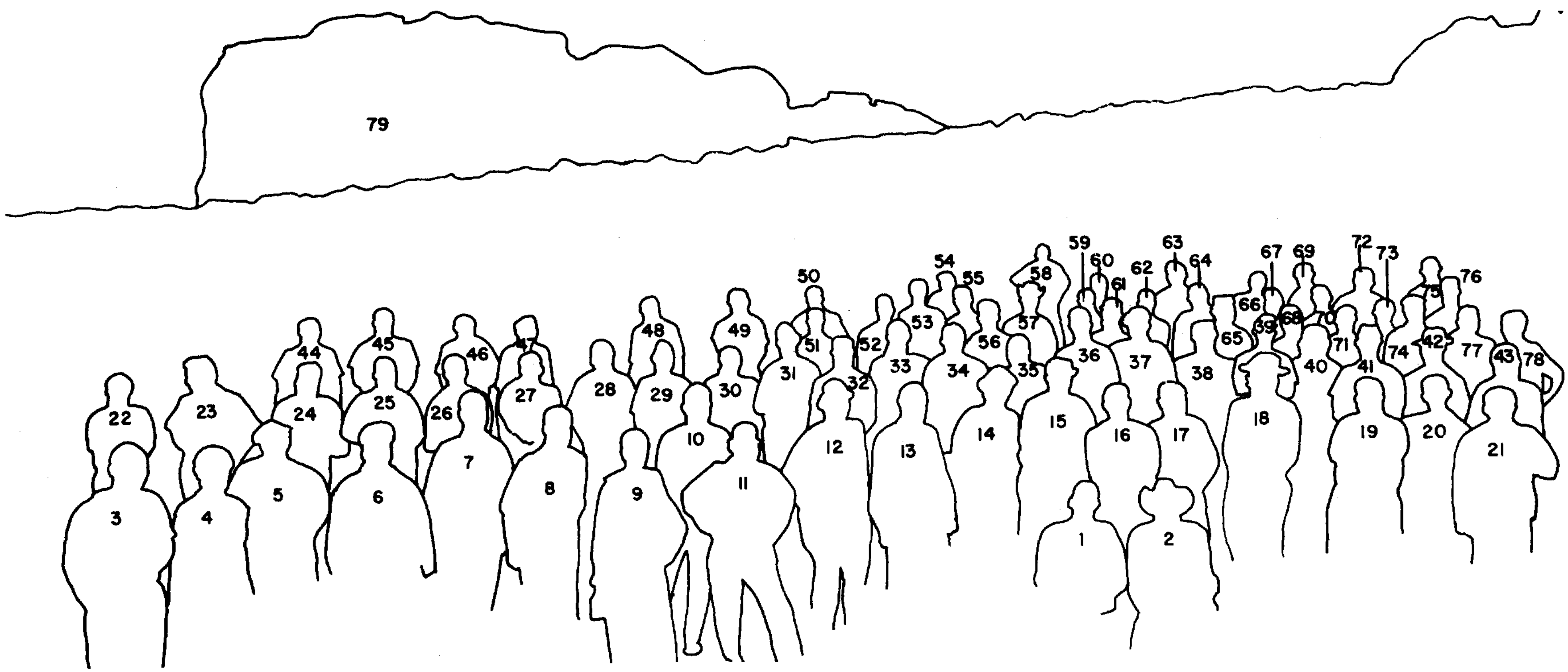
August 28, 65

Having enjoyed a week's sojourn and study in the magnificent volcanic landscapes of Oregon, we, the undersigned wish to express our sincere gratitude to the organizers and sponsors of the Conference.
We also wish to thank the citizens of the beautiful City of Bend for their most gracious and generous hospitality.

S. Miyamoto
Earl Ingerson
Haroun Tazieff
Hoyt M. Weathers
Gordon A. Macdonald
John D. Halajian
Willy Hafner
B B Brock
Robert G. Strom
George & Martina Kocher
Bob Baragar
Bevan M. French
Dan Hall
Aaron C. Waters
John Eliot Allen
Winifred S. Cameron
Wolf von Engelhardt
(KANEKO KATSU)
Howel Williams
M. Saito
Edward M. Taylor
William H. Pinson

Members of the International Lunar Geological Field Conference

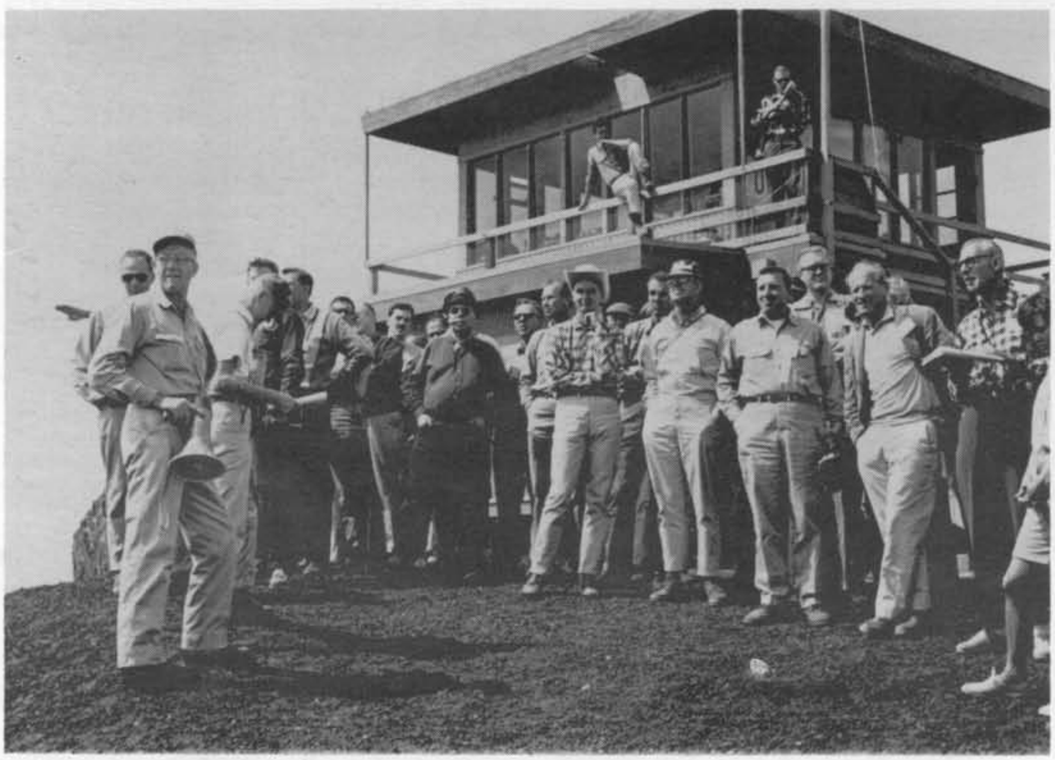




Lunar Geological Field Conference participants at the base of Fort Rock are identified by the numbered outlines above. Sixteen are from foreign countries, as indicated; all others are from the United States.

(1) Dinneen, (2) Long, (3) Tazieff (Belgium), (4) Mrs. Tazieff (Belgium), (5) Gant, (6) Matumoto (Japan), (7) Bullard, (8) Elston, (9) Kaneko (Japan), (10) Wood, (11) Saito (Japan), (12) Walker, (13) Ingerson, (14) Brown, (15) Raymond, (16) Taylor, (17) Wilkinson, (18) Allen, (19) Tiffany, (20) Saari, (21) Halajian, (22) Gass (England), (23) Dietz, (24) McCall (Australia), (25) Wilson (Canada), (26) Strom, (27) Robinson, (28) Bodvarsson (Iceland), (29) Vaughan, (30) Oftedahl (Norway), (31) Macdonald, (32) Cook, (33) Kocher, (34) McBirney, (35) Howard, (36) Hale, (37) Ronca (Italy), (38) Groh, (39) Fogelson, (40) Cameron, (41) Mason, (42) Hoch, (43) Schloss, (44) Weathers, (45) Van Lopik, (46) Waters, (47) Von Englehardt (West Germany), (48) Benson, (49) Pinson, (50) Arnett, (51) French, (52) Short, (53) Dence, (54) Bryson, (55) Baragar (Canada), (56) Kopecky (Czechoslovakia), (57) Currie (Canada), (58) Denny, (59) Manton, (60) Rogers, (61) Corcoran, (62) Richardson, (63) Kennedy, (64) Cronin, (65) Bledsoe, (66) Hill, (67) Green, (68) Zaitzeff, (69) Bowen, (70) Hafner, (71) Staples, (72) Ryan, (73) Azmon, (74) Brock (Union of South Africa), (75) Lounsbury, (76) Tooley, (77) Williams, and (78) Greiner. No. 79 indicates Fort Rock. (Photograph by Earl C. Roarig)

A stop along the Cascade Lakes Highway by Devils Hill. The party is inspecting and sampling one of the dacite flows of very recent origin.



Viewing the surrounding country from the top of Lava Butte. This fresh cinder cone, its crater, and rugged black lava field was of great interest to the field party.

Phil Brogan, well known for his popular writing on the geology of central Oregon, stands beside the Forest Service sign that names the trail to the Lava Butte gutter in his honor.

Three leading volcanologists having a field lunch at Paulina Falls Forest Camp. From left to right: Dr. Matumoto, University of Kumamoto, Japan; Dr. Williams, University of California; and Dr. Gass, University of Leeds, England.

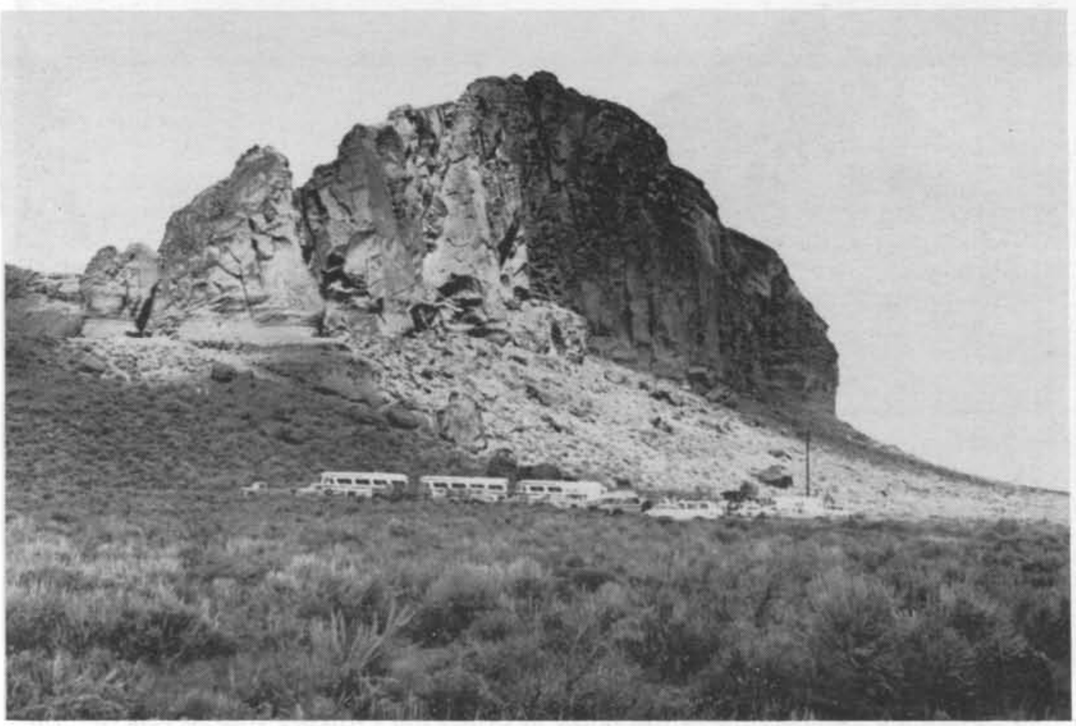
The conversation between Dr. McBirney and Dr. Waters (center of photograph) on the Paulina Lake maar in Newberry Crater was one of the many interesting discussions that took place during the field conference.

Conference group listening intently as Dr. Tazieff, University of Brussels, Belgium, describes the operation of a portable volcanic gas analyzer at the East Lake Hot Spring in Newberry Crater.

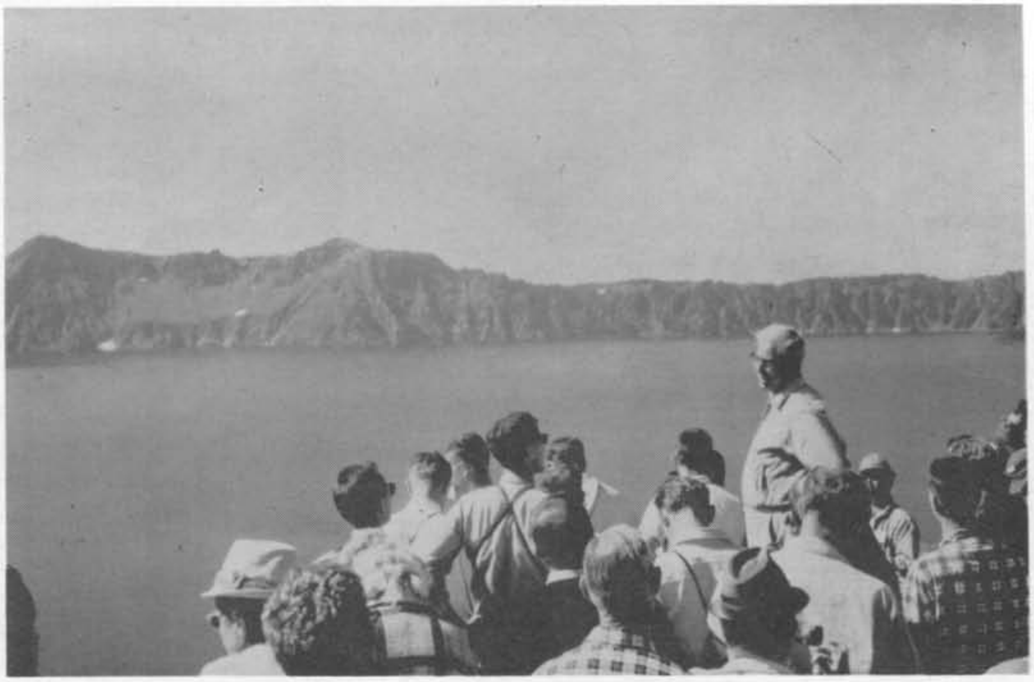
Field trip guide Norman Peterson, Oregon Department of Geology and Mineral Industries, describing Hole-in-the-Ground to the conference group. This feature, so much like a lunar crater, fascinated everyone.

Conference members leave the buses to climb the clinkery side of one of "The Blowouts," a large spatter cone in the Devils Garden area. The Lunar Conference sign on the bus gives a humorous twist to the Trailways slogan, "Easiest travel on earth."

At Fort Rock State Park the group enjoys a genuine western-style barbecue lunch prepared to gourmet taste by the members of the Fort Rock Grange.



Towering above the state park where the barbecue was held is Fort Rock, an eroded tuff ring.



Dr. Williams, authority on the geology of Crater Lake, is giving the conference group the benefit of his knowledge and experience. This spectacular caldera was the climax of the field conference.

Two pipe-smoking earth scientists in friendly discussion at Crater Lake. Dr. Brock, Union of South Africa, on the left and Dr. Macdonald, University of Hawaii, on the right.

Dr. Staples, Department of Geology, University of Oregon and co-chairman of the conference, at left, and Dr. Matumoto, with other members in the background, give their attention to the lecture by Dr. Williams at the viewpoint overlooking Wizard Island.

