The Ore Bin

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OREGON'S MINERAL AND METALLURGICAL INDUSTRY IN 1968

By Ralph S. Mason*

Oregon mineral production, pacing the state's growing economy, reported a healthy 16-percent increase in value of production over 1967 (table 1). The demand for "growth minerals" such as sand, gravel, and stone by public works, industry, and domestic consumers varies from year to year and from place to place within the state. The mineral industry meets this demand promptly and efficiently without recourse to outside assistance. Its remarkable resiliency and vitality stem from the fact that it must compete vigorously in an ever-changing market place. The economic impact of this segment of the state's natural-resource industry is clearly shown in table 2.

Growth Minerals

The demand for sand, gravel, and stone in Oregon in 1968 amounted to 40 million tons. If all of this vast pile of material were transported in 10-ton trucks making a delivery every 30 minutes, it would require 1000 trucks hauling 8 hours every working day of the year. Last year each man, woman, and child in the state used an average of 20 tons of sand, gravel, and stone -- two truckloads per person. A considerable portion of this cargo of aggregate was used in large-scale projects such as highway and dam construction; lesser amounts were used as fill, riprap, and for numerous miscellaneous purposes. The most specialized use for aggregate was in concrete, which was available in a wide variety of mixes -- a far cry from the time-honored 1:2:4 cement-sand-gravel ratio popular a few years ago. The versatility of concrete can be illustrated by the numerous structures that are being built currently. One building, the State of Oregon parking facility in downtown Portland, will use nearly 11,500 cubic yards of concrete when it is completed early in 1969. The unusual thing about this block-square, six-floor building is that all of the concrete was pumped from ready-mix trucks to the forms through a 4-inch-diameter hose. The year 1968 was designated the "Year of the Meteorite" by this Department. It might be equally fitting to call the year 1969 the "Year of the Ready-Mix Truck."

* Mining Engineer, State of Oregon Dept. Geology & Mineral Industries.

Table 1. Some of Oregon's Minerals at a Glance. Preliminary Figures for 1968 (in thousands of dollars)

	1967	1968
Clays	$ 295	$ 338
Gem stones	750	750
Lime	2,059	2,311
Mercury	461	509
Pumice; volcanic cinders	1,195	1,200
Sand and gravel, stone	45,406	55,440
Miscellaneous*	16,394	16,999
Total	$66,560	$77,547

*Cement, copper, peat, nickel, perlite, silver, gold, diatomite, talc, and soapstone.

Most certainly, these huge vehicles clearly symbolize community growth and state development. In an era of rapidly increasing costs the aggregate-producing industry of Oregon stood out almost alone in holding the price line. The average price per ton surprisingly declined one cent from that of the previous year. This makes the 21.8 percent increase in total value of the aggregate produced in the state last year even more significant.

The rapidly increasing demand for aggregate in Oregon is creating some problems which must be solved in the very near future. Despite the existence of numerous planning groups in the state, no steps have yet been taken to guarantee that adequate supplies of aggregate will be available in the years ahead. Supplies of aggregate in the state as a whole are plentiful, but their location with respect to markets in many cases is poor. Aggregate is a low-cost commodity which generally must be produced within a short distance of the market. Deposits of aggregate are not harmed by fire, frost, or flood but they must remain fixed in one place until used. It is this last feature that makes planning so vitally necessary. Aggregate deposits are located for the most part close to population centers, and these settlements are, almost without exception, rapidly extending out to the vicinity of the deposits. Many deposits have already been engulfed and thus wasted. Some have been zoned out of existence and others have been checkmated for various reasons. Comprehensive and effective steps must be taken shortly to provide planning for timely extraction of the aggregate, followed by conversion of sites for use in the communities' long-range development. Unless this type of consecutive conservation is programed, many areas will be facing shortages of aggregate which will be costly to obtain from distant sources.

The production of cement increased slightly over that of the previous year and was furnished by one company, Oregon Portland Cement, operating plants at Lime in Baker County and at Lake Oswego in Clackamas. Limestone for the Baker County operation was obtained locally, that for the Lake Oswego plant came from Texada Island, B. C. The manufacture of lime increased more than 10 percent with four companies in operation. Oregon Portland Cement Co. opened a pit in weathered sandstone on Gnat Creek in eastern Clatsop County during the year and began shipments to its Lake

Table 2. The Million-Dollar-a-Year Club, 1967*

County	Value	County	Value
Baker	$5,985,000	Klamath	$1,716,000
Clackamas	7,574,000	Lane	7,890,000
Deschutes	1,054,000	Multnomah	6,748,000
Douglas	9,730,000	Polk	1,129,000
Jackson	2,843,000	Umatilla	5,378,000
	Washington	$2,441,000	

* In addition to the values shown, there was a total of $5,706,000 which could not be assigned to specific counties. Production from Columbia and Wallowa Counties was concealed to avoid disclosing individual company confidential data. If the state's total mineral production had been divided equally among the 36 counties, each county would have produced an average of $1,850,000 during the year.

Oswego plant. The pit is located on State Board of Forestry lands. Royalties accruing to the board amounted to $4,643 for the year. Approximately three acres were involved in the operation, which will reclaim the worked-out areas as the work progresses. The sandstone is trucked to the Columbia River at Wauna and then barged to Lake Oswego, where it is unloaded with the same equipment used for the limestone shipped from Texada Island, B.C.

Consumption of Oregon-produced pumice, scoria, and volcanic cinders continued at about the same level as last year. Most of the demand for these materials was for road construction. An increased interest in red scoria in a wide range of sizes for roofing material was reported.

Common brick and tile were fired at kilns located in 10 different counties. Production was at about the same level as in the previous year. Red-firing clays have been produced in the state since 1855. Production of expansible shale was confined to one operation in northwestern Washington County, where Empire Building Materials furnaced Keasey shale to make a lightweight aggregate. Empire also fine-ground some of its product to make a pozzolan.

Skeletons of microscopic fossil plants (diatoms) from a deposit in Christmas Lake Valley in central Lake County were marketed by Archie M. Matlock for use as an extender in plywood glue. Matlock has been mining and processing diatomite in Lake County for a number of years. The diatomite is sold as a floor-sweeping compound, as an absorbent for oil and various liquids, as a poultry and animal litter, a soil conditioner, and as an additive in concretes. Matlock announced plans to erect a diatomite processing plant at the quarry. Plans for constructing a perlite "popping" plant at the same location were under consideration. The plant would process crude perlite from a deposit southeast of the town of Paisley.

Minor Industrial Minerals

Central Oregon Bentonite Co. helped Keep Oregon Green during one of the worst droughts in recent years. Bentonite produced from the company's pits in eastern Crook County was used to seal water reservoirs and canals, and as an additive in drilling muds used by well drillers. Minor amounts of bentonite were also used in foundries and as a stock-feed binder.

Jewell's Mother Earth expanded its plant facilities near Enterprise in Wallowa County. The company digs and processes peat humus from a large bog. The product is sold under the company label and is also distributed through other large outlets.

Blocks of talc and soapstone suitable for sculpture were quarried by John Pugh at a quarry located on Powell Creek in Josephine County. Approximately 3 tons were produced during the year.

Bristol Silica Co. continued to quarry and process lump silica from a pit near Gold Hill in Jackson County. The company has been in continuous operation since the 1930's.

A small tonnage of perlite was mined by Del Harmon from a deposit on Dooley Mountain in Baker County.

Recreation Materials

Oregon's large and varied treasure house of semi-precious gems provided the state with the basis for its most popular recreational activity. "Rockhounding" now accounts for more family hours of time than any other natural-resource based recreation. Rockhounding appeals to all ages and is an all-season, day and night pursuit. Finding raw gem material in the field is only half the fun, since cutting, polishing, tumbling, shaping, and jewelry making comprise an equally important place in the rockhound's activities. Rockhounds are understandably reticent about revealing certain favorite locations, but they are communal by nature and the state is spotted with agate and mineral clubs which sponsor a wide range of associated activities such as the study of geology, lapidary, gemmology, mineralogy, and crystallography. Numerous club-sponsored exhibitions are held each year which attract record-breaking crowds. Several counties have organized annual rockhound get-togethers which draw enthusiasts from all over the United States. The Prineville Pow-Wow hosted 18,000 visitors during the week-long session, and the Chamber of Commerce estimates that rockhounds spent 80,000 visitor days in the county last year, leaving $1 million to perk up the local economy.

It is extremely difficult to assess the dollar value of the semi-precious gems produced in the state. Compared to the rest of the state's mineral industry, the number of operators is very large and many sales are consummated on an informal basis. The U.S. Bureau of Mines estimates that $750,000 worth of stones are produced annually, but no detailed canvass has ever been made.

Closely related to rockhounding, but aimed at an even wider audience, was the interesting geology-based program that got under way in Grant County during the year. Under the auspices of the Grant County Chamber of Commerce and the Grant County Planning Commission, initial steps were taken to provide roadside geological information for tourists. With the cooperation of the U.S. Geological Survey, the State of Oregon Department of Geology and Mineral Industries, the State Highway Department, and the Division of Parks and Recreation, a series of geological points of interest was selected and informational material prepared. In addition to roadside plaques that will identify and explain the geologic features, a brochure will be printed for distribution to give a running account of the geology visible from the highways and roads.

The Metals

The production of ferronickel by Hanna Mining Co. at its mine and smelter in Douglas County continued at very nearly the same rate as that of last year. Hanna quarried 1.1 million tons of ore containing 1.4 percent nickel. The operation is the only producer of primary nickel in the United States and the mainstay of the state's metal-producing industry.

Mercury production remained at almost exactly the same rate as last year's, with 940 flasks weighing 76 pounds each reported. The average annual price per flask climbed more than $50 above that of 1947 to $542, the second highest level ever attained. Oregon mercury production came principally from three mines, the Black Butte in Lane County, the Bretz in Malheur, and the Glass Buttes in Lake County. The Bretz and Glass Buttes shut down late in the year. Minor amounts of the metal were furnaced at the Elkhead mine in Douglas County, the Canyon Creek mine in Grant, the Whiting prospect in the Horseheaven mine area in Jefferson, the Mercury Queen prospect in Crook, and the Polaris prospect in Lake.

With a reported production of only 15 ounces of gold during 1967, the gold miner practically disappeared from the scene. Very probably additional gold was produced in the state by small, part-time operators who failed to report their production. This is a sad come-down for a state that has invigorated the local economy with 5,797,000 fine troy ounces of gold since it was first discovered in 1852. At today's prices ($40 per ounce) that much gold would be worth $231,880,000.

Iron-ore slurry originating in Peru will be processed into steel in a new plant to be operated by Oregon Steel Mills in North Portland. The

PRINCIPAL PRODUCERS OF NONMETALLIC MINERALS IN OREGON, 1968

Commodity and company	Type of activity	County	Address
Cement:			
Oregon Portland Cement Co.	Plant	Baker and Clackamas	Portland
Clay:			
Central Oregon Bentonite Co.	Pit	Crook	Prineville
Columbia Brick Wks.	Pit & plant	Multnomah	Portland
Empire Lite-Rock, Inc.	Pit & plant	Washington	Portland
McMinnville Brick Co.	Pit & plant	Yamhill	McMinnville
Monroe Clay Products Co.	Pit & plant	Benton	Monroe
Needy Brick & Tile Co.	Pit & plant	Clackamas & Marion	Hubbard
Oregon Portland Cement Co.	Plant	Baker	Portland
Willamina Clay Products Co., Inc.	Pit & plant	Yamhill	Tigard
Diatomite:			
Keating Diatomaceous Earth Co.	Mine	Baker	Baker
A.M. Matlock	Mine & plant	Lake	Eugene
Lime:			
Ash Grove Lime & Portland Cement Co.	Plant	Multnomah	Portland
Chemical Lime Co.	Plant	Baker	Baker
Pacific Carbide & Alloys Co.	Plant	Multnomah	Portland
Peat:			
Jewell's Mother Earth	Mine	Wallowa	Enterprise
Perlite:			
Del T. Harmon	Mine	Baker	Stanfield
Pumice:			
L.V. Anderson	Mine & plant	Lane	Oakridge
Central Oregon Pumice Co.	Mine & plant	Deschutes	Bend
Graystone Corp.	Mine & plant	Deschutes	Bend
Kaiser Cement & Gypsum Corp.	Mine & plant	Gilliam	Permanente, Calif.
Oregon Portland Cement Co.	Mine	Baker	Portland
D. W. Parks	Mine	Klamath	Klamath Falls
Silica:			
Bristol Silica Co.	Mine & plant	Jackson	Gold Hill
Building stone:			
Ray Bohlman	Quarry	Jefferson	Madras
Anthony Brandenthaler	Quarry	Baker	Baker
Talc and soapstone:			
John H. Pugh	Mine	Josephine	Grants Pass

PRINCIPAL PRODUCERS OF METALLIC MINERALS IN OREGON, 1968

Commodity and company	Type of activity	County	Address
Aluminum:			
Harvey Aluminum Co.	Plant	Wasco	The Dalles
Reynolds Metals Co.	Plant	Multnomah	Troutdale
Ferroalloys:			
Hanna Nickel Smelting Co.	Plant	Douglas	Riddle
Union Carbide Corp. Mining & Metals Division	Plant	Multnomah	Portland
Gold:			
M & B Logging Co.	Mine (lode)	Jackson	Canyonville
Russell Mitchell	Mine (lode)	Jackson	Medford
Osee Oden	Mine (lode)	Josephine	Wolf Creek
George Slade	Mine (lode)	Josephine	Applegate
Mercury:			
Alcona Mining, Inc.	Mine	Douglas	Springfield
Black Butte Mining Company	Mine	Lane	Cottage Grove
Canyon Creek Mercury Mine	Mine	Grant	Canyon City
Jackson Mt. Mining	Mine	Lake	Winnemucca Nev. (Hampton, Or.)
Nickel:			
Hanna Mining Co.	Mine	Douglas	Riddle
Silicon:			
National Metallurgical Corp.	Plant	Lane	Springfield

plant is scheduled to go into production in 1969. Cascade Steel Rolling Mills began construction of a rolling mill which will turn out bars and angles. The plant site is at McMinnville in Yamhill County.

Smelting of primary aluminum at the state's two aluminum plants increased 4 percent over the 1967 mark. The Harvey Aluminum plant at The Dalles imported alumina from a company-owned facility located at St. Croix in the Virgin Islands. Reynolds Metals Co. announced that a 40,000-ton-per-year potline would be added to its Troutdale complex located a few miles east of Portland on the Columbia River. Employment at the two plants totaled almost 1300 workers. Ground was broken last summer for the state's third aluminum-reduction plant. Northwest Aluminum Co. announced plans to erect a $140 million aluminum complex in the Warrenton-Astoria area of Clatsop County. Annual capacity would be 130,000 tons of primary aluminum. The plant would also recover 310,000 tons of alumina annually from bauxite imported from Australia. When fully operative, the complex will employ 1000 men on a year-around basis.

Ferroalloy production in the state included ferromanganese and silicomanganese produced by Union Carbide at its North Portland plant and ferrosilicon produced by Hanna for its own use at the Riddle ferronickel plant.

Refined silicon metal was reduced by National Metallurgical at its Springfield plant. National is a subsidiary of Kawecki Berylco Industries, Inc. Silicon is used principally as an alloy in aluminum.

Modern Metals

The city of Albany reinforced its position as a center for the space-age metals columbium, zirconium, and titanium during 1968. Four firms, Wah Chang Albany, Oregon Metallurgical, REM Metals, and TiLINE were joined late in the year by a newcomer, Zirconium Technology Corp. Zirtech will manufacture seamless zirconium tubing and finished products from other specialty metals. Plant construction will get under way early in 1969 with production by midyear.

TiLINE installed the world's largest titanium-casting furnace during the summer. The unit stands 44 feet high and can accommodate 1000-pound castings up to 100 inches in diameter. Oregon Metallurgical Corp. increased its plant capability by installing a new ingot-melting facility which can produce a 30-inch-diameter ingot. OREMET specializes in titanium ingot and casting production. REM Metals Corp. operated its newly built precision casting and machining plant throughout the year. REM produces exotic metal shapes for the aircraft industry.

Wah Chang Albany Corp., in response to increased demands for zirconium in the commercial nuclear power industries, doubled its zirconium-sponge reduction capacity. This increase was accomplished by conversion to a new furnace design which allows more rapid cycles and virtually eliminates release of contaminants to the atmosphere. Zirconium-oxide production remained at 1967 levels. New air-pollution control devices were added to the crude and pure chlorination facilities and a new 100-foot-diameter clarifier was placed in operation for improved water-pollution control. The melting capacity was increased by the addition of a vacuum arc remelt furnace and improved electrode-welding facilities. A 2000-ton forging press was installed in the fabrication plant. The new 20,000-square-foot technical center, housing the analytical laboratories, plant engineering, assurance, library, and research and development functions, was occupied during the summer. Employment increased from 950 to 1075 during the year.

Mineral Exploration

During 1968 more exploration for minerals was conducted in the state than ever before. At least 21 exploration programs were fielded, most of them by major mining companies. The Nuclear Fuels Division of Gulf Oil Corp., which leased large acreages of state-owned land in southeastern Oregon in 1967, conducted an active campaign during the year. The company drilled more than 100 test holes, some of them deeper than 1000 feet, to verify indications reported by geophysical exploration. A report filed with the Division of State Lands by Gulf late in the year revealed that it plans to retain its interest in approximately three-fourths of the 82,327.56 acres leased originally from the state. Leased lands were relinquished in Crook, Grant, and Wheeler Counties and retained in Harney, Lake, and Malheur Counties.

The most comprehensive exploration program for low-grade copper ore ever carried out in the state was in full swing during 1968. Two companies, Cyprus Mines, Inc., and Bear Creek Mining Co., which is a subsidiary of Kennecott Copper Co., drilled prospects in eastern Baker County. Interest by the companies in the area stems from a geochemical study made by the Department of Geology and Mineral Industries several years ago.

The continuing high price for mercury has induced several companies to look at various cinnabar prospects. The Canyon Creek mine in Grant County and the Glass Buttes mine in Lake County were both examined by major companies. Interest in the quicksilver district east of Prineville in Crook County was also shown by several firms, but no serious programs were inaugurated.

Omega Mining Co., Ltd., of Vancouver, B.C., continued its intensive exploration of the base-metal mines in the Bourne area of eastern Baker County. Omega, now entering its third year on year-around activity, has reopened old workings at the Golconda, E&E, Tabor Fraction, and North Pole mines. The company holds nearly 1500 acres over a continuous 3-mile distance along the strike of one of the most important mineralized zones in eastern Oregon. Omega has so far rehabilitated 1540 feet of drifts and 200 feet of raises, driven 1900 feet of new drifts and 165 feet of new raises, and core-drilled 4250 feet from 7 surface and 15 underground stations. Late in the year Omega announced plans to construct a 1000-ton-per-day mill. If the program develops as planned, Omega will become Oregon's second largest mine operator with 300 men employed. The Hanna Mining Co. nickel mine and smelter in Douglas County is the largest mining operation in the state and has been a major economic factor in the area ever since 1954.

In response to a steadily increasing demand by the mining industry for information on Oregon gold and silver deposits, the State of Oregon Department of Geology and Mineral Industries published its two-pound-five-ounce, 337-page bulletin No. 61, "Gold and Silver in Oregon." The report contains information on 400 lode and 50 placer mines. Numerous mine maps and several regional maps showing the gold placers are included. Originally prepared for the professional geologist and mine operator, the bulletin has enjoyed wide acceptance by the general public, which is using the volume as a guide book to mineral deposits and old mines.

Cornucopia Placer Co. continued with its work of stripping overburden from a deeply buried placer on Pine Creek. Pine Creek is situated in the same general area as the famous Cornucopia mine in the foothills of the Wallowa Mountains of northeastern Baker County. The creek was worked in a small way by drift placers in the 1930's. Full-scale production is scheduled for early 1969.

In sharp contrast to the large amount of private exploration in the state, there was only one project (the Argonaut mine in Baker County) cooperatively financed by the Office of Minerals Exploration. OME contracts are for exploration and development of properties containing certain minerals. The monies advanced by OME are repaid out of profits from production resulting from the program.

Atlantic Richfield flew over much of southeastern Oregon last summer making a geophysical reconnaissance for radioactivity. Atlantic acquired the old Lakeview uranium mill from Commercial Discount Corp. of Chicago. At year's end no plans for using the plant had been disclosed. Western Nuclear exercised its two-year-old option to purchase the White King uranium mine near Lakeview. The White King was discovered in 1955, with first ore production starting in 1957. The Lakeview uranium plant was constructed in 1958 and processed White King ore until late in 1960, when the mine shut down.

During 1968 a cooperative project to assess the mineral potential of about 6000 square miles of Klamath and Lake Counties was carried out by the Department with financial assistance from the Great Northern Railroad Co. and Pacific Power & Light Co. A geological map and bulletin discussing the metallic and industrial mineral occurrences and potential is scheduled for publication in 1969. A total of 350 geochemical stream-sediment samples was collected by the Department and analyzed for copper, zinc, molybdenum, mercury, and uranium. The sampling area was in the Fremont Mountains west of Lakeview.

The Heavy Metals Program of the U.S. Geological Survey, which was initiated in 1966 to stimulate the production of a small group of critical metals, principally gold and platinum, was continued during 1968. Following publication of a Survey report on the gold distribution in surface sediments on the continental shelf off southern Oregon, further exploration of some of the areas containing above-normal concentrations of gold was started late in the summer with work scheduled to be continued in 1969. The current program is designed to determine the thickness and tenor of the previously delineated areas, all of which lie at depths of 40 fathoms or less. This Department cooperated with the Survey by supplying 3000 stream-sediment samples collected from adjacent onshore locations. The Survey also has a joint research contract with the Department of Oceanography at Oregon State University and with the Geology Department of the University of Oregon.

Selected List of Department Publications on Minerals

The following publications on Oregon minerals have been selected from those issued by the Department. In addition, the Department has numerous unpublished reports on mines and prospects in its files. The publications that have gone out of print may be examined at the Department's offices or at repository libraries in the state and at many universities across the country.

Brooks, Howard C., 1963, Quicksilver in Oregon; Bulletin 55 (out of print).

Brooks, Howard C., and Ramp, Len, 1968, Gold and Silver in Oregon; Bulletin 61 ($5.00).

Corcoran, R. E., and Libbey, F. W., 1956, Ferruginous Bauxite Deposits in the Salem Hills, Marion County, Oregon; Bulletin 46 ($1.25).

Koch, George S., 1959, Lode Mines of the Central Part of the Granite Mining District, Grant County, Oregon; Bulletin 49 ($1.00).

Libbey, F. W., Lowry, W. D., and Mason, R. S., 1945, Ferruginous Bauxite Deposits in Northwestern Oregon; Bulletin 29 (out of print).

Libbey, F. W., and Corcoran, R. E., 1962, The Oregon King Mine (silver), Jefferson County, Oregon; Short Paper 23 ($1.00).

Libbey, F. W., 1967, The Almeda Mine, Josephine County, Oregon (copper); Short Paper 24 ($2.00).

Ramp, Len, 1961, Chromite in Southwestern Oregon; Bulletin 52 ($3.50).

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OAS TO MEET AT UNIVERSITY OF PORTLAND

The Oregon Academy of Science will hold its annual meeting February 22 at the University of Portland. Presentation of papers will begin at 9:30 a.m. and continue through the morning. In the afternoon there will be a symposium on "Man and his natural environment." M. Alan Kays is chairman of the geology section.

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OIL AND GAS EXPLORATION IN OREGON

By V. C. Newton, Jr.*

During 1968 field investigations were conducted by one major oil company in western Oregon while five other large firms had exploration staff members assigned, at least on a part-time basis, to geologic studies of the Pacific Northwest. Mobil, Standard, and Texaco hold an estimated 85,000 acres of leases in the western half of the state. Approximately 5000 acres are leased to Central Oils, Inc. southeast of the town of Madras in central Oregon, and several hundred acres of oil leases are scattered throughout eastern Oregon, many of them held for speculative purposes. Union Oil Co. emerged as the only offshore leaseholder in Oregon when rentals came due December 1, 1968 (table 1). No other firms renewed outer-continental shelf leases in Oregon and Washington for the year 1969. Standard Oil Co. relinquished its interest in offshore leases held jointly with Union in the Pacific Northwest, so that Union now is the sole owner of the leases. Standard, Texaco, Mobil, and Atlantic-Richfield held federal leases off the Oregon coast last year. Leases on the offshore tracts expire December 1, 1969 and can be extended only if production is obtained.

No work was done under the drilling permit (No. 59) held by William Craig, Tacoma, Wash. on his Marion County wildcat, in spite of plans to drill below the 1560-foot depth reached in 1967 (table 2). The test was designed to explore shallow Eocene sands and was located near a hole drilled by Portland Gas & Coke Co. in 1935, which encountered several gas shows. R. F. Harrison began work to deepen an old hole drilled by Central Oils, Inc. of Seattle, Wash. on the Morrow Bros. ranch 10 miles southeast of Madras. No new hole was drilled in 1968. Harrison had drilled out the abandonment plugs and conditioned the hole for deepening by the end of the year.

Geology and Drilling

There is geologic evidence that Oregon has been invaded by the sea many times during the past 400 million years. Sediment deposited on the

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Table 1. Federal OCS Leases - 1968

Company	OCS No.	Tract No.	Area	Present Status
Shell	PO -73	19	Tillamook, Ore.	Relinquished 12/1/68
Shell	PO -75	22	Tillamook, Ore.	Relinquished 12/1/68
Texaco-Mobil	PO-113	105	Florence, Ore.	Relinquished 12/1/68
Texaco-Mobil	PO-116	113	Florence, Ore.	Relinquished 12/1/68
Texaco-Mobil	PO-122	126	Florence, Ore.	Relinquished 12/1/68
Texaco-Mobil	PO-078	28	Florence, Ore.	Relinquished 12/1/68
Union	PO -85	39	Florence, Ore.	Renewed 11/25/68
Union	PO -86	40	Florence, Ore.	Renewed 11/25/68
Union	PO-144	10	Hoh Head, Wash.	Renewed 11/25/68
Union	PO-145	11	Hoh Head, Wash.	Renewed 11/25/68
Union	PO-146	12	Hoh Head, Wash.	Renewed 11/25/68

Table 2. Active Drilling Permits - 1968

Permit No.	Company	Well Name	Location	Depth	Status
59	William Craig	Gilmour 1	Sec. 24, T. 9 S., R. 4 W. Marion County	1560'	Work suspended, abandonment pends.
60-D	R.F. Harrison	Morrow 1	Sec. 18, T. 12 S., R. 15 E. Jefferson County	3300'	Drilled out plugs and conditioned hole. Lost tools in hole - recovered.

ancient ocean floors accumulated as rock strata which today measure more than 100,000 feet in thickness (Youngquist, 1961; Dickinson and Vigrass, 1963). Since petroleum hydrocarbons are found predominantly in marine rocks throughout the world, it appears as though large areas in Oregon consisting of this type of rock are likely to contain oil and gas deposits. Favorable geologic conditions have encouraged oil companies and wildcatters to drill 170 test holes in the state over the past several decades, but none of the tests found hydrocarbons in commercial amounts.

Marine sedimentary rocks in Oregon range in age from Devonian to late Tertiary. Exposures of Paleozoic and Mesozoic marine rocks occur in the Klamath Mountains and in the Blue Mountains (see accompanying map). These older rocks are not exposed anywhere in western Oregon outside of the Klamath Mountains and the bordering areas, and none of the deep holes drilled thus far has reached them. Presumably Paleozoic and Mesozoic rocks do underlie much of western Oregon, and they are believed to extend beneath the Cascades and to be contiguous with rocks exposed in the Blue Mountains (Weaver, 1945; Wells and Peck, 1961; Dott, 1965). The area of unmetamorphosed Paleozoic-Mesozoic marine rocks in central Oregon is estimated to be 8000 square miles (Corcoran, 1956). Tertiary marine rocks ranging in age from early Eocene through middle Oligocene are exposed over a large area of western Oregon, whereas late Oligocene rocks are less extensive. Miocene marine beds are found in the Lower Columbia River valley of northwestern Oregon and in some of the small coastal embayments, indicating that the sea had nearly withdrawn from the continent by that time. Most of the later Tertiary marine rocks lie west of the present shore line.

The western Tertiary basin, including the continental shelf out to the 600-foot water depth, encompasses an area of nearly 14,000 square miles. More than 40,000 feet of sediments and interbedded volcanic rocks were deposited in the Tertiary seaway (Youngquist, 1961). Thirty deep tests have been drilled in the western basin (see accompanying map and table 3).

All of the sedimentary basins in Oregon have been tested by deep drilling. This drilling density compares with a 30-mile grid covering the basin areas, so that exploration thus far can be seen to be of stratigraphic importance only. Not enough drilling has been done in any area to define subsurface structure. The offshore area was the last to be drilled because of deep-water environment of the Pacific shelf.

Petroleum and Economy

It is often asked what effect an oil discovery would have on the state. When one considers that Oregon residents and visitors to the state use more than 43 million barrels of petroleum products (Independent Petroleum Assn. of America, 1976) and 65 billion cubic feet of natural gas each year, it

MAP of OREGON SHOWING GENERALIZED BASINS and DEEP DRILLINGS

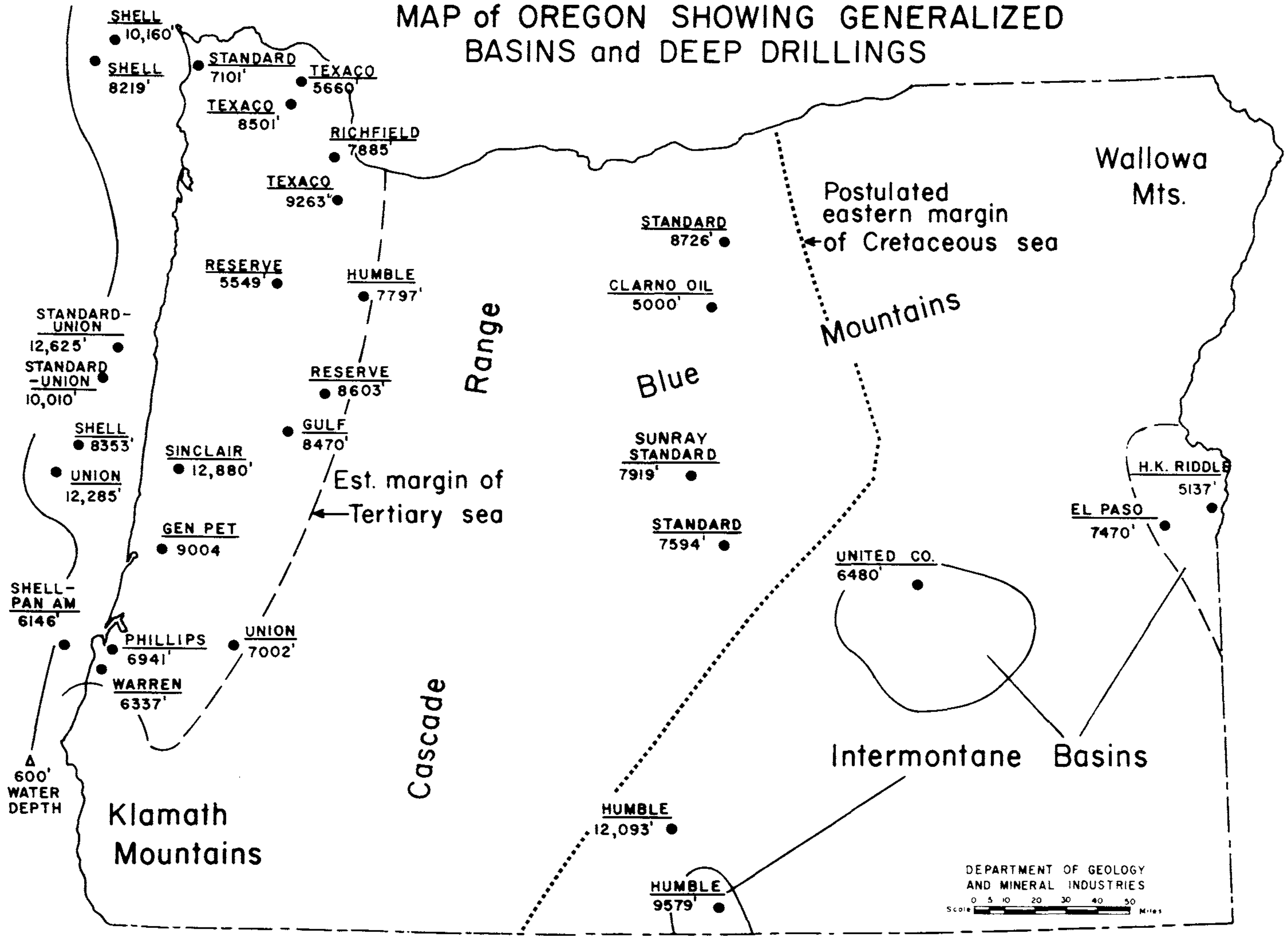


Table 3. Deep Wells with Hydrocarbon Shows.