Some of the conference scientists observing the jagged lava surfaces at McKenzie Pass from the top of Dee Wright Observatory. North Sister and Middle Sister peaks are in the background.

The ORE BIN
Volume 27, No. 11
November, 1965

COASTAL LANDSLIDES OF NORTHERN OREGON

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Introduction

The increased development of the Oregon coast for domestic housing, recreation, and industry makes it economically important to understand processes of coastal erosion and deposition. Of all the erosional processes, landsliding is undoubtedly the most important. It is active along 70 of the 150 miles of northern Oregon coast, from the Columbia River to Florence.

In the past, investigations of coastal landslides have followed mainly a reactionary approach. Only after property has been damaged or rendered valueless by landslides have detailed studies been made to determine the causes of the movements and the feasibility of preventive measures. In Oregon, studies of coastal landslides have been few. Diller (1896) and Smith (1933) described landslides as they occurred in accessible wave-cut cliffs and areas of local subsidence. Broad erosional processes effecting changes in the Oregon coast were studied by Dicken (1961), who included references to coastal landslides as they altered shoreline topography and composition of beaches. General estimates of the length of coast already affected by landslides were made by Byrne (1963, 1964). Terrace subsidence in the Newport area was studied by Allen and Lowry (1944) after a 1,000-foot section of the coast dropped 20 feet, opening fissures and shifting houses. A spectacular 125-acre slide in Ecola Park, near Tillamook Head, was described in detail by Schlicker, Corcoran, and Bowen (1961).

Most general literature on landslides is contained in various engineering publications that deal directly with road building, railroad engineering, or some phase of construction. This literature is voluminous, and extensive bibliographies are given by Eckel (1958), Ladd (1935), and Sharpe (1938). An excellent summary of landslides

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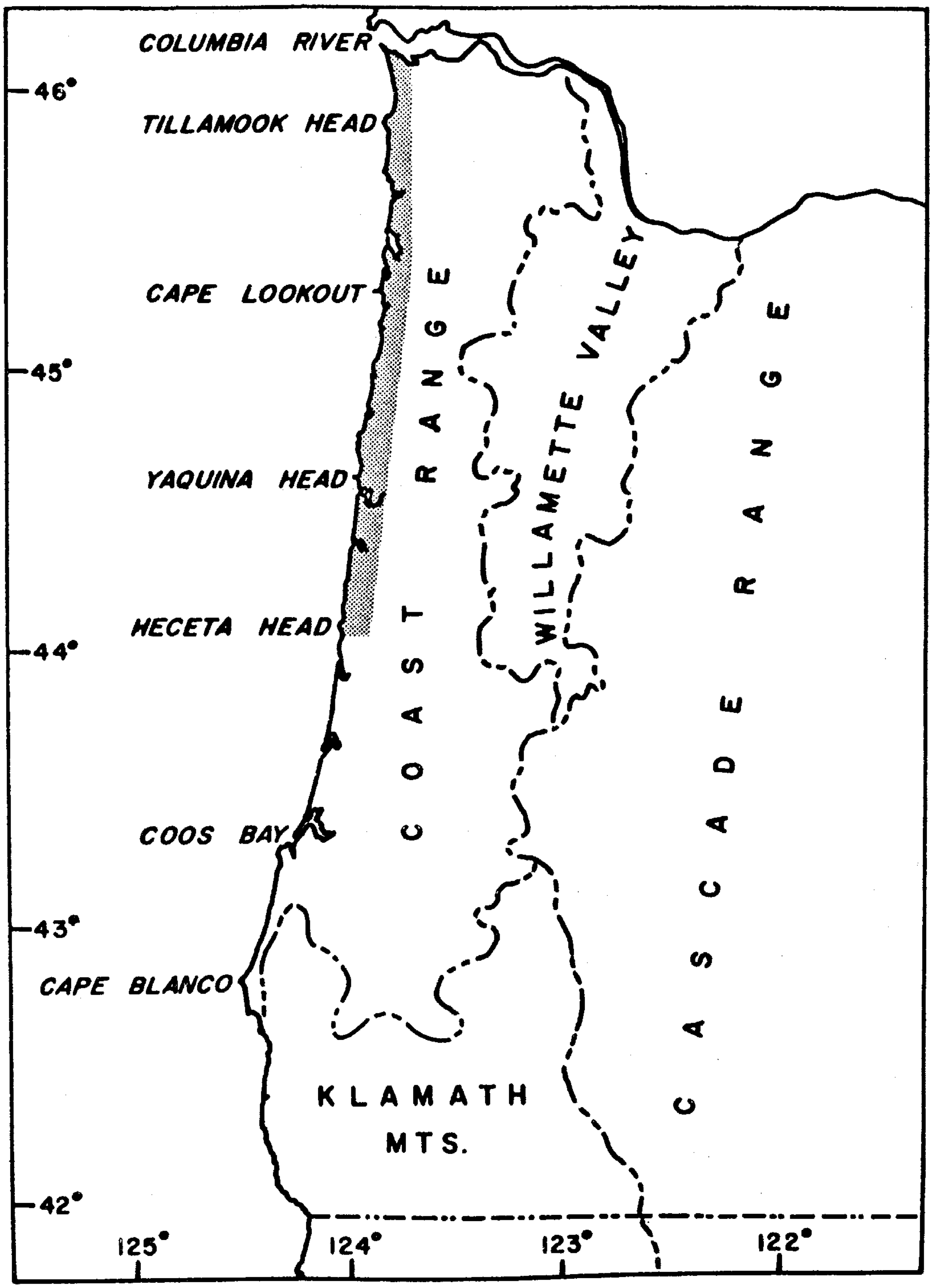


Figure 1. Index map showing geomorphic provinces of western Oregon. Shaded portion indicates area studied.

in general was presented by Schlicker in The ORE BIN of May 1956.

The field study represented by this report was undertaken to provide data on the location and causes of active landslides, and to determine, if possible, the frequency of landslides and rate of coastal retreat.

Coastal Physiography and General Geology

The northern Oregon coast, from the Columbia River to a point six miles north of the Siuslaw River (Figure 1), includes a wide variety of shoreline features. Short, narrow beaches lie at the base of low cliffs which form the seaward edge of uplifted marine terraces. Numerous headlands, estuaries, and bays interrupt the continuity of the terraces and beaches. Where the coastline is low, near the bays, active sand dunes are present. Stabilized dunes are evident in some of the low areas and on some of the terraces.

Tertiary marine sediments dominate the rocks exposed to erosion. These rocks range in age from Eocene to Miocene, and consist of micaceous and tuffaceous sandstones, siltstones, mudstones, and shales, with some glauconite beds.

Sediments of Pleistocene(?) age are exposed in marine terraces along the coast. These deposits consist of cross-bedded sand and silt with layers of gravel and very coarse sand, fossil wood, peat, and, in some places, thin beds of sandy clay. The Pleistocene sediments occur as terrace caps that unconformably overlie Tertiary rocks. Although often unreported on geological maps, these deposits figure prominently in local landslides and must be included when the total material available for mass movement is considered.

Igneous rocks of Eocene and Miocene age form all but one of the headlands (Cape Kiwanda) and constitute the most resistant features of the northern coast. These rocks are dense to very finely crystalline basalt flows, pillow lavas, flow breccias, agglomerates, and tuffs. Dikes of gabbro, diabase, and diorite intrude both igneous and sedimentary rocks, forming resistant "spines" and locally disrupting and contorting the sediments. A summary of the lithologies exposed along the coast is presented in Table 1.

TABLE 1. Coastal lithology significant to landslides along the northern Oregon Coast (figures in statute miles).

Material	Total length	Terrace Cap
Sedimentary rock	33.38 mi.	20.42 mi.
Igneous rock	36.76	16.90
Beach, dune sands	79.60	- - -

Distribution of Tertiary sedimentary and igneous rocks and Quaternary sediments is shown in some detail on geologic maps that cover the following coastal areas: Astoria to Cape Lookout (Warren and others, 1945); Cape Kiwanda to Cape Foulweather (Snavely and Vokes, 1949); Newport to Waldport (Vokes and others, 1949);

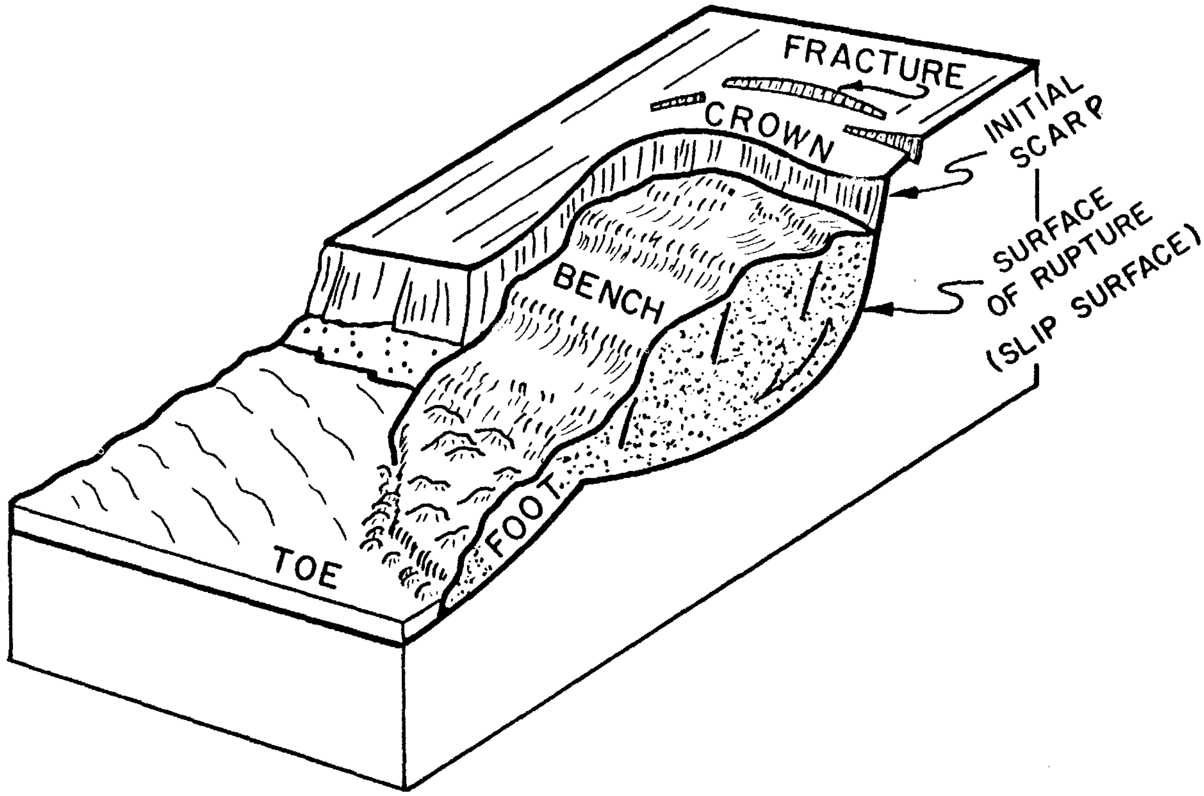


Figure 2. Landslide nomenclature.

and Heceta Head to Florence (Baldwin, 1956). A geologic map of western Oregon (Wells and Peck, 1961) combines in a generalized way the information of the four maps cited above.

Landslide Characteristics

The term "landslide" has been used to represent a variety of types of mass wasting. Although specific cases of landslides may involve an earthflow or a block fall rather than the strict slide of a mass along a plane, the word is used to describe what is apparent: that a portion of land has slid or moved from one position to another. A landslide, then, is a relatively rapid displacement of a mass of rock, residual soil, or sediments adjoining a slope, in which the center of gravity of the moving mass advances in a downward and outward direction (Terzaghi, 1950).

Landslide morphology

Each landslide has its own characteristics. The mechanisms, materials, and boundary restrictions may be quite different from slide to slide. However, slide nomenclature has been more or less standardized and is summarized in Figure 2.

For coastal landslides the toe usually is in direct contact with the ocean. When a slide reaches the ocean, waves immediately begin to act on the toe, removing the finer material and leaving larger boulders and cobbles to outline roughly the original toe. Where slide toes are composed of smaller fragments, wave activity may carry away most of the toe material. This produces a wave-cut cliff in what was formerly the bottom or foot of the slide. The cliff is often backed by a gently sloping bench; the surface upon which the slide moved is located beneath this bench.

Landslide mechanism

The force of gravity acts to produce landslides. Prior to the actual movement, earth material beneath a slope is subjected to shearing stress. If the shearing stresses in the material are less than the average shearing resistance, the slope is stable. When the stress is equal to or exceeds the resistance, a landslide occurs. It is the failure of material under gravity-induced shear stress that allows slope material to slide.

The actual mechanism of slide development has been described by numerous workers. The following is from Schlicker's report in The ORE BIN for May 1956.

"External causes of landslides are due to the undercutting of the toe of a slope (oversteepening), addition of weight from embankment material or waste deposited along the upper edge of the slope, and from added weight of increased moisture content. Earthquakes or vibrations can be a cause and there is no doubt that vibrations from any source may 'trigger' a slide.

"Internal causes of landslides are due to water in the ground. The groundwater produces both immediate and progressive decrease in shear strength of the soil. Immediate decrease of shear strength is generally caused by increase in pressure from water in the voids. This pressure is analagous to the forces exerted by a hydrostatic head. Seepage pressure is a force exerted by ground-water flow due to the viscosity of water moving through minute passages in the soil. Continued seepage through slopes expels the air and apparent cohesion between the soil particles is eliminated, further weakening the soil. Although this mainly concerns conditions of rapid draw-down in reservoirs and stream channels, it is also true of saturated soils below the water table. Progressive decrease in shear strength results from removal of the soil binder and chemical decomposition of the mineral grains by ground-water action.

"As the shearing forces approach the shear strength of a soil mass, certain sections fail by rearrangement of the soil grains and the formation of hairline cracks. Excess water in the disturbed soil is forced into other sections of the soil and failure of the soil mass continues as if by chain reaction. When the shear strength along a possible slide plane is reduced sufficiently, the entire mass becomes mobile and slide occurs. At the moment a slide begins the shearing forces are but slightly greater than the shear strength of the soil, but sliding causes a reduction in strength of 20 to 90 percent, depending on the sensitivity of the soil (Terzaghi, 1950, p. 112). Movement of the slide rapidly increases as the soil loses its strength. As the slide progresses, the driving force is reduced through reduction in slope and mixing of the slide material with more stable foreign soil. When the resisting force again is equal to the shearing force of the soil the movement passes from sliding into slow creep. The surface of an old slide is particularly susceptible to the effects of excessive rainfall, since numerous deep fissures provide easy entrance for water and drainage is greatly disrupted."

When a slide stops moving, equilibrium between gravity and the slide material's shearing resistance is established. Removal of the toe may upset the equilibrium by unloading the base, thus permitting repeated movement of the slide.

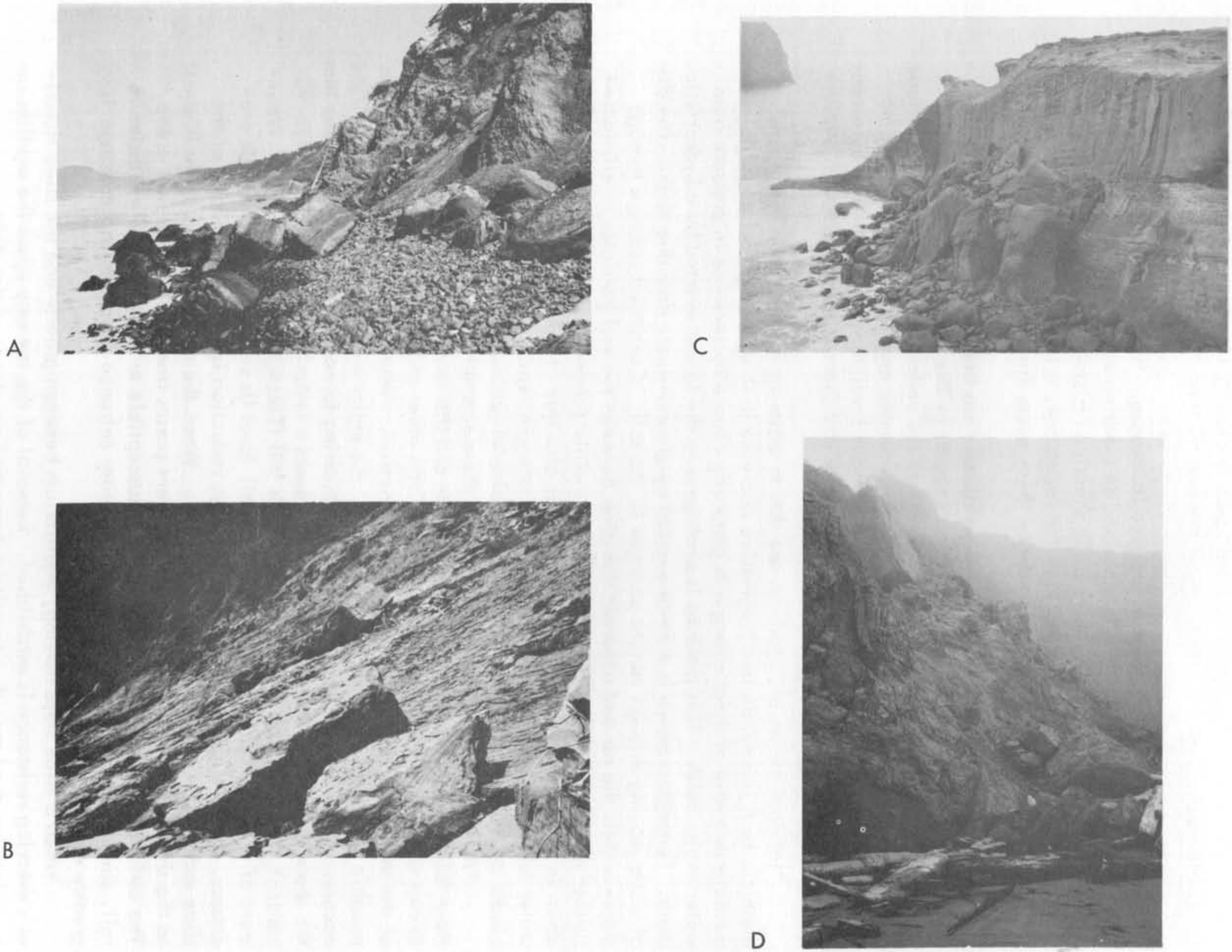


Figure 3. Landslide types: A, rock and debris slump; B, block and rubble slide; C, rock fall; D, debris shift.

Landslide classification

Numerous attempts have been made to classify landslides. Most classifications have been based on size and rate of movement, type of movement, type of material, and organization of material in the moving mass.

The simplified classification used in this paper is a modification of the classification used by Eckel (1958). Four categories based on the nature of the slip surface constitute the classification. These basic types are summarized in Table 2 and are depicted in Figure 3.

TABLE 2. Basic landslide types.

Landslide type*	Nature of slip surface
Slump	Concave
Slide	Planar
Fall	Indeterminate - movement essentially vertical
Shift	Indeterminate - movement indeterminate

*The type of material moved can be used as a modifier, for example, movement of rock and terrace material along a concave slip surface would be termed "rock-terrace slump." If materials are considerably mixed, the word "debris" is applied to the landslide type.

Distribution of landslides

The distribution of coastal landslides according to this classification is shown in Plate 1, pages 228 and 229. The pattern plotted in the offshore position represents the landslide type; the lithologic symbol indicates the general lithology at the coastline modified from the geologic map of western Oregon (Wells and Peck, 1961). No attempt has been made to show the distribution of terrace deposits. However, mention is made in the text where terrace sediments are significant to landsliding.

The following discussion, divided into three sections for sake of convenience, describes landslides of the northern Oregon coast, from north to south.

Tillamook Head to Cape Meares

Landslides have cut deeply into the sea cliffs of Tillamook Head and have moved more than 180 acres of property on the entire headland. On the north side of Tillamook Head, mudstones of the Astoria Formation form cliffs nearly 200 feet high. In two places where old slides have occurred, vegetation is too thick for details of slide configuration to be observed. These landslides were viewed near their crown from a trail over the headland. The slides are long and narrow and are being eroded by small streams. At West Point, the contact between basalt and Astoria sediments is exposed in the cliff face. From this point southward to Indian Beach, rock and debris falls are the main mass movements. Highly weathered basalt continually falls to narrow rocky beaches or directly into the ocean.

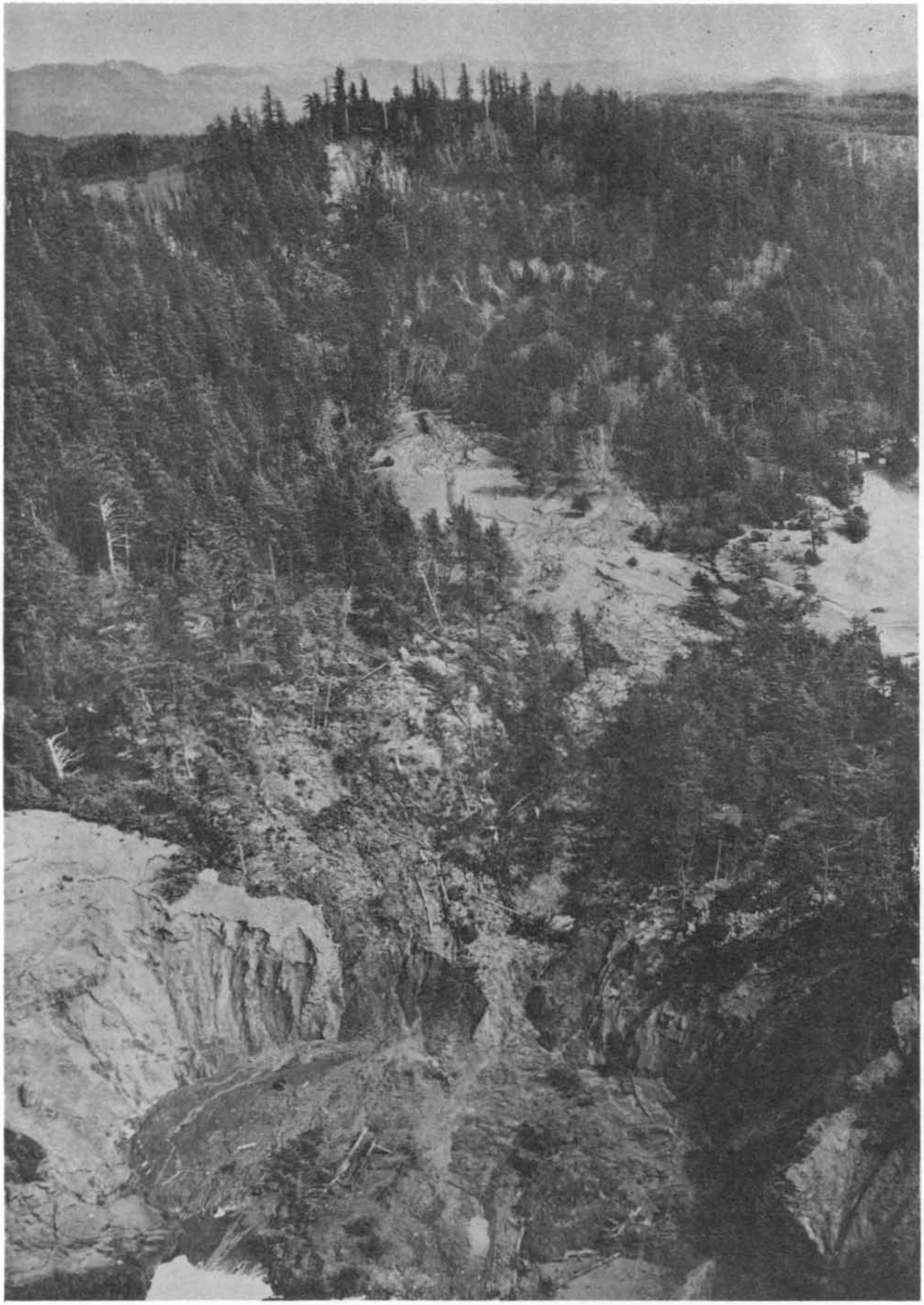


Figure 4. Ecola State Park landslide of February, 1961.

Three active landslides are included within the 1.6 miles of Ecola Park coastline on the south side of Tillamook Head. Sedimentary rocks in the park are thin-bedded sandstones, silty shales, and clayey siltstones of the Astoria Formation. Basalt flows and agglomerates are associated with the sediments; numerous dikes and sills have intruded the strata. According to Schlicker and others (1961), igneous intrusion took place before complete sediment consolidation, squeezing the sands and silts into complex folds with small axial faults. The most recent large landslide in the park occurred in February, 1961 and involved 125 acres of land, extending half a mile inland from the shore (Figure 4). The slide moved three feet per day at the outset, slowing down and stopping two weeks later. This 300-yard-wide slide was channelled between two basalt masses at the shoreline. Its toe has since been greatly eroded by waves. This slide which began as a debris slump, exhibited a vertical displacement of 40 feet at the crown and a maximum horizontal displacement of 100 feet at the middle.

Other landslides have occurred within the park. One slide is visible at Bald Point between Indian Beach and Ecola Point; an older landslide has its crown about half a mile inland from Bald Point. Sedimentary rocks in the landslide appear to be riding over basalt flows at the base of the toe. Erosion by wave action has removed material from the toe and has left only basalt boulders and cobbles to outline its extent. The basalt base may protect Bald Point from complete erosion by waves.

Between Ecola and Chapman Point steep scarps are associated with rock and debris fall. An old landslide near the north end of Chapman Point is partly concealed by vegetation, although the general slide outline is still visible.

Minor terrace debris slumps with some rock falls occur on small, local headlands from Chapman Point eight miles southward to Cove Beach, on the north side of Cape Falcon. Along Chapman and Cannon Beaches minor terrace sand slumps are prevalent, and near the village of Tolovana Park erosion and subsequent movement of unconsolidated terrace sands have shifted the foundations of some cottages. Between Cannon Beach and Tolovana Park, opposite Haystack Rock, the seaward-dipping Astoria Formation crops out on the cliff and provides natural slip planes for the overlying loose sands. Most slumps along this part of the coast occur along cliffs less than 20 feet high. South of Silver Point, mudstones of the Astoria Formation are intruded by basalt and are overlain by about 15 feet of terrace sand. Basalt dikes exposed as small, resistant promontories separate minor slumps of sedimentary rocks. The largest landslide in this area forms a bench 120 feet wide and 60 feet long, with a 20-foot-high initial scarp. On the south side of Humbug Point, intrusions have disrupted and contorted the sediments. Minor terrace debris shifts with 10-foot-high wave-cut cliffs in the toes are continuous in this area. Arch Cape, 250 feet high, is eroding by rock fall with some soil creep on the top.

Along Cape Falcon, an igneous headland, rock falls are common. Near the western point of the cape, basalt is overlain by sedimentary rock dipping westward. This, in turn, is overlain by a thin terrace sand cap.

In Smuggler Cove (Short Sand Beach), nearly 1,700 feet of dark-gray shale interbedded with fine-grained sandstone of Blakely age (Oligocene-Miocene) are exposed. Thin beds of siltstone, graded shale, and tuffaceous sandstone occur in this sedimentary section. At the north end of the beach, blocks of fine-grained sandstone, averaging 7 by 4 by 2 feet, move as dip-block slides over beds dipping 29° to the south. Debris slumps appear to be more prevalent along the southern

Figure 5. Rock-terrace slump which has destroyed 20 acres of land on Cascade Head.

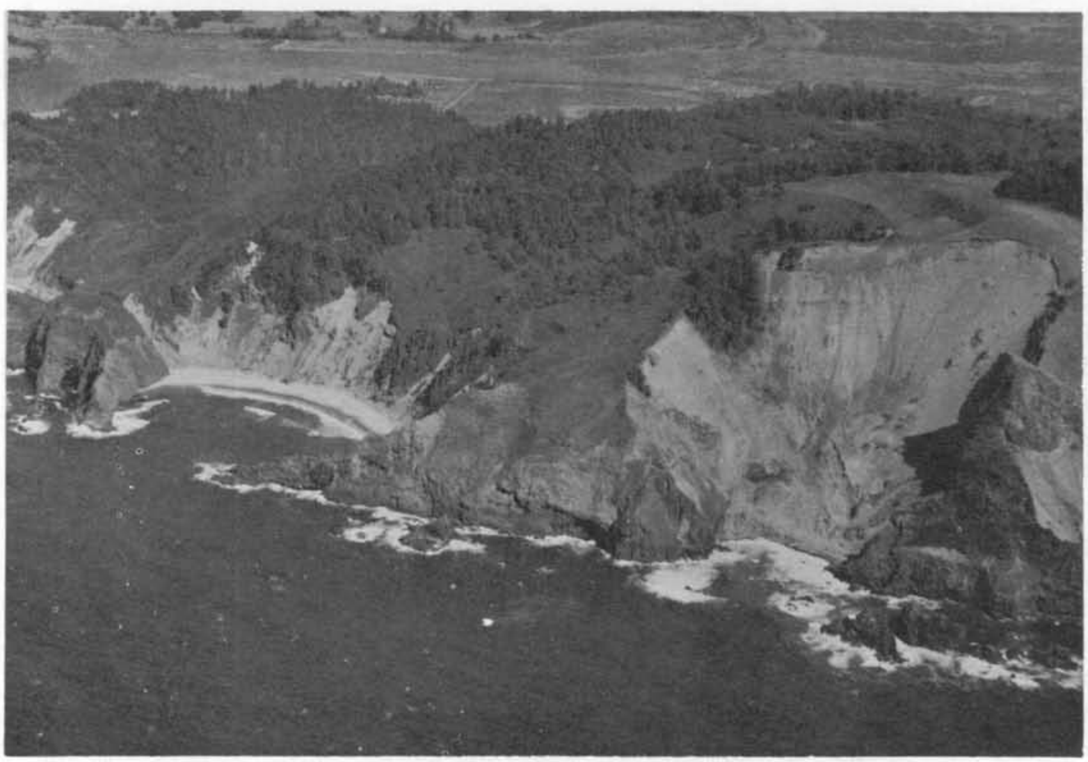


Figure 6. Slumping of Eocene shale south of the Salmon River. Where basalt cap has been breached, landsliding has been most rapid.

section of the beach, however. Part of the cliff behind the southern portion of the beach is protected by a 6-foot-high berm of cobbles and driftwood. This berm decreases undercutting of the cliff by acting as a partial wave barrier. Such a barrier is lacking on the northern third of the beach. A cross section of the hillside on the north shows vegetation and soil creep on the upper hillside, debris slump or shift in the middle, and block slide on the lowest reaches of the hill. The southern portion of this headland area, namely Neahkahnie Mountain, is eroded by block falling. Near Neahkahnie Beach, there is a vegetated remnant of an old debris shift consisting of Astoria rocks or terrace deposits.