Company	Well Name	Year Drilled	Total Depth	Description of Show
Gulf Oil	Porter 1	1963	8470'	High pressure salt water at 4650', registered 74 units on gas logging instrument. (Tertiary)
Pan American et al.	Coos Bay 1	1967	6146'	Hydrocarbon shows tested, found to be noncommercial. (Tertiary)
Reserve Oil & Gas	Bruer 1	1960	5549'	Test at 1550' recovered 358' gassy, muddy salt water, registered 60 units on gas logging instrument. (Tertiary)
Reserve Oil & Gas	Esmond 1	1962	8603'	Gas in sandstone at 2900', registered 85 units, gas in tuff at 6400'-7100' registered 400+ units. Test at 7100' flowed 2100 Bbl/day very gassy salt water. Gas at 8050' in volcanics registered 300 units on logging instrument. (Tertiary)
Sunray-Standard	Bear Creek 1	1958	7919'	Gas in siltstone 3950'-4250', registered 30 units on logging instrument. (Cretaceous)
Texaco, Inc.	Cooper Mt. 1	1946	9263'	Test 7862'-9263' flowed 29 Bbl/hr. gassy salt water from sandstone and interbedded volcanics. (Tertiary)
Warren	Coos 1-7	1963	6337'	Gas shows 3500'-4100', registered 300+ units on logging instrument. Wire-line test 4320' recovered oil. Hydrocarbon fluorescence on cuttings 4860'-5200'. (Tertiary)

becomes evident that a local market of significant size is available. The market has an estimated well-head value of $150 million. The value of finished products is several times greater.

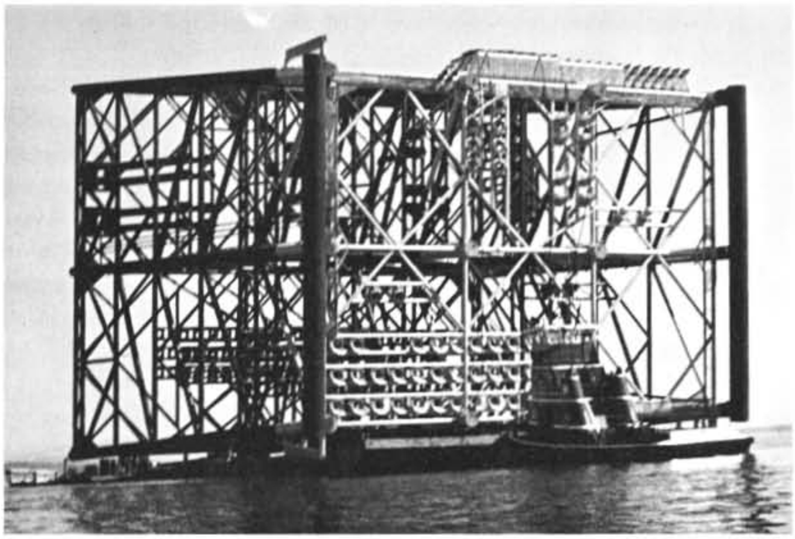
Recent oil discoveries in the Cook Inlet of Alaska and offshore from Santa Barbara in California have been felt as far away as Portland, Oregon. American Pipe & Construction Co. in Portland has started construction on its sixth drilling platform for offshore development (see photograph). Each structure represents a contract for several million dollars. Albina Engine & Machine Works, Inc. of Portland has received ship repair contracts on vessels used in Alaskan exploration in past years and in 1968 constructed a two-story platform to house separating units for Texaco's Cook Inlet production. Atlantic-Richfield Co. has laid plans to construct a $100 million refinery in northwestern Washington to process crude from the recent Alaskan North Slope discovery. When completed, the facility will be the largest in the Pacific Northwest. Mobil, Texaco, and Shell have large refineries in the area to treat Canadian oil. The advent of an oil discovery of size within the state would add greatly to the economy of Oregon.

The bringing of natural gas to Oregon and Washington in 1957 has resulted in good jobs for hundreds of workers. Pipe-line construction boomed for 10 years until the present interstate systems were completed. El Paso (Northwest system to be operated by Colorado Interstate Corp.) and Pacific Gas Transmission Co. operate the two transmission systems which cross the state. Northwest Natural Gas, California-Pacific Utilities, and Cascade Natural Gas operate distributing systems within the state. The availability of low-rate natural gas and hydro-electric power in the industrial areas of Oregon has stimulated economic growth and helped to provide a high living standard for residents.

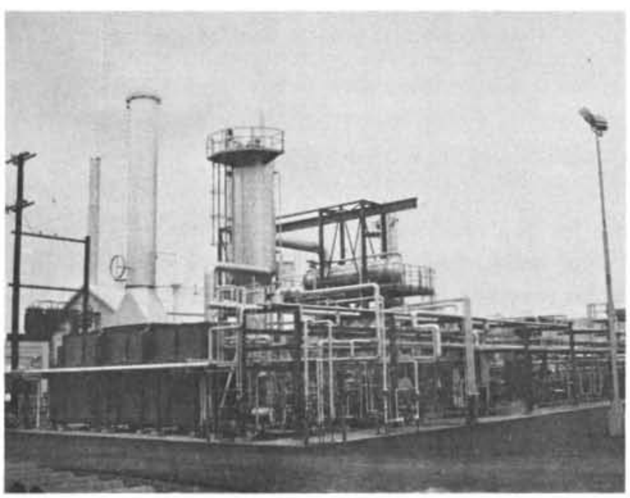
Will Oil Be Found?

The odds for discovering petroleum in Oregon are just as good as in any other wildcat area. Results of drilling have not been entirely discouraging, as can be seen in table 3. Reservoir strata do exist but thus far have yielded only salt water in tests. Such strata have not been found offshore as yet, but drilling is too sparse to reach any definite conclusion about the shelf geology. Gauging from the depth of the holes drilled, sedimentary rocks are at least 13,000 feet thick on the shelf, probably much thicker. There are still many good locations onshore to test in Tertiary rocks of western Oregon. The Paleozoic-Mesozoic basin of central Oregon, which challenges the sophisticated geoscientist because of its complex geology and cover of younger volcanics, is virtually unexplored.

There is no question that the $600 million offshore lease sale near Santa Barbara in California and the continuing development of the Cook Inlet fields in Alaska make it difficult to attract exploration money to



Offshore production platform starts its journey to Santa Barbara, Cal., down the Columbia River. The large structure was built in 1968 by American Pipe & Construction Co. of Portland.



Completely automated refinery completed by Union Oil Co. in 1968 at its northwest Portland storage complex. Plant capacity is rated at 7500 BBL/D of asphalt.

Oregon and Washington. The latest drain on West Coast capital is for development of the huge North Slope, Alaska discovery made by Atlantic-Richfield and Humble jointly in 1968. The remote location of the field, the extreme operating conditions, and the competition for leases will tax industry heavily. The North Slope may become the largest oil field on the continent.

Julius Babisak, exploration manager for Atlantic-Richfield Co., said at the July 1968 meeting of the International Oil Scouts Association in San Antonio, Texas, "The critical data need is stratigraphic." He outlined a $100 million program for group drilling projects in the United States, of which $10 million was projected to be spent on Oregon-Washington drilling. An urgent need for crude reserves by domestic companies to supply the United States market with 3.6 billion barrels of oil a year (U.S. Bureau of Mines, Nov. 1968) will stimulate more such thinking among explorationists. Oregon should see several more deep tests in the future.

Bibliography

Buddenhagen, H. J., 1967, Structure and orogenic history of the southwestern part of the John Day Uplift, Oregon: The ORE BIN, v. 29, no. 7, p. 129-138.

Corcoran, R. E., 1956, What is the status of exploration activity in Oregon: World Oil magazine, October 1956.

Dickinson, W. R., and Vigrass, L. W., 1965, Geology of the Suplee-Izee area, Crook, Grant, and Harney Counties, Oregon: State of Oregon Dept. Geology and Mineral Industries Bull. 58.

Dott, R. H., Jr., 1965, Mesozoic-Cenozoic tectonic history of the southwestern Oregon coast in relation to Cordilleran orogenesis: Jour. Geophys. Res., v. 70, p. 4687-4707.

Eardley, A. J., 1951, Structural Geology of North America: Harper & Bros., New York, 624p.

Gay, T. E., 1966, Economic mineral deposits of the Cascade Range, Modoc Plateau, and Great Basin region of northeastern California: Cal. Div. Mines and Geology Bull. 190, p. 97-104.

Huntting, M. T., et al., 1961, Geologic map of Washington: Wash. Div. Mines and Geology.

Independent Petroleum Association of America, 1967, The oil producing industry in your state: Indep. Petr. Assn. of Amer., Tulsa, Okla.

Peck, D. L., 1964, Geologic reconnaissance of the Antelope-Ashwood area, north-central Oregon: U.S. Geol. Survey Bull. 1161-D.

Petersen, G. L., 1967, Lower Cretaceous discontinuity in northern California and Oregon: American Assn. Petroleum Geologists Bull., v. 51, no. 6, p. 864-872.

U.S. Bureau of Mines, 1968, Annual petroleum statement, 1967: U.S.

Bur. Mines, Nov. 22, 1968.
Weaver, C. E., 1945, Geology of Oregon and Washington and its relation to occurrence of oil and gas: American Assn. Petroleum Geologists Bull., v. 29, no. 10, p. 1377-1415.
Wells, F. G., and Peck, D. L., 1961, Geologic map of Oregon west of the 121st meridian: State of Oregon Dept. Geology and Mineral Industries in cooperation with U.S. Geol. Survey.
Wilkinson, W. D., and Oles, K., 1968, Stratigraphy and paleoenvironments of Cretaceous rocks, Mitchell quadrangle, Oregon: American Assn. Petroleum Geologists Bull., v. 52, no. 1, p. 129-161.
Youngquist, Walter, 1961, Annotated lexicon of names applied to Tertiary stratigraphic units in Oregon and Washington west of the Cascade Mountains, with bibliography: Ann Arbor, Mich., Edwards Bros., Inc.

* * * * *

THE DEPARTMENT ASSISTS OIL EXPLORATION

Many research organizations and most of the major oil companies have consulted the Department's sample library during the past few years. Extensive use of the sample library by industry continued this past year, while during the same period the Department used samples in a paleontological study of northwestern Oregon.

Cores and cuttings now on hand in the library represent 220,000 feet of stratigraphic section drilled. Availability of deep-well samples allows the geologist to inspect visually material which is otherwise hidden from their view by thousands of feet of overlying rock.

The Department has also assisted oil explorationists over the past decade by its variety of geological publications. Three such articles are now in the process of completion and will be published in 1969. The geology of the southwest portion of the John Day Uplift in central Oregon, by H. J. Buddenhagen, describes unmetamorphosed marine rocks ranging in age from Devonian to Cretaceous. Detailed mapping of these old marine beds and their structural features in the uplift region provides important clues to the geologic history of several thousand square miles of central Oregon now covered by young volcanic rocks. These sedimentary rocks may hold promise of producing oil.

The geology of the Ironside Mountain quadrangle (30' Quad.) by W. D. Lowry covers a complexly folded region of the Blue Mountains which has undergone a wide range of metamorphism. The possibility of finding petroleum in commercial quantities in the area is remote; however, a knowledge of the geology in this part of the Blue Mountain uplift may lead to important conclusions regarding the oil and gas possibilities in the region to the south and southeast, where several thousand feet of Tertiary volcanic rocks and lacustrine beds cover pre-Tertiary formations. A knowledge of the rocks exposed in uplifted regions enables geologists to evaluate drilling locations in adjacent basins where contemporaneous rocks lie at great depth below the surface.

Subsurface geology of the Willamette and lower Columbia River Valleys is described in a study by V. C. Newton and will be published as an Oil and Gas Series bulletin. The report interprets regional stratigraphy in northwestern Oregon by use of deep well data and surface mapping. Tables of well data and descriptions of stratigraphic sections are contained in the report.

The Department has many publications available which are of interest to the oil explorationist. A selected list of Department maps, miscellaneous papers, bulletins, and Ore Bin articles follows.

Maps:

Wells, F. G., and Peck, D. L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geol. Survey in coop. with State of Oregon Dept. Geology and Mineral Industries Map I -325.

Berg, J. W., Jr., and Thiruvathukal, J. V., 1967, Free air gravity anomaly map of Oregon: Geol. Map Series 4-a.

__________________, 1967, Complete Bouguer gravity anomaly map of Oregon: Geol. Map Series 4-b.

Dehlinger, P., and others, 1967, Free air gravity anomaly map west of Oregon: Geol. Map Series 4-c.

Corcoran, R. E., and others, 1962, Geologic map of the Mitchell Butte quadrangle, Oregon: Geol. Map Series 2.

Miscellaneous Papers:

No. 4 Rules and regulations for the conservation of oil and natural gas.
No. 6 Summary of oil and gas exploration in Oregon.
No. 8 List of available well records on file.
No. 9* Reprints of articles on Oregon oil exploration.
No. 12 Geologic map index of Oregon.

Bulletins:

No. 5* Geological report of the Clarno basin, 1938: D. K. Mackay.
No. 15* Geology of Salem Hills and North Santiam River basin, 1939: T. P. Thayer.
No. 27* Geology of coal resources of Coos Bay quadrangle, 1944: J. E. Allen and E. M Baldwin.
No. 31* Geology of the St. Helens quadrangle, 1946: W. D. Wilkinson, W. D. Lowry, and E. M. Baldwin.

* Out of print, but available for reference in the Department library.

No. 35 Geology of the Dallas and Valsetz quadrangles, rev. 1963: E.M. Baldwin.
No. 36 Vol. I. Tertiary foraminifera of western Oregon, 1947: J. A. Cushman, R. E. Stewart, and K. C. Stewart.
Vol. II. Tertiary foraminifera of western Oregon and Washington; mollusca and microfauna of Wildcat section, Humboldt County, Cal., 1949: R. E. Stewart and K. C. Stewart.
No. 37 Geology of the Albany quadrangle, 1953: I. S. Allison.
No. 58 Geology of the Suplee-Izee area, central Oregon: W. R. Dickinson and L. W. Vigrass.

The ORE BIN:

Baldwin, E. M., Thrust faulting in the Roseburg area: v. 26, no. 10, October 1964.
Baldwin, E. M., Some revisions of the geology of the Coos Bay area, Oregon: v. 28, no. 11, November 1966.
Brooks, H. C., and Vallier, T. L., Geology of part of the Snake River Canyon from Farewell Bend to Granite Creek: v. 29, no. 12, December 1967.
Brooks, H. C., Distinctive conglomerate layer near Lime, Baker County, Oregon: v. 29, no. 6, June 1967.
Buddenhagen, H. J., Structure and orogenic history of the southwestern part of the John Day Uplift, Oregon: v. 29, no. 7, July 1967.
Burt, W. V., and Borden, S., Ocean current observations from offshore drilling platform: v. 28, no. 3, March 1966.
Byrne, J. C., Geomorphology of the continental terrace off the central coast of Oregon: v. 24, no. 5, May 1962.
__________, Geomorphology of the Oregon continental terrace south of Coos Bay: v. 25, no. 9, September 1963.
__________, Geomorphology of the continental terrace off the northern coast of Oregon: v. 25, no. 12, December 1963.
Dott, R. H., Geology of the Cape Blanco area, southwestern Oregon: v. 24, no. 8, August 1962.
__________, Late Jurassic unconformity exposed in southwestern Oregon: v. 28, no. 5, May 1966.
Ehlen, Judi, Geology of state parks near Cape Arago, Coos County, Oregon: v. 29, no. 4, April 1967.
Emilia, D. A., Berg, J. W., Jr., and Bales, W. E., Oceanic extension of coastal volcanics, northwestern Oregon: v. 30, no. 2, February 1968.
Fowler, G. A., Notes on late Tertiary foraminifera from off the central Oregon coast: v. 28, no. 3, March 1966.
Hopkins, W. S., Jr., Palynology and its paleoecological application in the Coos Bay area, Oregon: v. 29, no. 9, September 1967.

Howard, J. K., and Dott, R. H., Geology of Cape Sebastian State Park and its regional relationships: v. 23, no. 8, August 1961.

Maloney, N. J., and Byrne, J. V., Sedimentary rocks from the continental shelf and slope off the central coast of Oregon: v. 26, no. 5, May 1964.

Morrison, R. F., Angular unconformity marks Triassic-Jurassic boundary in Snake River area of northeastern Oregon: v. 23, no. 11, November 1961.

Newton, V. C., Jr., Summary of oil and gas exploration off the coast of Oregon and Washington, 1961-1966: v. 29, no. 2, February 1967.

Newton, V. C., Jr., and Newhouse, C. J., Oil leasing on the outer continental shelf adjacent to Oregon and Washington: v. 26, no. 11, November 1964.

Peterson, N. V., and Mason, R. S., Limestone occurrences in western Oregon: v. 20, no. 4, April 1958.

Schlicker, H. G., The occurrence of Spencer sandstone in the Yamhill quadrangle, Oregon: v. 24, no. 11, November 1962.

Schlicker, H. G., and Dole, H. M., Reconnaissance geology of the Marcola, Leaburg, and Lowell quadrangles, Oregon: v. 19, no. 7, July 1957.

Snavely, P. D., Jr., Rau, W. W., and Wagner, H. C., Miocene stratigraphy of the Yaquina Bay area, Newport, Oregon: v. 26, no. 8, August 1964.

Snavely, P.D., Jr., Wagner, H. C., and MacLeod, N. S., Preliminary data on compositional variations of Tertiary volcanic rocks in the central part of the Oregon Coast Range: v. 27, no. 6, June 1965.

Stewart, R. E., Stratigraphic implications of some Cenozoic foraminifera from western Oregon [Pleistocene, Pliocene, Miocene]: v. 18, no. 1, January 1956.

__________, Stratigraphic implications of some Cenozoic foraminifera from western Oregon [Oligocene, Eocene (upper)]: v. 18, no. 7, July 1956.

__________, Stratigraphic implications of some Cenozoic foraminifera from western Oregon [Eocene]: v. 19, no. 2, February 1957.

Vallier, T. L., Geology of a portion of the Snake River Canyon between Granite Creek and Pittsburg Landing, Oregon-Idaho: v. 30, no. 12, December 1968.

Wagner, N. S., Limestone occurrences in eastern Oregon: v. 20, no. 5, May 1958.

__________, Important rock units of northeastern Oregon: v. 20, no. 7, July 1958.

NOTE: Many of these issues of The ORE BIN are out of print, but are available for reference in the Department library.

* * * * *

W. D. WILKINSON

Dr. William D. Wilkinson, former head of the Department of Geology at Oregon State University, died Friday, January 3. Dr. Wilkinson had been on the University faculty since 1932 and head of the geology department from 1960 until last summer. He belonged to a number of national scientific organizations and was the first president of the Oregon chapter of the American Institute of Professional Geologists. For many years Dr. Wilkinson and his students conducted geologic field work in central Oregon and other parts of the state. The popular "Field Guidebook to Geologic Trips Along Oregon Highways," which went out of print soon after its publication by the Department of Geology and Mineral Industries in 1959, was prepared under his direction. Dr. Wilkinson's most recent work, a joint effort with Dr. K. F. Oles, was on the Cretaceous rocks of the Mitchell quadrangle in central Oregon and was published in the January 1968 issue of the American Association of Petroleum Geologists Bulletin.

* * * * *

INDEX TO PUBLISHED GEOLOGIC MAPS UPDATED

The index to published geologic maps in Oregon, which was last assembled in 1958, has now been brought up to date. For easier access to the information, the index maps have been arranged in the following catagories: geologic maps that have appeared in The ORE BIN; ground-water and engineering geology maps; geologic quadrangle maps; geophysical surveys; miscellaneous geologic maps published prior to 1960; miscellaneous geologic maps published 1960 through 1967. Also included in this report are topographic index maps and one showing geomorphic provinces of Oregon. Miscellaneous Paper 12, "Index to Published Geologic Maps in Oregon," is available free upon request.

* * * * *

MADRAS AND DUFUR QUADRANGLES MAPPED

Reconnaissance geologic maps of the Madras and Dufur 30' quadrangles, by A. C. Waters, have been published in multicolor at a scale of 1:125,000 by the U.S. Geological Survey. The two adjacent maps are bounded by lat. 44°30' and 45°30' and long. 121° and 121°30'. The Madras map, I-555, and the Dufur map, I-556, can be purchased for 75 cents each from the U.S. Geological Survey, Denver Center, Denver, Colorado 80225.

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AVAILABLE PUBLICATIONS

(Please include remittance with order. Postage free. All sales are final and no material is returnable. Upon request, a complete list of the Department's publications, including those no longer in print, will be mailed.)

BULLETINS

2.	Progress report on Coos Bay coal field, 1938: Libbey	$ 0.15
8.	Feasibility of steel plant in lower Columbia River area, rev. 1940: Miller	0.40
26.	Soil: Its origin, destruction, preservation, 1944: Twenhofel	0.45
33.	Bibliography (1st supplement) of geology and mineral resources of Oregon, 1947: Allen	1.00
35.	Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1963: Baldwin	3.00
36.	(1st vol.) Five papers on Western Oregon Tertiary foraminifera, 1947: Cushman, Stewart, and Stewart	1.00
	(2nd vol.) Two papers on Western Oregon and Washington Tertiary foraminifera, 1949: Cushman, Stewart, and Stewart; and one paper on mollusca and microfauna, Wildcat coast section, Humboldt County, Calif., 1949: Stewart and Stewart	1.25
37.	Geology of the Albany quadrangle, Oregon, 1953: Allison	0.75
46.	Ferruginous bauxite deposits, Salem Hills, Marion County, Oregon, 1956: Corcoran and Libbey	1.25
49.	Lode mines, Granite mining dist., Grant County, Ore., 1959: Koch . . .	1.00
52.	Chromite in southwestern Oregon, 1961: Ramp	3.50
53.	Bibliography (3rd supplement) of the geology and mineral resources of Oregon, 1962: Steere and Owen	1.50
56.	Fourteenth biennial report of the State Geologist, 1963-64	Free
57.	Lunar Geological Field Conference guide book, 1965: Peterson and Groh, editors	3.50
58.	Geology of the Suplee-Izee area, Oregon, 1965: Dickinson and Vigrass .	5.00
60.	Engineering geology of the Tualatin Valley region, Oregon, 1967: Schlicker and Deacon	5.00
61.	Gold and silver in Oregon, 1968: Brooks and Ramp	5.00
62.	Andesite Conference Guidebook, 1968: Dole, editor	3.50
63.	Sixteenth Biennial Report of the State Geologist, 1966-1968	Free

GEOLOGIC MAPS

Preliminary geologic map of Sumpter quadrangle, 1941: Pardee and others	0.40
Geologic map of the St. Helens quadrangle, 1945: Wilkinson, Lowry & Baldwin .	0.35
Geologic map of Kerby quadrangle, Oregon, 1948: Wells, Hotz, and Cater . .	0.80
Geologic map of Albany quadrangle, Oregon, 1953: Allison (also in Bull. 37) .	0.50
Geologic map of Galice quadrangle, Oregon, 1953: Wells and Walker	1.00
Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts	0.75
Geologic map of Bend quadrangle, and reconnaissance geologic map of central portion, High Cascade Mountains, Oregon, 1957: Williams	1.00
GMS-1 - Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka	1.50
GMS-2 - Geologic map, Mitchell Butte quad., Oregon, 1962: Corcoran et al. .	1.50
GMS-3 - Preliminary geologic map, Durkee quad., Oregon, 1967: Prostka . . .	1.50
Geologic map of Oregon west of 121st meridian: (over the counter) . . . . . . folded in envelope, $2.15; rolled in map tube, $2.50	2.00
Gravity maps of Oregon, onshore and offshore, 1967: [Sold only in set]: flat . . folded in envelope, $2.25; rolled in map tube, $2.50	2.00

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Available Publications, Continued:

SHORT PAPERS

2.	Industrial aluminum, a brief survey, 1940: Leslie L. Motz	$ 0.10
18.	Radioactive minerals the prospectors should know (2nd rev.), 1955: White and Schafer	0.30
19.	Brick and tile industry in Oregon, 1949: Allen and Mason	0.20
20.	Glazes from Oregon volcanic glass, 1950: Charles W.F. Jacobs	0.20
21.	Lightweight aggregate industry in Oregon, 1951: R. S. Mason	0.25
23.	Oregon King Mine, Jefferson County, 1962: F.W. Libbey and R.E. Corcoran	1.00
24.	The Almeda Mine, Josephine County, Oregon, 1967: F.W. Libbey	2.00

MISCELLANEOUS PAPERS

2.	Key to Oregon mineral deposits map, 1951: R. S. Mason	0.15
3.	Facts about fossils (reprints), 1953	0.35
4.	Rules and regulations for conservation of oil and natural gas (rev. 1962)	1.00
5.	Oregon's gold placers (reprints), 1954	0.25
6.	Oil and gas exploration in Oregon, rev. 1965; Stewart and Newton	1.50
7.	Bibliography of theses on Oregon geology, 1959: H.G. Schlicker	0.50
7.	(Supplement) Bibliography of theses, 1959 to Dec.31, 1965: M. Roberts	0.50
8.	Available well records of oil & gas exploration in Oregon, rev. '63: Newton	0.50
10.	Articles on Recent volcanism in Oregon, 1965: (reprints, The ORE BIN)	1.00
11.	A collection of articles on meteorites, 1968: (reprints, The ORE BIN)	1.00
12.	Index to published geologic mapping in Oregon, 1968: R. E. Corcoran	Free

MISCELLANEOUS PUBLICATIONS

Oregon mineral deposits map (22 x 34 inches), rev. 1958	0.30
Oregon quicksilver localities map (22 x 34 inches), 1946	0.30
Landforms of Oregon: a physiographic sketch (17 x 22 inches), 1941	0.25
Index to topographic mapping in Oregon, 1961	Free
Geologic time chart for Oregon, 1961	Free

OIL and GAS INVESTIGATIONS SERIES

1.	Petroleum geology of the western Snake River basin, Oregon-Idaho, 1963: V. C. Newton, Jr., and R. E. Corcoran	2.50

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65th ANNUAL MEETING - CORDILLERAN SECTION GEOLOGICAL SOCIETY OF AMERICA
Eugene, Oregon, March 27-29, 1969

FIELD TRIP GUIDEBOOK

GEOLOGY OF THE NEWPORT AREA, OREGON [1/]

By Parke D. Snavely, Jr.[2/], Norman S. MacLeod[2/], and Weldon W. Rau[3/]

Cape Foulweather, first sighted by Captain Cook in 1778, is a former center of middle Miocene volcanism on the central Oregon coast.

1/ Publication authorized by the Director, U.S. Geological Survey.
2/ Geologist, U.S. Geological Survey, Menlo Park, California.
3/ Geologist, Washington Division of Mines and Geology, Olympia, Washington.

Scope and Arrangement of Guidebook

This guidebook is designed to provide a general geologic background for the Newport area of west-central Oregon, and a field trip route along which a representative sequence of Tertiary rock units can be best studied. The guidebook consists of two parts: Part I, "Geologic Sketch of the Newport Area, Oregon," and Part II, "Geologic Field Trip Guide, Newport Area, Oregon." Part I is presented in this issue of The ORE BIN and Part II will be published in the March issue.

Acknowledgments

The writers acknowledge unpublished geologic mapping and stratigraphic studies by H. C. Wagner which are included in this article. Paul Carlson and H. C. Wagner critically reviewed this report and offered valuable suggestions. The assistance in the field of Parke D. Snavely III during the planning phase of this field trip is appreciated.

PART I - GEOLOGIC SKETCH OF THE NEWPORT AREA, OREGON

Introduction

The Newport area (figure 1) provides an exceptional locale for an introduction to Oregon Coast Range geology, as this area contains one of the thickest and most complete sequences of Tertiary sedimentary and volcanic rocks (figure 2). The sequence exposed here contains rock units that are correlative with lithologically similar Tertiary rocks that crop out elsewhere in the Oregon Coast Range (figure 3). This report summarizes published and new data on the geology of the Newport area in the central part of the Oregon Coast Range. Several other recent publications concerned with the geology of the area have been written by Wilkinson (1959), Snavely and Wagner (1963, 1964), Baldwin (1964), and Snavely and others (1964, 1965, 1968, and 1969).

Several formational units referred to in this report are informally named. Some of the locations referred to in this part of the guidebook article are shown on the geologic strip maps contained in Part II.

Although the authors are cognizant of the biostratigraphic value of the molluscan faunas that occur in the late Tertiary sequence, checklists of these fauna are not given here since they have previously been published (Vokes and others, 1949; Snavely and Vokes, 1949; Snavely and others, 1964). Lists of selected foraminiferal species are presented in this report inasmuch as this information is not available in the literature.