Although landslide erosion is not very active along the coast from Neahkahnie Beach to Cape Meares, significant changes have taken place along Bayocean Peninsula at Tillamook Bay. Wave erosion of this sand spit is now well known and will not be discussed in this report. Wave erosion is rapid at the village of Cape Meares near the south end of the Bayocean Peninsula, but resistant igneous dikes help to decrease the rate of wave erosion and of landsliding close to the cape.

Cape Meares to Yaquina Head

Cape Meares headland exhibits rock and debris fall all along the wave-cut cliffs. Massive basalt is capped by unconsolidated sand at an elevation of about 350 feet; small areas of soil creep disrupt vegetation and contribute to the debris fall from the cliffs. A 300-foot-wide benched slump on the north end of Short Beach, south of the lighthouse, has moved down to the beach. Boulders now outline the landslide toe, since finer slide debris has been removed by waves.

Stacks and wave-cut platforms in the basalt give some protection from wave attack on Cape Meares. This type of protection varies along the cape, but is present to some degree as far south as Oceanside. South of Oceanside, terrace and dune sands are involved in small local slumps. This type of minor movement extends southward to Cape Lookout.

Cape Lookout is a narrow igneous headland jutting 1.75 miles into the sea. Rock and debris falls are common along its sheer cliffs. On the north, at the landward end of the cape, 20-foot-high dune and terrace shifts partially cover basalt. The remainder of the cape has rock falls, with minor soil creep on the slopes above the cliffs. Generally, there is no visible talus from these falls, because rocks fall directly into 40 to 60 feet of water.

A 1,000-foot-wide benched slump is exposed on the south landward end of the headland. South of the cape for one mile, small shifts of terrace material partially conceal sedimentary rock outcrops. Near Camp Meriwether, terrace sands with tree and stump debris compose the sea cliff.

From Camp Meriwether to Sand Lake, there are 40- to 60-foot cliffs of terrace and dune sands. This area, notable for the high dunes extending one mile inland, is retreating by minor dune and terrace slumps. From the end of the dune area southward to Sears Lake, there are no landslides.

Near Sears Lake, one mile south of Tierra del Mar, the coast road cuts through a small slump in deeply weathered siltstone. The slump, having moved down the west face of a small hill, extends to the sea west of the road cut. Judging from the appearance of a 15-foot-deep fracture, part of the hillside broke away at this initial scarp and moved downslope; smaller step-scarps are common above the main scarp.

Sedimentary rocks in the vicinity of this slump dip seaward 5°.

Cape Kiwanda, four miles north of the entrance to Nestucca Bay, is the only major headland composed of sedimentary rock on the northern Oregon coast. Sandstone of the Astoria Formation, which erodes as block fall, constitutes the promontory. Comparison of photographs taken about 1915 with recent pictures suggests that little erosion has taken place on the seaward edge of the cape. Block falls have removed sandstone from the sides of the cape, however, and continue to produce visible erosion of the headland.

Several thin dikes have combined with the joint pattern of the rocks to control the erosion which has resulted in the southwest orientation of the headland. Haystack Rock, 0.5 mile to the southwest, probably offers some protection against waves from the southwest.

From Cape Kiwanda southward along North Kiwanda Beach and Kiwanda Beach, minor sand shifts are evident. For most of the distance low coastline relief and wide beach conditions extend to 0.6 mile south of Neskowin at the north end of Cascade Head.

Cascade Head is a volcanic mass composed of basalt flows, pyroclastic rocks, and sediments of the Nestucca Formation of late Eocene age. The headland has been greatly modified by erosion. Extensive landsliding has taken place in six small embayments that have been eroded into the headland after wave activity removed resistant basalt. Siltstones are now exposed in cliffs behind the beaches. On portions of the headland that are composed entirely of basalt, rock fall is the principal type of mass movement.

Twenty acres of pasture have slumped to the sea in the largest landslide on Cascade Head (Figure 5). This slide is 0.1 mile north of the Salmon River and contributes soil and boulder debris to a narrow crescent beach at the base of the seacliff. The whole feature is about 2,500 feet wide, but consists of two slides partly separated by a dike that diverts the smaller of two movements. Residents of the area report that the main slide occurred in 1934. Trees and low brush now cover the gently-sloping slump bench. The crown scarp, at an approximate elevation of 600 feet, is 8 feet high. A series of sub-parallel fractures, 2 to 6 feet deep, are present up-slope from the crown. The toe of the slide has been eroded by waves, producing a cliff 30 to 60 feet high in the slide debris.

Between the mouth of the Salmon River and the village of Roads End, landsliding takes place along a series of crescent-shaped bays (Figure 6). The bays have been eroded in siltstones and shales of the upper Eocene Nestucca Formation. The points of the crescents consist of more resistant basalt. The bays have developed as a result of slumping of the shales following erosion of the north-trending basalt cap which protected the shales. Lack of vegetation on the slumps indicates that they are active. Rock falls are common in the basalt areas.

From the village of Roads End to Lincoln Beach, terrace and beach sands are involved in small, local shifts. Near Oceanlake (now part of Lincoln City), cliffs of terrace sand on sedimentary rock rise to 50 feet in height. Serious property loss is occurring where residents do not attempt to protect or strengthen the cliff. Debris slumps are continually taking place in Lincoln City, from the former towns of Oceanlake through Delake and Nelscott. Seaward-dipping sandstone crops out near Gleneden and Fogarty Creek Beaches and provides natural planes along which overlying terrace sands are moving as minor slumps.

Figure 7. Riprap at Boiler Bay helps to slow down landsliding and to protect U.S. Highway 101.

Figure 8. Terrace slump near Beverly Beach.

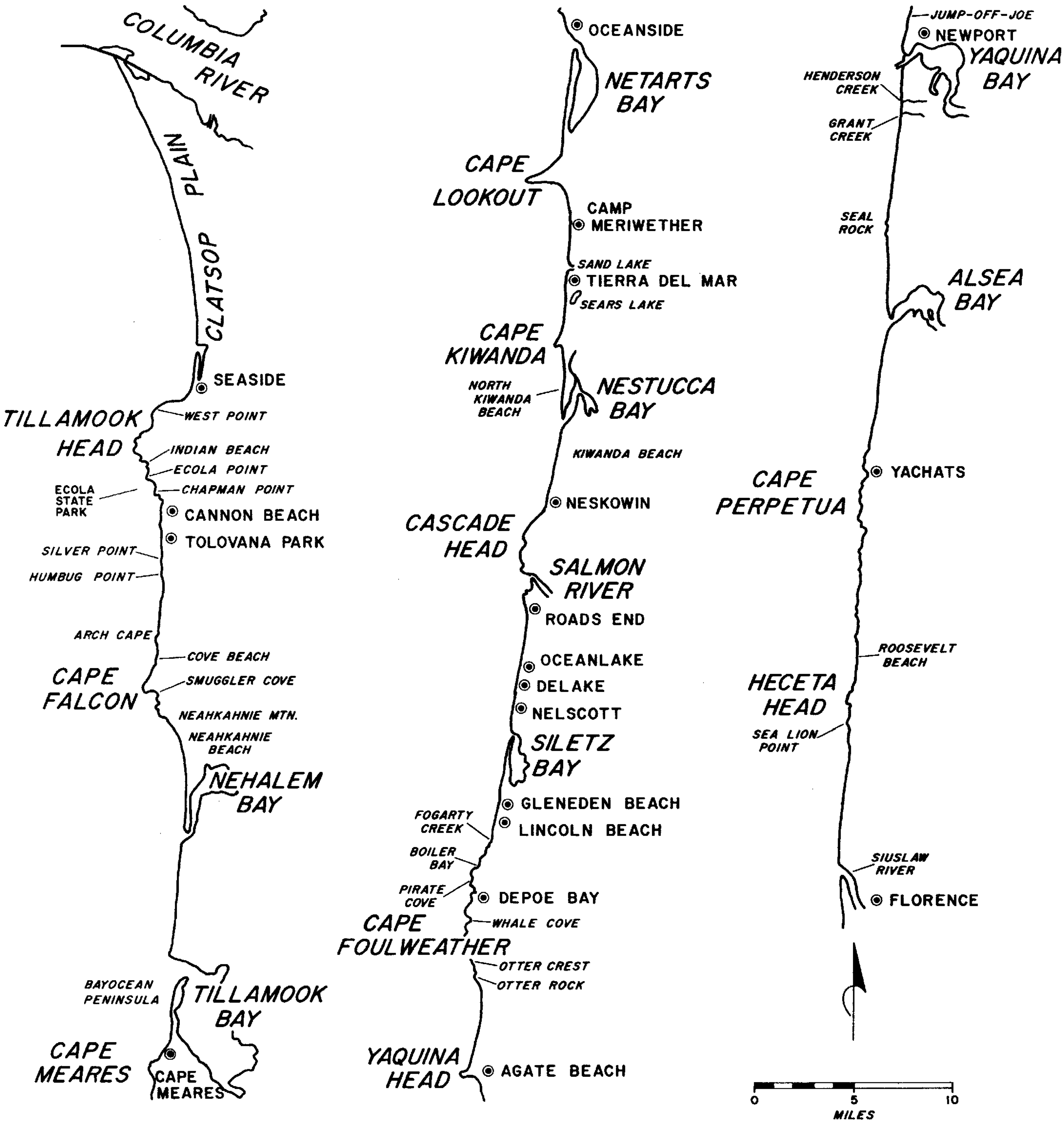
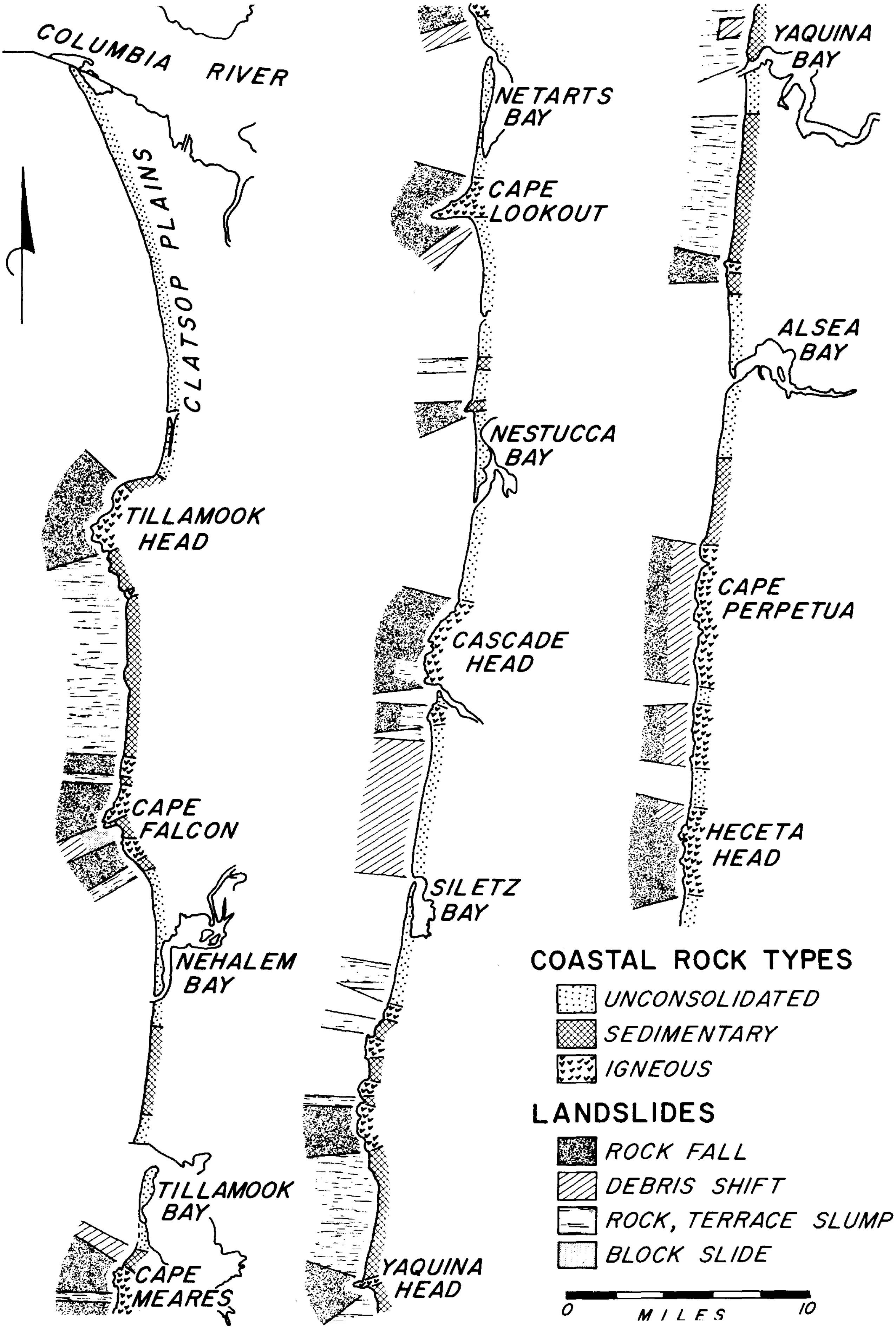


PLATE 1. LANDSLIDE DISTRIBUTION ALONG NORTHERN OREGON COAST.



COLUMBIA RIVER
CLATSOP PLAINS
TILLAMOOK HEAD
CAPE FALCON
NEHALEM BAY
TILLAMOOK BAY
CAPE MEARES
NETARTS BAY
CAPE LOOKOUT
NESTUCCA BAY
CASCADE HEAD
SILETZ BAY
YAQUINA HEAD
YAQUINA BAY
ALSEA BAY
CAPE PERPETUA
HECETA HEAD
COASTAL ROCK TYPES
UNCONSOLIDATED
SEDIMENTARY
IGNEOUS
LANDSLIDES
ROCK FALL
DEBRIS SHIFT
ROCK, TERRACE SLUMP
BLOCK SLIDE
0
MILES
10

Figure 9. Slumping of Astoria Formation and overlying terrace deposits adjacent to north side of Yaquina Head.

Figure 10. Terrace slump in an area of seaward-dipping Miocene sandstones and shales at Newport.

Fishing Rock, a small headland 0.3 mile south of Lincoln Beach, marks the start of Miocene pillow lavas, flow breccias, and tuffs which interfinger with sandstones of the Astoria Formation. For the next 6 miles southward, the Miocene basalts and sandstones are covered by terrace sands. Sedimentary rock is exposed in four coves but is partially protected from direct wave attack by barrier stacks and basalt benches. This is the situation in Boiler Bay, Pirate Cove, part of Depoe Bay, and Whale Cove. In these coves, sedimentary rocks dip 12° to 16° to the southwest. Between the coves, basalt-flow breccias resist erosion and the overlying terrace sands remain in place. At the east end of Boiler Bay, strata under the highway have been weakened by waves. Large basalt blocks have been dumped at the base of this sea cliff to retard landsliding (Figure 7). At Cape Foulweather, south of Whale Cove, basalt forms resistant cliffs with small indentations which have been cut back into overlying terrace sands. The mass movement on Cape Foulweather is primarily block and debris fall.

Yaquina Formation sandstone overlain by terrace sands is exposed in wave-cut cliffs 0.3 mile south of Otter Crest to the beach south of Otter Rock. This material is eroded by block and debris slump. Strata dip 17° to the northwest in this area, but many blocks have slumped and rotated on the surface of rupture, causing tilting of the beds and anomalous bedding attitudes near the beach. Local slumping loosens the rock, and later debris slides roll blocks onto the beach. Slide areas 60 feet wide have resulted where block slumping has been most intense.

From Otter Rock to Yaquina Head, shales, sandstones, and mudstones of the Astoria Formation, which are overlain by unconsolidated terrace sands, are continually slumping down 10- to 80-foot cliffs (Figure 8). Vegetation on cliff edges is disrupted as undercutting of the cliff and terrestrial erosion progresses. Consolidated rock dips 14° to the southwest throughout this area.

Yaquina Head to Heceta Head

On the north end of the village of Agate Beach, severe cliff slumps and subsidence have resulted in extensive property damage. Immediately north of Yaquina Head is a 1,000-foot-long benched debris slump. The bench is well vegetated. Evidence for continued cutting back of the cliff can be seen on the crown edge from a trail over the south side of the bench. Partially coherent blocks of terrace sands have calved off the edge of the slump. Rocks underlying the terrace deposits dip southwest with an average inclination of 14°. Adjacent to Yaquina Head, about one acre of land at the foot of Fossil Street in Agate Beach has been destroyed by cliff-block slumping (Figure 9). A ragged 15-foot-deep crack has opened at the crown where a large block of Astoria Formation and terrace sands have pulled away from the land. This fissure has been widened by erosion. Seaward, blocks become progressively broken and skewed from original attitudes and finally accumulate as debris shift on the beach. Reorientation of the blocks increases seaward as the removal of cliff debris by waves makes the leading edge of the slide less stable and hence prone to further downward movement. Mass movement just north of Yaquina Head is much more severe than erosion in areas of similar lithology and rock attitude within two miles of the headland. Interpretation of U.S. Coast and Geodetic Survey Chart 6056 (1962) shows that underwater contours effecting changes in approaching wave-front directions would greatly concentrate wave energy within 0.3 mile of the headland. Convergence of wave energy is an additional erosional factor near headlands. Basalt rock fall is common to the remainder of Yaquina Head. Some protection is given the headland by offshore basalt remnants.

From Yaquina Head to Yaquina Bay, wave-cut cliffs rise to about 80 feet with debris slumps, rock-terrace slumps, and rock falls dominating mass movement. At Jump-off-Joe, on the north end of Newport, a number of large rock-terrace slumps have abruptly terminated several roads and have moved houses and associated property down and toward the sea. Subsidence of loosely consolidated Pleistocene terrace sands and underlying Tertiary sediments has affected an area 1,000 feet long and 200 feet wide on the north side of the point called Jump-off-Joe and an equivalent area on the south side (Figure 10). Sandy shales and argillaceous sandstones of the Astoria Formation and mudstones of the Nye Formation underlie terrace deposits and dip seaward about 21°. Land movement has been attributed to ground-water lubrication and slippage along bedding planes of the Astoria and Nye (Allen and Lowry, 1944). More than 16 acres of property have been involved in the Newport subsidences.

From Yaquina Bay to Alsea Bay there are three areas where lithology distinctly controls the type of mass wasting. Minor dune-sand slumps occur in the unconsolidated sands two miles south of Yaquina Bay and four miles north of Alsea Bay. Relief is low and the slumps do not materially affect houses or other cultural features. Terrace subsidence and debris shift occur on seaward-dipping mudstone of the Nye Formation about two miles south of Yaquina Bay in the vicinity of Henderson and Grant Creeks. The present slump near Grant Creek is 300 yards long, 200 yards wide, and has an initial crown scarp varying from 6 to 20 feet high (Figure 11). Vegetation is thick on the subsided bench, but hummocky topography is visible, as is the disrupted jackstraw arrangement of trees. A few houses on the crown have not as yet been affected by the movement. From this point to Seal Rock there are continuous minor terrace-debris shifts over seaward-dipping Nye and Yaquina rocks. The rocks dip to the northwest with an average inclination of 14°. Within a mile north and south of Seal Rocks, sea stacks form a solid line about 300 feet from the cliff. The cliff of terrace sand is partially protected from erosion by this line of basalt stacks, but where the stacks are farther apart more intense wave activity acts on the coastline. Spaces in the stacks north of Seal Rock have allowed waves to cut the cliff back 100 feet farther than on the protected cliff to the south. Intermittent protection is continuous to Squaw Creek, one mile south of Seal Rock.

For 6.3 miles south of Alsea Bay there is a little erosion. The terrace is low, averaging about 20 feet high, and some minor slumps occur in unconsolidated sand.

About a mile north of Yachats, the longest basalt outcrop on the northern Oregon coast begins. For 9.8 miles to the southward, late Eocene basaltic rocks form a resistant edge along the coast in the Cape Perpetua area. Unconsolidated terrace sands overlying the basalt are protected from significant marine erosion. The basalt bench receives full impact of the waves, and this greatly reduces erosion of the overlying sand. The basalt is well jointed (Byrne, 1963) and has been eroded along these fractures. Joint-controlled surge channels permit waves to erode the base of the terrace sands, producing local areas of debris slumping. The basalt coastal strip becomes well dissected and terminates 0.4 mile south of Roosevelt Beach. From there to Heceta Head low terrace slumps are common (Figure 12). In the Heceta Head - Sea Lion Point headland area, the basalt mass again crops out. It has sheer cliffs where minor soil or debris creep contributes to headland rock falls.

Figure 11. Large slump south of Newport.

Figure 12. Terrace slumps in the Roosevelt Beach area south of Cape Perpetua.

Summary of Landslide Types and Lithology

Landslides on the Oregon coast occur as the four basic types: slump, slide, fall, and shift. Each type is usually associated with a definite coastal lithology or combination of lithologies. Igneous headlands and the headland material overlying igneous rocks are most susceptible to falls, either rock or debris. The resistant igneous rock is massive, providing few if any bedding planes upon which slopes can develop. Undercutting is slow and, when rocks break off, they fall in tabular masses leaving vertical cliffs. Joints and faults control the erosion of the igneous headlands. These fractures are zones of weakness that are eroded by waves. Evidence for weakening by joints is seen in each headland but is most prominent on the western side of Tillamook Head and along Cape Perpetua.

Sedimentary rocks are involved in each type of landslide. Deep weathering of the sediments weakens the rock and makes the cliffs susceptible to undercutting by the waves. Unloading of the cliff base disrupts equilibrium of the relatively coherent rock mass and slumping occurs. Block slides or "glides" are unusual in the sedimentary sequence, because beds are usually too thin for a separate block to detach and slide. Where sandstone has resisted deep weathering, some slides of tabular bodies on bedding planes have occurred, as on Cape Falcon.

Unconsolidated sands, silts, and gravels of uplifted marine terrace and dune deposits usually have no specific plane of movement and move as debris shifts. Mineral and rock grains, acting as individual particles, provide no firm plane for movement of one mass over another. Slip-face sand movement, resulting in a cone or small fan, is common on dune and terrace faces. However, more often the over-steepened terrace cliffs move as debris shifts.

Landslide Frequency and Rate of Coastal Retreat

Frequency of landsliding on the coast appears to be correlated with high winter waves and increased precipitation. Byrne (1963) graphed the occurrence of major landslides by months of the year as reported in The Newport Journal News (1925-1949) and the Tillamook Headlight Herald (1916-1936). His graph is shown in Figure 13. It is obvious that most landslides occur from late fall to early spring and that the highest frequency of slides is during December and January, the period of major storms. Most of the newspaper articles indicated that sliding occurred during or immediately after extended periods of torrential rains.

Property losses have been extensive in sparsely populated regions of the northern coast. Ecola Park and Cascade Head have undergone considerable alteration. Landsliding has destroyed or disrupted more than 200 acres of land in four separate slides. The 1961 Ecola Park slide moved about 125 acres of recreation land during a two-week period. The slide north of the Salmon River on Cascade Head occurred in 1934, and carried 20 acres of pasture downward to the sea; the noise of the rock movement was heard at that time by a nearby resident. Two other landslides on Cascade Head have each destroyed more than 14 acres of grazing land.

Severe damage to buildings, roads, and utilities has occurred in the village of Cape Meares and in the city of Newport. Reliable maps showing sea-cliff recession have been obtained from Township deed plats in Tillamook and Lincoln Counties (Figure 14, A and B).

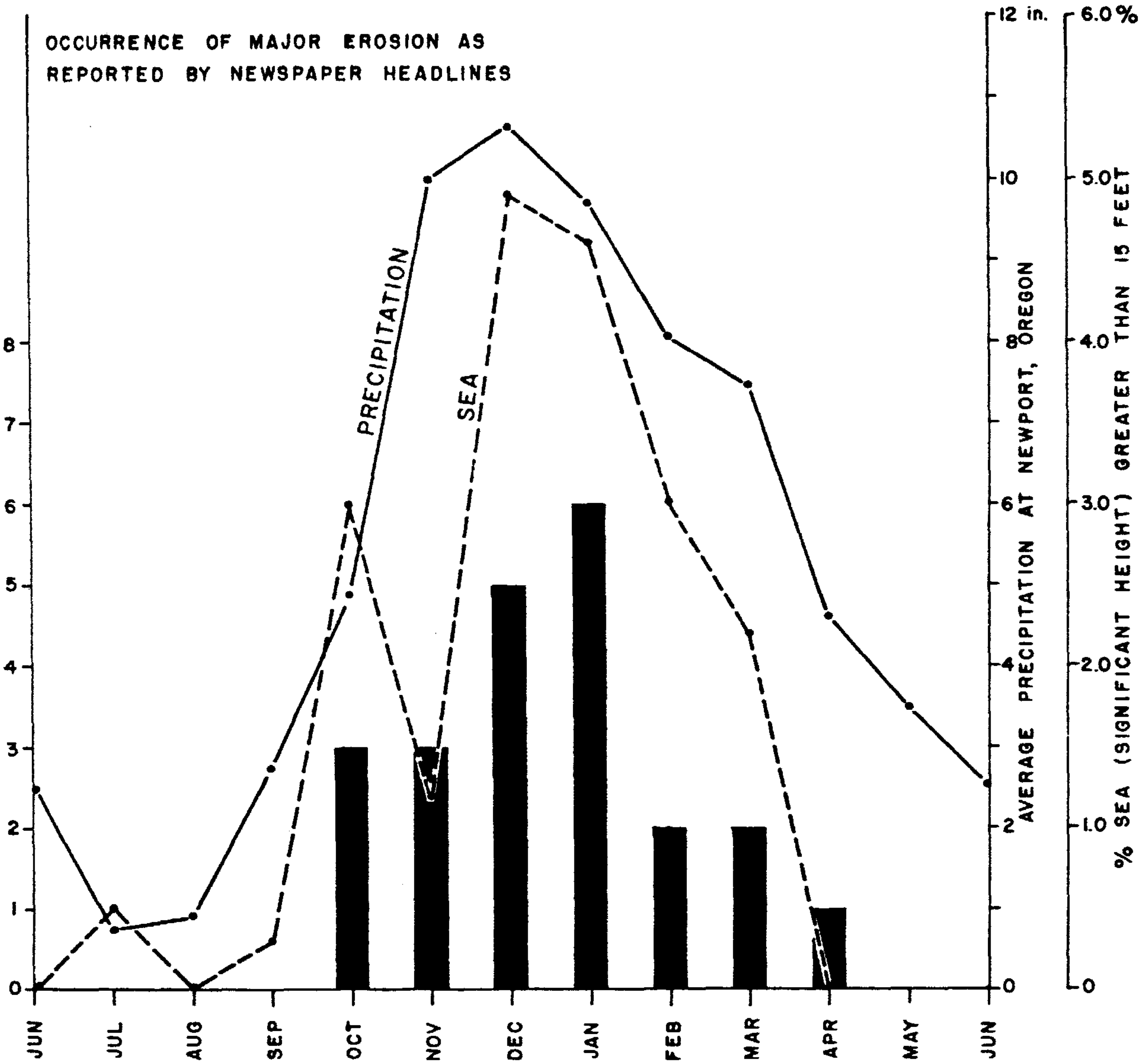


Figure 13. Monthly occurrence of landslides, high seas, and precipitation (after Byrne, 1963).

Coastline erosion in the vicinity of Cape Meares has been affected by jetty construction on the north side of the entrance to Tillamook Bay. This jetty apparently upset equilibrium of sand transport by waves along the coast, causing a starvation of sand in the area south of the jetty. This resulted in the subsequent cut-back of the entire sand and gravel spit including the Cape Meares village area. Dicken (1961) estimated erosion of the southern portion of Bayocean Beach to be about 500 feet from 1939 to 1961. Closer to Cape Meares headland, the coastline is composed of more resistant marine clays and sandstone overlain by terrace sands and angular landslide debris. Here, the coastline was cut back 320 feet between 1939 and 1961. During the winter of 1960-1961, a street at right angles to the coastline in Cape Meares retreated 75 feet, with most of the loss occurring from September to April. Figure 14A shows the retreat of the bluff line from 1953 to 1964 as determined from aerial photographs and field inspection. Minimum coastal retreat in this area has