Geologic Setting

In early to middle late Eocene time an elongate marine trough (figure 1) occupied the area between the Klamath Mountains and Vancouver Island, Canada. It extended eastward at least as far as the present site of the Cascade Range and westward to the present edge of the continental shelf (Snavely and Wagner, 1963). The Eocene sedimentary and volcanic rocks that accumulated in this trough were deformed in middle late Eocene time, and a number of smaller basins were produced, which

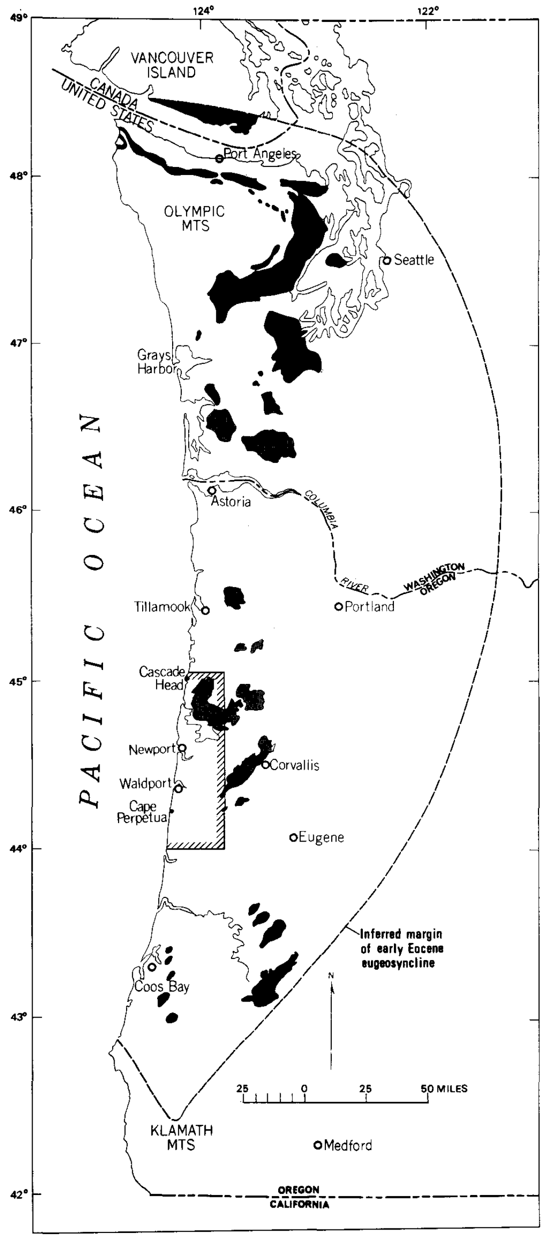

Figure 1. Map of western Oregon and Washington showing the location of the Newport area. The inferred margin of the eugeosyncline that occupied this area in early Eocene time is shown by the dashed line and the present distribution of lower and middle Eocene volcanic rocks by shaded areas.

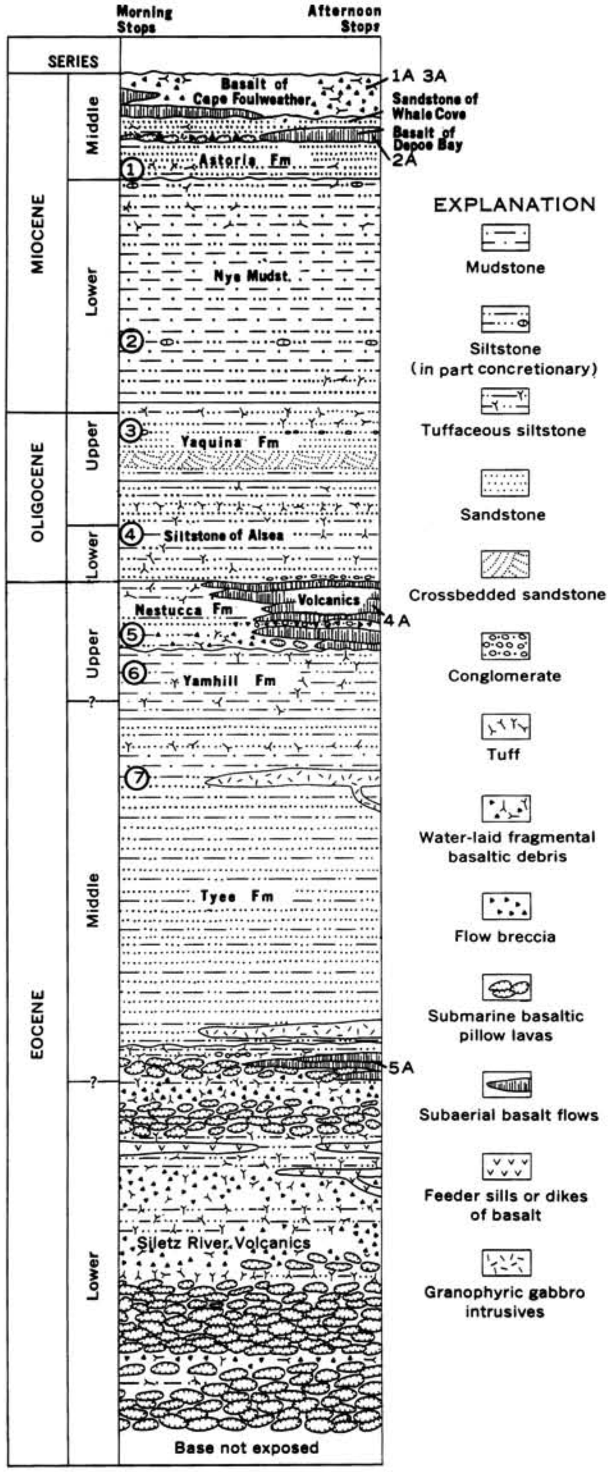

Figure 2. Composite section showing formational units and lithologies of the Tertiary sedimentary and volcanic rocks exposed in the Newport area. Stratigraphic position of outcrops visited on morning segment of the field trip (1-7) are shown on the left, and of afternoon segment (1A-5A) on the right.

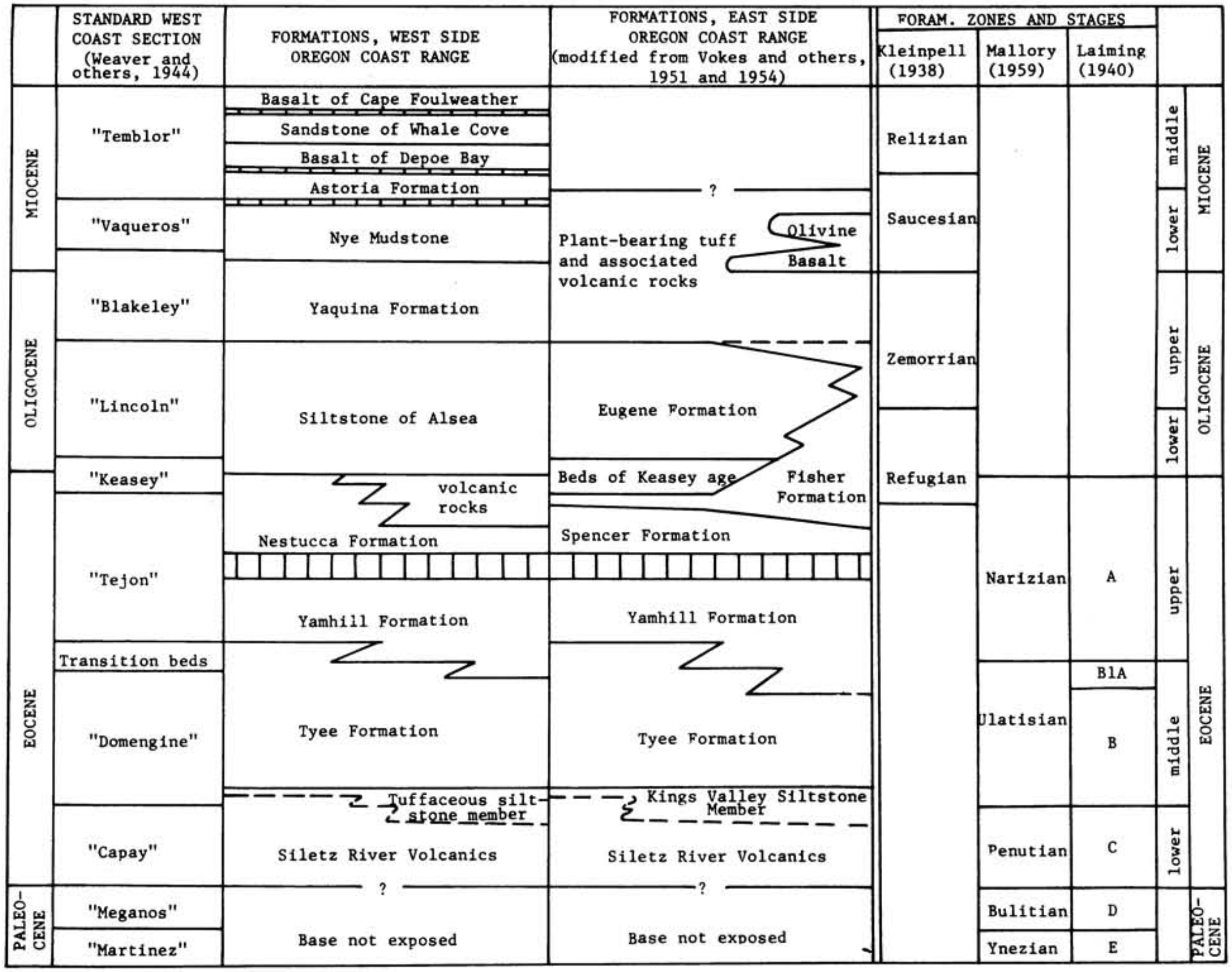

Figure 3. Chart showing the correlation between formations on the west (Newport area) and east sides of the Oregon Coast Range.

were interconnected and open to the sea. The eastern strand line shifted generally westward with time, and by mid-Oligocene time lay near the present coastline except for several structural embayments such as those near Astoria, Tillamook, Newport, and Coos Bay. Sedimentation in these embayments continued through middle Miocene time. Post-middle Miocene marine sedimentation occurred principally west of the present Oregon coast.

A composite thickness of more than 25,000 feet of marine sedimentary and volcanic rocks that range in age from early Eocene to middle Miocene crop out in the Newport area. Unconformities of regional extent are present within the upper Eocene and middle Miocene sequences. Local unconformities between Tertiary formations occur in many places, such as along the margins of lower to middle Eocene volcanic buildups, but most contacts between formations are gradational.

Stratigraphy

Siletz River Volcanics

The oldest rocks exposed in the Oregon Coast Range are a thick eugeosynclinal accumulation of basaltic pillow lava and breccia with interbedded tuffaceous siltstone and basaltic sandstone of early to early middle Eocene age. This sequence of predominantly volcanic rocks is referred to as the Siletz River Volcanics (Snavely and Baldwin, 1948; Snavely and others, 1968) and probably is as much as 20,000 feet thick near former centers of volcanism.

The Siletz River Volcanics has been divided on petrochemical criteria into two parts, a lower submarine tholeiitic basalt unit and an upper unit characterized by alkalic basalt and porphyritic basalt flows and breccia which is in part subaerial (Snavely and others, 1968).

The lower unit forms the bulk of the Siletz River Volcanics and is chiefly of early Eocene age. It crops out in a northeast-trending belt just west of Corvallis and in the Newport area where it is overlain by the upper unit. The lower unit consists predominantly of submarine lava composed of close-packed radial-jointed ellipsoidal pillows that are typically 3 to 4 feet in diameter. The pillows have chilled selvages up to half an inch thick of waxy greenish-black clay minerals which have replaced former basaltic glass. Tuff-breccia that contains broken pillows or small isolated pillows is interbedded with or grades laterally into the pillow flows. Massive to rudely columnar-jointed basalt sills and flows up to 100 feet thick occur locally in the pillow and breccia sequence. Zeolites and calcite commonly form the cementing material in the breccia, fill interstices between pillows, and occur as amygdules in the basalt.

The predominant rock type of the lower unit is amygdaloidal dark greenish-gray aphanitic to fine-grained tholeiitic basalt. Older rocks in this unit differ somewhat in composition from younger rocks (table 1, cols. 1 and 2). Tholeiitic basalt of the Siletz River Volcanics is similar in composition to oceanic basalt (Snavely and others, 1968).

The upper unit resulted from restricted volcanic activity that continued into early middle Eocene time at some major volcanic centers in the Tertiary basin. This upper unit is best known from exposures in the Ball Mountain area, 20 miles northeast of Newport. The late stage of volcanism that formed the upper unit was sporadic, moderately explosive, and produced a differentiated alkalic suite consisting of flows of alkalic basalt, porphyritic basalt, porphyritic augite basalt, feldspar-phyric

Table 1. Average chemical composition of volcanic rocks in the central part of the Oregon Coast Range (analyses recalculated water-free to 100 per cent).

	Lower to lower middle Eocene			Upper Eocene to lowermost Oligocene			Middle Miocene	
	1	2	3	4	5	6	7	8
SiO_2	49.0	48.3	48.2	51.4	47.1	41.7	55.8	51.8
Al_2O_3	14.5	14.6	16.0	17.6	15.5	12.7	14.1	13.9
Fe_2O_3	3.9	5.3	4.1	4.1	5.0	7.7	2.2	3.5
FeO	7.7	8.5	7.9	6.8	7.0	8.8	9.9	11.0
MgO	8.3	5.8	6.1	3.6	6.6	7.8	3.6	3.9
CaO	12.2	11.5	7.4	8.7	10.3	10.3	7.1	7.9
Na_2O	2.3	2.6	4.3	3.6	3.0	2.1	3.3	3.1
K_2O	0.17	0.14	1.9	1.0	1.3	2.7	1.3	1.0
TiO_2	1.6	2.7	3.3	2.6	3.3	4.4	2.0	3.0
P_2O_5	0.15	0.31	0.71	0.59	0.78	1.6	0.36	0.69
MnO	0.19	0.25	0.20	0.16	0.23	0.23	0.21	0.23
Number of Analyses	3	5	9	20	12	4	8	11

1. Tholeiitic basalt from older part of lower tholeiitic unit, Siletz River Volcanics (Snavely and others, 1968, Table 3).
2. Tholeiitic basalt from younger part of lower tholeiitic unit, Siletz River Volcanics (Snavely and others, 1968, Table 3).
3. Alkalic basalt from upper unit of Siletz River Volcanics (Snavely and others, 1968, Table 7, cols. 14 and 15, and Table 8, cols. 1-3 and 4a-7a).
4. Basalt near Yachats, Oregon.
5. Basalt near Cascade Head, Oregon.
6. Camptonitic volcanics from near Cannery Mountain, lower Siletz River, Oregon.
7. Basalt of Depoe Bay (Snavely and others, 1965, Table 1).
8. Basalt of Cape Foulweather (Snavely and others, 1965, Table 1).

Analyses used in above averages were done by Paul Elmore, Ivan Barlow, Samuel Botts, Gillison Chloe, Lowell Artis, H. Smith, Leonice Beatty, and Albert Bettiger, U.S. Geological Survey, using chemical and (or) x-ray fluorescence methods.

basalt, and picrite-basalt interbedded with basaltic tuff and breccia. An average composition of alkalic basalt from the upper unit is shown in table 1, column 3. A few flows and numerous sills of tholeiitic basalt are also present. Massive beds of water-laid basaltic fragmental debris, as much as 100 feet thick, and thick- to thin-bedded fine tuff to lapilli tuff and tuffaceous siltstone are common in the upper unit. Some tuff beds contain abundant euhedral augite crystals up to three-fourths of an inch in width.

Foraminiferal assemblages from sedimentary interbeds in the Siletz River Volcanics can be compared variously with those of Laiming's (1940) B zones and possible C zone, and may, therefore, be referred to Mallory's (1959) Ulatisian and possibly Penutian Stages of middle and possible early Eocene age. Some more common and well-known species of Foraminifera, most of which are from the upper unit, are listed below:

Amphimorphina californica Cushman and McMasters
Asterigerina crassaformis Cushman and Siegfus
Bifarina nuttalli Cushman and Siegfus
Bulimina lirata Cushman and Parker
Cibicides spiropunctatus Galloway and Morrey
Cibicidoides venezuelanus (Nuttall)
Discocyclina sp.
Eponides mexicana Cushman
Globanomalina micra (Cole)
Globorotalia aragonensis Nuttall
Operculina sp.
Robulus ulatisensis Boyd
Silicosigmoilina californica Cushman and Church
Spiroplectammina directa (Cushman and Siegfus)
Vaginulinopsis asperuliformis Nuttall
Vaginulinopsis mexicana var. B. (of Laiming)

Tyee Formation

A sequence of more than 6000 feet of rhythmically bedded sandstone and siltstone (turbidites) of middle Eocene age, the Tyee Formation (Diller, 1898), disconformably overlies the Siletz River Volcanics. Fifty to 100 feet of siltstone is present in many places at the base of the Tyee, overlying limey sandstone and conglomerate at the top of the Siletz River Volcanics. This siltstone unit probably thickens away from areas of volcanic highs and represents pelagic clays deposited in the eugeosyncline prior to the turbidite deposition which formed the bulk of the Tyee (Snavely and others, 1964).

The Tyee Formation consists of graded beds 2 to 10 feet thick (figure 4). The lower part of individual beds consists of medium-grained micaceous arkosic, lithic, or volcanic wacke (argillaceous sandstone) and grades upward into carbonaceous siltstone. In some graded beds the upper siltstone part has been completely eroded by the succeeding turbidity current, producing a sandstone-upon-sandstone relationship. Angular to sub-round siltstone clasts are common in the sandstone and were derived by erosion of underlying beds by the turbidity currents. The base of each recurrent graded unit is sharply defined and commonly contains casts of sedimentary structures; groove casts are most common, but flute casts occur locally as do a variety

Figure 4. Rhythmically bedded sandstone and siltstone of the Tyee Formation of middle Eocene age. Road-cut exposure along the Siletz River between the towns of Siletz and Kernville, Oregon.

of drag marks and load casts.

A paleocurrent analysis based on more than 600 sedimentary structures indicates that the Tyee Formation was formed by turbidity currents that transported sediment northward down the basin axis (Snavely and others, 1964). The principal source of the sediment, as indicated by paleocurrent data and petrographic studies, was an igneous and metamorphic terrain along the south end of the eugeosyncline in the present area of the Klamath Mountains.

Although fossils are rare within the turbidite units that constitute the bulk of the Tyee, Foraminifera occur in the siltstone unit at its base, and in siltstone interbeds near the top of the formation. Foraminifera also occur in thin (1/4- to 1-inch) light-gray discontinuous claystone layers at the tops of a few graded beds. Although mixed-layer montmorillonite-illite or montmorillonite is the principal clay mineral in the graded beds, illite is the predominant clay material in the thin Foraminifera-bearing claystone beds. These claystone beds probably represent hemipelagic clay deposited in the geosyncline during intervals between turbidite deposition.

Foraminiferal assemblages from the Tyee Formation are virtually indistinguishable and, therefore, suggest a relatively short period of deposition during middle Eocene, Ulatisian, time. Furthermore, a somewhat uniform environment of deposition (open-sea at substantial depths, probably at least upper bathyal) is also suggested. Some of the more commonly occurring and well-known species of Foraminifera in the Tyee Formation are:

Amphimorphina californica Cushman and McMasters
Asterigerina crassaformis Cushman and Siegfus
Bifarina nuttalli Cushman and Siegfus
Bulimina corrugata Cushman and Siegfus
Bulimina lirata Cushman and Parker
Cibicides cushmani Nuttall
Cibicides spiropunctatus Galloway and Morrey
Globigerina decepta Martin
Globorotalia aragonensis Nuttall
Globorotalia cerro-azulensis (Cole)
Silicosigmoilina californica Cushman and Church
Spiroplectammina directa (Cushman and Siegfus)
Tritaxilina colei Cushman and Siegfus

Yamhill Formation

The Tyee Formation is conformably overlain by more than 2000 feet of dark-gray siltstone named the Yamhill Formation by Baldwin and others (1955). Interbeds of similar siltstone also occur within the upper part of the Tyee, and north of the 45th parallel the Tyee intertongues with the lower part of the Yamhill Formation.

Strata mapped as the Yamhill Formation by the writers were included in the lower member of the Toledo Formation by Vokes and others (1949). Although poorly exposed in most places in the Newport area, a thick and unweathered sequence of beds crops out along the banks of the Siletz River immediately west of the town of Siletz.

The Yamhill Formation consists of massive to thin-bedded siltstone which in places contains thin beds of arkosic, basaltic, or glauconitic sandstone. Light-gray-weathering concretions and nodules are common within the siltstone. Megafossils are rare in the Yamhill, but most of the unit contains abundant Foraminifera. Selected species of Foraminifera that occur locally in the Yamhill Formation include:

Amphimorphina californica Cushman and McMasters
Bifarina nuttalli Cushman and Siegfus
Bolivina basisenta Cushman and Stone
Bulimina corrugata Cushman and Siegfus
Bulimina jacksonensis Cushman
Bulimina schencki Beck
Cassidulina globosa Hantken
Cibicides warreni Cushman and R. E. and K. C. Stewart
Discorbis cf. D. samanicus (W. Berry)
Eponides yeguaensis Weinzierl and Applin
Plectofrondicularia searsi Cushman and R. E. and K. C. Stewart
Robulus welchi Church
Uvigerina garzaensis Cushman and Siegfus
Vaginulinopsis asperuliformis (Nuttall)
Vaginulinopsis mexicana nudicostata (Cushman and G. D. Hanna)
Valvulineria chirana Cushman and Stone

The Foraminifera of the Yamhill Formation in the Newport area can be compared with those of Laiming's B1A and A-2 zones and therefore may be referred to the uppermost part of the Ulatisian Stage and lower part of the Narizian Stage of Mallory (1959). Furthermore, they suggest bathyal depths during deposition.

Nestucca Formation

Thin-bedded tuffaceous siltstone of the Nestucca Formation of latest Eocene age unconformably overlies the Yamhill Formation and in places completely overlaps older rocks to rest directly on the Siletz River Volcanics. The mid-late Eocene unconformity represents a major period of deformation and erosion; older rocks are in many places folded and faulted, but many structures do not extend into the Nestucca or younger formations. The deformation divided the marine trough that occupied western Oregon and Washington in the Eocene into several interconnected basins and reduced the area of marine deposition.

The Nestucca Formation varies considerably in thickness--along the Yaquina River it is about 800 feet thick, whereas in other areas it is as much as 5000 feet thick. Although thin-bedded tuffaceous siltstone is most common, thin ash beds, massive mudstone, and arkosic, basaltic, and glauconitic sandstone interbeds are abundant. Friable arkosic sandstone is particularly common in the upper part of the formation where it occurs principally in sandstone dikes and sills. The thin bedding which characterizes the Nestucca Formation differs from the more massive or thickly bedded appearance of the underlying Yamhill Formation and overlying siltstone of Alsea, both of which are also predominantly siltstone.

Sequences of basalt flows and breccia up to 2000 feet thick interbedded in the Nestucca Formation form the precipitous sea cliffs between Cape Perpetua and Heceta Head south of Newport, and at Cascade Head to the north (Vokes and others, 1949; Snavely and Vokes, 1949). Camptonitic extrusives of this same age occur interbedded in the Tertiary sedimentary rocks along the lower reaches of the Siletz River, 1 to 2 miles east of Kernville.

Most basalt flows are 10 to 20 feet thick, have scoriaceous oxidized tops, and are of subaerial origin. Some subaerial flows grade laterally into submarine pillow lavas and breccia. Conglomerate and basaltic sandstone occur interbedded in the volcanic sequence, particularly on the flanks of the volcanic accumulations. The volcanics intertongue laterally with marine tuffaceous siltstone of the upper part of the Nestucca Formation which accumulated in areas between volcanic centers. Feeder dikes are abundant; they intrude the volcanic rocks and also cut older rocks to the east of the present volcanic outcrops, suggesting that the flow sequence may have originally covered parts of the interior of the present Coast Range.

The basalt is almost always porphyritic; basalt in the flow sequence near Cape Perpetua is characterized by abundant plagioclase phenocrysts whereas in the lavas at Cascade Head augite and olivine phenocrysts generally abound. The basalt shows a large variation in composition both within individual volcanic centers and between centers. The flows are characterized by high alkali, Al_2O_3, TiO_2, and P_2O_5 content (table 1, cols. 4 and 5). Although the volcanic sequences at Cascade Head and at Cape Perpetua both show a large variation in silica content, the former tends to be lower. Consanguineous dacitic dikes cut both volcanic sequences.

Camptonitic volcanic rocks which occur in the lower reaches of the Siletz River consist predominantly of tuff breccia with some pillow flows and massive flows as well as sills and dikes. Angular fragments in the breccia consist of altered glass crowded with pyroxene, opaque mineral, and apatite microlites. Cognate xenocrysts of biotite, hornblende, and apatite are common and serve to identify the camptonites. The matrix of the breccia consists of finely comminuted altered camptonitic glass and zeolites. Dikes and sills of biotite camptonite, which fed the extrusive sequence, cut the volcanics and intrude older rocks to the east; the largest dike is exposed in a small quarry on State Highway 229 about 8 road miles east of Kernville. An average chemical analysis of the biotite camptonite extrusives and directly associated feeder dikes is shown in table 1, column 6. The camptonite is characterized by low silica and high total alkali, TiO_2, and P_2O_5 content. Some of the least silicic volcanics at Cascade Head differ only slightly in composition from the camptonites and are considered to be consanguineous.

Megafossils are not common in the Nestucca Formation but Foraminifera are abundant. Some of the more common species locally occurring in the Nestucca Formation are:

- *Cassidulina globosa* Hantken
- *Cibicides haydoni* (Cushman and Schenck)
- *Cibicides hodgei* Cushman and Schenck
- *Gyroidina condoni* (Cushman and Schenck)
- *Gyroidina orbicularis planata* Cushman
- *Plectofrondicularia packardi packardi* Cushman and Schenck
- *Uvigerina cocoaensis* Cushman
- *Uvigerina garzaensis* Cushman and Siegfus

Nestucca foraminiferal assemblages are referable to the upper Narizian and lower Refugian Stages of late Eocene age. Most assemblages suggest upper bathyal depths during deposition.

Oligocene siltstone

A massive to thick-bedded tuffaceous siltstone to very fine-grained sandstone unit, informally referred to as the "siltstone of Alsea," conformably overlies the Nestucca Formation and upper Eocene volcanic rocks in the Newport area. The siltstone of Alsea was included in the upper part of the Toledo Formation as mapped by Vokes and others (1949). This siltstone unit is about 1500 feet thick where exposed along Yaquina Bay; it is particularly well exposed on the northwest side of Alsea Bay about 10 miles to the south.

Ash is a ubiquitous and abundant constituent of the siltstone and fine-grained sandstone and was derived from contemporaneous volcanism in the Cascade Range to the east (Snavely and Wagner, 1963). The tuffaceous siltstone contains abundant concretions which commonly have small shell fragments or fossil crabs in their cores. Interbeds of glauconitic sandstone and pumiceous mudflow breccia are also present.

Both megafossils and Foraminifera occur in this unit. The latter are referable to the upper Refugian and the Zemorrian Stages of Oligocene age. A few of the characteristic Foraminifera are:

Anomalina californiensis Cushman and Hobson
Bolivina marginata adelaidana Cushman and Kleinpell
Buccella mansfieldi oregonensis (Cushman, R. E. Stewart and K. C. Stewart)
Buliminella bassendorfensis Cushman and Parker
Cassidulina galvinensis Cushman and Frizzell
Cibicides elmaensis Rau
Elphidium cf. *E. smithi* Cushman and Dusenbury
Gyroidina soldanii d'Orbigny
Plectofrondicularia packardi multilineata Cushman and Simonson
Pseudoglandulina cf. *P. inflata* Bornemann
Quinqueloculina imperialis Hanna and Hanna
Quinqueloculina weaveri Rau

In general, Foraminifera of this siltstone unit suggest open-sea, cool-to-cold water conditions ranging from neritic to upper bathyal depths, possibly 300 to 2000 feet.

Yaquina Formation

Massive to well-bedded and cross-bedded sandstone, siltstone, and conglomerate constitute the Yaquina Formation (Harrison and Eaton, 1920; Schenck, 1927, 1928; and Vokes and others, 1949) of late Oligocene age. Along Yaquina Bay this unit is about 1700 feet thick. It thins to less than 1000 feet at Beaver Creek near the coastline 7 miles to the south, and towards the north thickens to more than 2000 feet in the area east of Cape Foulweather. Farther to the north near Siletz Bay it again thins to less than 1000 feet.

Sandstone, occurring as thin to thick beds, is the most common rock type. It varies from fine to coarse grained and commonly is pebbly. Cross-bedding and large-scale foreset bedding are common as are channel and fill structures. The sandstone is micaceous and carbonaceous; it may in part have been derived from erosion of the Tyee Formation. Pumice clasts are abundant and suggest continued volcanism in the Cascade Range to the east. Conglomerates are more common in the Yaquina Formation east of Cape Foulweather, where the formation is thickest, than near Yaquina Bay. The conglomerate occurs in beds up to several tens of feet thick which have lenslike shapes in outcrop pattern. Clasts in the conglomerate are of a variety of rock types most of which are foreign to the older Tertiary formations in the Coast Range. Thin to thick interbeds of tuffaceous siltstone, lithologically similar to that of the underlying siltstone of Alsea, and of glauconitic sandstone are also common. In places coal lenses and ash beds occur within the sandstone and siltstone. The distribution, lithology, and sedimentary structures of the Yaquina Formation suggest that it represents a deltaic deposit.

Megafossils are common in the Yaquina and indicate a late Oligocene age. Foraminifera, which occur in some siltstone beds, are largely confined to the following species of which only the unnamed species of Elphidium is common in most samples:

Bolivina cf. B. advena Cushman 1/
Buccella mansfieldi oregonensis (Cushman, R.E. Stewart, and K.C. Stewart)
Bulmina ovata d'Orbigny
Elphidium sp. (large, numerous chambers, very fine septal pores)
Elphidium cf. E. minutum (Reuss) 1/
Nonion costiferum (Cushman) 1/
Nonion incisum kernensis Kleinpell
Plectofrondicularia californica Cushman and Stewart 1/
Pyrgo sp. 1/
Robulus spp.

1/ Uppermost part of formation

Nonion costiferum in the uppermost part of the formation suggests an age no older than the Saucesian Stage (early Miocene). However, the remainder of the formation is assigned to the Zemorrian Stage (late Oligocene). Foraminiferal assemblages suggest relatively cool temperatures at shallow depths of deposition (littoral to inner neritic, not exceeding 300 feet).

Nye Mudstone

The Nye Mudstone (Harrison and Eaton, 1920; Schenck, 1927; Vokes and others, 1949; Snavely and others, 1964) is well exposed in road cuts along the north shore of Yaquina Bay. At its base it intertongues with sandstone beds of the Yaquina Formation. Along Yaquina Bay the Nye Mudstone is about 4400 feet thick. The thickness decreases rapidly northward to less than 500 feet about 4-1/2 miles north of the bay in the vicinity of Moloch (Moolack) Creek. The rapid narrowing of the outcrop belt northward is a result of onlap of the overlying Astoria Formation onto a broad pre-Astoria structural high. Also, north of the bay the Nye Mudstone contains thick interbeds of very fine-grained sandstone. Inasmuch as the sandstone of the Yaquina Formation thickens north of the bay, it is thought that the Nye sea may have shoaled northward onto a constructional high formed by a broad submarine fan or delta of Yaquina time.

The Nye consists predominantly of medium to dark olive-gray, massive, organic-rich mudstone and siltstone. Freshly broken samples have a strongly petroliferous odor. Calcareous and dolomitic concretions, as much as 4 feet across, and lenticular beds 2 inches to more than 1 foot thick occur locally. Thin carbonate-cemented beds are common in the lower part of the sequence; large isolated concretions generally occur in the upper part. A prominent zone of lenticular concretionary dolomitic beds occurs about 1200 feet above the base of the formation on the north side of Yaquina Bay.

The Nye Mudstone contains abundant brown fish scales and vertebrae, Foraminifera, and a meager molluscan fauna. In the uppermost part of the sequence, however, mollusks are abundant. Foraminiferal species found in the Nye Mudstone have been listed by Snavely and others (1964); some of the more common species are:

- Bolivina advena Cushman
- Bolivina marginata adelaidana Cushman and Kleinpell
- Buccella mansfieldi oregonensis (Cushman and R.E. Stewart and K.C. Stewart)
- Buliminella subfusiformis Cushman
- Bulimina inflata alligata Cushman and Laiming
- Bulimina ovata d'Orbigny
- Cassidulina laevigata carinata Cushman
- Epistominella parva (Cushman and Laiming)
- Gyroidina soldanii d'Orbigny
- Nonion costiferum (Cushman)
- Nonion incisum (Cushman)
- Plectofrondicularia californica Cushman and Stewart
- Uvigerina auberiana d'Orbigny
- Uvigerinella obesa impolita Cushman and Laiming
- Virgulina californiensis Cushman

The assemblages are referable to the Saucesian Stage and the composition of the fauna suggests cold temperatures at upper bathyal depths -- perhaps 1000 to 2000 feet.

Astoria Formation

The Astoria Formation (Packard and Kellogg, 1934; Schenck, 1936; Weaver, 1937; Vokes and others, 1949; Snavely and others, 1964) unconformably overlies the Nye Mudstone. The unconformity between the two formations is sharp and well exposed in the sea cliff at Jumpoff Joe, about 1-1/2 miles north of Yaquina Bay, where sandstone of the Astoria Formation rests with slight angular discordance on typical mudstone of the Nye. This mudstone is stratigraphically lower in the Nye than sandy siltstone exposed at the mouth of the Yaquina River directly below the Astoria Formation.

Although only a narrow belt of Astoria strata is exposed along the sea cliffs and the wave-cut platform near Newport, a thicker and more continuous section crops out between Yaquina Head and Beverly Beach. Here more than 500 feet of strata is exposed. Farther to the north, in the area east of Depoe Bay where the former strand line swings to the east, the Astoria Formation attains its maximum onshore thickness in the Newport area, some 2000 feet.

The Astoria Formation consists principally of olive-gray, fine- to medium-grained micaceous, arkosic sandstone and dark-gray carbonaceous siltstone. The sandstone beds range from massive to thin-bedded and generally are thicker bedded in the upper part of the sequence. Thin bedding in the sandstone is accentuated by siltstone and claystone laminae, finely macerated plant material, or concentrations of mica. Commonly the original bedding has been greatly disturbed by the activity

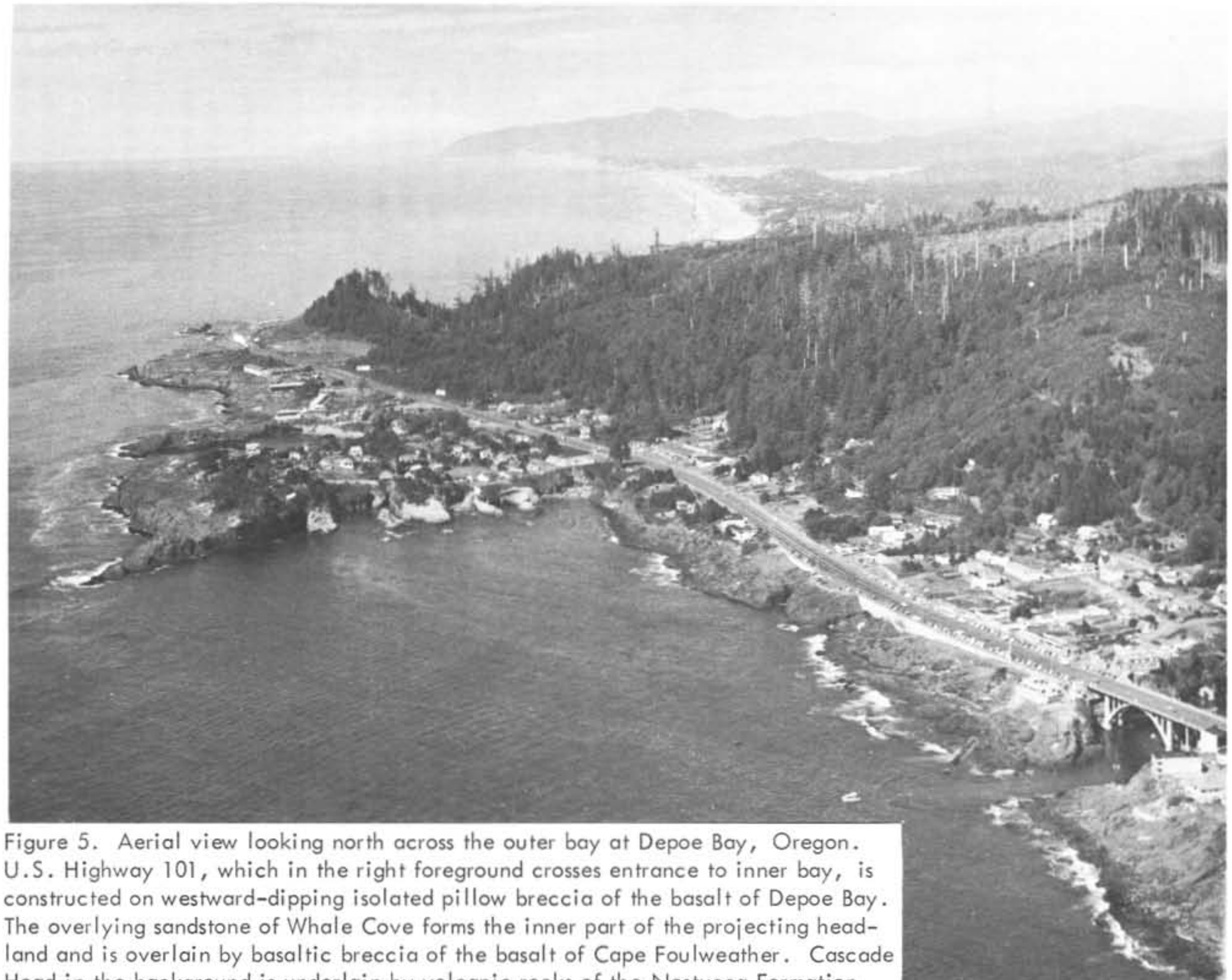

Figure 5. Aerial view looking north across the outer bay at Depoe Bay, Oregon. U.S. Highway 101, which in the right foreground crosses entrance to inner bay, is constructed on westward-dipping isolated pillow breccia of the basalt of Depoe Bay. The overlying sandstone of Whale Cove forms the inner part of the projecting headland and is overlain by basaltic breccia of the basalt of Cape Foulweather. Cascade Head in the background is underlain by volcanic rocks of the Nestucca Formation.

of marine organisms which have produced a "churned" appearance. Small-scale cross-bedding, ripple marks, and penecontemporaneous slump structures due to submarine sliding are common. The slump structures range from small overturned folds within beds only 1 inch thick to large infolds several feet in amplitude; the direction of overturning indicates a general westward to northwestward gliding of some beds during deposition.

A few granule- to coarse-grained basaltic sandstone beds up to 15 feet thick occur in the lower part of the formation. Concretionary ledges 6 inches to 2 feet thick and individual concretions 2 to 3 feet in diameter occur locally. Ledge-forming calcareous sandstone beds are more common in the lower than in the upper part of the formation. The most distinctive stratigraphic markers in the Astoria Formation are light-yellowish-gray water-laid siliceous tuff beds that in places contain altered pumice fragments and carbonaceous material. The beds range from a few inches to 18 feet in thickness and, being more resistant to erosion than the adjacent sandstone and siltstone, generally form ribs in the outcrops on wave-cut platforms. The tuff is of andesitic to dacitic composition which suggests that its source was from pyroclastic eruptions in an ancestral Cascade Range to the east.

Well-preserved mollusks are generally abundant throughout the lower part of the formation in both the sandstone and siltstone units and locally are concentrated in calcareous ledges or concretions. Many of the pelecypods have articulated valves indicating that they have not undergone extensive transport. The molluscan fauna indicates a middle Miocene age (Vokes and others, 1949; Snavely and others, 1964). Foraminifera are locally abundant in siltstone of the Astoria Formation and indicate a Saucesian age. The fauna suggests that water temperature may have been temperate, and depths possibly not more than 500 feet (Snavely and others, 1964). The following are common species:

Bolivina advena Cushman
Buccella mansfieldi oregonensis (Cushman and R.E. Stewart and K.C. Stewart)
Buliminella elegantissima (d'Orbigny)
Buliminella subfusiformis Cushman
Epistominella parva (Cushman and Laiming)
Nonion costiferum (Cushman)
Nonionella miocenica Cushman
Robulus mayi Cushman and Parker
Uvigerinella californica ornata Cushman

Middle Miocene volcanic and sedimentary rocks

A middle Miocene sequence comprising a lower unit of basalt flows, a medial massive to well-bedded sandstone and siltstone unit, and an upper unit of basalt breccia is well exposed in sea cliffs along the coast from Cape Foulweather to Boiler Bay (Snavely and Vokes, 1949; Snavely and others, 1965). Miocene basalt flows, pillow lavas, breccia, and water-laid fragmental debris form the precipitous headlands along the Oregon coast north of Newport at Yaquina Head, Cape Foulweather (see page 25), Cape Lookout, and Cape Meares; thick sills formed during the Miocene volcanism occur at Cape Falcon and Tillamook Head. These volcanic rocks were extruded from local centers near a middle Miocene strand and are of both subaerial and submarine origin (Snavely and Wagner, 1963).

The middle Miocene basalt exposed along the central and northern Oregon coast consists of two mappable and petrochemically distinctive units. The older unit, here referred to as the "basalt of Depoe Bay," is composed of subaerial basalt flows and submarine palagonitic pillow lava and breccia; the younger unit, locally referred to as the "basalt of Cape Foulweather," consists predominantly of subaerial basalt flows and breccia and subaqueous water-laid fragmental basaltic debris. Between Whale Cove and Depoe Bay (figure 5), these two basalt units are separated by a massive nearshore arkosic sandstone and thin-bedded brackish-water sandstone unit, informally called the "sandstone of Whale Cove."

Unconformities, in places marked by fossil soil zones, occur at the base of each of the two basalt units; the basalt of Cape Foulweather overlaps the basalt of Depoe Bay south of Depoe Bay where it rests on older rocks.

Basalt of Depoe Bay: A 75-foot-thick isolated pillow breccia unit forms the north-trending shoreline between the inner and outer bays of Depoe Bay (figure 5). The unconformable contact between the basalt of Depoe Bay and the Astoria Formation is well exposed in the inner bay. Pillows in the isolated pillow breccia are typically 2 to 4 feet wide; some are very elongate. Many pillows have hollow (drained) centers. The pillows are enclosed in a matrix of finely comminuted partially palagonitized basaltic glass and angular glassy to aphanitic basalt fragments. Immediately south of Depoe Bay the pillow lavas grade laterally into a rudely columnar-jointed subaerial flow approximately 50 feet thick. Numerous dikes and sills of Depoe Bay type basalt intrude the Astoria and Yaquina Formations immediately east of Depoe Bay and attest to the local origin of this unit.

The general petrography of these rocks is described by Snavely and others (1965). The basalt is medium to dark gray, glassy to fine grained, equigranular, and commonly contains patches of apple-green (on fresh breaks) to brownish-black chlorophaeite. The average composition of basalt from this unit is shown in table 1, column 7. Fresh basalt shows a very restricted range in composition and is characterized by relatively high SiO_2. Basalt of similar composition and age forms the headlands at Cape Lookout, Cape Meares, Cape Falcon, and Tillamook Head, and forms thick flows along the lower part of the Columbia River and in the northern part of the Willamette Valley. The Yakima type of basalt (Waters, 1961) of the Columbia River Group on the Columbia River Plateau is also of similar composition and age, even though extruded many tens of miles to the east. Flows in the northern part of the Willamette Valley and along the lower part of the Columbia River were derived from a Columbia Plateau source, but the Depoe Bay type volcanics along the coast were erupted from local vents near the present coastline.

Sandstone of Whale Cove: Two to three hundred feet of clastic sedimentary rocks occur in places between the basalt of Depoe Bay and the basalt of Cape Foulweather (Snavely and Vokes, 1949). These sedimentary rocks, referred to as the sandstone of Whale Cove, are best exposed along the northern and southern shores of the outer bay at Depoe Bay and in Whale Cove about 1 mile to the south. Massive to thick-bedded medium- to fine-grained arkosic sandstone and thin-bedded micaceous carbonaceous siltstone to fine-grained sandstone constitute the bulk of the unit. Crossbedding, cut-and-fill structures, convolute laminations, and slump structures are common. The chemical composition of a sandstone from this unit and of older sedimentary rocks from the Newport area are shown in table 2.

Part of the sediment that comprises younger Tertiary sandstone in the Newport area was derived by erosion of older sandstone such as that of the Tyee Formation.

Table 2. Average chemical composition of sedimentary rocks in the central part of the Oregon Coast Range (analyses recalculated water-free to 100 percent).

Formation:	Tyee Formation	Nestucca Formation	Siltstone of Alsea	Nye Mudstone	Astoria Formation	Sandstone of Whale Cove
Rock type:	Sandstone and Siltstone	Siltstone	Siltstone	Siltstone	Sandstone	Sandstone
No. of analyses	11	2	5	1	3	1
SiO_2	62.3	67.5	67.3	68.4	69.6	74.4
Al_2O_3	16.8	17.6	15.8	15.6	14.8	12.9
Fe_2O_3	2.1	4.3	4.7	4.5	2.5	2.0
FeO	4.6	2.1	1.8	2.3	2.5	2.1
MgO	3.1	2.0	1.8	2.5	2.2	1.6
CaO	3.7	1.8	3.1	1.1	2.2	1.2
Na_2O	3.1	1.3	2.0	2.5	2.8	2.3
K_2O	2.6	2.2	2.1	1.9	2.2	2.7
TiO_2	1.0	0.84	0.95	0.83	0.96	0.69
P_2O_5	0.2	0.14	0.19	0.28	0.14	0.08
MnO	0.13	0.03	0.07	0.04	0.07	0.05

Analyses used in above averages were done by Paul Elmore, Ivan Barlow, Samuel Botts, Gillison Chloe, Lowell Artis, H. Smith, Leonice Beatty, and Albert Bettiger, U.S. Geological Survey, using chemical and (or) x-ray fluorescence methods.

Consequently, younger sandstone tends to be progressively more mature and have higher SiO_2 content. Fossils are rare in this unit, but a few mollusks are present in large calcareous concretions at Whale Cove.

Basalt of Cape Foulweather: The youngest Tertiary rock unit in the Newport area, the basalt of Cape Foulweather, crops out along the coast for about 6 miles north between Cape Foulweather (see page 25) and Government Point. It forms the projecting small headland on the outer part of Depoe Bay (figure 5) where it overlies the sandstone of Whale Cove. East of Cape Foulweather this volcanic sequence overlaps this sandstone, the basalt of Depoe Bay, and much of the Astoria Formation. The basalt of Cape Foulweather is also exposed at Yaquina Head and Otter Rock Island.

The basalt of Cape Foulweather consists predominantly of basalt breccia and water-laid fragmental debris, and lesser amounts of massive flows and pillow lavas. Numerous feeder dikes and volcanic necks such as are exposed on Cape Foulweather indicate that the volcanic rocks were locally derived. Much of the basalt was erupted subaerially, but fringing aprons of marine basaltic breccias such as crop out at Government Point apparently developed around the volcanic centers.

Basalt of Cape Foulweather is glassy to very fine grained and characteristically contains a small number of yellowish plagioclase phenocrysts as much as 2 cm in length. Presence of these phenocrysts serves to distinguish these basalts from those of the basalt of Depoe Bay.

An average chemical composition of basalt from Cape Foulweather is shown in table 1, column 8. The basalt shows only slight variation in composition, is characterized by relatively high TiO_2 and P_2O_5, and is chemically distinct from basalt of Depoe Bay.

Basalt flows and intrusives of Cape Foulweather type crop out at Cape Lookout and Ecola State Park along the northern Oregon coast where they are also younger than Depoe Bay type basalt. The Late Yakima petrographic type (Waters, 1961) of the Columbia River Group of the Columbia Plateau is similar to the basalt of Cape Foulweather both in age and composition.

Fossils diagnostic of age are not present in this basalt flow--sedimentary rock sequence in the Newport area. However, farther north at Cape Meares, basalt flows equivalent in composition to the basalt of Depoe Bay are associated with siltstone of Relizian age. Based on regional geologic consideration, the basalts of Depoe Bay and Cape Foulweather are considered to be of middle Miocene age.

Post-middle Miocene sedimentary rocks

A thick sequence of marine sedimentary rocks of late Miocene and Pliocene ages underlies the continental shelf off the Newport area. Interpretation of subbottom acoustical profiles (figure 6), gravity data (Dehlinger and others, 1967), and magnetic data (Emilia and others, 1966) indicates that several thousand feet of post-middle Miocene sedimentary rocks overlie the Astoria Formation on the adjacent continental shelf off Newport. Bottom samples from an anticlinal high, Stonewall Bank, on the shelf contain Foraminifera indicative of Pliocene and middle Miocene ages (Fowler, 1966). A test hole drilled cooperatively by the Standard Oil Company of California, Union Oil Company, and Pan American Petroleum Corporation on this structure is reported to have encountered more than 10,000 feet of marine sedimentary rocks.

Quaternary deposits

Unconsolidated to poorly consolidated mud, silt, sand, and gravel of Quaternary age blanket much of the Newport coastal area (Vokes and others, 1949; Baldwin, 1950; Cooper, 1958). In most lowland coastal areas the Quaternary deposits extend several hundred yards to 2 miles inland. Along the Yaquina River, estuarine deposits occur as much as 7 miles from the coast. The Quaternary deposits include

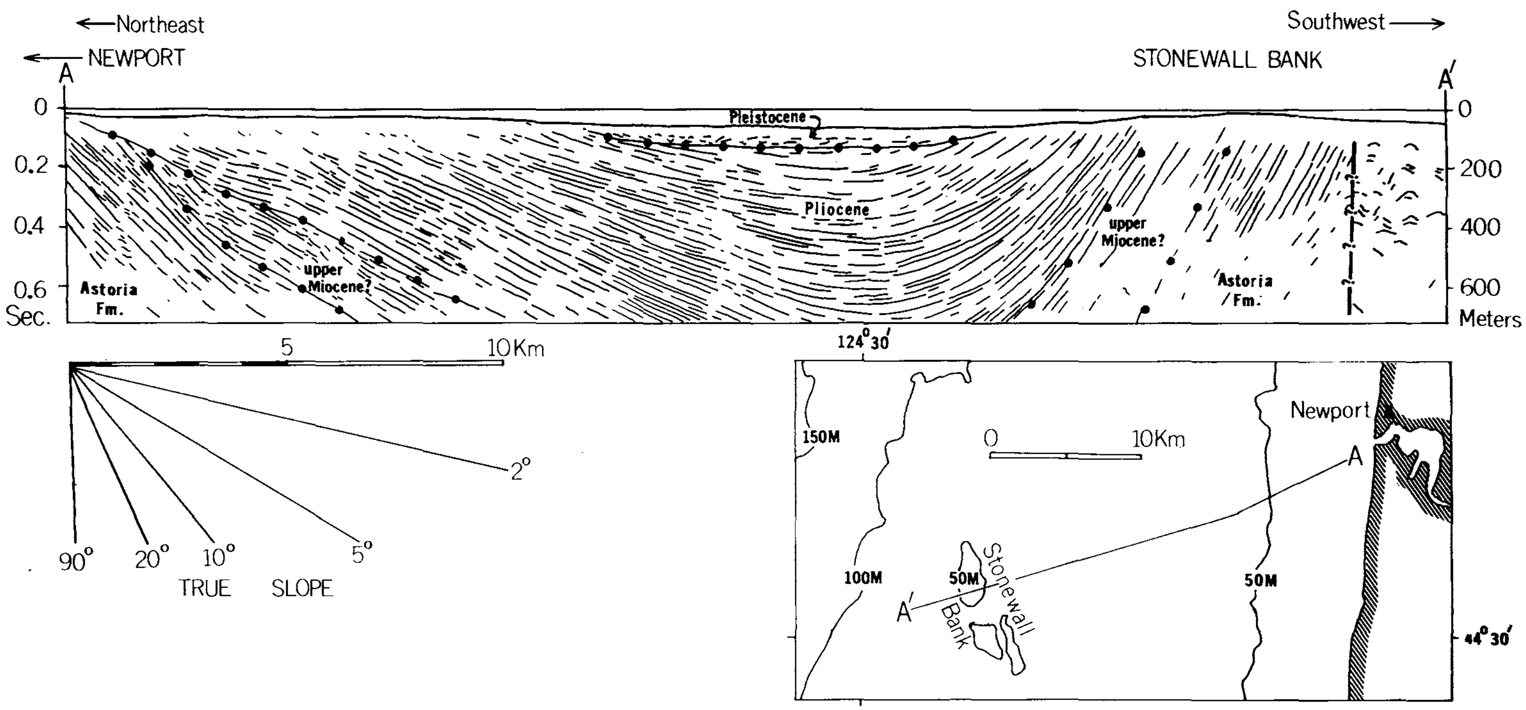

Figure 6. Acoustic reflection profile of the continental shelf off Newport, Oregon, with added geologic interpretations. Note that the profile reads with northeast on the left. Ages of acoustic units, delimited on the profile by dots, are based on extrapolation of onshore mapping and on bottom sampling near Stonewall Bank. Reflection time is given in seconds, depth is in meters based on a two-way acoustic velocity of 1000 meters/sec. Profile was provided by Gene A. Rusnak, U.S. Geological Survey.

several distinguishable units separated by disconformities; individual units differ in degree of consolidation, weathering characteristics, and composition. Several wave-cut terraces are developed along coastal stretches; one of these, the 500-foot-high flat-topped surface at Otter Crest on Cape Foulweather, is shown on page 25. Individual terraces are warped and vary more than 100 feet in elevation.

Intrusive rocks

Several suites of igneous rocks intrude the Tertiary sedimentary and volcanic rocks in the central part of the Oregon Coast Range. Several of these are consanguineous with extrusive rocks; others have no known extrusive equivalents.

The most voluminous igneous suite consists of sills and dikes of granophyric gabbro or ferrogabbro of middle Oligocene age. They cap many of the higher mountains in the Coast Range such as Marys Peak, Euchre Mountain, and Stott Mountain. Most are strongly differentiated and contain rocks ranging in composition from granophyric gabbro to aplite. They are characterized by the mineral assemblage Fe-rich olivine, ferroaugite, and quartz-feldspar intergrowth. Their petrochemistry and petrology is briefly described by Snavely and Wagner (1961).

Basalt, diabase, or gabbro sills of late Eocene to early Oligocene age and of Miocene age cap many of the higher areas along the crest of the Oregon Coast Range north of lat. 45° N. These sills and smaller bodies near the coast are intrusive equivalents of the volcanic sequences.

In addition to intrusives of basaltic composition, alkaline igneous rocks are also abundant in the central part of the Oregon Coast Range. Nepheline syenite sills, dikes, and small stocks occur over a large area 10 to 30 miles south and southeast of Newport; the most prominent of these is the 200-foot-thick sill at Table Mountain. The abundance of nepheline syenite clasts in Quaternary deposits strongly suggests that the outcrop areas of the nepheline syenite sills were considerably more extensive. The nepheline syenite intrusives are briefly described by Snavely and Wagner (1961).

Camptonite (hornblende-augite-plagioclase lamprophyre) dikes and sills are common in the area between the Siletz and Salmon Rivers extending from near the coast to the crest of the Coast Range. The largest camptonite intrusive occurs at Cougar Mountain about 24 miles northeast of Newport. Several camptonite dikes are located south of Newport in the same general area as the nepheline syenite intrusives. Several dike swarms in that area contain both nepheline syenite and camptonite dikes, suggesting a common origin for these two rock types. The camptonites vary considerably in composition and mineralogy (Snavely and Wagner, 1961); all are characterized by high alkali, TiO_2 and P_2O_5 content. Biotite camptonite dikes and extrusives are a compositional variant (higher K_2O, lower Na_2O) of the camptonite intrusives.

References

Baldwin, E. M., 1950, Pleistocene history of the Newport, Oregon region: Geological Society of the Oregon Country Geol. News Letter, v. 16, no. 10, p. 77-81.

_________, 1964, Geology of Oregon: Eugene, Ore., Univ. Oregon Cooperative Bookstore, 2nd ed., 165 p.

Baldwin, E. M., Brown, R. D., Jr., Gair, J. E., and Pease, M. H. Jr., 1955, Geology of the Sheridan and McMinnville quadrangles, Oregon: U.S. Geol. Survey Oil and Gas Inv. Map OM-155, scale 1:62,500.

Cooper, W. S., 1958, Coastal sand dunes of Oregon and Washington: Geol. Soc. America Mem. 72, 169 p.

Cushman, J. A., Stewart, R. E., and Stewart, K. C., 1949, Upper Eocene Foraminifera from the Toledo formation, Toledo, Lincoln County, Oregon: Oregon Dept. Geology and Mineral Industries Bull. 36, pt. 6, p. 126-145.

Dehlinger, P., Rinehart, R. W., Couch, R. W., and Gemperle, M., 1967, Free-air gravity anomaly map west of Oregon: Oregon Dept. Geology and Mineral Industries Geol. Map Series, Map GMS 4-c.

Diller, J. S., 1898, Description of the Roseburg quadrangle [Oregon]: U.S. Geol. Survey Geol. Atlas, Folio 49, 4 p.

Emilia, D. A., Berg, J. W., and Bales, W. E., 1966, A magnetic survey off the Pacific northwest coast: The ORE BIN, v. 28, no. 12, p. 205-210.

Fowler, G. A., 1966, Notes on late Tertiary foraminifera from off the central coast of Oregon: The ORE BIN, v. 28, no. 3, p. 53-60.

Harrison and Eaton [firm], 1920, Report on investigations of oil and gas possibilities of western Oregon: Oregon Bur. Mines and Geology, Mineral Resources of Oregon, v. 3, no. 1, p. 3-37.

Kleinpell, R. M., 1938, Miocene stratigraphy of California: Tulsa, Okla., Am. Assoc. Petroleum Geologists, 450 p.

Laiming, B. G., 1940, Some foraminiferal correlations in the Eocene of the San Joaquin Valley, California: Pacific Sci. Cong. 6th, 1939, Proc., v. 2, p. 535-568.

Mallory, V. S., 1959, Lower Tertiary biostratigraphy of the California Coast Ranges: Tulsa, Okla., Am. Assoc. Petroleum Geologists, 416 p.

Packard, E. L., and Kellogg, A. R., 1934, A new cetothere from the Miocene Astoria formation of Newport, Oregon: Carnegie Inst. Washington Pub. 447, Contr. Paleontology, p. 1-62.

Schenck, H. G., 1927, Marine Oligocene of Oregon: California Univ., Dept. Geol. Sci. Bull., v. 16, no. 12, p. 449-460.

_________, 1928, Stratigraphic relations of western Oregon Oligocene formations: California Univ., Dept. Geol. Sci. Bull., v. 18, no. 1, 50 p.

_________, 1936, Nuculid bivalves of the genus <u>Acila</u>: Geol. Soc. America Spec. Paper 4, 149 p.

Snavely, P. D., Jr., and Baldwin, E. M., 1948, Siletz River volcanic series, northwestern Oregon: Am. Assoc. Petroleum Geologists Bull., v. 32, no. 5, p. 805-812.

Snavely, P. D., Jr., and Vokes, H. E., 1949, Geology of the coastal area between Cape Kiwanda and Cape Foulweather, Oregon: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 97, scale 1:62,500.

Snavely, P. D. Jr., and Wagner, H. C., 1961, Differentiated gabbroic sills and associated alkalic rocks in the central part of the Oregon Coast Range, Oregon, <u>in</u> Geological Survey research, 1961: U.S. Geol. Survey Prof. Paper 424-D, p. D156-D161.

_________, 1963, Tertiary geologic history of western Oregon and Washington: Washington Div. Mines and Geology Rept. Inv. 22, 25 p.

Snavely, P. D., Jr., Wagner, H. C., and MacLeod, N. S., 1964, Rhythmic-bedded eugeosynclinal deposits of the Tyee Formation, Oregon Coast Range: Kansas Geol. Survey Bull. 169, v. 2, p. 461-480.

Snavely, P. D., Jr., and Wagner, H. C., 1964, Geologic sketch of northwestern Oregon: U.S. Geol. Survey Bull. 1181-M, p. M1-M17.

Snavely, P. D., Jr., Rau, W. W., and Wagner, H. C., 1964, Miocene stratigraphy of the Yaquina Bay area, Newport, Oregon: The ORE BIN, v. 26, no. 8, p. 133-151.

Snavely, P. D., Jr., Wagner, H. C., and MacLeod, N. S., 1965, Preliminary data on compositional variations of Tertiary volcanic rocks in the central part of the Oregon Coast Range: The ORE BIN, v. 27, no. 6, p. 101-117.

Snavely, P. D., Jr., MacLeod, N. S., and Wagner, H. C., 1968, Tholeiitic and alkalic basalts of the Eocene Siletz River Volcanics, Oregon Coast Range: Am. Jour. Sci., v. 266, no. 6, p. 454-481.

Snavely, P. D., Jr., Wagner, H. C., and MacLeod, N. S., 1969, Geology of western Oregon north of the Klamath Mountains, in Mineral and water resources of Oregon: U.S. Senate Document, Comm. Interior and Insular Affairs, in press.

Vokes, H. E., Norbisrath, Hans, and Snavely, P. D., Jr., 1949, Geology of the Newport-Waldport area, Lincoln County, Oregon: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 88, scale 1:62,500.

Vokes, H. E., Snavely, P. D., Jr., and Myers, D. A., 1951, Geology of the southern and southwestern border areas of the Willamette Valley, Oregon: U.S. Geol. Survey Oil and Gas Inv. Map OM-110, scale 1 inch to 1 mile.