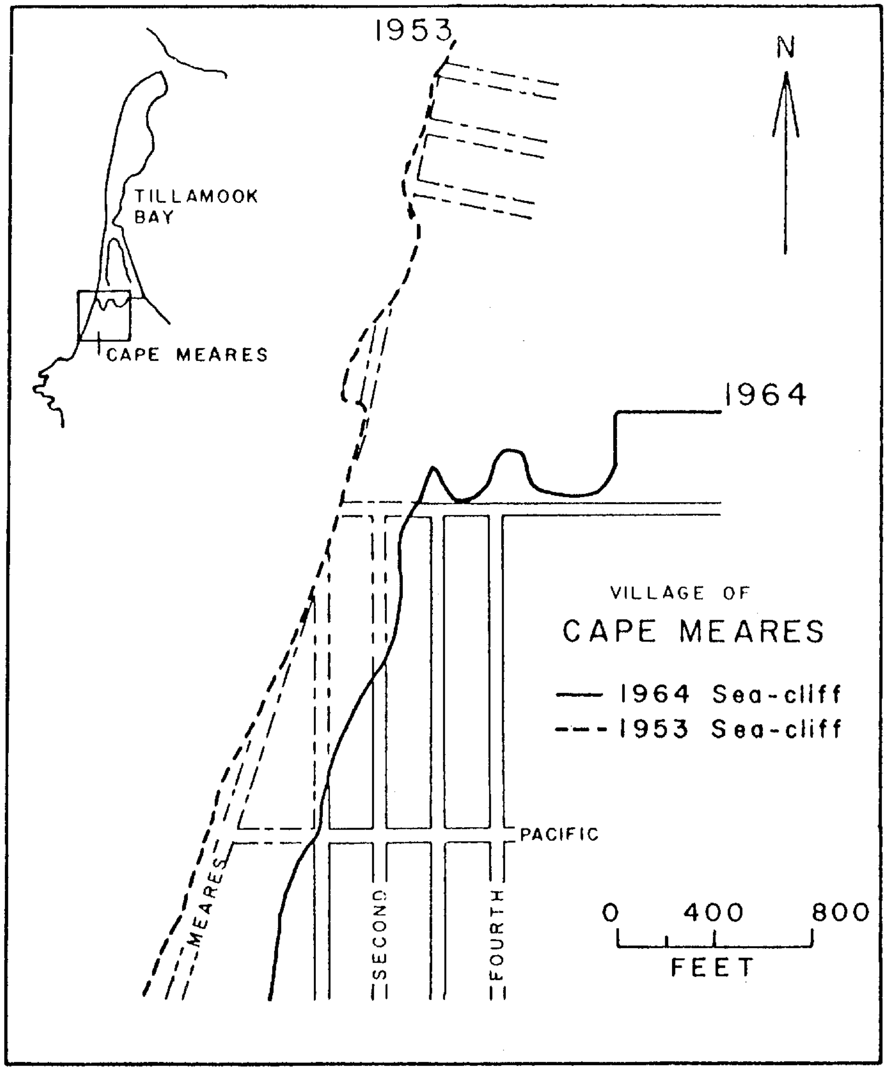


Figure 14A. Coastal retreat at Cape Meares, 1953 to 1964. ↑

Figure 14B. Coastal retreat at Newport, 1902 and 1912 to 1964. →

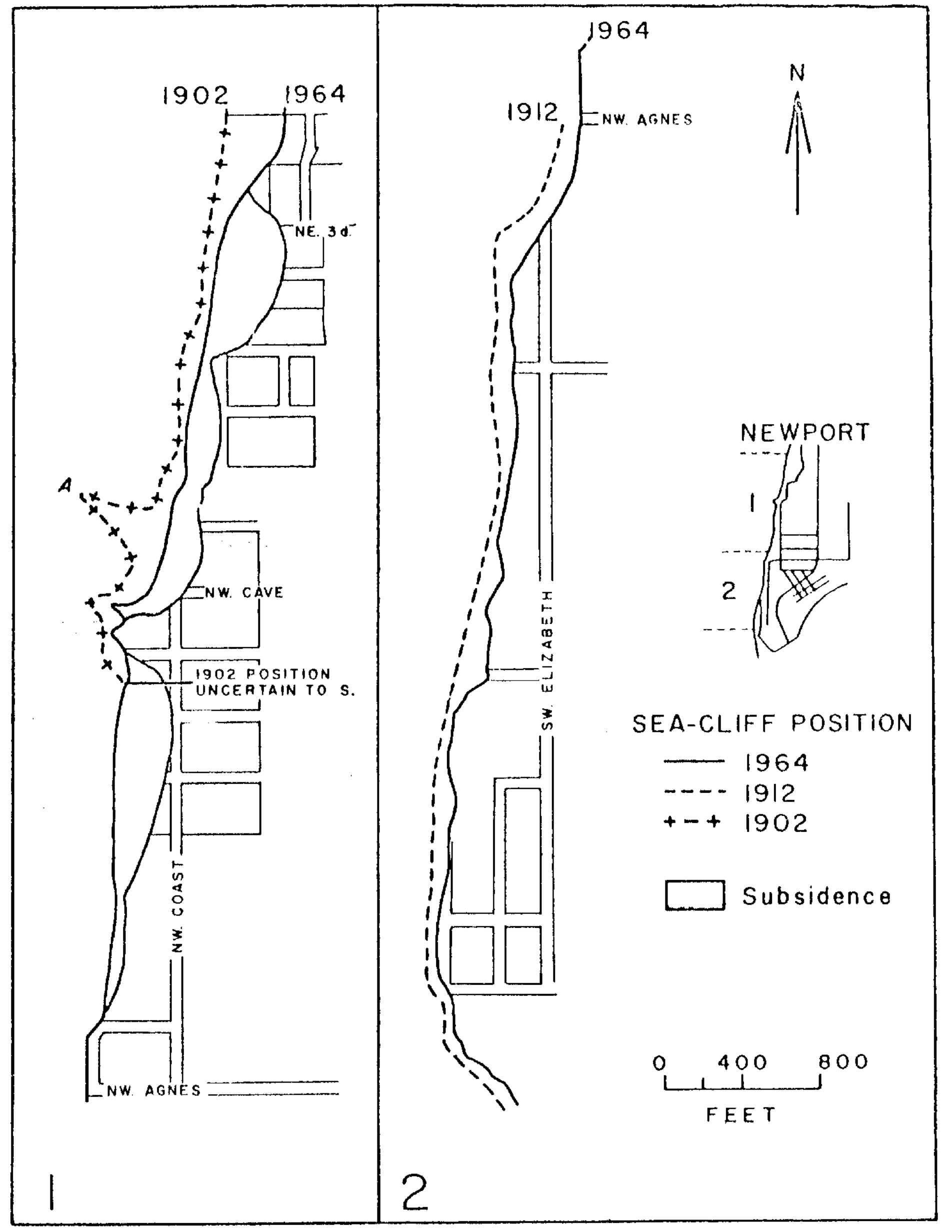


Figure 15. Low-cost preventive measures: riprap and "keep off" signs at Oceanlake (Lincoln City).

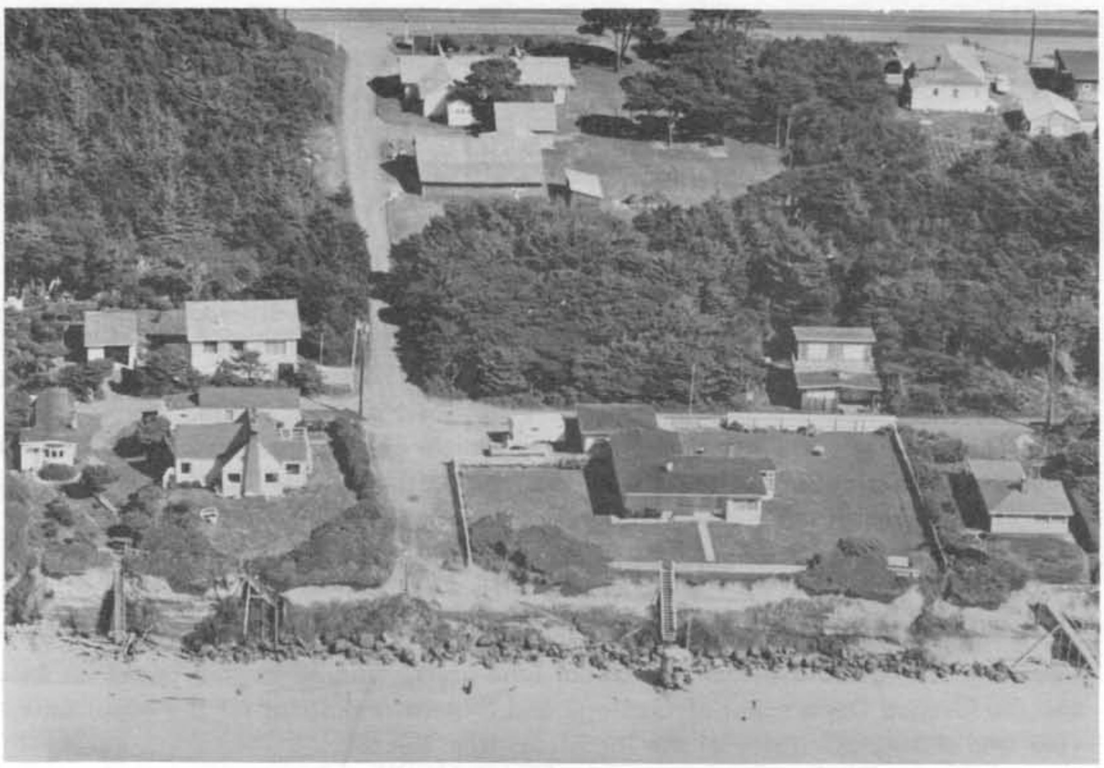


Figure 16. Riprap at base of sea cliff north of Seal Rock.

been 300 feet since 1953. Thus, in this area the average yearly coastal retreat is about 30 feet.

In Newport, coastal retreat has been equally serious (Figure 14B). Historical plat survey maps of 1902 and 1912 were used to indicate former positions of the sea cliff. Retreat of the coastline within the northern half of the city from 1902 to 1964 ranges from 35 to 490 feet. The range is smaller in the southern part, 40 to 220 feet for the period from 1912 to 1964. Thus, here the coast has experienced an average retreat of about half a foot to 8 feet annually.

Landslide Prevention

Total prevention of coastal landslides is an expensive undertaking. Such procedures as rock bolting, construction of complicated drainage systems, retaining walls and sea walls, and buttressing are well beyond the means of the average property owner. However, where limited steps have been taken to retard small but economically damaging slides, the results appear to be well worth the effort.

In Oceanlake and near Seal Rock attempts are now being made to control the undercutting of the terrace material. Basalt boulders piled at the base of the cliffs serve to weight the cliff base and prevent outward movement (Figures 15 and 16). Such riprap also lessens the wave impact on the cliff base by providing a leading edge of resistant material to absorb much of the wave energy.

On U.S. Highway 101 at Boiler Bay, north of Depoe Bay, a successful attempt has been made to prevent waves from undercutting the highway on the east edge of the bay (Figure 7). The entire exposure of Astoria Formation and overlying terrace sand has been covered by riprap. This inexpensive measure has retarded cliff recession and probably has saved a section of the highway.

Grass and low brush planted on slopes hold sand in place and help to prevent rain and runoff from eroding property. On the inhabited slopes of Tillamook Head, property owners who allow brush and grass to flourish have had little trouble with slippage or destruction of stairs or structures on the hillside. Even in very soft terrace sands of Lincoln City, the few attempts at planting to stabilize slopes have helped local erosional problems. Extensive planting of grass on unconsolidated sands along the beach at Salishan is helping to hold steep slopes.

Other preventive measures include terracing and reduction of cliff angle by lowering and leveling the cliff top and dumping extra material in front of the cliff. Wooden rain covers have been built on some cliffs. Warning signs and fences have partially succeeded in protecting cliff faces from public destruction.

Where property owners have remained indifferent to implementation of nominal preventive measures, beach stairways, cottage yards, and even dwellings have tumbled over cliffs. Simple safeguards, however, have more than paid for themselves.

Acknowledgments

Appreciation is expressed to the County Assessors of Tillamook and Lincoln Counties, who made available historical land plats. Thanks go to Richard G. Bowen and the Oregon Department of Geology and Mineral Industries for the opportunity to view and photograph many of the landslides from the air.

This report is based on a master's thesis by William B. North carried out under Office of Naval Research contract NONR 1926 (02).

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NEW RECORD SET IN WORLD MINERAL PRODUCTION

The U.S. Bureau of Mines has announced that world mineral production reached a new high in 1964. On the basis of a detailed study of 65 mineral products, the bureau estimated that production of 43 of them reached new peaks in 1964.

The bureau's appraisal showed that aluminum production in the world was 10.7 percent above its former record of 1963. Production of bauxite increased 9.7 percent. Copper also reached a new world peak in 1964; mining output was 4 percent larger than 1963. Production of zinc and tin rose 9 and 2 percent respectively over 1963, but lead declined 2 percent. World production of steel ingots and castings in 1964 was 13 percent higher than in 1963.

Of the precious metals, gold rose to a new high, more than 4 percent above 1963. Silver production declined about 1 percent in 1964, compared with the previous year.

Against a background of growing world energy requirements, coal remains the chief source of power. However, its proportional share of total energy requirements continued the declining trend which has generally prevailed since the turn of the century. The production of coal increased 3.8 percent over 1963 and petroleum rose 8 percent.

Most of the 23 nonmetallic minerals included in the Bureau of Mines tabulation rose to new production highs in 1964. They were: asbestos, hydraulic cement, diatomite, feldspar, fluorspar, gypsum, magnesite, mica, phosphate rock, potash, pyrites, salt, strontium, sulfur, talc, and vermiculite. (American Mining Congress News Bulletin No. 65-22, Oct. 27, 1965)

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MINING ACTION PENDS IN CONGRESS

<u>H. R. 11711 - Mineral Exploration:</u> Ullman (Ore.). Committee on Ways and Means (a clean bill, substituted by the committee for H. R. 4665). Would allow current deduction of exploration expenditures incurred before development stage, subject to recapture as ordinary income or depletion deduction at producing stage. Committee amendment limits application of bill to deposits within the United States or outer continental shelf, and excludes coal. The committee report is expected in January.

<u>H. R. 10194 - Recordation of Mining Claims:</u> Aspinall (Colo.) (by request of the Interior Department) (Leg. Bull. 65-8, p. 1). Identical to S. 2248 by Senator Jackson (Wash.) (Leg. Bull. 65-7, p. 1). In House Interior Committee; no hearings yet scheduled.

Would require owners of all unpatented mining claims to file a statement with the Secretary of the Interior regarding the location and ownership of their claims. Statements pertaining to claims located prior to enactment would have to be filed with BLM within two years after enactment, and statements relating to locations made after enactment would have to be filed within 90 days following location of the claim. Failure to comply with these requirements within the times specified would terminate the rights of the holder to the mining claim.

Would also require mining claimants to file with the Secretary, within 90 days after the expiration of every annual assessment year, a statement of the assessment work performed during that year. Failure to file such a statement for two consecutive years would result in termination of the mining claimant's rights to the claims involved. (American Mining Congress Legislative Bull. No. 65-10, Nov. 5, 1965)

* * * * *

AMERICAN MINING CONGRESS PASSES RESOLUTIONS

The American Mining Congress passed a number of resolutions on policy statements at its annual meeting, held this year at Las Vegas, Nevada, October 11 to 14. Statements from resolutions on public lands and on gold are given in digest below.

Public lands

Our growing population, expanding economy and modern armament require a constant increase in the supply of minerals and metals. This is the responsibility of the American mining industry. For the mining industry to meet these demands under a free-enterprise system, the public lands of the United States must be freely open to location so that the prospector and engineer can make new discoveries and open new mines.

The law of discovery, as intended by Congress in enacting the mining laws and as interpreted by the contemporaneous decisions of the courts, encouraged the search for and development of new ore deposits. The law of discovery recently has been so far distorted by the office of the Solicitor of the Department of Interior as to discourage rather than encourage this search. And as a result of such an interpretation of the mining laws, the titles of unpatented mining claims have become uncertain. The original concept of discovery, it was continued, should be restored.

The Department of Agriculture and its Forest Service and the Department of Interior and its Bureau of Land Management, and all other governmental agencies dealing with the public lands, were urged to administer their regulations fairly and uniformly, and to formulate and carry out their regulations in a manner which will encourage and not discourage the development of our mineral resources.

Gold

It was urged that immediate steps be taken to stimulate domestic gold production. While the United States' complex monetary problems will not be solved by any probable increase in gold production, nevertheless, since any increment in the gold reserve is in the national interest, the organization recommended enactment of legislation by the Congress of the United States to provide tax incentives or financia assistance payments, or both, to present and potential domestic gold producers to stabilize and insure greater life of existing properties, to reopen closed mines, and to stimulate aggressive search for new gold ore reserves.

It was recalled that a federal financial incentive program activated exploration which led eventually to the creation of a vigorous domestic uranium mining industry, and it was urged that by the same token federal financial assistance payments would lead to revitalization of the gold mining industry in the mining camps of the West.

* * * * *

ANOTHER 7,600 ACRES TO BE WITHDRAWN

The Corps of Engineers, United States Department of the Army, has filed an application for the withdrawal of nearly 4,000 acres of land from all forms of appropriation under the public land laws, including the mining and mineral leasing laws. The land involved lies along Elk Creek, a tributary to the Rogue River in Jackson County. The applicant desires to use the land for flood control, irrigation, hydroelectric generation, and other authorized purposes in connection with the Elk Creek Reservoir Project.