Vokes, H. E., Myers, D. A., and Hoover, Linn, Jr., 1954, Geology of the west-central border area of the Willamette Valley, Oregon: U.S. Geol. Survey Oil and Gas Inv. Map OM-150, scale 1:62,500.

Waters, A. C., 1961, Stratigraphic and lithologic variations in the Columbia River Basalt: Am. Jour. Sci., v. 259, no. 8, p. 583-611.

Weaver, C. E., 1937, Tertiary stratigraphy of western Washington and northwestern Oregon: Washington Univ. Pubs. Geology, v. 4, 266 p.

Wilkinson, W. D., ed., 1959, Field guidebook, college teachers conference in geology, Oregon State College, Corvallis, Oregon, June 15-27, 1959: Oregon Dept. Geology and Mineral Industries Bull. 50, 148 p.

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GEOLOGICAL SOCIETIES TO MEET AT EUGENE

The Cordilleran Section of the Geological Society of America and the Pacific Coast branch of the Paleontological Society will hold their annual meetings on the 27th to 29th of March, 1969 at the University of Oregon in Eugene, hosted by the University's Department of Geology and Center for Volcanology. In addition to the regular presentation of papers, one symposium will be held: The late Mesozoic paleotectonic history of western Oregon and adjoining areas.

Following are the four field trips: Tuesday and Wednesday, March 25 and 26, Northern Klamath Mountains, led by E. M. Baldwin and M. A. Kays of the University and Len Ramp of the State of Oregon Department of Geology and Mineral Industries; and volcaniclastic rocks of central Oregon, led by Ernest Lund and Gordon Goles of the University; and Sunday, March 30, geology of the Newport Embayment, led by P. D. Snavely, Jr. and Norman MacLeod, U.S. Geological Survey, and engineering geology of the Blue River, Cougar, and Green Peter dam sites, led by Del Snyder, U.S. Corps of Engineers.

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FIELD TRIP GUIDEBOOK

GEOLOGY OF THE NEWPORT AREA, OREGON 1/

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This report on the "Geology of the Newport area, Oregon" was written specifically for a field trip to be held during the 65th Annual Meeting of the Cordilleran Section of the Geological Society of America in March, 1969. Part I of this article, "A geologic sketch of the Newport area, Oregon," was published in the February issue of The ORE BIN (Snavely and others, 1969). Part II, presented here, is the guidebook for a field trip designed to provide a synoptic view of the Tertiary sedimentary and volcanic rocks of the Newport area. The writers hope that the geologic data and road logs presented in these two articles will be useful not only to the geologists attending the meeting, but also to others interested in the stratigraphy, petrology, and paleontology of the Oregon Coast Range.

PART II. GEOLOGIC FIELD TRIP GUIDE, NEWPORT AREA, OREGON

The field trip consists of two geologic tours. On Tour 1, the Tertiary sedimentary rocks exposed along the Yaquina River between Newport and Toledo, Oregon, will be examined. This tour will start at the mouth of Yaquina Bay where Miocene sedimentary rocks are exposed and will proceed generally eastward and downsection. Tour 2 is primarily concerned with volcanic rocks of early Eocene, late Eocene, and middle Miocene age that form important stratigraphic units in the Oregon Coast Range. Figure 1 shows the locations of geologic maps for areas to be visited on Tour 1 (plate 1) and Tour 2 (plate 2). The reader is referred to Part I of this article (Snavely and others, 1969) for other geologic data pertinent to the field trip.

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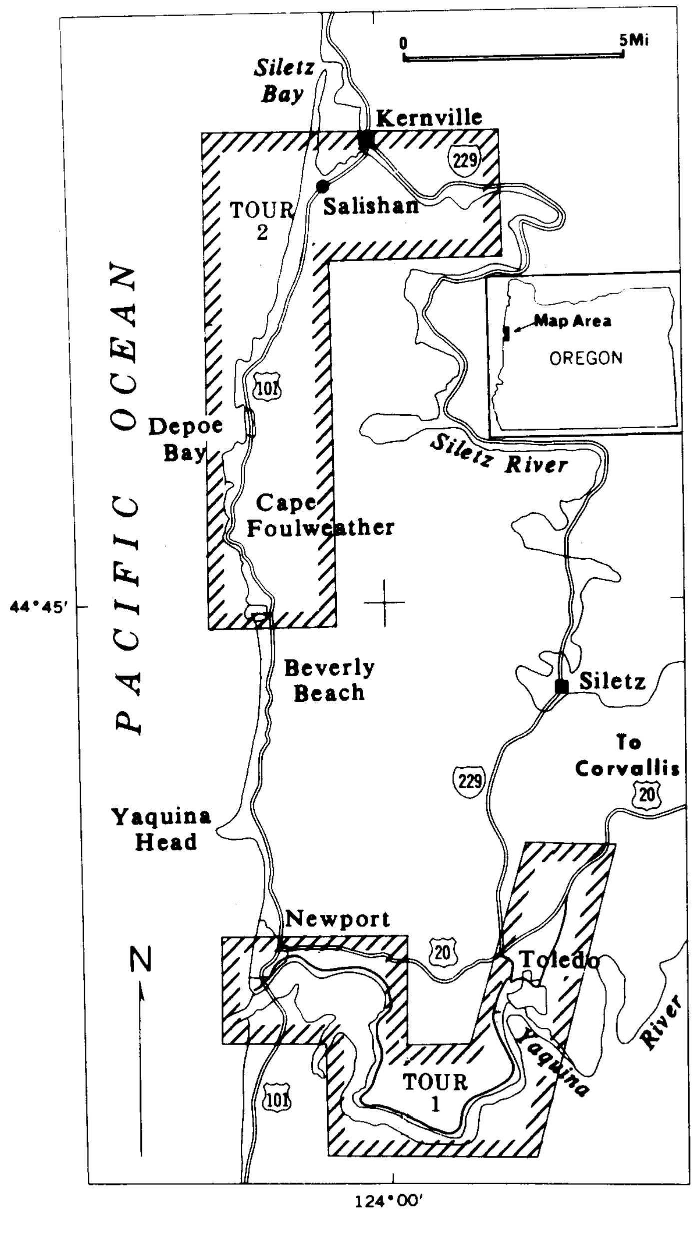


Figure 1. Index map showing locations of Tours 1 and 2 (plates 1 and 2) in the Newport area of central western Oregon.

Mileage

0 Start of trip. Yaquina Bay State Park, Newport, Oregon (see plate 1).

Stop 1 Follow path to base of jetty, north side of Yaquina Bay. The unconformable contact between the basal concretionary arkosic sandstone of the middle Miocene Astoria Formation and the underlying lower Miocene Nye Mudstone is exposed in the sea cliff (Snavely and others, 1964). The following foraminiferal species are among those that occur in the Astoria Formation but do not occur below this contact:

Buliminella elegantissima (d'Orbigny)
Robulus mayi Cushman and Parker
Uvigerinella californica ornata Cushman.

Common species occurring in the Nye Mudstone up to the contact but not above are:

Elphidium cf. E. minutum (Reuss)
Uvigerina auberiana d'Orbigny
Uvigerinella obesa impolita Cushman and Laiming.

Although the unconformity between the Astoria and Nye Formations is not always apparent in single exposures, regional mapping has shown that the Astoria Formation overlaps the Nye Mudstone and rests on the upper Oligocene Yaquina Formation about 8½ miles north of this stop. The Nye-Astoria contact is best exposed at Jumpoff Joe (fig. 2), 1½ miles north of Stop 1. Marine Pleistocene terrace deposits overlie both Miocene units at this stop. To the north along the beach, massive to well-bedded fossiliferous sandstone of the Astoria Formation contains interbedded siltstone, basaltic sandstone, and water-laid dacitic tuff beds up to 12 feet thick.

Proceed east along Yaquina Bay Road which descends over Pleistocene terrace deposits to the bay front. The old fishing community of Newport rests on the Nye Mudstone.

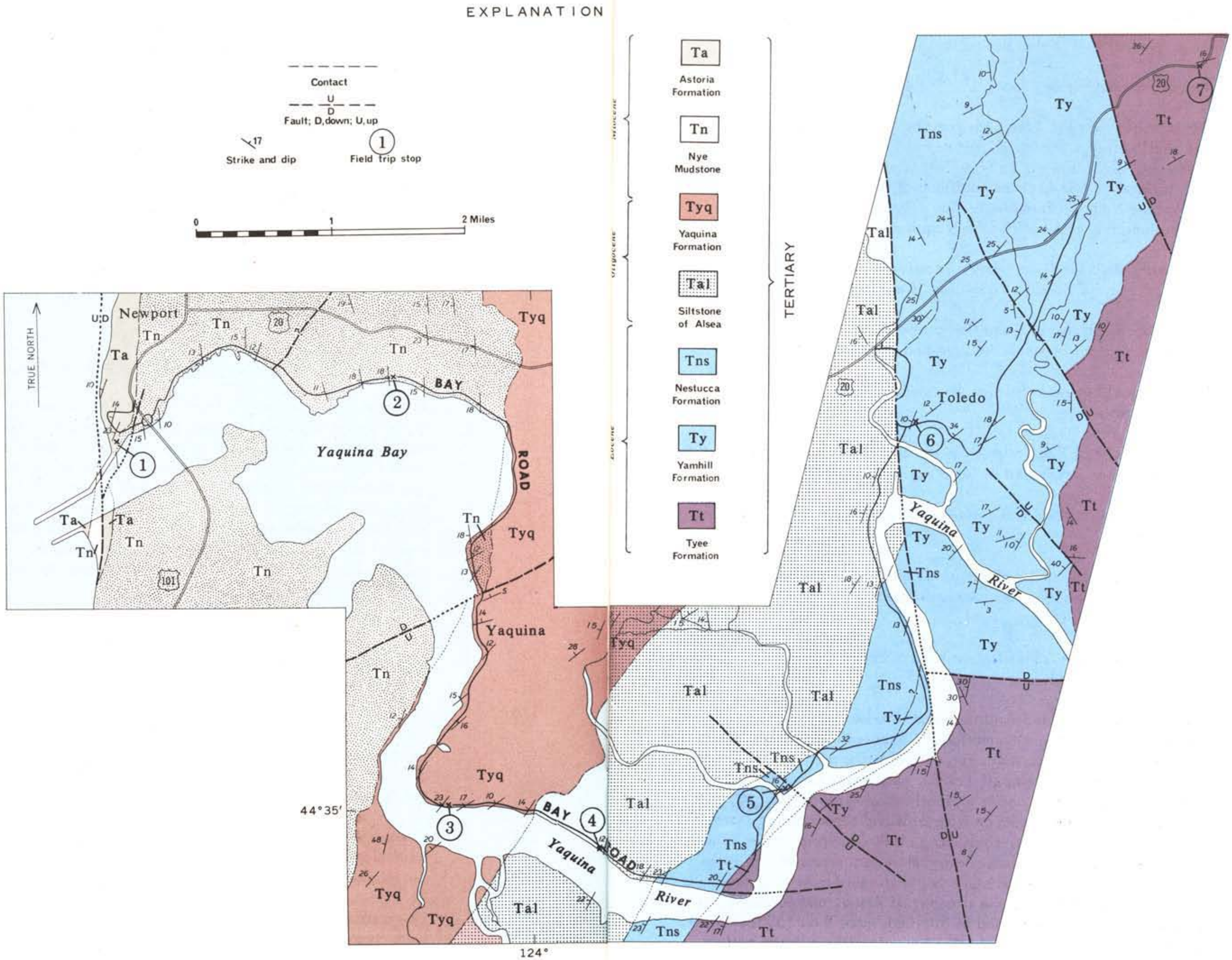
1.0 On the north side of the road are lower Pleistocene sands that fill channels cut into the Nye Mudstone. They are overlain by light-brown weathering upper Pleistocene marine sand and gravel. Landslides are common on the north side of Yaquina Bay, which is underlain by the Nye Mudstone.

1.7 Oregon State University Marine Science complex is visible on the south side of the bay. Flat upland areas north and south of the river are marine Pleistocene terrace deposits modified by large sand dunes.

2.6 Stop 2 The middle part of the Nye Mudstone, which here contains dolomite beds, is exposed in the road cut (fig. 3). The Nye Mudstone consists predominantly of massive, organic-rich mudstone and siltstone. Brown

Plate 1.

Geologic map showing locations of field-trip stops on Tour 1. Pleistocene deposits not shown.



fish scales and vertebrae are common. Although the rocks contain only a sparse molluscan fauna, Foraminifera, which are assigned to the Saucesian Stage of Kleinpell (1938), are generally abundant. The Foraminifera, as well as oxygen isotope ratios, indicate a cold-water environment during deposition.

Proceed east along Bay Road.

3.5 Contact between the Nye and Yaquina Formations is concealed in the small valley. The lower part of the Nye Mudstone becomes increasingly sandy toward its base and grades over a 50-foot interval into tuffaceous fine-grained sandstone of the upper part of the upper Oligocene Yaquina Formation. The contact is well exposed 2 miles south along the west bank of the Yaquina River.

Road turns southward along bay. Massive tuffaceous siltstone of the upper part of the Yaquina Formation is exposed in road cuts.

4.6 Road loops southwest at Coquille Point and cuts up-section to cross again the contact between the Nye and Yaquina Formations.

5.0 Fault contact between the Nye Mudstone and upper part of the Yaquina Formation.

5.3 Fishing village of Yaquina. Massive fossiliferous concretionary Yaquina sandstone is exposed in large cut north of village.

5.7 Thin- to thick-bedded and cross-bedded sandstone of the Yaquina Formation.

6.2 Road follows along strike of Yaquina Formation. Across the river (west) the Yaquina-Nye contact is exposed along river bank about 10 to 20 feet above water level.

6.5 Riverbend Moorage. Pleistocene terrace deposits overlie the Yaquina Formation on the left.

6.9 Stop 3 Massive to well-bedded sandstone and interbedded dark-gray marine siltstone of the Yaquina Formation are exposed in road cut. The siltstone in this outcrop contains Foraminifera that are referred to the Zemorrian Stage of Kleinpell (1938). Sandstone forms the bulk of the Yaquina Formation and is typically cross-bedded (fig. 4), gritty, and contains abundant pumice fragments and carbonaceous material. Thick conglomerate beds, containing clasts of silicic volcanic and metamorphic rocks, and less common thin coal seams occur in the sandstone. Intercalated siltstone is indistinguishable in appearance from the underlying unit, the siltstone of Alsea, and occurs as thin beds such as at this stop, and as interbeds more than 150 feet thick. Regionally, the Yaquina Formation has a lenslike outcrop pattern, and to the north and south it strikes into offshore areas. At Seal

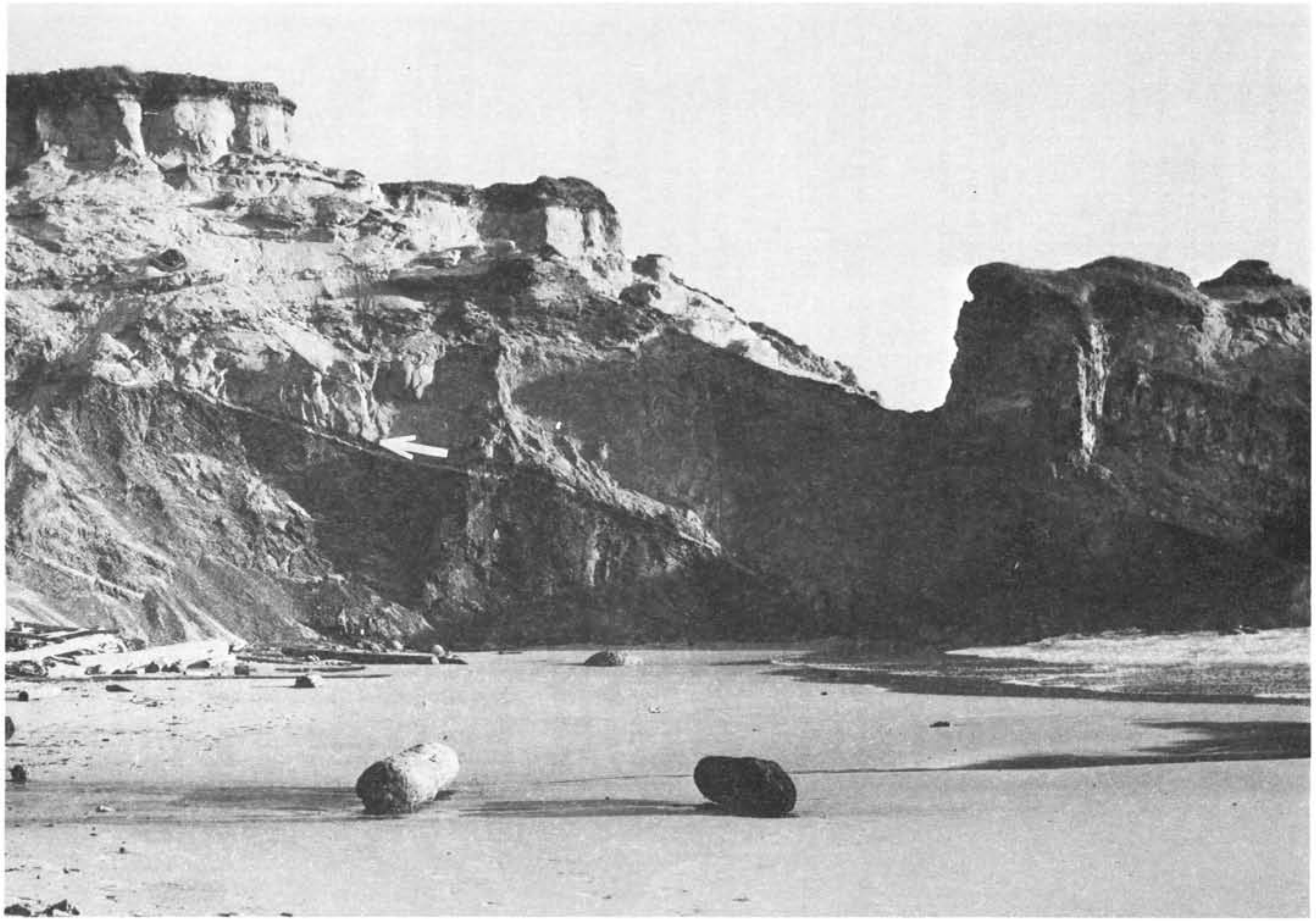


Figure 2. Unconformable contact (arrow) between the Nye Mudstone and overlying Astoria Formation at Jumpoff Joe, $1\frac{1}{2}$ miles north of Stop 1. Both these Miocene units are overlain by Pleistocene marine terrace deposits.

Rocks, its most southern onshore exposure, the Yaquina Formation is less than 500 feet thick. In the type section along the Yaquina River it is 1700 feet thick, and 10 to 15 miles to the north in the drainages of Spencer and Rocky Creeks it is well over 2000 feet thick. Near Kernville, 22 miles north of Stop 3, the Yaquina Formation again thins to about 500 feet. The lenticular shape and sedimentological characteristics of the Yaquina Formation suggest that it is of deltaic origin.

Proceed east along Bay Road.

7.1 Yaquina Formation. Carbonaceous siltstone and tuff beds overlie cross-bedded sandstone; pyrite nodules occur locally in the sandstone. Several subcommercial lignite beds were mined in this area near the turn of the century.

7.6 Conformable contact between the Yaquina Formation and an underlying siltstone unit of Oligocene age. This unnamed unit, well developed along Alsea Bay, is herein informally referred to as the "siltstone of Alsea."

8.2 Stop 4 Siltstone of Alsea. Massive concretionary tuffaceous siltstone and fine sandstone, contains thin tuff beds. Mollusks from this part of the unit indicate a middle Oligocene age. The abundant ash and pumice in the Oligocene strata in western Oregon and Washington were derived from pyroclastic volcanism in an ancestral Cascade Range. Pumiceous mudflow breccias with clasts of felsic volcanic rocks occur in this part of the sequence at Alsea Bay.

Proceed eastward on Bay Road.

8.6 The basal part of the siltstone of Alsea is exposed in road cut. Foraminifera from this outcrop indicate an early Oligocene age (Refugian Stage of Kleinpell, 1938).

8.8 Contact between the siltstone of Alsea and thin-bedded tuffaceous siltstone of the Nestucca Formation.

8.9 Glauconitic sandstone in the Nestucca Formation of latest Eocene age (A-1 zone of Laiming, 1940) is exposed in road cut.

9.3 Unconformable contact between the Nestucca Formation and Tyee Formation (middle Eocene). The unconformity at the base of the Nestucca Formation is the major unconformity in the Oregon Coast Range.

9.4 Graded sandstone and siltstone beds of the middle Eocene Tyee Formation.

9.7 Road turns north and cuts back up-section into the Nestucca Formation.

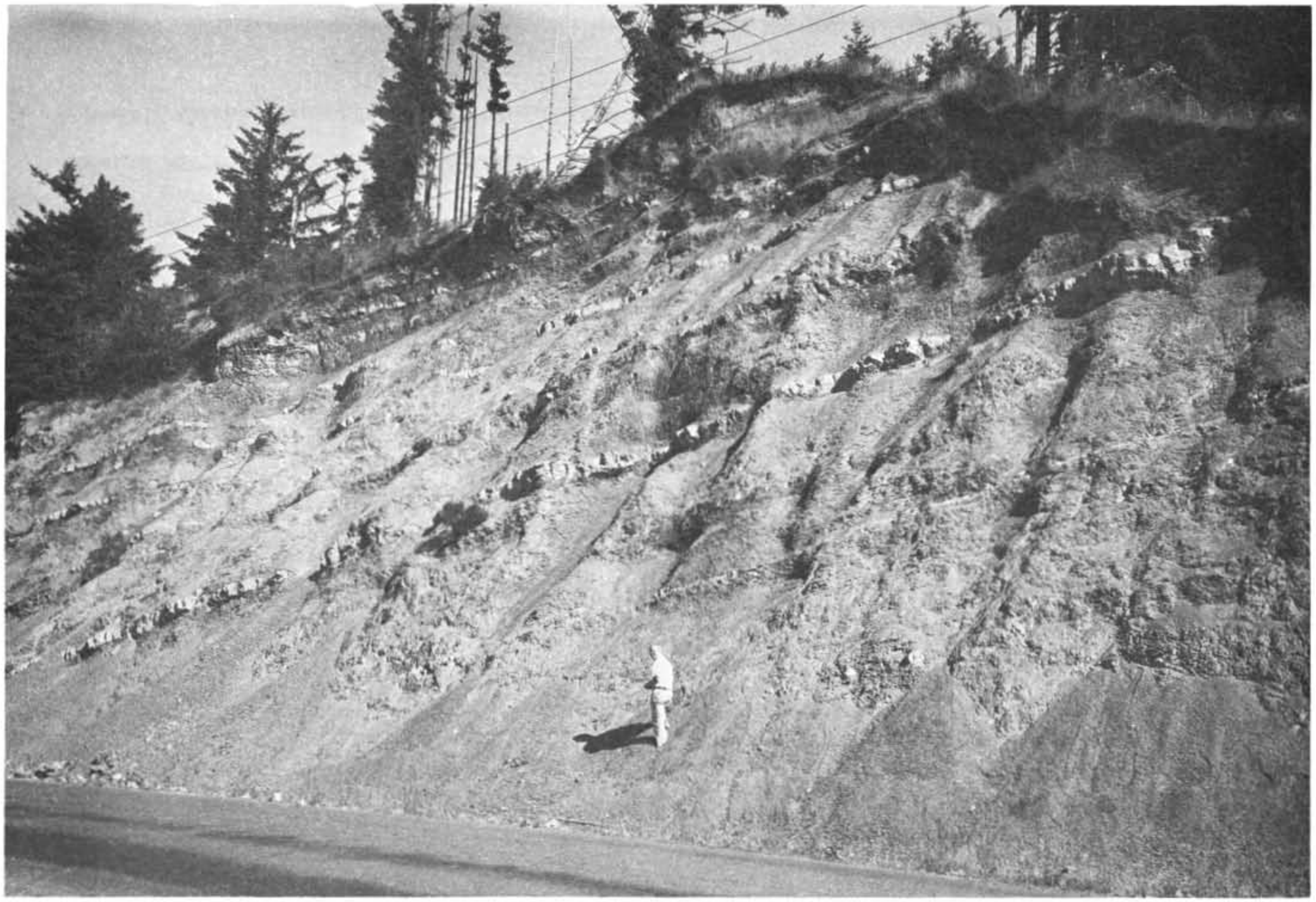


Figure 3. Dolomitic beds and lenses in the Nye Mudstone, north side of Yaquina Bay (Stop 2).

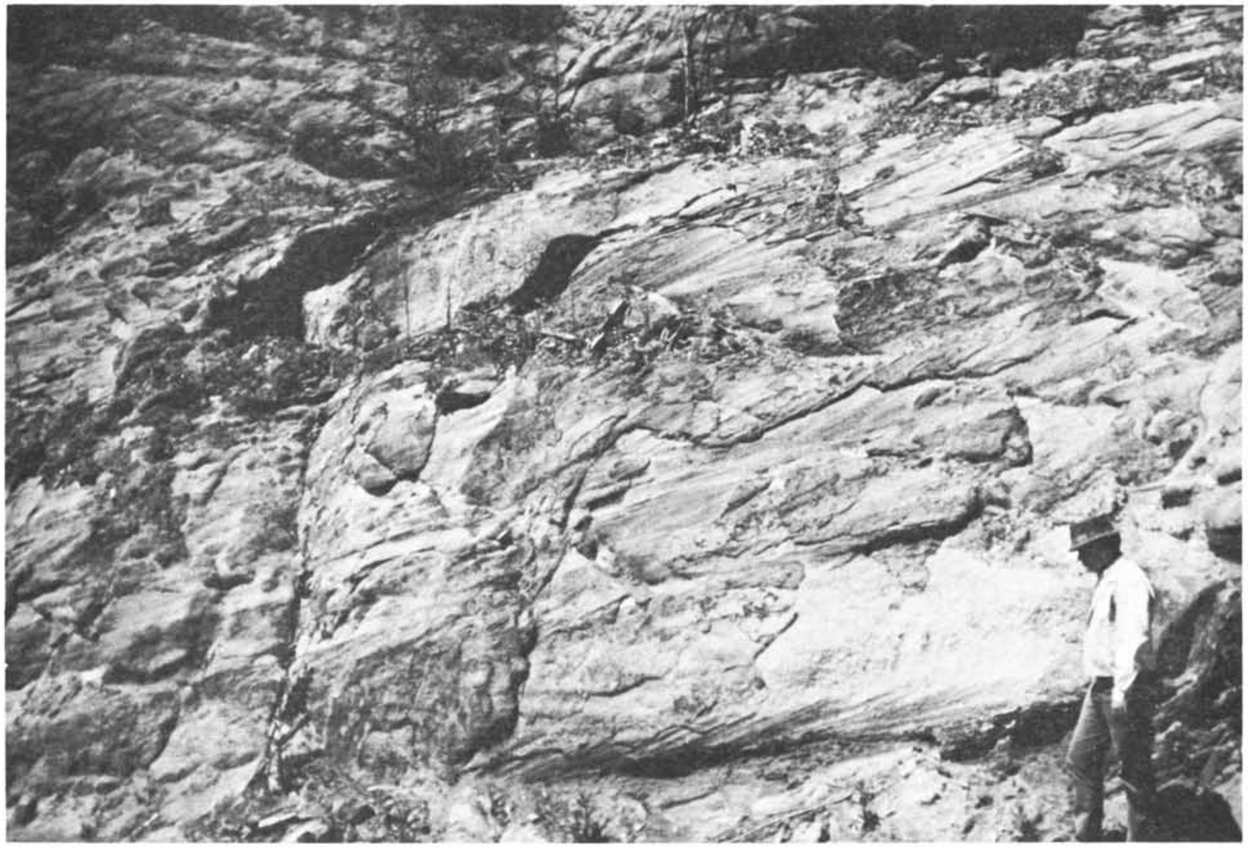


Figure 4. Cross-bedded sandstone of the Yaquina Formation along Rocky Creek, 1 mile northeast from Otter Crest.

10.1 Channel Marker No. 37 (mileage check).

10.3 Stop 5 Upper Eocene Nestucca Formation; thin-bedded tuffaceous siltstone contains 1- to 4-inch-thick light-brown ash beds and 1-foot-thick beds of tuffaceous glauconitic siltstone. Siltstone from this location contains a foraminiferal fauna assigned to the late Narizian Stage of Mallory (1959) and early Refugian Stage of Kleinpell (1938). The Nestucca in this area is only about 800 feet thick, whereas in the type area 30 to 40 miles to the north in the Hebo quadrangle it is more than 5000 feet thick. In the Toledo area it onlaps a structural high of middle Eocene rocks and in turn is overlapped by the siltstone of Alsea. The small fault at the east end of the outcrop downdrops the overlying siltstone of Alsea.

Continue northeast on Bay Road.

11.0 Flat-lying Pleistocene estuarine deposits.

12.3 Glauconitic sandstone in the upper part of the Nestucca Formation.

13.2-13.5 Large exposure of the siltstone of Alsea contains thin, light-colored volcanic ash beds. Georgia-Pacific Corp. sawmill and paper plant are on right.

13.9 Junction of old Highway 20 and Yaquina Bay Road. Turn right. Intersection is near the fault contact between the lower and middle Oligocene siltstone of Alsea and concretionary siltstone of the Yamhill Formation of late middle and early late Eocene age.

14.0 "Minnie's Sunset Cafe" locality (Cushman and others, 1949) of the Yamhill Formation. This formation underlies the town of Toledo and although poorly exposed is more than 2000 feet thick. Foraminifera at this location are assigned to the A-2 zone of Laiming (1940), whereas the lower part of the sequence contains a B1-A fauna. The Yamhill is an organic-rich siltstone and mudstone which contains abundant yellowish-gray calcareous concretions and thin arkosic sandstone beds. The Yamhill and older formations (Eocene) are more structurally complex than the Tertiary sequence above the upper Eocene unconformity. In the area between Toledo and Siletz many folds and faults mapped within the Yamhill and Tyee Formations do not extend above the unconformity at the base of the Nestucca Formation.