A second withdrawal totalling 3,309 acres has been requested by the Corps in Jackson County. The withdrawal is related to the Lost Creek Reservoir Project on the Rogue River.

Still another withdrawal involves 320 acres in Morrow County for use in connection with the John Day Wildlife Management Area.

* * * * *

WORLD-WIDE SURVEY OF THERMAL SPRINGS PUBLISHED

"Thermal Springs of the United States and Other Countries of the World -- a Summary," by Gerald A. Waring, revised by R. R. Blankenship and Ray Bentall, has been published by the U.S. Geological Survey as Professional Paper 492.

The first part of the 383-page book describes briefly the origin and characteristics of thermal springs in general; presents maps showing their distribution, including a map of Oregon; and tabulates the springs throughout the world by country and geographic area. Information given includes location, temperature, rate of flow, chemical quality, and associated rocks. For Oregon, 126 thermal springs are reviewed. The second part of the paper is devoted to bibliographic references, also arranged geographically.

Professional Paper 492 is for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C., 20402. The price is $2.75 (paper cover).

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ENGINEERING GEOLOGISTS FORM LOCAL CHAPTER

A local chapter of the Association of Engineering Geologists was founded on June 29, 1965, at a meeting held in Portland, Oregon. The AEG is a national organization made up primarily of geologists whose work is related to engineering. There are several classes of membership, depending upon the interest and experience of the member.

Anyone wishing to inquire about the local chapter should contact Douglas A. Williamson, Chairman of the Oregon Section of the AEG, 697 W. 12th Street, Eugene, Oregon, or Paul W. Howell, Membership Chairman, 9130 S. W. Borders Street, Portland, Oregon.

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The ORE BIN
Volume 27, No. 12
December, 1965

WHAT PRICE GOLD?

PART III. The Relief Given to Foreign Gold Mines by Their Governments*

By Pierre R. Hines**

Canada, Australia, the Philippines, South Africa, and other countries have given subsidies or aid to their gold-mining industries. Why hasn't the United States done so, too? The reason is that the executive branch of the Government, particularly the U.S. Treasury, has opposed it, the grounds for its opposition being "...would in our considered and deliberate judgment, disrupt the monetary system upon which not only their [the gold miners'] own livelihood, but also that of all the rest of us depends" (U.S. Congress, 1962, p. 180).

It is not as well known as it should be that the International Monetary Fund has approved the gold subsidies given by the countries mentioned above. Nor has any proof been offered which shows that the livelihood of the gold miners has been harmed, but, on the contrary, certain mining communities have been saved from extinction. The Bretton Woods Agreement provides in Article IV, Sec. 2 (Internat. Monetary Fund, 1948, p. 79-80) "...that the Fund members are prohibited from buying gold at a price above parity plus the prescribed margin. In the view of the Fund, a subsidy in the form of a uniform payment per ounce for all or a part of the gold produced would constitute an increase in price which would not be permissible if the total price paid by the member for gold were thereby to become in excess of parity plus the prescribed margin. Subsidies involving payments in another form may also, depending upon their nature, constitute an increase in price."

Under Article IV, Sec. 4 (a), "each member of the Fund undertakes

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* Part I, "Proposed plans for the improvement of the international monetary system," and Part II, "The official policy of the U.S. Treasury upon international monetary systems," were published in the September, 1965 ORE BIN.

** Mining Engineer, Portland, Oregon.

to collaborate with the Fund to promote exchange stability, to maintain orderly exchange arrangements with other members, and to avoid competitive exchange alternatives. Subsidies on gold production regardless of their form are inconsistent with Article IV, Sec. 4 (a) if they undermine or threaten to undermine exchange stability. This would be the case, for example, if subsidies were to cast wide-spread doubt on the uniformity of the monetary value of gold in all member countries."

"Subsidies which do not directly affect exchange stability may, nevertheless, contribute directly or indirectly to monetary instability in other countries and hence be of concern to the Fund." (Internat. Monetary Fund, 1948, p. 79-80). The IMF further states: "The International Monetary Fund has a responsibility to see that the gold policies of its members do not undermine or threaten to undermine exchange stability. Consequently, every member which proposes to subsidize the production of gold is under obligation to consult with the Fund on the specific measures to be introduced."

It is possible to give subsidies to gold producers which do not conflict with the sections quoted above from the Bretton Woods Agreement and to secure the approval of the International Monetary Fund. The measures which have been approved by the IMF are found in its annual reports from 1948 on to the present day. The gold subsidies of various countries now in effect follow.

Canada

Canada's assistance to its gold industry is the best example of a gold subsidy approved by the International Monetary Fund. It is based upon the cost to each gold mine of producing an ounce of gold in excess of Can$26.50. Thus it is not a "uniform" or flat gold price.

Sixty-five Canadian gold mines received a subsidy in 1962 (Table 1) and these mines produced 56.7 percent of Canada's total gold (Table 2). Gold mines which were not eligible for a subsidy produced 28.3 percent. Gold which was a by-product of base-metal mines was 15.0 percent and was not eligible for assistance. The total cost to Canada for 1962 was Can-$14,700,000 for a total production of about Can$146,000,000. Canada has assisted its gold-mining industry since 1948. In doing so, it has saved many communities, some with as many as 25,000 inhabitants, from becoming ghost towns.

A mine to be eligible to receive a gold subsidy must fulfill the following basic conditions (Internat. Monetary Fund, 1948, p. 79-80; Dept. of Mines and Tech. Surveys, Ottawa, Canada, 1964):

1. The value of the gold produced must be 70 percent or more of

TABLE 1. Assistance to Canadian Gold Mines, Distribution by Costs, 1962*

Cost per Ounce	Number of Mines	Gold Production (oz.)	Percent of Total Production	Assistance Payable**	Percent of Total Assistance Payable	Assistance Payable per Ounce Produced**
A. Lode Gold Mines						
$20.51 to 30.00	1	99,829	4.21	$ 137,689.40	0.94	$ 1.37
30.01 to 35.00	5	461,847	10.48	1,396,222.68	9.50	3.02
35.01 to 40.00	13	1,088,070	45.90	6,594,019.77	44.86	6.06
40.01 to 45.00	10	408,704	17.24	3,620,077.69	24.63	8.86
45.01 and more	13	259,997	10.97	2,671,471.56	18.18	10.27
	42	2,318,447	97.80	14,419,481.10	98.11	6.22
B. Placer Gold Mines	23	52,085	2.20	278,460.31	1.89	5.35
Total	65	2,370,532	100.00	$14,697,941.41	100.00	(average) $ 6.20

* Dept. of Mines & Tech. Surveys, 1964, p. 16.
** Canadian dollars varied between $37.00 and $38.00 per ounce.

the total value of the output of the mine.

2. The mine or operation must produce at least 50 troy ounces in a designated year.
3. Ore reserves of commercial significance must be developed and there must be a possibility of attaining production of gold on a commercial basis within a reasonable time.

Other requirements are:

The cost of production per ounce of gold, computed on all ounces of gold produced from the mine during the designated period, must exceed Can$26.50. Assistance payments are made only for those ounces of gold produced from the mine during the designated period which are:

a. Sold in the form of bullion to the Royal Canadian Mint by the operator; or

b. Sold in the form of ore or concentrate to a domestic smelter, provided the smelter operator certifies that a number of ounces equivalent to those paid for by the smelter have been sold to the Royal Canadian Mint as soon as is practical after the shipment of the ore or concentrate and the separation of the gold therefrom; or

c. Exported and sold in the form of ore or concentrate to a foreign smelter.

Quoting from Canada's report on the administration of the Emergency Gold Mining Assistance Act, "The amount of assistance payable to the operator of a gold mine is computed under the current formula by adding 25 percent to the product of the rate of assistance and the number of assistance ounces. The number of assistance ounces is two-thirds of the total number of ounces produced in the calendar year. The rate-of-assistance factor is two-thirds of the amount by which the average cost of production per ounce of gold for the calendar year exceeds Can$26.50. The amount of assistance per ounce increases as the average cost of production per ounce increases from Can$26.50 to Can$45.00. A maximum rate of assistance of Can$12.33 per ounce specified in the Act has the effect of precluding an increase in the amount of assistance as the average cost of production rises above Can-$45.00."

The average cost of gold eligible for assistance from gold mines in 1962 was Can$37.70 and the average assistance was Can$6.20 an ounce.

The Canadian Gold Assistance Act was extended to 1967. The new Canadian legislation contains provisions under which new lode gold mines commencing production after June 30, 1965 will be eligible for assistance only if the mine provides direct support for an existing gold-mining community.

TABLE 2. Canadian gold production in 1962.

	Ounces	Percent
Gold eligible for assistance produced from gold mines	2,370,532	56.7
Gold not eligible for assistance produced from gold mines	1,182,049	28.3
Gold not eligible for assistance produced as a by-product from base-metal mines	625,815	15.0
Total gold produced	4,178,396	100.0
Approximate value: Can$146,000,000		

Australia

The Australian Government introduced a plan in October 1954 (Internat. Monetary Fund, 1955, p. 94), whereby certain gold producers whose annual output exceeded 500 ounces and who satisfied the conditions prescribed would be eligible during financial years 1954-55 and 1955-56 for a subsidy per fine ounce equal to three-quarters of the excess cost of production over A£13 10s ($30.24) provided that the subsidy in not any case exceeded A£2 ($4.48) per ounce; and producers whose annual output is less than 500 ounces would be eligible at a flat rate subsidy of A£1 10s ($3.36) per ounce. The flat rate subsidy for small producers was adopted for reasons of administrative convenience in view of their large numbers and of the possibility of imperfections in their records.

Australia increased its gold subsidy in 1958 (Internat. Monetary Fund, 1958, p. 145). The maximum expenditure on mine development in ascertaining costs of production for subsidy purposes was also raised from A£3 10s ($7.84) to A£5 5s ($11.76). Australia again raised the subsidy in 1959; for producers whose output was more than 500 ounces the maximum rate became A£3 5s ($7.28), and for small producers not exceeding 500 ounces per annum A£2 8s ($5.38). This amendment did not change the basic structure for a subsidy. The program was extended for three years from June 30,

1959. The flat rate was extended to producers whose output did not exceed 1,075 ounces per annum. The Australian gold subsidy was again extended from June 30, 1962 to June 30, 1965.

The Philippines

The Philippine Government gave subsidies to gold producers first in 1954. They were made through the exchange system and were allowed to expire in 1957 (Internat. Monetary Fund, 1955, p. 94; 1958, p. 144). The Philippine Republic (Internat. Monetary Fund, 1962, p. 104) in 1961 introduced direct subsidies to gold producers. All producers were classified into categories - marginal and overmarginal - depending on whether or not their net profits fell short of "base profits" which are calculated separately for each mine. In order to be eligible for the subsidy, gold producers are requested to sell their entire output to the Central Bank at the official price, which is defined as the peso equivalent to U.S. $35.00 an ounce or other price set by the Government. The maximum subsidy, in addition to the official price, is ₱65 per ounce for marginal producers and ₱50 an ounce for overmarginal producers. However, the total amount received is not to exceed ₱170 an ounce for marginal producers and ₱155 an ounce for overmarginal producers (on June 30, 1962 the approximate dollar figures were $17 and $13, and $44 and $40 respectively).

A change in the method of calculating the official price was made in January, 1962 (Internat. Monetary Fund, 1963, p. 180-181), as a result of the inauguration of floating exchange rates. While the rate of the gold subsidy remains the same, at ₱65 and ₱50 per ounce for marginal and overmarginal producers, the total amount of the official price plus the subsidy cannot exceed ₱200 or fall below ₱160 per ounce of gold for both marginal and overmarginal producers (at the free rate the approximate equivalents of these figures are $17 - $13, and $51 - $41 respectively. Assurances were given that if, at any time, the exchange rate moved to a point at which a uniform premium price for gold would seem likely to arise contrary to the terms of Article IV, Sec. 2 of the Fund Agreement and the Fund's statement on gold subsidies, the Government would be prepared to adopt appropriate corrective measures after consultation with the Fund.

South Africa

South Africa gave assistance to certain marginal gold mines to meet the cost of pumping water from interconnected workings for one year through June , 1964, and this was extended another year (Internat. Monetary Fund, 1964, p. 109). These marginal mines would have had to abandon substantial tonnages of ore without further assistance in the form of unsecured loans guaranteed by the State to cover working losses up to a maximum of 10 percent of revenue, as well as for certain capital expenditures approved by the Government Mining Engineer, for example for shaft sinking, major development, and the purchase of items such as refrigeration or compressed air plants.

Others

Colombia (Internat. Monetary Fund, 1955, p. 94) in 1955 gave a subsidy of Col$20 (20 pesos, $10.25 at that time) to small gold producers and pan miners producing not more than 20 ounces a month.

"The United Kingdom (Internat. Monetary Fund, 1964, p. 109) consulted the Fund on behalf of Southern Rhodesia with regard to an Act approved by the Government of Southern Rhodesia on December 30, 1963, which provides for the granting of financial assistance to potentially economic gold mines in Southern Rhodesia during the period September 1, 1963 to August 31, 1968. These mines are those from which gold is being or will be mined at a loss, but from which gold may, at some future time, be mined at a profit. The Minister of the Treasury has discretion both to eligibility of mines and the amount of any proposed financial assistance."

The above subsidies and incentives are well known to the U.S. Treasury Department. Dr. Leland Howard, Director of the Office of Gold and Silver Operations of the Treasury, presented a memorandum at the U. S. Senate Hearings (U.S. Congress, 1962, p. 172-175) on S.J. Res. 44* on March 15 to June 8, 1962 which covers the subject thoroughly. It is clear that the International Monetary Fund will not approve a "uniform" subsidy per ounce of gold. It is equally clear that the International Monetary Fund will approve subsidies in certain forms. The opposition of the U.S. Treasury has never been based on the fact that the proposed subsidy would not be approved by the International Monetary Fund. Instead, the Treasury has relied upon dogmatic statements without supporting argument.

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* The Hearings before the Subcommittee on Minerals, Materials, and Fuels of the Committee on Interior and Insular Affairs, United States Senate 87th Congress, Second Session, on S.J. Res. 44, March 15 and June 8, 1962. U.S. Government Printing Office, Washington 82666, 1962. It will be referred to as S. J. Res. 44, 1962.

Bills Introduced in Congress

Many bills designed to assist the gold-mining industry have been introduced in Congress since the end of World War II. They were all defeated by the U.S. Treasury, no matter in what form they were drawn. Nothing can be gained by repeating all of them here. One will be sufficient, the Hearings on S. J. Res. 44, 1962. It is a large document containing 248 pages. Fifteen Senators appeared or filed statements. The Departments of the Interior and State and the Bureau of the Budget all supported the Treasury Department in opposition to the Bill. The Bureau of the Budget's reason for disapproving it was, "The Bill is regarded as an undesirable approach to the basic problem of the balance of payments." Charles Merrill, Chief of the Division of Minerals, Bureau of Mines, deferred to the Treasury Department with respect to the monetary aspect and bowed out without committing himself.

The gold-mining industry presented an enormous amount of testimony, reports, articles, and statements to provide a thorough set of facts on the condition of the industry. One economist appeared for the gold-mining industry and qualified himself as having had experience in money, banking, and finance, both in governmental and private work. His most interesting statement follows (U.S. Congress, p. 146):

"These aspects of the gold question, however, lie in the field of monetary considerations and since monetary legislation is beyond the purview of this committee, I will confine my comments to one aspect of the operation of the Government monopoly which might be the subject or recommendation for legislation by your committee."

This quotation is worth discussing further. It brings up several questions.

1. Is the price of newly mined gold a monetary or a mining-industry production problem?
2. If it is a monetary problem, is it a domestic or an international one?
3. If it is not a mining-industry production problem, then to whom should the gold-mining industry appeal for assistance?

If the Treasury can oppose assistance to the gold-mining industry on the ground it is a monetary matter, why can't it be disputed on the same basis? Recognized monetary authorities do not agree upon the price for gold. Mr. Merrill in his short statement said as follows: "The Department of the Interior recognizes the dual nature of this problem, the monetary and the technical. The Department defers to Treasury with respect to its monetary aspect." (S.J. Res. 44, 1962, p. 216)

Gold does have dual qualities, one as a metal newly mined and refined for market. The other is as money, but it does not become money until it is legally declared so and delivered to the proper governmental agency. The gold-mining industry does not mine money - it mines gold.

1. If one agrees that the price of gold is a monetary problem, then on which one of these many plans to reform the international payments system is the appeal to be based? Which one will be picked as the right one? As the first part of this review shows, help for gold from the U.S. monetary authorities is doubtful.

2. Whether the subsidy or incentive granted to the gold-mining industry is a domestic or an International Monetary Fund decision depends upon the word "uniform." Article IV, Sec. 2 of the Bretton Woods Agreement stresses "a uniform payment per ounce for all or a part of the gold produced would constitute an increase in price which would not be permissible." Uniform is used by the International Monetary Fund in the sense of "the same or alike." A graduated price based on the cost of producing an ounce in the case of a particular mine is permissible as in the case of Canada's assistance, while a uniform or flat price of, for instance, $70.00 an ounce to all gold mines regardless of cost of producing an ounce is not permissible. In any case, the International Monetary Fund's approval is necessary, according to established agreement.

3. It is certain that an act to pay a subsidy or provide an incentive to the gold-mining industry could be drafted which would meet the approval of the International Monetary Fund - one which also would pass the Senate and House if it were cleared by the Administration or classified as not monetary legislation. Where monetary and fiscal policies - both domestic and international - are involved, it is not sufficient to take up a gold subsidy or an increase in the price of gold with a single Senate Subcommittee such as the one for Minerals, Materials, and Fuels.

The Report of the Commission upon Money and Credit (Commission on Money and Credit, 1961) gives some excellent advice upon how legislation is enacted in Washington. The section entitled "An Organizational Focus" (p. 264-268) is a practical guide on how to introduce a Bill in Congress. A single approach will not do. The gold-mining industry should present its case to several of the following committees and agencies: the President's Council of Economic Advisers; the National Advisory Council on International Monetary and Financial Policies; the Joint Economic Committee; the Subcommittee on Monetary and Fiscal Policies; and the Senate Banking and Currency Committee.

The President's Council of Economic Advisers: Gardner Ackley is chairman of this three-man board which reports directly to the President. It is now making a study of steel prices for him. The price of gold is in the same classification as the price of steel and in several respects of equal importance. It is logical to present the gold-mining industry's case if for nothing else than a ruling as to where its case should be heard and decided.

The National Advisory Council on International Monetary and Financial Policies (Bell and Spahr, 1960, p. 149): This council is made up of the Secretaries of the Treasury, State, and Commerce, and the Chairman of the Board of Governors of the Federal Reserve System and of the Board of Trustees of the Export-Import Bank. Foreign transactions in finance, exchange, or monetary affairs come under its jurisdiction. Whatever the outcome, the economic facts of the gold-mining industry should be placed before this council.

The Joint Economic Committee: This committee is made up of seven Senators and seven Congressmen who are drawn from ranking members of related committees. It differs from other Congressional committees in that it studies problems in the field of economic policy and makes reports but does not introduce bills.

Joint Committee upon the Economic Report: The annual Economic Report of the President is criticized and analyzed by this committee in an economic report of its own. This committee has a Subcommittee on Monetary, Credit, and Fiscal Policies.

Senate Banking and Currency Committee: This committee deals with a broad range of subjects, including the affairs of the International Monetary Fund. If the committee decided the price of newly mined gold was not a monetary matter and referred it to the Committee of Interior and Insular Affairs, it would handicap the Treasury Department in its opposition to any assistance to the gold-mining industry.

How should legislation for obtaining relief for the gold-mining industry be handled: It should not be referred to a single committee or agency, because of the dual nature of gold. The legislation should be co-ordinated by a senior Senator from a gold-producing state - a Senator who is thoroughly familiar with the subject and is sympathetic towards the gold-mining industry, one who has served long enough to know the strategy of securing attention and action. It should be taken up also with the Executive branch and the shackled position of the gold-mining industry explained. Congress eventually will write the legislation, but not without prodding and urging from all forces.

References for Part III

Bell, J. W., and Spahr, W. E., 1960, A proper monetary and banking system for the United States: New York, The Ronald Press, p. 149.

Commission on Money and Credit, 1961, Money and Credit: Report, Englewood Cliffs, N. J., Prentice-Hall, Inc.

Dept. of Mines & Tech. Surveys, 1964, Report on the administration of the

Emergency Gold Mining Assistance Act, year ended March 31, 1964: Ottawa, Canada, p. 16.
Internat. Monetary Fund, 1948, Ann. Rept., Appendix II, p. 79-80.
Internat. Monetary Fund, 1955, Ann. Rept., p. 94.
Internat. Monetary Fund, 1958, Ann. Rept., p. 144-145.
Internat. Monetary Fund, 1962, Ann. Rept., p. 104.
Internat. Monetary Fund, 1963, Ann. Rept., p. 180-181.
Internat. Monetary Fund, 1964, Ann. Rept., p. 109.
U. S. Congress, Senate Subcommittee on Minerals, Materials, and Fuels of the Committee on Interior and Insular Affairs, 1962, S. J. Res. 44, 1962, Hearings: U. S. 87th Cong., 2nd Sess., p. 146, 172-175, 180, and 216.

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AIME CONFERENCE SCHEDULED FOR 1966

Plans are being completed for the 1966 Pacific Northwest Minerals and Metals Conference to be held at the Olympic Hotel in Seattle on April 21 and 22. The conference is sponsored by the North Pacific Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., and the Puget Sound Chapter of the American Society for Metals. The two-day meeting will feature papers on exploration and geology, mining, minerals processing, nuclear explosives, extractive metallurgy, and physical metallurgy.

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WATERS TO DELIVER FEBRUARY 1966 CONDON LECTURES

Dr. A. C. Waters, Chairman of the Department of Geology at the University of California at Santa Barbara, will come to Oregon in February, 1966 to deliver the Condon Lectures. Dr. Waters, a well-known authority on the geology and volcanology of Oregon, will give two lectures on the timely subject of "Moon Craters and Oregon Volcanoes." He will speak first at the University of Oregon in Eugene February 8 and 10; then at Oregon State University in Corvallis February 15 and 17; and, finally, at the Portland State College auditorium February 22 and 24 at 8:00 p.m. Condon Lectures are designed especially for the layman interested in results of scientific research. The public is invited to attend. There is no admission charge. At a later date, Dr. Waters' lectures will be adapted for publication, as previous Condon Lectures have been.

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LIBRARY AUGMENTED BY REPORTS ON OREGON GEOLOGY

Listed below are the publications, open-file reports, and unpublished theses concerned with Oregon's geology and mineral resources that were added to the Department's library during 1965. The lists do not include papers published in trade magazines and technical journals. Although the listed reports are not available for loan, anyone wishing to consult them is welcome to do so at the Department's Portland office.

United States Geological Survey:

Bailey, E. H., and Smith, R. M., 1965, Mercury - its occurrence and economic trends: U. S. Geol. Survey Circular 496.

Blank, R.H., Jr., 1965, Southwest Oregon gravity data: U.S. Geol. Survey open-file rept.

Bromery, R. W., 1965, Aeromagnetic map of the Albany-Newport area, Oregon, and its geologic interpretation: U.S. Geol. Survey Geophysical Investigations Map 481.

Goddard, E. N., Chairman, North American Geol. Map Committee, 1965, Geologic Map of North America: U.S. Geol. Survey.

Hart, D. H., and Newcomb, R. C., 1965, Geology and ground water of the Tualatin Valley, Oregon: U.S. Geol. Survey Water Supply Paper 1697.

Hogenson, G. M., and Foxworthy, B. L., 1965, Ground water in the east Portland area, Oregon: U.S. Geol. Survey Water-Supply Paper 1793.

Phillips, K. N., Newcomb, R. C., Swenson, H. A., and Laird, L. B., 1965: Water for Oregon: U.S. Geol. Survey Water-Supply Paper 1649.

Price, Don, Hart, D. H., and Foxworthy, B. L., 1965, Artificial recharge of ground water in Oregon and Washington, 1962: U.S. Geol. Survey Water-Supply Paper 1594-C.

Walker, G. W., and Repenning, C. A., 1965, Reconnaissance geologic map of the Adel quadrangle, Lake, Harney, and Malheur Counties, Oregon: U.S. Geol. Survey Misc. Geol. Invest. Map I-446.

Waring, G.A. (revised by Blankenship, R.R. and Bentall, Ray), 1965, Thermal springs of U.S. and other countries of the world - a summary: U.S. Geol. Survey Prof.Paper 492.

Wayland, R. G., 1965, The correlation of coal beds in Squaw Basin and part of Eden Ridge, T. 33S., R. 11W., southwestern Oregon: U.S. Geol. Survey open-file report.

United States Bureau of Mines:

Fulkerson, F. B., and Gray, J. J., 1965, Economic trends in the Pacific Northwest aluminum mill-products industry: U.S. Bureau of Mines Inf. Circ. 8267.

Kauffman, A. J., Jr., and Hold, D. C., 1965, Zircon: A review, with emphasis on West Coast resources and markets: U.S. Bureau of Mines Inf. Circ. 8268.

Kingston, Gary A., 1964, Iron and steel scrap in the Pacific Northwest: U.S. Bureau of Mines Inf. Circ. 8243.

U. S. Bureau of Mines, 1965, Mercury potential of the United States: U.S. Bureau of Mines Inf. Circ. 8252.

Oregon Division of Planning and Development:

Olcott, G. W., 1965, Aggregate and rock sites, Mid-Columbia planning study: State of Oregon Dept. of Commerce, Division of Planning and Development.

Oregon Department of Geology and Mineral Industries:

See: List of Available Publications appearing on back cover of The ORE BIN.

Washington Department of Conservation:

Mackin, J. H., and Cary, A. S., 1965, Origin of Cascade Landscapes: Washington Div. of Mines and Geology Inf. Circ. 41.

Newcomb, R. C., 1965, Geology and ground-water resources of the Walla Walla River basin, Washington-Oregon: Washington Div. of Water Resources Water-Supply Bull. No. 1.

Thorsen, G. W., 1964, Mineralogy of black sands at Grays Harbor, Wash.: Washington Div. of Mines and Geology Rept. Invest. 23 (similar deposits in Oregon).

Idaho Bureau of Mines and Geology:

Savage, C. N., 1965, Economic geology of carbonate rocks adjacent to the Snake River south of Lewiston, Idaho: Idaho Bureau of Mines and Geology Mineral Res. Rept. 10.

Special Research Studies:

Dott, R. H., Jr., 1965, Mesozoic-Cenozoic tectonic history of the southwest Oregon coast in relation to cordilleran orogenesis: (submitted for publication to Journal of Geophysical Research).

Sceva, Jack E., 1965, A reconnaissance of the ground-water resources of the Hood River valley and the Cascade Locks area, Hood River County, Oregon: Oregon State Engineer, unnumbered report, May 1965.

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Chiburis, Edward F., 1966, Crustal structures in the Pacific Northwest states from phase-velocity dispersion of seismic surface waves: Oregon State Univ. (Oceanography) doctoral dissertation.

Forth, Michael, 1965, Geology of the southwest quarter of the Dayville quadrangle (Crook County), Oregon: Oregon State Univ. master's thesis.

Glenn, Jerry Lee, 1965, Late Quaternary sedimentation and geologic history of the north Willamette Valley, Oregon: Oregon State Univ. doctoral dissertation.

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Johnson, Wallace, R., 1965, Structure and stratigraphy of the southeast quarter of the Roseburg 15' quadrangle, Douglas County, Oregon: Univ. Oregon master's thesis.

Larson, Edwin Eric, 1965, The structure, stratigraphy, and paleomagnetics of the Plush area, southeastern Lake County, Oregon: Univ. Colorado doctoral dissertation.

Maddox, Terrance, 1965, Geology of the southern third of the Marcola quadrangle, Oregon: Univ. Oregon master's thesis.

Patterson, Robert L., 1965, Geology of part of the northeast quarter of the Mitchell quadrangle, Oregon: Oregon State Univ. master's thesis.

Rinehart, Verrill Joanne, 1964, Investigation of 12 earthquakes off the Oregon and northern California coasts: Oregon State Univ. (Oceanography) master's thesis.

White, Willis H., 1964, Geology of Picture Gorge quadrangle (Wheeler and Grant Counties): Oregon State Univ. master's thesis.

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STEENS MOUNTAIN REGION MAPPED

"Reconnaissance geologic map of the Adel quadrangle, Lake, Harney, and Malheur Counties, Oregon," by George W. Walker and Charles A. Repening, has been published as Misc. Geol. Invest. Map I-446 by the U. S. Geological Survey. This is the second in a series of Oregon geologic maps to be issued at this scale (1 inch equals approx. 4 miles) on AMS sheets, preparatory to publication of the eastern half of the State Geologic Map.

The report covers the geology of a large area of southeastern Oregon from Hart Mountain on the west to the Trout Creek-Sheepshead Mountains on the east (lat. 118° - 120°W., long. 42° - 43°N.). This part of Oregon lies within the Basin-Range province of the western United States, and there are several excellent examples of fault-block mountains to be seen within the quadrangle. Chief among these is Steens Mountain, which rises to a height of 9,670 feet at its highest point on the rim.

The oldest rocks in this area crop out along the base of the Pueblo Mountains and are Late Paleozoic and Mesozoic metamorphosed sedimentary and volcanic rocks intruded by granodiorite and quartz diorite. The rest of the rocks in the Adel region are continental sediments and volcanics of Oligocene(?) age or younger.

Copies may be obtained from the U.S. Geological Survey, Federal Center, Denver, Colo. 80225. The price is 75 cents.

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U.S.G.S. PUBLISHES NEW MAP OF NORTH AMERICA

The U.S. Geological Survey has recently published a new geologic map of North America which replaces the 1946 map by the Geological Society of America. This map is the result of more than 10 years of effort, with many individuals and organizations contributing.

The map has a scale of 1:5,000,000 (approximately 1 inch to 80 miles), and covers almost 23,000,000 square miles of the earth's surface from the northern tip of Greenland to the northwest corner of South America. Sedimentary, igneous, and metamorphic rocks are grouped into systems, generally with one color for the continental sedimentary rocks, two or three colors for the marine sedimentary rocks, and one or two colors for the igneous rocks. More than 90 separate color patterns and symbols are shown. The offshore submarine margins are contoured, including the Arctic Ocean, the Gulf of Mexico, and the Caribbean Sea.

Copies of the map may be obtained from the U.S. Geological Survey, Federal Center, Denver, Colo. 80225. The price is $5.00.

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Publications (non-Department) announced:
    Albany-Newport aeromagnetic map (27:2:35)

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