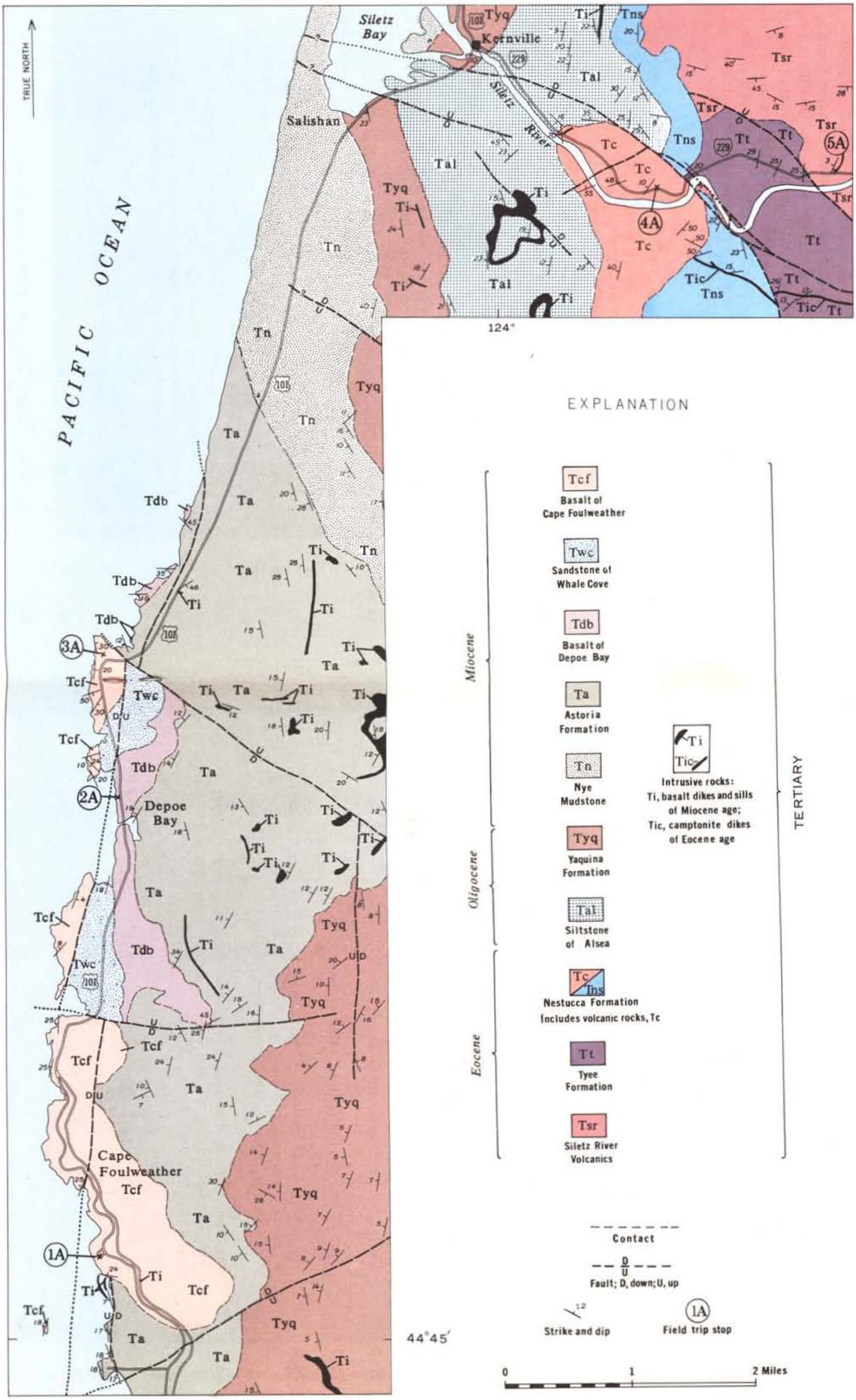
Proceed east toward Corvallis on old Highway 20.

14.7 Siltstone of the Yamhill Formation is exposed in road cuts on left.

16.5 Junction, Highway 20. Turn right toward Corvallis.

17.8 Contact between the Yamhill and Tyee Formations.

Plate 2. Geologic map showing locations of field-trip stops on Tour 2. Pleistocene deposits not shown.



18.2 Stop 7	Sandstone and siltstone of the Tyee Formation are exposed in new road cut. Individual beds are graded from sandstone at the base to siltstone at the top. Beds contain sole markings such as groove and flute casts (fig. 5) that have a northerly orientation. Siltstone clasts are abundant in the lower sandy parts of most beds, and carbonaceous material is generally scattered throughout. Except for Foraminifera in rare, thin pelagic claystone partings that occur at the tops of a few beds, fossils are absent. The graded beds, sole markings, internal structures, and lack of fossils indicate that the sandstone and siltstone beds that constitute the Tyee Formation are turbidites (Snavely and others, 1964). The northerly orientation of flute and groove casts in the Tyee Formation over much of the Oregon Coast Range indicates that the source area was about 150 miles to the south of this locality in the ancestral Klamath Mountains. About 30 miles to the north the turbidites grade laterally into a predominantly siltstone sequence (lower part of the Yamhill Formation).
	Turn around and return west toward Newport on Highway 20.
20.2-20.9	Road cuts in the Yamhill Formation.
21.5	Contact between the Yamhill and Nestucca Formations.
21.7	Junction between Highways 20 and 229.
21.9	Road cut on north is in the siltstone of Alsea.
23.0	Contact between siltstone of Alsea and Yaquina Formation.
23.6	Outcrop of Yaquina sandstone on north.
25.0	Contact between the Yaquina and Nye Formations.
26.0	East city limits of Newport, Oregon, with outcrop of Nye Mudstone on north side of road. The city of Newport is built on Pleistocene marine-terrace deposits which have been modified by sand dunes.
27.7	Junction, Highway 20 and U.S. Highway 101. Turn north on Highway 101 and continue to Otter Crest on Cape Foulweather (9 miles) where Tour 2 begins.

Field Trip Guide - Tour 2

<u>Mileage</u>

0 Stop 1A	Otter Crest Lookout, Cape Foulweather (see plate 2). Otter Crest and much of the coastal area for some 6 miles to the north are underlain by middle Miocene volcanic rocks which are informally referred to as the "basalt of Cape Foulweather." This unit is the younger of two middle Miocene volcanic sequences which are exposed along the

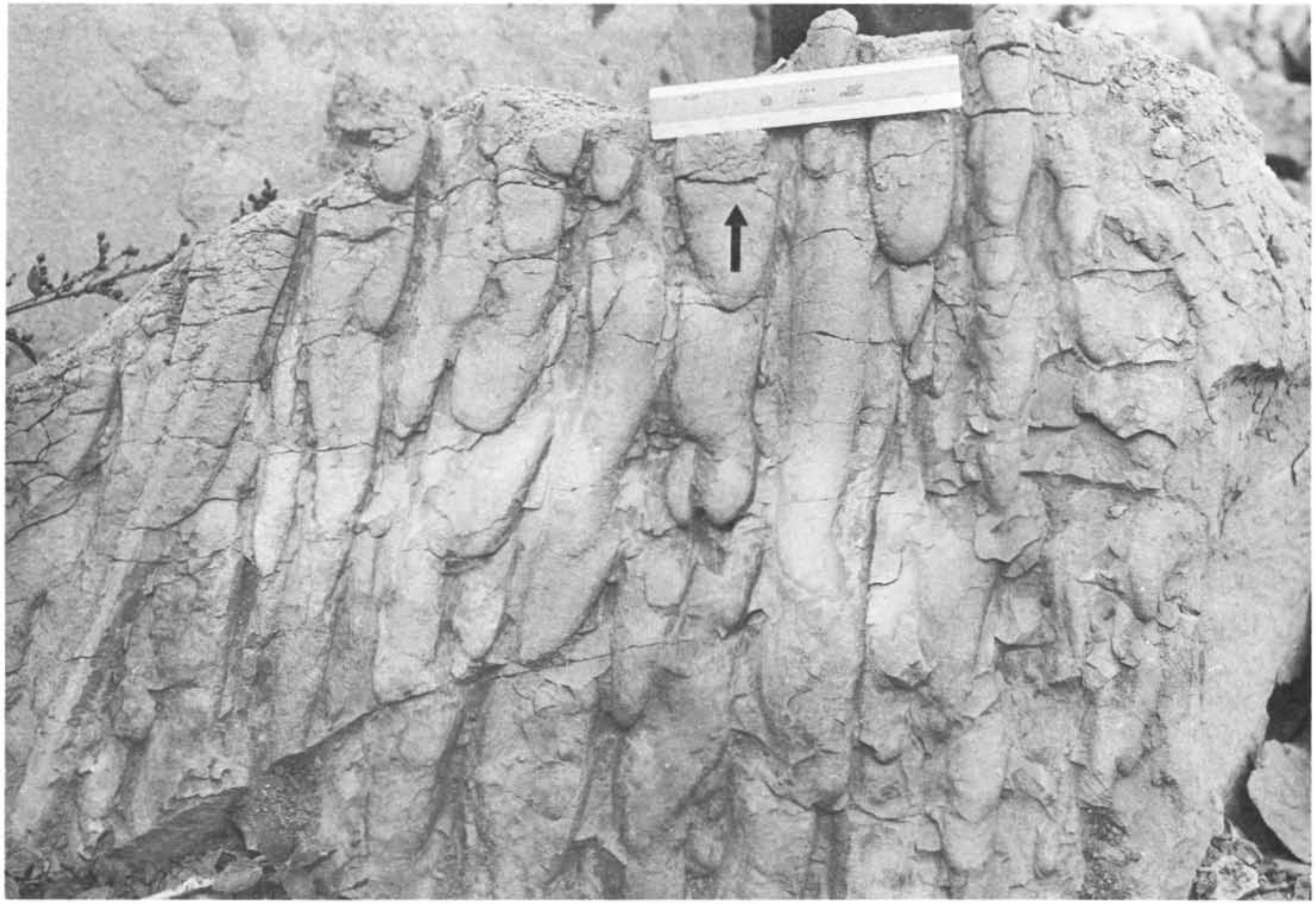


Figure 5. Flute casts on the sole of a sandstone bed in the Tyee Formation, Green Mountain, near Valsetz, Oregon. Arrow indicates direction of current movement. Scale is approximately 6".

Figure 6. Ring dikes intruding sandstone of the Astoria Formation on the wave-cut platform immediately south of Otter Crest Radial dike (lower left), offset along inner ring dike, extends to outer ring dike. Marine Pleistocene terrace deposits cap both headlands in upper part of photograph.

northern part of the Oregon coast. Flow breccia, extrusive breccia, and intercalated massive flows constitute the bulk of the basalt of Cape Foulweather at Otter Crest, whereas farther from the vent area (Stop 3A), water-laid lapilli tuff predominates. Blocks of Astoria sandstone are contained within some breccia units. An example is located immediately north of Otter Crest at the base of the cliff. Numerous dikes, sills, and small plugs intrude the breccia near Otter Crest indicating that this area was a local center of Miocene volcanism. Two ring dikes and several radial dikes are exposed on the wave-cut platform just south of Otter Crest (fig. 6). The basalt of Cape Foulweather also crops out at Yaquina Head, about 5 miles south of Otter Crest, and on the large island (Otter Rock) immediately west of Otter Crest. The two smaller islands immediately to the south (Gull Rock and Whaleback), however, are composed of subaerial basalt flows of an older (middle Miocene) unit. This unit, well exposed at Depoe Bay, is informally called the "basalt of Depoe Bay." The terrace on Otter Crest is about 500 feet above sea level and is the highest of several Pleistocene terraces developed along this coastline. Constructional marine terraces about 50 feet above sea level are developed on westward-dipping sandstone and siltstone of the Astoria Formation on the two nearby headlands to the south (fig. 6). The headland on the far southern horizon (35 miles distant) is composed of a 2000-foot-thick sequence of subaerial basalt flows of late Eocene age. Table Mountain, the prominent flat-topped mountain on the southeast horizon, is underlain by a 250-foot-thick nepheline syenite sill.

Proceed northward on old Highway 101.

0.5 Basalt sill exposed in road cut.

1.6 West-dipping flow breccia is exposed near tideline.

1.9 Intersect Highway 101.

2.3 Whale Cove on left is underlain by sandstone of middle Miocene age, herein referred to as the "sandstone of Whale Cove," which separates the basalt of Cape Foulweather from the slightly older basalt of Depoe Bay.

4.1 Bridge at Depoe Bay.

4.3 Stop 2A The basalt of Depoe Bay is exposed on the east margin of the outer bay on which Highway 101 is constructed. Dikes, sills, and plugs are abundant immediately east of Depoe Bay. At Depoe Bay the volcanic unit lies unconformably on the Astoria Formation, which is exposed in the inner bay, and is overlain by sandstone and siltstone of middle Miocene age -- the sandstone of Whale Cove. The basalt of Cape Foulweather overlies the sandstone and siltstone and forms the projecting headlands on the outer bay. At this stop, the basalt of Depoe

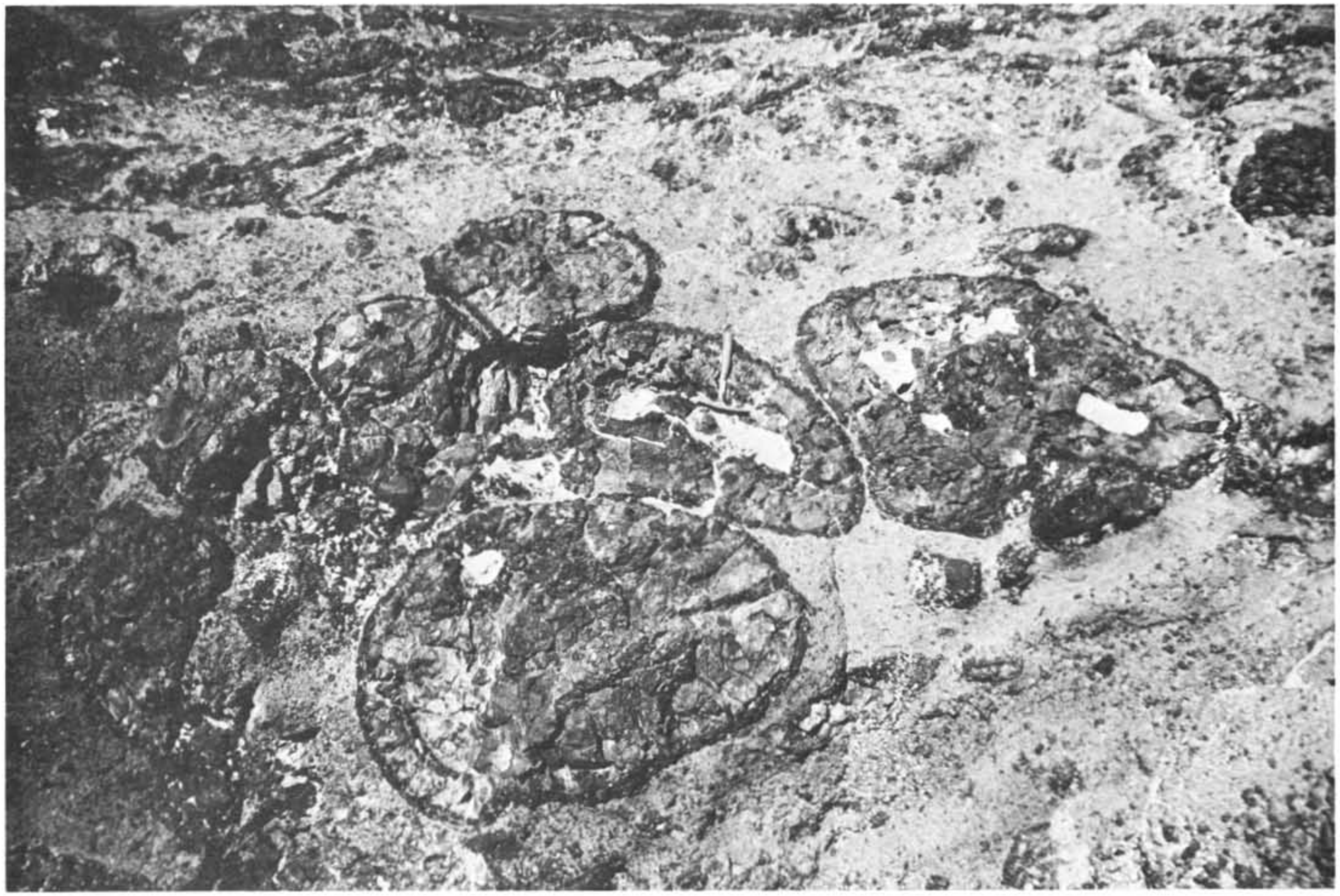


Figure 7. Isolated pillow breccia at Depoe Bay, Oregon (Stop 2A).

Bay is composed of exceptionally well-developed isolated pillows in breccia (fig. 7). The pillows have ropy rims and some have multiple chilled margins and drained-out cores. Inclusions of Astoria sandstone within the pillows are common. Rims of pillows and fragments in the breccia are composed of basaltic glass (sideromelane and tachylite); some glass is palagonitized.

Proceed north on Highway 101.

5.4 Turn left at State Park entrance.

5.6 Stop 3A Boiler Bay State Park, Government Point.
Water-laid, well-bedded lapilli tuff and breccia of the basalt of Cape Foulweather are exposed along the coast (fig. 8). These deposits probably formed a broad apron around the vent at Cape Foulweather. Grading in many individual beds suggests that they were deposited by density currents; more massive units probably represent breccia transported by mass movement such as submarine landsliding. Boiler Bay, immediately to the north, is eroded in the Astoria Formation and is capped by a 50-foot-high terrace deposit. On the north side of Boiler Bay, dikes of peperite and massive basalt cut the Astoria Formation. Cascade Head, the prominent headland on the skyline 15 miles to the north, is underlain by upper Eocene subaerial porphyritic basalt flows.

Proceed north on Highway 101.

6.4 Peperite dikes exposed on east side of roadway.

6.7 Fogarty Creek State Park. Sandstone of the Astoria Formation and Miocene basalt breccia are well exposed along coast.

7.1 Highway constructed on Pleistocene terrace modified by sand dunes.

10.6 Salishan Lodge and Siletz Bay.

10.8 Tuffaceous siltstone and glauconitic sandstone of the Yaquina Formation are exposed on southeast side of highway.

11.8 Siletz River bridge.

Turn right on Highway 229 toward Siletz.

11.9 Iron-stained sandstone of the Yaquina Formation is exposed on north side of highway.

12.1 Outcrops of tuffaceous siltstone and ash beds of the siltstone of Alsea are exposed on north side of highway.

Figure 8. Middle Miocene water-laid lapilli tuff and breccia at Government Point (Stop 3A). These deposits of fragmental basaltic debris formed a broad apron around the former local center of volcanism near Cape Foulweather.

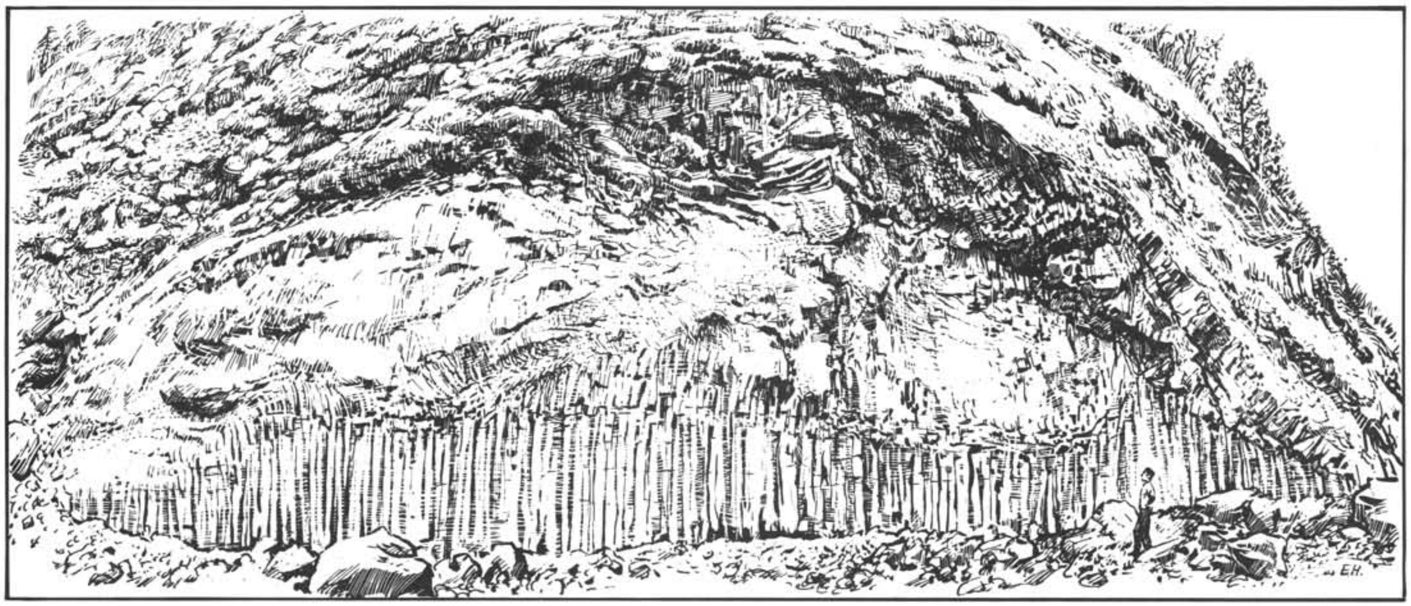


Figure 9. Filled feeder-tube in the Siletz River Volcanics at Kauffman quarry (Stop 7A). Columnar-jointed alkalic basalt in the center of the filled tube is surrounded by a carapace of pillow basalt. Line drawing from photographs.

12.7 Quarry on ridge on south side of Siletz River is in a basalt sill equivalent to the basalt of Depoe Bay.

12.9 Top of extrusive camptonite sequence of late Eocene age.

13.7 Stop 4A Quarry in camptonite breccia. The base of the camptonite sequence is made up of pillow lava which grades upward into interbedded water-laid tuff and breccia. Most of the fragmental material was originally camptonitic glass clouded with crystallites, but the glass is now largely altered. Sparse biotite and hornblende phenocrysts are scattered through the breccia. Dikes of biotite camptonite fed this extrusive sequence. One of these dikes is well exposed in a roadside quarry 6 road miles east along the Siletz River on Highway 229. The camptonite flow sequence is a temporal equivalent of the upper Eocene basalt exposed at Cape Perpetua and Cascade Head; some basalt at Cascade Head is transitional to camptonite in composition.

Proceed east on highway.

14.9 Tyee Formation exposed in road cut.

15.2 Natural levees developed along the Siletz River.

15.3 Contact between the Tyee Formation and Siletz River Volcanics.

15.4 Turn left on small road to Kauffman quarry.

15.4 Stop 5A Kauffman quarry (private property). Columnar-jointed filled feeder-tube is exposed at base of quarry and is surrounded on the sides and top by large elongate pillows (fig. 9). The pillows and filled feeder-tube rest on fine-grained basaltic sandstone. The basalt is part of the lower and lower-middle Eocene Siletz River Volcanics which is the oldest exposed unit in the Oregon Coast Range. The lower part and bulk of the Siletz River Volcanics is composed of tholeiitic basalt. The upper part in the Euchre Mountain quadrangle consists of a thin veneer of alkalic basalt, ankaramite, feldspar-phyric basalt, and picrite-basalt (Snavely and others, 1968). The somewhat altered alkalic basalt exposed in the Kauffman quarry is typical of this upper unit. A small, filled feeder-tube on the east side of the quarry contains aphyric alkalic basalt at the base and grades upward into porphyritic augite basalt in the center. It formed by lava erupted from a shallow magma chamber in which crystals had settled to the base during differentiation. Feeder-tubes such as these exposed at Kauffman quarry are common in the Siletz River Volcanics. Lava flowed downslope in these tubes below a self-formed protective cover of pillow lava.

End of field trip.

References

Cushman, J. A., Stewart, R. E., and Stewart, K. C., 1949, Upper Eocene Foraminifera from the Toledo formation, Toledo, Lincoln County, Oregon: Oregon Dept. Geology and Mineral Industries Bull. 36, pt. 6, p. 126-145.

Kleinpell, R. M., 1938, Miocene stratigraphy of California: Tulsa, Okla., Am. Assoc. Petroleum Geologists, 450 p.

Laiming, B. G., 1940, Some foraminiferal correlations in the Eocene of San Joaquin Valley, California: Am. Assoc. Petroleum Geologists Bull., v. 24, p. 1923-39.

Mallory, V. S., 1959, Lower Tertiary biostratigraphy of the California Coast Ranges: Tulsa, Okla., Am. Assoc. Petroleum Geologists, 416 p.

Snavely, P. D., Jr., Rau, W. W., and Wagner, H. C., 1964, Miocene stratigraphy of the Yaquina Bay area, Newport, Oregon: The ORE BIN, v. 26, no. 8, p. 133-151.

Snavely, P. D. Jr., Wagner, H. C., and MacLeod, N. S., 1964, Rhythmic-bedded eugeosynclinal deposits of the Tyee Formation, Oregon Coast Range: Kansas Geol. Survey Bull. 169, v. 2, p. 461-480.

Snavely, P. D. Jr., MacLeod, N. S., and Wagner, H. C., 1968, Tholeiitic and alkalic basalts of the Eocene Siletz River Volcanics, Oregon Coast Range: Am. Jour. Sci., v. 266, no. 6, p. 454-481.

Snavely, P. D., Jr., MacLeod, N. S., and Rau, W. W., 1969, Geology of the Newport area, Oregon, Part I: The ORE BIN, v. 31, no. 2, p. 25-48.

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YEAR OF THE METEORITE CONTINUED

The interest expressed by the science departments of grade and high schools, rock and mineral clubs, and the general public has encouraged the committee which established the Year of the Meteorite to extend the effort through 1969.

To date the committee has answered hundreds of letters and examined a great number of specimens. So far, all specimens have been "meteor-wrongs."

With the momentum that was gathered in 1968, the committee feels this effort should be continued, and as more people become interested the better the chance will be for a meteorite discovery. So won't you join with us in the search?

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ROCKHOUND PARK ESTABLISHED

The New Mexico Park and Recreation Commission has developed Rockhound State Park in the southwest part of the state. The 250-acre park is 12 miles southeast of Deming in the Little Florida Mountains. Deming Ranchettes, a land-development corporation, donated the land. The park may be unique in that rock-hunters are encouraged to take samples home with them. Amethyst, opal, and agate are among minerals found in the park. (The AGI Report, December 23, 1968.)

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METALS AND MINERALS CONFERENCE SITE CHOSEN

The city of Coeur d'Alene, Idaho will play host this year to the Pacific Northwest Metals and Minerals Conference on April 17, 18, and 19. The site chosen for the conference reflects the booming interest in silver, which is produced in three of the nation's largest silver mines nearby. Half of the entire national output of silver comes from mines in the Coeur d'Alene district.

Delegates to the conference will have the unusual opportunity to take field trips through various mines and mills in the district on the first day of the session. The district boasts the deepest lead-zinc mine in the world. The Coeur d'Alenes also have the only mines in the world where silver is found at great depth.

After the full day of field trips there will be two days of technical sessions devoted to the following topics: Mining, Mineral Processing, Geology, Exploration and Geophysics, Extractive Metallurgy, Non-metallic Minerals, and Automatic Data Processing. In addition to the technical sessions, there will be luncheons on both days and a banquet on Friday evening. Special events are also planned for ladies by the women's auxiliary of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

The Pacific Northwest Metals and Minerals Conference was conceived by the Oregon Section of AIME, and the first of a continuing series of annual meetings was held in April 1948. Subsequent meetings of the conference have been hosted at Seattle, Spokane, and Vancouver, B.C. This year marks the first time that Coeur d'Alene has held the conference.

Following the practice adopted more than 20 years ago, the conference will be open to the general public. Registration materials and additional information on the conference may be obtained by writing to: A.I.M.E., c/o Northwest Mining Assn., W. 522 First Avenue, Spokane, Wash. 99204.

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FOSSIL VERTEBRATES ON EXHIBIT IN PORTLAND

A remarkable collection of skulls, teeth, jaws, and other bones of extinct mammals of Oligocene and Miocene ages has been loaned to the Department by Dave Taylor and Bruce Welton of Portland. The exhibit is in one of the hall cases opposite the elevator on the 10th floor of the State Office Building in Portland. The fossils were discovered, dug out, and prepared with great pains by these two young men. Most of the specimens are from the John Day Formation in central Oregon, although a few are from the Oligocene White River beds of South Dakota. Not all of the specimens have been identified with certainty as yet, but among those determined are oreodons and early forms of horses, cats, dogs, foxes, rodents, pigs, and rhinos. In addition to the mammals, there are three giant fossil turtles.

Adjacent to the case of fossil animals is the outstanding collection of fossil plants from the John Day Formation which is on loan from Lee Jenkins of Hood River. The two exhibits as a unit exemplify the flora and fauna typical of western North America 30 million years ago. All of these fossils show by their excellence why the John Day Formation in Oregon is one of the finest sources in the world for fossil remains of Tertiary plants and animals.

* * * * *

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THE AGES OF SOME HOLOCENE VOLCANIC ERUPTIONS IN THE NEWBERRY VOLCANO AREA, OREGON

By N. V. Peterson* and E. A. Groh**

Several episodes of volcanism of Holocene age (since the last 11,000 years) are well recorded within Newberry Crater and on the flanks of Newberry Volcano in central Oregon. Newberry Volcano is a huge shield volcano which rises from the basalt plateau south of Bend and east of the Cascade Range. At the summit of the shield is a large caldera with two lakes and a variety of fresh volcanic features. On its flanks are lava flows that post-date the volcano. Of particular interest are the flows that erupted from a rift zone which extends northwest for 20 miles from the crater to Lava Butte and beyond (plate 1).

How old are these rocks? How long ago did all this happen? These are the questions most frequently asked by visitors who view the shiny black obsidian domes in Newberry Crater, the spiny black lava flows by the Lava Cast Forest campground, or those by Lava Butte.

There has been much speculation by geologists and others on the age of these events, and their guesses range from a few hundred years to a few thousand years. We are never completely satisfied with guesses, so are continually looking for ways to establish the exact sequence and timing of the volcanic eruptions. For the past several years, as a secondary project while studying the extensive and varied volcanic features of central Oregon (Oregon Dept. of Geology and Mineral Industries, 1965), we have been gathering radiocarbon age data on the basaltic flows between Newberry Volcano and Lava Butte. Recently a new technique, developed by geologists of the U.S. Geological Survey for dating obsidian, has given us additional information about the latest volcanic eruptions within the Newberry Caldera.

Lava Butte - Northwest Rift Zone

High-altitude aerial photographs show a more-or-less continuous zone of recent faults and fissures trending N. 30° W. from The Fissure at East

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* Geologist, State of Oregon Dept. of Geology and Mineral Industries.
** Private Geologist, Portland, Oregon.

Lake within Newberry Caldera (figure 1) to Lava Butte (figure 2) and beyond. The sketch map (plate 1) shows that at least eight separate basaltic lava flows have been erupted from this zone, which we referred to previously as the Northwest Rift Zone (Peterson and Groh, 1965). All are aa flows that vary in area and thickness from the smallest North Summit Flow high on Newberry's north flank (less than half a square mile in extent) to the largest and thickest, Lava Butte Flow, at the north end of the rift. The Lava Butte Flow covers nearly 10 square miles and ranges from 30 to 100 feet in thickness. Its vent (figure 2) is at the base of Lava Butte, a symmetrical cinder cone. The U.S. Forest Service has recently designated the cinder cone and the lava field surrounding it as a National Geological Area.

In the central part of the rift zone, sporadic eruptions along fissure vents have produced lava fountains or "fire fountains" which threw out bombs and scoria on the flowing lava (figure 3). The hot, pasty aa lava flowed sluggishly northward and westward down the moderate slope, engulfing pine forests much like those growing in the area today (figure 4). Some of the growing trees remained upright and were surrounded by quickly cooling lava; others were tilted or knocked down by the slowly moving molten mass. The smaller trees and shrubs were burned as the lava approached.

It is believed that within a few minutes after the lava surrounds a tree it cools and forms a thin shell of dense rock; gases and steam are driven from the green wood and the tree is ignited. In most instances the vertical tree burns slowly but completely, leaving a mold the shape and size of the original trunk and extending through the lava flow to the surface. Many of the vertical molds have a prominence or collar on the upstream side which may project a few feet above the surface of the lava (figure 5).

Countless fallen logs must have been covered completely by the flows from the Northwest Rift Zone and, in some places near the margins, subsequent collapse of the thin lava shell has exposed a long horizontal mold (figure 6). Burning of the wood in these molds was not always complete, and charcoal has been found in a few places encased in the lava. This charcoal is ideal for radiocarbon dating.

Our first chance to obtain charcoal for radiocarbon dating was in 1964, when Bill Winney of Bend guided us to a horizontal tree mold in the Lava Cast Forest Flow, where we collected charcoal encased in the lava. This sample was sent to Isotopes, Inc., which determined its age to be 6150 ± 120 years B.P. (before present). We were rather surprised to find that such fresh-looking rocks were this old, but several other radiocarbon dates obtained later confirmed this age. We knew that all the lavas of the Northwest Rift Zone were younger than the climactic eruptions of Mount Mazama (now the site of Crater Lake), which occurred about 6600 years ago, because there was no mantle of Mazama pumice on their surfaces. However, the actual age of the flows was not known until we had obtained radiocarbon data.

Figure 1. Rising from the shore of East Lake is The Fissure. It is located on the north wall of Newberry Crater, and represents the southern terminus of the Northwest Rift Zone.

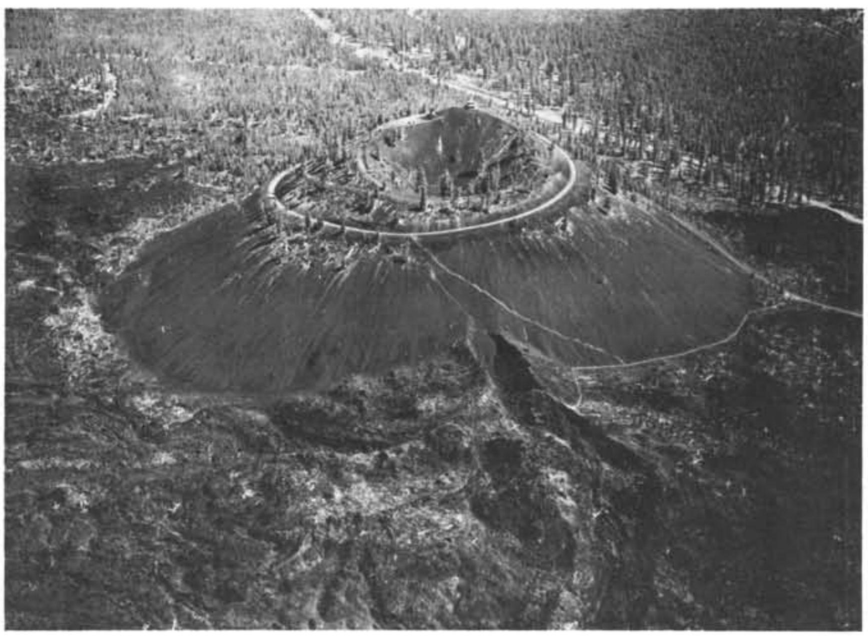

Figure 2. Lava Butte viewed from the south. It is adjacent to U. S. Highway 97, about 10 miles south of Bend, and is one of the prime geologic attractions in Oregon.

Table 1. Radiocarbon ages of some Holocene eruptions on Newberry Volcano.

Name of flow	Age - years before present (B.P.)*	Laboratory
Pumice bed in Newberry Crater	1270 ± 60	University of Texas
Lava Cascade Flow	5800 ± 100	Gakushuin Univ.
Gas-Line Flows	5800 ± 150	Columbia University
Forest Road Flow	5960 ± 100	Gakushuin Univ.
Surveyor Flow	6080 ± 100	Gakushuin Univ.
Lava Cast Forest Flow	6150 ± 210	Isotopes, Inc.
	6380 ± 130	Gakushuin Univ.

* Based on Libby half-life.

Because of the difficulty in finding charcoal in horizontal tree molds, our attention turned to the idea that perhaps the roots of the now vanished trees might have become carbonized and would still be present in the soil zone beneath the lava flow. The generalized sketch (figure 7) shows what we found in almost every vertical tree mold we explored. After removing debris from the bottom, we encountered a pumiceous soil layer, reddish near the top where oxidized by the heat of the lava. Then, 6 inches to a foot into the soil zone, lay the charred root material. The only tools needed to extract it were a small shovel, a bucket on a rope, and persistence. A hard hat and a helper to hoist the bucket aided the operation.

We were successful in obtaining charcoal from tree molds in four out of eight flows along the Northwest Rift Zone and also one sample from the Surveyor Flow, which is a similar basaltic aa lava on the south flank of the broad Newberry shield. Table 1 shows that the radiocarbon ages of these five flows range from 5800 ± 100 years B.P. to 6380 ± 130 years B.P., indicating that most, if not all, of these volcanic events were confined to a short eruptive period about 6000 years ago.

Radiocarbon dating is in agreement with the stratigraphic relationship shown by Lava Cascade Flow which spread over part of the Lava Cast Forest Flow. This is the only visible example of superposition of one flow over the other along the Northwest Rift Zone. A radiocarbon date was obtained for only one of the Gas-Line Flows, but we believe that both were erupted simultaneously from the same short fissure.

We searched for tree molds along some of the margins of both the Lava Butte and Mokst Butte Flows without success. It is probable that these thick outpourings of lava completely overwhelmed and buried every tree

Figure 3. A large, almond-shaped bomb thrown out from a fissure vent of the Lava Cascade Flow during an explosive eruption.

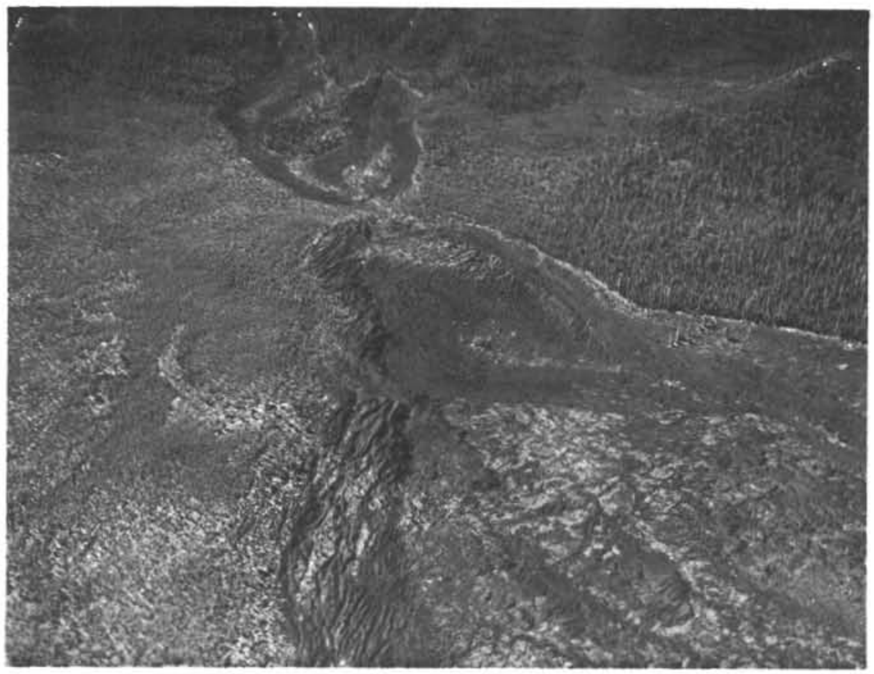

Figure 4. Looking south across upper part of the Lava Cascade Flow. Basaltic lavas were erupted as fire fountains near the eastern (left) edge of the flow and moved westward (right).

Table 2. Hydration ages of obsidian flows within Newberry Crater.*

Name of flow	Age - years**
Big Obsidian Flow	1350
Interlake Obsidian Flow	1700
East Lake Obsidian Flow - Western	1900
East Lake Obsidian Flow - Eastern	2600
Pumice Cone Crater Obsidian Dome	5000

* Laboratory: U.S. Geological Survey, Branch of Isotope Geology.
** Calculations based on a hydration rate of 5 microns ^{2}/1000 years.

in their paths. At this time we can state only that the Lava Butte Flow is younger than the nearby Gas-Line Flows (dated at 5800 ± 150 years) because the Gas-Line Flows are mantled by volcanic ash from Lava Butte.

Newberry Caldera

Excellent descriptions of the geology and landforms of the Newberry Volcano have been written by Williams (1935) and by Higgins and Waters (1967, 1968), who recognized that the obsidian flows and domes were some of the latest volcanic eruptions in the caldera. Williams described the Big Obsidian Flow as by far the largest and youngest of the group (figure 8 and plate 1). In 1966, charcoal from a log in pumice just beneath the Big Obsidian Flow was submitted to the University of Texas by U.S. Clanton of NASA and was determined to be 1270 ± 60 years B. P. (table 1).

Not long ago, Friedman and Smith (1960) of the U.S. Geological Survey devised a technique for dating obsidian artifacts by measuring the hydration rind that develops on a surface exposed to the atmosphere (explained more fully in a later section of this report). Their method is also useful in dating volcanic glasses such as obsidian flows (Friedman, 1968). Samples of five obsidian domes and flows (listed in table 2) were sent to Dr. Friedman at the Branch of Isotope Geology, U.S. Geological Survey, in Denver. His measurements revealed that the specimens vary in age but that all are Holocene. The two nearly contiguous East Lake Obsidian Flows (figure 9) appear to have been erupted contemporaneously from the same fissure, but since the hydration-rind dates show a 700-year difference in their ages, the two flows may have erupted several hundred years apart. The age difference may be due also to the range in hydration-rate error, or to a misinterpretation in sampling what was considered to be the original

Figure 5. Lava tree mold showing an exposed chilled collar above the lava surface at Lava Cascade Flow.

Figure 6. Mold of horizontal tree entombed by the Lava Cascade Flow. The shell formed when violent emission of steam and gases from the burning wood rapidly chilled the lava. (Oregon State Highway Department photograph.)

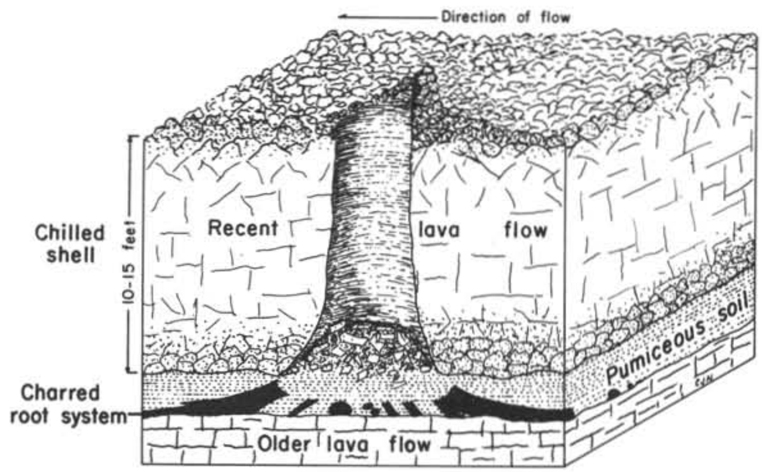

Figure 7. Cross section of a typical vertical tree mold formed in recent lava flows on the flanks of Newberry Volcano.

Figure 8. Big Obsidian Flow. A light coating of snow accentuates the flow ridge pattern. Paulina Lake in the foreground.

surface.

In general, the hydration-rind dates confirm the relative ages inferred by the earlier investigators. The Pumice Cone Crater Obsidian Dome is by far the oldest, at 5000 years. Next in age are the East Lake Obsidian Flows at 2600 and 1900 years. The Interlake Obsidian Flow (figure 10) is next at 1700 years; and, as expected, the Big Obsidian Flow is the youngest at 1350 years. The discrepancy between this date and the radiocarbon date for charcoal in the underlying pumice (1270 $\pm$ 60) is within the range of errors inherent in the dating techniques.

Perhaps the oldest of the recent obsidian flows in Newberry Caldera is the Game Hut Obsidian Flow, which is heavily mantled by pumice. Samples of this volcanic glass did not prove satisfactory for hydration dating.

Dating Methods

Radiocarbon dating

This procedure for dating carbonaceous materials derived from previously living plant or animal matter has been in use for some 20 years. The method is used also on nonorganic carbonaceous substances such as caliche and carbonate precipitates. Many thousands of dates or ages that otherwise could not have been determined have been established for archaeological sites and late Quaternary stratigraphic units.

The radioactive carbon isotope, called carbon-14 (C^{14}), is produced in the atmosphere by the neutron-proton reaction of cosmic rays on the abundant isotope nitrogen-14. The radiocarbon thus formed emits a low-energy beta particle and gradually changes back into the stable isotope nitrogen-14. Its half-life is about 5700 years, which allows dating to a maximum of about 50,000 years. Thus, the radiocarbon method is extremely useful for dating man's early history and recent geologic events.

The radiocarbon formed in the atmosphere is soon oxidized to radioactive carbon dioxide and follows ordinary carbon dioxide in its distribution about the earth and in the oceans. Through photosynthesis it becomes converted to plant tissue and by means of the plant-animal food cycle it reaches equilibrium throughout all living matter. Therefore, every living organism in the world at present has essentially the same amount of radiocarbon per unit of contained carbon, and this constant ratio is maintained by the turnover of food consumption and respiration.

An exception to the above is found in long-lived organisms such as trees. As new wood tissue is formed, it no longer takes part in the carbon-exchange cycle and thus passes from equilibrium. The radiocarbon now begins to diminish. The innermost annual ring of the living tree has a radiocarbon age equivalent to the age of the tree, and the wood becomes progressively younger in radiocarbon age, reaching zero with the newest sap-wood.

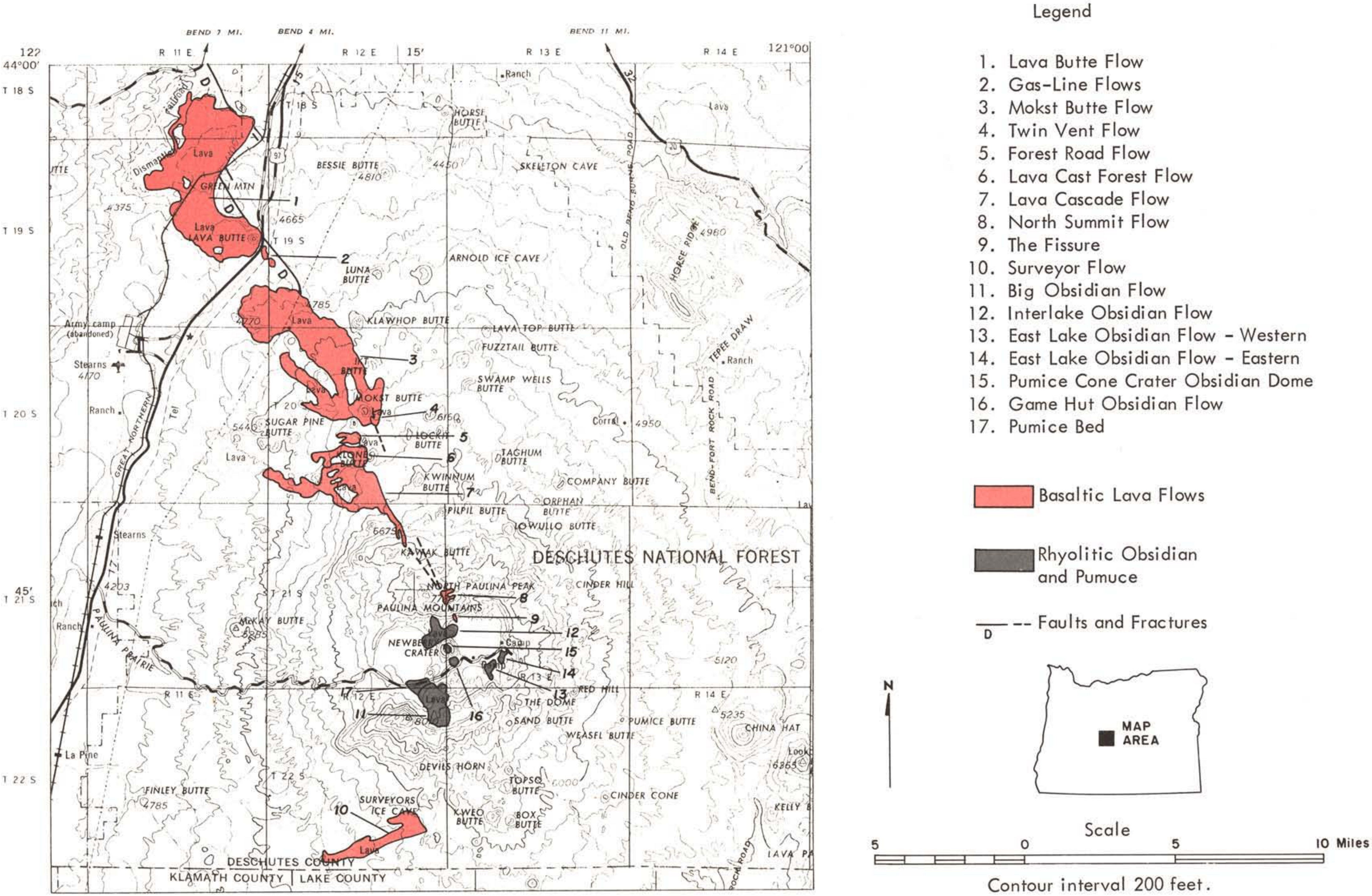

Plate 1. Sketch map of some Holocene lava flows of Newberry Volcano, Deschutes County, Oregon.

When an organism dies, the equilibrium is disrupted, because the radiocarbon content is no longer maintained. Radiocarbon in the parts of these organisms that will remain preserved, such as bone, shell, wood, charcoal, or peat, now begins its radioactive decay. Figuratively, the "clock" is set to ticking. In the laboratory a sample of these materials is cleaned of any visible modern contaminants such as hair roots or fungi. The sample is then treated with sodium hydroxide to remove humic acids and with hydrochloric acid to remove extraneous carbonate deposits, except in the case of carbonate samples such as bone or shell. In the presence of radon-free oxygen the sample is ignited and oxidized to carbon dioxide, which is drawn into special gas-handling equipment. Here the carbon dioxide may be given one of several chemical treatments for further purification. In some laboratories the carbon dioxide is converted to another gas containing carbon such as methane or acetylene. Finally, a specific volume of the purified gas is introduced into a specially shielded counter tube and its radioactivity is measured over a period of time, generally several days. The amount of radiocarbon present is thus determined and the age calculated, that is, the time on the "clock" is read.

The radiocarbon ages listed in Table 1 are based on a half-life of 5568 years for the radiocarbon isotope, called the Libby half-life. In recent years, more accurate measurements have raised this value to 5730 years, or about a 3 percent increase. To give a closer approximation to the true age this correction can be added, although it is usually considered negligible in geologic dating. To avoid any misunderstanding in the literature, all dates continue to be based on the Libby half-life.

More important in absolute chronology, as supported by radiocarbon dating, is the discrepancy between the true age in calendar years and the ages dated in radiocarbon years (Stuiver and Suess, 1966). Radiocarbon ages older than about 2200 B.P. are progressively younger than true ages obtained from tree rings and historically dated samples. This divergence as found at this time continues back to about 6000 years B.P. Thus conversion of the radiocarbon ages of the lava flows given in Table 1 to their true ages would date them at 7000 to 8000 calendar years ago. The cause for the variation in past radiocarbon levels is not definitely known, but it may be due to changes in cosmic ray flux and as a consequence an increased production of radiocarbon in the past. Another factor may have been changes in the earth's climate which could have altered the total carbon-dioxide content of the atmosphere.

Hydration dating

The hydration method was developed a few years ago to determine the age of obsidian artifacts found in many archaeological sites (Friedman and Smith, 1960). This method can also be applied to dating obsidian flows (Friedman, 1968).

Figure 9. The East Lake Obsidian Flows. Uppermost is the Western Flow and below, the Eastern Flow.

Figure 10. Looking south across Newberry Crater. In the foreground, Interlake Obsidian Flow has divided into two tongues, one flowing left into East Lake and the other in the opposite direction to the shore of Paulina Lake. In the center is the notched crater of Pumice Cone. In the distant right is Big Obsidian Flow (see figure 8).

An exposed obsidian surface adsorbs a film of water which diffuses into the rock along a distinct and sharply defined front. The hydrated layer, or rind, has a higher index of refraction. When viewed microscopically in a thin section cut perpendicular to the surface, this layer shows a distinct phase contrast under ordinary light. Because the thickness of this hydration layer is usually only a few microns, high magnification and capability of precise measurement to within 0.2 microns are necessary.

The rate of hydration for obsidian is not dependent on the humidity present in the particular environment; rather, the rate is determined by the temperature the obsidian is subjected to over its history. Data from experimental studies and from obsidian samples throughout the world have established a hydration rate for several climatic zones (Friedman and others, 1966). At present the hydration rate is liable to an error of about 20 percent, but further research will undoubtedly reduce the magnitude of the error.

The hydration ages listed in table 2 appear to present good approximate ages for those particular eruptive events in Newberry Crater. Further sampling and refinement of the hydration rate may provide more accurate dates for these flows, although no radical changes are expected.

Conclusions

Radiocarbon dating of charcoal and hydration-rind dating of obsidian from the Newberry Volcano area give us a sequence of volcanic eruptions ranging from 6380 $\pm$ 130 years to 1270 $\pm$ 60 years ago.

These events are but a few of the many volcanic eruptions that have occurred in the region since late Pleistocene time (Oregon Dept. Geology and Mineral Industries, 1965). There are numerous other examples of recent volcanism in central Oregon and also in the eastern part of the state and in the High Cascades. The ages for some of the High Cascade eruptions have been obtained by the radiocarbon method (Taylor, 1965).

As part of its continuing studies on volcanism in central and eastern Oregon, the State of Oregon Department of Geology and Mineral Industries will attempt to date more of these volcanic episodes. It is hoped that other investigators of young volcanic rocks in the state will also be interested in obtaining dates for the events in their areas and that eventually we can establish the chronology of late Quaternary volcanism in Oregon.

Acknowledgments

We wish to thank Bill Winney and Phil Brogan of Bend, Oregon, who were very helpful in supplying locality information during the extended time we were gathering data for this report. We are greatly indebted to the various persons who provided age data: Dr. Irving Friedman of the U.S. Geological Survey determined the hydration dates on the samples of obsidian

we collected from Newberry Crater; Harry Gibbon, through Columbia University, provided the radiocarbon dates for root charcoal from the Gas-Line Flows; and U.S. Clanton of NASA Manned Spacecraft Center, Houston, Texas, submitted the charcoal from the Newberry Crater Pumice Bed to the University of Texas for dating.

References

Friedman, Irving, 1968, Hydration rind dates rhyolite flows: Science, v. 159, no. 3817, p. 878-880.

Friedman, Irving, and Smith, R.L., 1960, A new dating method using obsidian: part 1, the development of the method: American Antiquity, v. 25, no. 4, p. 476-493.

Friedman, Irving, Smith, R. L., and Long, W. D., 1966, Hydration of natural glass and formation of perlite: Geol. Soc. America Bull., v. 77, no. 3, p. 323-328.

Higgins, M. W., and Waters, A. C., 1968, Newberry caldera field trip: Andesite Conference Guidebook: State of Oregon Dept. Geology and Mineral Industries Bull. 62, p. 59-77.

__________, 1967, Newberry caldera, Oregon: a preliminary report: The ORE BIN, v. 29, no. 3, p. 37-60.

Libby, W. F., 1952, Chicago radiocarbon dates: Science, v. 116, no. 3025, p. 673-681.

Michels, J. W., 1967, Archaeology and dating by hydration of obsidian: Science, v. 158, no. 3798, p. 211-214.

Nichols, R. L., and Stearns, C. E., 1938, Fissure eruptions near Bend, Oregon [abst.]: Geol. Soc. America Bull., v. 49, no. 12, pt. 2, p. 1894.

Oregon Dept. Geology and Mineral Industries, 1965, Articles on Recent volcanism in Oregon, reprinted from The ORE BIN: Oregon Dept. Geology and Mineral Industries Misc. Paper 10.

Peterson, N.V., and Groh, E.A., editors, 1965, State of Oregon Lunar Geological Field Conference Guidebook: Oregon Dept. Geology and Mineral Industries Bull. 57, 51 p.

Stuiver, Minze, and Suess, H. E., 1966, On the relationship between radiocarbon dates and true sample ages: Radiocarbon, v. 8, p. 534-540.

Taylor, E. M., 1965, Recent volcanism between Three Fingered Jack and North Sister, Oregon Cascade Range: The ORE BIN, v. 27, no. 7, p. 121-147.

Williams, Howel, 1935, Newberry volcano of central Oregon: Geol. Soc. America Bull, v. 46, no. 2, p. 253-304.

* * * * *

Hollis M. Dole leaving State Office Building
for new post in Washington, D. C.

DOLE NAMED TO MINERALS POST UNDER NIXON

The U.S. Senate confirmed the appointment of Hollis M. Dole as Assistant Secretary of the Interior for Mineral Resources March 20, 1969. Dole was named to the post by President Nixon. As Assistant Secretary he will aid and advise Secretary of the Interior Walter Hickel and will have under his jurisdiction the Bureau of Mines, the Geological Survey, and the Offices of Geography, Coal Research, Oil and Gas, Solid Fuels, and Oil Import.

Dole has been a resident of Oregon since 1917. He received his Bachelor's and Master's degrees in geology at Oregon State University and did further graduate work at the University of California at Los Angeles before entering the Navy in World War II. He joined the staff of the Department of Geology and Mineral Industries in 1946 as head of the Grants Pass office, and in 1947 was transferred to the Portland office. During a 2-year leave of absence he completed scholastic requirements for a doctoral degree at the University of Utah. In November 1954, upon retirement of F. W. Libbey, Director, Dole became Acting Director, and in July 1955 he was appointed Director. The title of State Geologist was conferred on him in 1963.

During his 22 years with the Department and 14 years as Director, Dole has become well known and highly respected for his competence and vision. He has been a leader in developing the rare metals industry in Oregon, the off-shore oil exploration, and the use of central Oregon lava beds for moon-landing programs. He has carried out the publishing of comprehensive surveys of chromite, mercury, and gold deposits in the state. In addition, he has been successful in awakening public awareness of the importance of geology in the planning and growth of population centers, and in promoting the enjoyment of geology as a recreation.

He will be greatly missed in Oregon, but all who know him here are proud of his achievements and know that the Minerals Resources branch of the Interior Department is in good hands.

* * * * *

SURVEY RELEASES OPEN-FILE REPORTS

Three open-file reports recently made available to the public by the U.S. Geological Survey are listed below. They can be consulted at the Department's library in the State Office Building in Portland.

1. Preliminary evaluation of infrared and radar imagery, Washington and Oregon coasts, by P.D. Snavely and N.S. MacLeod, 1968.
2. Continuous seismic profiling investigation of the southern Oregon continental shelf between Cape Blanco and Coos Bay, by A. J. Mackay, 1969.
3. Sediment transport in streams in the Umpqua River basin, Oregon, by C. A. Onions, 1969.

* * * * *

CRATER, EAST, AND DAVIS LAKES DESCRIBED

"Hydrology of Crater, East, and Davis Lakes, Oregon," by K. N. Phillips and A. S. Van Denburgh, has been published by the U.S. Geological Survey as Water-supply Paper 1859-E. These three small, fresh-water lakes occupy topographically enclosed basins in Holocene volcanic terranes in Deschutes and Klamath Counties. They have no outlets, and drain by seepage through the rocks. Hydrologic and chemical data are presented for each lake and the geologic history summarized. Water-supply Paper 1859-E is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington D.C. 20402. The price is 40 cents.

* * * * *

CORCORAN NAMED STATE GEOLOGIST

The Governing Board of the State of Oregon Department of Geology and Mineral Industries appointed Raymond E. (Andy) Corcoran as State Geologist on Monday, March 24, 1969. Corcoran succeeds Hollis M. Dole, who resigned recently to accept the position of Assistant Secretary of the Interior for Mineral Resources.

Corcoran was born in Norfolk, Va., but moved to California at an early age. He attended school in Long Beach and received his Bachelor of Science degree in geology from the University of California at Los Angeles. Between 1948 and 1951, Corcoran was a geologist with Union Oil Co.'s Rocky Mountain Division. Subsequently he did graduate work at the University of Oregon and obtained a Master's Degree, selecting part of the Mitchell Butte quadrangle in northeastern Malheur County for his thesis area.

In 1953, Corcoran joined the geology staff of the State of Oregon Department of Geology and Mineral Industries at its Portland office. He made a detailed study of bauxite deposits in the Salem Hills of northwest Oregon and collaborated with F.W. Libbey, former Director of the Department, on a report of the investigations. In 1957, Corcoran left the Department to accept a position with Harvey Aluminum Co., and spent the following three years on bauxite exploratory work in Oregon, Washington, Hawaii, Jamaica, and British Guiana.

Corcoran returned to the Department, under Hollis M. Dole, in 1960. Since that time he has been engaged in a wide range of programs that have resulted in various Department publications. For the past 8 years Corcoran has been in charge of coordinating the program of geologic mapping for the eastern half of the State Geologic Map, working on this endeavor in cooperation with the U.S. Geological Survey, the universities, and other agencies.

As State Geologist, Corcoran will continue to carry out the Department's functions, which are, primarily, to conduct studies and publish reports on the geology and mineral resources of the state. As a new objective he plans to begin a series of geologic environment studies related to population expansion and public safety.

* * * * *

OREGON ACADEMY OF SCIENCE PUBLISHES PROCEEDINGS

The Oregon Academy of Science has published its "Proceedings" for the first time since 1954. Volume IV, the latest issue of the "Proceedings," contains abstracts of the annual meetings in 1967 and 1968. Copies of Volume IV are available from Dr. Clarence A. Porter, Secretary, Oregon Academy of Sciences, Portland State University, P.O. Box 751, Portland, Oregon 97207.

* * * * *

BLM LEASES CAMP HANCOCK TO OMSI

Forty acres of public lands near the John Day River in Wheeler County, Oregon, have been leased by the U.S. Bureau of Land Management to the Oregon Museum of Science and Industry for use as a natural science camp for young people. Located 18 miles west of Fossil, the site affords a unique outdoor classroom due to the presence of significant geological values.

Camp Hancock derives its name from its founders, Alonzo "Lon" Hancock and his wife, Berrie, both of Portland, Oregon. Although a mail carrier in Portland, Hancock's lifelong interest in paleontology gained him national stature in this field. He spent many years researching and exploring the geology of the Clarno-Camp Hancock area until his death in 1961.

Hancock also had an intense love for children and their education. He combined his talents and interests, and began to teach natural science to small groups of children each summer at Camp Hancock. By 1957, the camp had grown until its demands exceeded one man's ability to operate it properly. He appealed to OMSI to sponsor the camp. OMSI responded, and today the camp enrolls about 150 young people in three two-week summer sessions. Courses of instruction include the outdoor sciences of geology, biology, and related fields.

Camp Hancock is leased to OMSI under provisions of the Recreation and Public Purposes Act. Future development plans include construction of new camp facilities and improvement of existing structures. [U.S. Bureau of Land Management news release, March 5, 1969.]

* * * * *

MINING SCHOLARSHIP ANNOUNCED

Dr. Vernon E. Scheid, Dean, Mackay School of Mines, announced March 14 that Newmont Mining Corp., owner of Carlin Gold Mining Co. near Elko, Nev., has awarded two all-expense scholarships covering fees, out-of-state tuition, if necessary, an allowance for books, and cost of board and room for 1969-70 for study at the Mackay School of Mines, University of Nevada. The scholarships are open to any high school graduate. The number of scholarships will be increased in the future until there are four available each year.

Students awarded scholarships must study in some field of mineral-industry engineering such as mining engineering, geological engineering, or metallurgical engineering. The scholarships are for one year, but will be renewed for succeeding years of undergraduate study if the student's scholastic record is satisfactory. Recipients of these scholarships will be offered summer employment at one of the mineral-industry operations of Newmont Mining Corp. There is no obligation upon the student, and at the end of his undergraduate studies, he will be free to choose his future career as he desires. [Nevada Mining Assn. "News Letter," March 15, 1969.]

* * * * *

GEOTHERMAL STEAM LEASING BILL REINTRODUCED IN CONGRESS

A bill to allow the leasing and development of geothermal steam on federally owned lands has recently been reintroduced to Congress by Senator Alan Bible, Nevada. A similar bill passed both houses of Congress during the 89th Session, but was pocket-vetoed by President Johnson in late 1966.

A great deal of controversy has been generated by this bill. One question is: Who owns the steam on lands where surface ownership resides with a private individual but where the ownership of underground minerals was reserved to the federal government under the Homestead Act of 1916? A second question is: What should be done about the "grandfather clause" which would allow companies who filed claims for geothermal steam as oil and gas leases to convert them for geothermal exploration?

Last year Bible thought he had worked out a plan that would gain favor with the Johnson Administration, but the act was bogged down in the Senate Interior Committee and never reached the floor.

This bill is considered to be of great importance to the 11 western states because the area has the greatest potential for natural steam development and also because the federal government owns more than 50 percent of the land, ranging from 30 percent in Washington to 87 percent in Nevada.

* * * * *

SAFETY IS FOR THE WARY

This is the time of year when the urge to explore the vast out-of-doors begins to rise to its maximum. This is a perfectly normal reaction that is heartily endorsed as one of the best recreational pursuits available to people of all ages. The only trouble with the out-of-doors is that all of the dangers ever encountered by man are still there--the uneven surfaces, steep slopes, unstable rock, overhanging cliffs, and hidden cracks and holes. Man's bipedal locomotion is an uncertain and chancy thing, best attempted on smooth, relatively level--or at least predictable--surfaces. Out in the hills these conditions are the exception rather than the rule. A bad fall which produces a broken leg or severely sprained ankle miles from camp or the car can be extremely serious. Just walking too far from camp and getting lost is not only embarrassing but may cause much discomfort and hardship, and in rare cases even death.

Along with the urge to explore the vast out-of-doors goes the urge to investigate old mine workings. Old mines pose especial hazards for the unwary. Many tunnels and shafts were once supported by timbers, but these are now rotten and the slightest jar may dislodge tons of rock. Tunnels may also contain pockets of gas, deep water-filled holes, old dynamite, and a wide variety of wild animals, some of which resent intrusion of humans into their dens.

* * * * *

AVAILABLE PUBLICATIONS

(Please include remittance with order. Postage free. All sales are final and no material is returnable. Upon request, a complete list of the Department's publications, including those no longer in print, will be mailed.)

BULLETINS

2.	Progress report on Coos Bay coal field, 1938: Libbey	$ 0.15
8.	Feasibility of steel plant in lower Columbia River area, rev. 1940: Miller	0.40
26.	Soil: Its origin, destruction, preservation, 1944: Twenhofel	0.45
33.	Bibliography (1st supplement) of geology and mineral resources of Oregon, 1947: Allen	1.00
35.	Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1963: Baldwin	3.00
36.	(1st vol.) Five papers on Western Oregon Tertiary foraminifera, 1947: Cushman, Stewart, and Stewart	1.00
	(2nd vol.) Two papers on Western Oregon and Washington Tertiary foraminifera, 1949: Cushman, Stewart, and Stewart; and one paper on mollusca and microfauna, Wildcat coast section, Humboldt County, Calif., 1949: Stewart and Stewart	1.25
37.	Geology of the Albany quadrangle, Oregon, 1953: Allison	0.75
46.	Ferruginous bauxite deposits, Salem Hills, Marion County, Oregon, 1956: Corcoran and Libbey	1.25
49.	Lode mines, Granite mining dist., Grant County, Ore., 1959: Koch . .	1.00
52.	Chromite in southwestern Oregon, 1961: Ramp	3.50
53.	Bibliography (3rd supplement) of the geology and mineral resources of Oregon, 1962: Steere and Owen	1.50
56.	Fourteenth biennial report of the State Geologist, 1963-64	Free
57.	Lunar Geological Field Conference guide book, 1965: Peterson and Groh, editors	3.50
58.	Geology of the Suplee-Izee area, Oregon, 1965: Dickinson and Vigrass .	5.00
60.	Engineering geology of the Tualatin Valley region, Oregon, 1967: Schlicker and Deacon	5.00
61.	Gold and silver in Oregon, 1968: Brooks and Ramp	5.00
62.	Andesite Conference Guidebook, 1968: Dole, editor	3.50
63.	Sixteenth Biennial Report of the State Geologist, 1966-1968	Free

GEOLOGIC MAPS

Preliminary geologic map of Sumpter quadrangle, 1941: Pardee and others . . .	0.40
Geologic map of the St. Helens quadrangle, 1945: Wilkinson, Lowry & Baldwin .	0.35
Geologic map of Kerby quadrangle, Oregon, 1948: Wells, Hotz, and Cater . .	0.80
Geologic map of Albany quadrangle, Oregon, 1953: Allison (also in Bull. 37) .	0.50
Geologic map of Galice quadrangle, Oregon, 1953: Wells and Walker	1.00
Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts	0.75
Geologic map of Bend quadrangle, and reconnaissance geologic map of central portion, High Cascade Mountains, Oregon, 1957: Williams. . . .	1.00
GMS-1 - Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka . . .	1.50
GMS-2 - Geologic map, Mitchell Butte quad., Oregon, 1962: Corcoran et al..	1.50
GMS-3 - Preliminary geologic map, Durkee quad., Oregon, 1967: Prostka . .	1.50
Geologic map of Oregon west of 121st meridian: (over the counter) . . . . . folded in envelope, $2.15; rolled in map tube, $2.50	2.00
Gravity maps of Oregon, onshore and offshore, 1967: [Sold only in set]: flat . . folded in envelope, $2.25; rolled in map tube, $2.50	2.00

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18.	Radioactive minerals the prospectors should know (2nd rev.), 1955: White and Schafer	0.30
19.	Brick and tile industry in Oregon, 1949: Allen and Mason	0.20
20.	Glazes from Oregon volcanic glass, 1950: Charles W.F. Jacobs	0.20
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23.	Oregon King Mine, Jefferson County, 1962: F.W. Libbey and R.E. Corcoran	1.00
24.	The Almeda Mine, Josephine County, Oregon, 1967: F.W. Libbey	2.00

MISCELLANEOUS PAPERS

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7.	(Supplement) Bibliography of theses, 1959 to Dec. 31, 1965: M. Roberts	0.50
8.	Available well records of oil & gas exploration in Oregon, rev. '63: Newton	0.50
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11.	A collection of articles on meteorites, 1968: (reprints, The ORE BIN)	1.00
12.	Index to published geologic mapping in Oregon, 1968: R. E. Corcoran	Free

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FOSSILIZED PALM WOOD IN OREGON

By Irene Gregory*

Introduction

To geologists, petrified palm wood is a significant material. Its occurrence in the fossil record serves as an indicator of past climates and age of the rocks. To hobbyists, its attractive patterns and ease of identification make it a sought-after species. Since its anatomy is one of the least complicated of fossil plant materials, it is easily recognized; its unique appearance makes it difficult to mistake it for any other species, with the possible exception of certain fossil ferns.

This report is concerned primarily with fossil palm wood; however, since leaves and fruits are also important in the fossil record these parts of the palm are reviewed. In addition, the geologic history of palms and their occurrence as fossils in Oregon is summarized.

Identification of Palm Wood

Paleobotanists in the past have generally assigned petrified palm trunks to Palmoxylon, a genus name designed to include fossil stems with scattered bundles having fibrous caps. Fossilized palm leaves can often be referred to living genera, and there is a trend to apply these names to fossil palm wood also, where warranted. The writer is following the procedure of applying names of living genera to fossil specimens that are sufficiently well preserved to reveal identifiable anatomical structures.

A type of palm present in an assemblage of semi-tropical Eocene woods being investigated by the author is palmetto (Sabal), collected from a small outcropping of the Clarno Formation in Crook County, Oregon. Material for thin sections of the transverse (figure 1 A & B) and longitudinal (figure 2 A & B) views shown was taken from a trunk specimen that was

---

* Mrs. James M. Gregory is an authority on fossil woods of Oregon. She is author of "The Fossil Woods near Holley in the Sweet Home Petrified Forest, Linn County, Oregon," which was published in the April 1968 issue of The Ore Bin and is in its second reprinting.

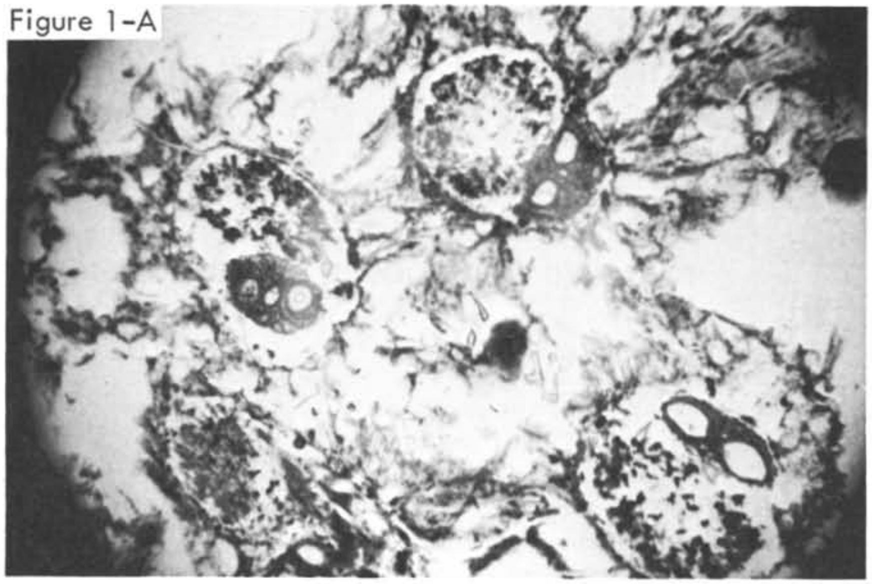

Figure 1-A

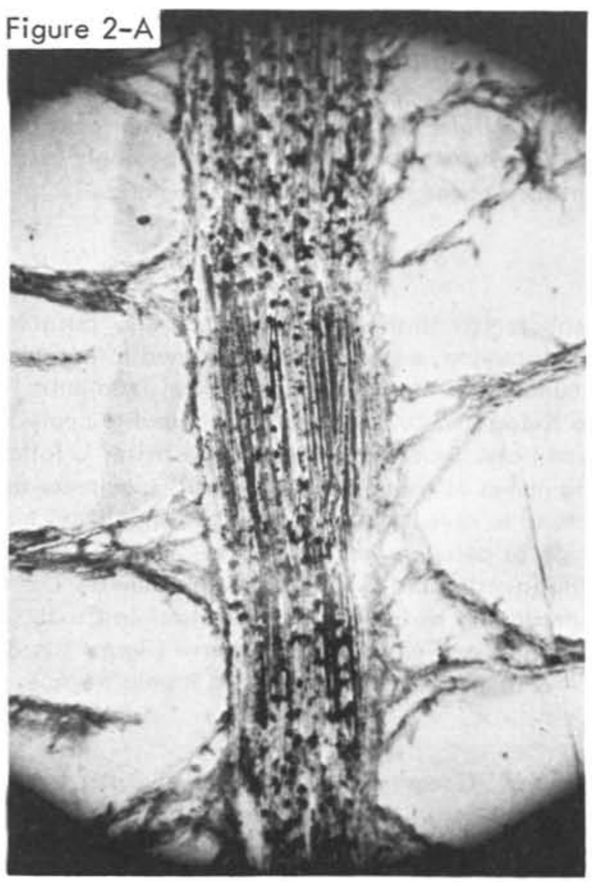

Figure 2-A

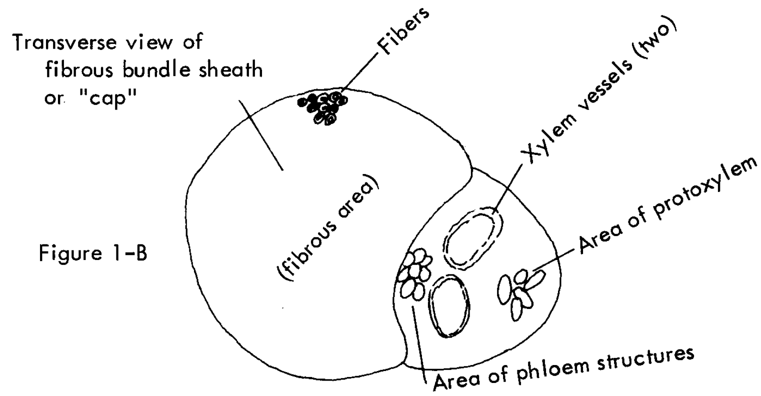

Figure 1. Transverse views of Eocene palm wood from Crook County.

A. (opposite page) Photomicrograph 45 X.

B. (above) Sketch showing detail of fibrovascular bundle in upper right portion of figure 1-A. Compression of wood before petrification produced oval shape of xylem vessels, which normally are circular.

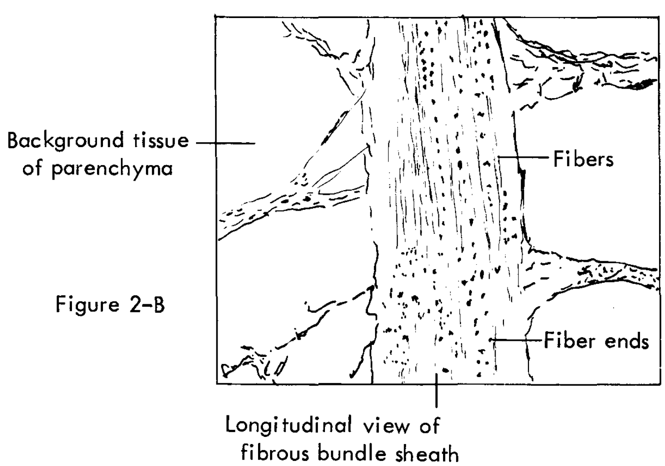

Figure 2. Longitudinal views of Eocene palm wood from Crook County.

A. (opposite page) Photomicrograph 45 X.

B. (above) Sketch showing detail of longitudinal view.

approximately 6 inches in diameter during growth, but was compressed to an oval shape by earth pressures before petrification took place. The specimen is silicified, its vascular bundles replaced with blue agate. The remainder appears black, owing to the presence of manganese, but in thin section it is a clear amber color. The unworn condition of this specimen, as well as that of other warm-climate species occurring with it, indicates the probability of its having been petrified in situ. The photomicrographs shown here are thought to be the first published record of the minute anatomy of the wood of a fossil palm from Oregon.

All of the genera, both living and fossil, making up the palm family exhibit similar anatomical structures. Their wood consists of separate fibrovascular bundles scattered in a pith-like background tissue of parenchyma cells. In cross section the parenchyma cells appear thin walled and somewhat hexagonal in shape, and fill all the spaces between the very conspicuous bundles which have prominent fibrous caps (bundle sheaths) (figure 1 A & B). The bundles run longitudinally in the stem and on out into the leaves; in cross section they show as dots or eyes and when cut lengthwise appear to be tubes (figure 2 A & B). The two (possibly three) larger pores in each bundle are xylem vessels; the area between the xylem and the fibrous cap may show phloem structures.

Although the characteristic anatomy of palm results in a distinctive appearance, on casual examination it may be confused with cross-section views of petioles of the fossil fern Acrostichum or portions of Tempskya fern masses in which cut leaf-traces resemble palm eyes.

General Botanical Background of Palms

Palms are considered to be the first angiosperms (flowering plants of today) to appear in the fossil record. Angiosperms include two groups:

1) Dicotyledons - having complicated net-like veining of leaves and producing two leaves (cotyledons) when their seed germinates; they make up most of our flowering plant species of today.

2) Monocotyledons - with but one seed-leaf (cotyledon) and parallel leaf-veining as in grasses, lilies, and palms; they provide the remaining small percentage of angiosperms.

In the fossil plant record, palms are significant as being one of the few monocotyledons to be preserved. Their durable woody nature lends itself to petrification, which is not so with the many other more herb-like plants of this group. Check lists of fossil plants invariably include but few monocotyledons.

Environment

Most palms require a minimum temperature of 42°F. and higher; only a few can adapt to a slight amount of frost. Of the several hundred recognized genera living today, nearly all are inhabitants of the tropics. The few representatives living in the United States are native only to the southern climates. Palmettos grow along the Atlantic Coast from North Carolina to Florida. Other types are limited to the Florida Keys, the area near the mouth of the Rio Grande in Texas, and to southern Arizona, California, and Hawaii. About 2000 species of palms are known today, of which 25 belong to the genus Sabal.

In the fossil record, the association of palm with other tropical species of plants shows that palms of the past had the same temperature needs as exist today, making their presence as fossils conclusive evidence of warm climate. Many of the floras containing palm leaves are associated with coal beds, signifying a swampy environment.

Stems (trunks)

Living palms can be separated into genera by cross-section views of their wood, which show different appearances based on the comparative number, size, and distribution of the fibrovascular bundles or "eyes." For example, Serenoa bundles are thin and widely but uniformly scattered through the whole wood; Thrinax has coarser, fewer and closer bundles; Cocos bundles are very numerous near the edge of a cross section and few in the center.

Palms have woody stems of varied habits, but most are well-proportioned trees remarkable for their uniformly cylindrical, typically unbranched shapes. The trunk is generally thickened near its base and is well anchored by a mass of simple, also unbranched, but contorted roots. The number of roots emerging from a coconut palm can be as many as 13,000. The fossil plant material known as "palm root" when cut shows wildly irregular oblong and circular shapes, each of which includes the typical stem structure and distribution of bundles as described above.

Since they lack a continuous cambial layer, palms are incapable of growth in thickness by adding new layers of cells as do our familiar timber trees. Thus no annual growth rings are formed. With no tree rings to count, age usually has to be based on associated historical data.

The girth of a palm is determined during its earliest years, the one main growing point being the terminal bud. Some tree types grow as much as 150 feet high. The diameter of palm stems may range from less than half an inch to two feet or more. Since palm trunks usually do not branch, the rock hunter's so-called "limb" sections of fossil palm probably represent the main stem or trunk of that individual plant. In some fossil species these may be so small as to appear reed-like, as in Reinharditia of Central

Figure 3. Fossilized trunk fragments of the rattan-type palm from the Eocene Green River Formation, Eden Valley, Wyoming. Approximately 3/4 natural size.

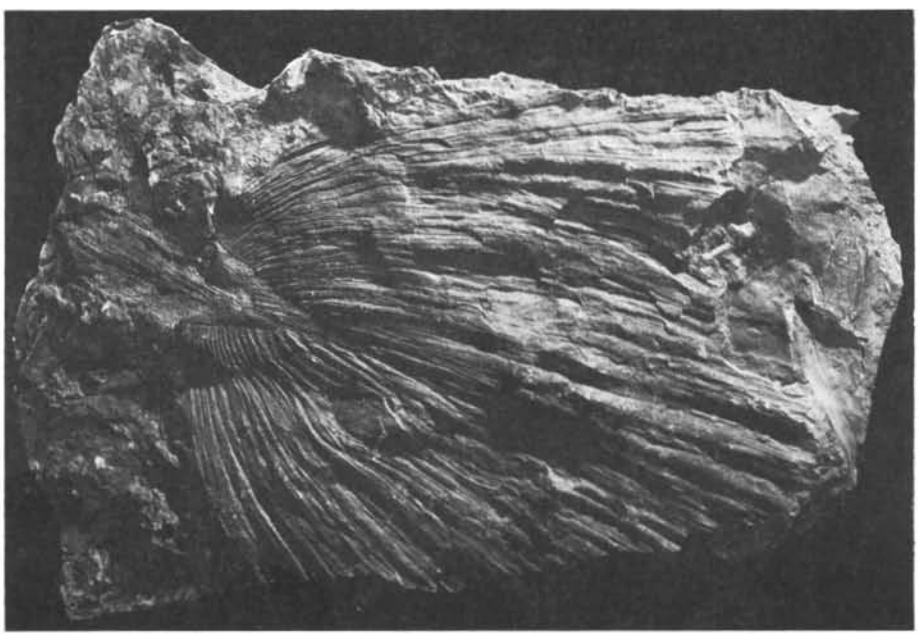

Figure 4. Portion of a fossil palm leaf (Sabalites eocenica) from Clarno-age rocks in northeastern Oregon, approximately ½ natural size. (From Hergert, 1961)

America today.

Other types of palm stems that might be found as fossils include the rattans, climbers of today in India and the East Indies living in semi-tropical environments similar to that of the Eocene in Oregon. The two main living genera of this type are Calamus and Daemonorops, which have slender, bamboo-like stems of uniform diameter with very long internodes. Their leaf rachis (leaf stalk) is prolonged into a spiny, hook-like tendril that enables them to climb over the tallest surrounding vegetation; their stems may grow as long as 500 to 600 feet, making them the lengthiest stem on earth, with the possible exception of seaweed. They produce the commercial rattan used for cane-chair matting, bentwood furniture, and the like. The familiar rockhunter's material, "cane," from the Eocene Green River Formation in Eden Valley, Wyoming, is a fossil representative of this type of palm stem (figure 3). Specimens are found with internodes as much as 10 or 12 inches in length and showing trunk rings (leaf-base scars).

Additional stem variations that could occur as fossils include the prostrate or creeping stems of certain palmettos (Sabal) which are surrounded by a dense mass of contorted roots. Other examples are the horizontal stem of Nipa, a genus confined to southeastern Asia today, and the short vegetative shoots of Bactris and Raphis which form bushy or shrub-like clumps.

A characteristic feature of most living palm stems is the leaf bases. If the leaf bases fall off, distinctive scars remain on the trunk, but if they remain attached to the trunk, the strong lower part of the leaf stalk often forms a clasping fibrous webbing that hangs in a ragged mass around the trunk. This mass can make a thick, dense mat several feet long. Some fragments of fossil palm show only this fibrous trunk cover.

Leaves

At an early stage, the single-leaf seedlings of most palm genera look much alike; as fossils, all can be easily confused with grasses. The mature leaf forms are distinctive, although those of cycads and some tree-ferns have a superficial resemblance. The leaves, in general, are borne as a crown at the tip of the trunk. Types of palm leaves include the fan-shaped leaves of palmetto; a simple pinnate or feathery form as in the coco palm; or a bi-pinnate as in fish-tail palms whose leaflets are attached to lateral branches of the main leaf rachis.

Most fossil-palm records refer to fan-shaped leaves; reports of pinnate-type leaves are rare in the literature. Fan-shaped palm leaves have been found at several localities in the Eocene of Oregon (figure 4), and silicified petioles or leaf stalks have also been collected.

Fruit and seeds

The fruit of palms, borne in clusters, is a drupe or berry and usually one seeded; seldom do 2 or 3 seeds occur. Sizes range from that of a currant to the double coconut weighing 40 or more pounds - the largest seed known. A great number of variations in the basic form occur. The fleshy part may be almost lacking or may be pulpy or oily; the pit layer may be hard and dense as in coconut or thin as in palmetto. Many palms continue flowering and fruiting throughout the year. The coconut is thought of as the typical palm seed or nut, but more typical are small seeds - some less than half an inch in diameter - that are produced in huge clusters by many species.

Figure 5. Two views of a small fossil seed of the coconut-type palm. Seed is 1 inch in diameter (photograph courtesy of T. J. Bones).

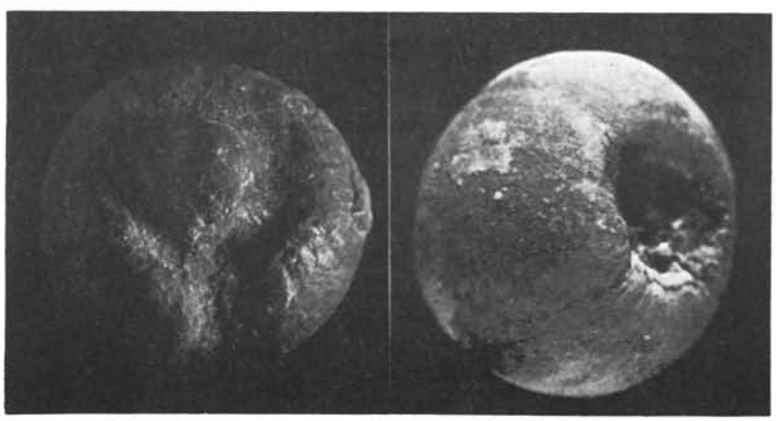

Figure 6. Two views of a tiny fossil palm seed 8 mm in diameter. Seeds were probably borne in clusters (photograph courtesy of T. J. Bones).

Fossil palm seeds are in general referred to the genus Palmocarpon. The durability of some palm seeds makes possible their remaining in excellent condition while traveling vast distances by ocean current, resulting in some confusion as to the validity of certain fossil-palm records at ancient coastal locations. Reports of Oregon palm-seed occurrences have been confined mainly to the Clarno area of central Oregon (figure 5, coconut type; figure 6, small seed).

Geologic History of Palms

The geologic history of palms goes far back into the fossil record, where they are considered to be the first of the angiosperms (flowering plants) to develop. Records of occurrences are numerous, with the earliest now tentatively considered to be the almost completely preserved palm-like leaves reported from the Middle to Upper Triassic of Colorado by Roland W. Brown (1956), who suggested they should be regarded "tentatively but credibly" as a primitive palm. The simple elliptic leaves of Sanmiguelia lewisi were borne alternately on a rapidly tapering stem. They were collected from red calcareous sandstone of the Dolores Formation near Placerville, Colo., in the vicinity of the San Miguel River, and constitute one of the more important paleobotanical discoveries of our time.

LaMotte (1952) cataloged a great many references to fossil palm throughout the world, including the earliest definite palm-wood record, Palmoxylon cliffwoodensis from the Upper Cretaceous Magothy Formation of New Jersey. Palm leaves occur in the Lower Cretaceous Dakota Group of the Rocky Mountains region, and in the Upper Cretaceous Nanaimo Group on Vancouver Island, British Columbia.

Records of palm from the Eocene are numerous. The famous Eocene London Clay flora in England contains an abundance of fossil fruits of Nipa, a tropical Asiatic palm of today (Reid and Chandler, 1933). In North America, palms are best displayed in Eocene rocks (Arnold, 1947). One particularly outstanding account is that by Knowlton (1930), who lists 14 forms from the Denver Basin, 8 based on leaves, 5 on fruits, and 1 on a silicified trunk. He reports huge leaves as large as 5 feet in diameter. Of the genera described, Sabal was the most abundant and widely distributed.

Among other notable North American Eocene floras containing palm are the Wilcox and Claiborne floras of the Gulf Coast areas (Berry, 1916 and 1924); the Raton flora of northern New Mexico and southern Colorado (Knowlton, 1918); the Jackson flora of Texas; the Eden Valley flora of Wyoming (Brown, 1934); the Puget flora of Washington and British Columbia; the LaPorte flora of California (Potbury, 1935); and the Clarno flora of Oregon.

Fossil palms, associated with other warm-climate plants, are found at the Alaskan leaf localities of Kupreanof Island and Matanuska Valley (Hollick, 1936). The flora is considered by Wolfe and others (1966) to be

Oligocene in age. Present here are two fossil-palm species, Flabellaria florissanti and Flabellaria alaskana, that are referable to the fan palms of the Arecaceae, a group that is today strictly subtropical and tropical and that bears out the suggested subtropical Oligocene climate of coastal Alaska.

Miocene palm occurrences noted by Arnold (1947) include that of the Tehachapi flora of the western Mojave Desert (Horse Canyon, Kern County, Cal.) and the Barstow beds (Mule Canyon, Yermo, Cal.). Axelrod (1950) describes Pliocene age palms from Palmdale, Cal.

The geologic history of palms in Oregon parallels that shown elsewhere in North America. Their first appearance during the Cretaceous was followed by relative abundance during the Eocene; Oligocene records are limited to palms in relict warm-climate floras of the coastal region. No fossil palms have been reported, as yet, from post-Oligocene rocks in Oregon. Miocene and Pliocene floras reflect a cooling trend in the climate. Some paleobotanists believe there was a gradual migration of palms southward during the Miocene and Pliocene toward their present association with tropical and subtropical floras of today in extreme southern United States, Mexico, and Central America.

Fossil Palm Record in Oregon

Cretaceous

The fossil record shows palms to have first occurred in Oregon during the Cretaceous. In 1958, a nut, together with an ammonite included in a concretion, was found near Mitchell, Wheeler County, and was identified as a palm seed of the genus Attalea from the Albian stage of the Cretaceous by the late Roland W. Brown, U.S. National Museum (see also Berry, 1929). This occurrence is noteworthy as being considered the earliest flowering-plant record (late Lower Cretaceous) of north-central Oregon. The specimen was kept in the U.S. National Museum (letter from E. M. Baldwin, October 24, 1958 to Lon Hancock; courtesy of Viola L. Oberson).

Eocene

Arbuckle Mountain area: The first Eocene palm record for Oregon was that of Mendenhall (1907) reporting on a coal prospect on Willow Creek, Morrow County. This location was about 22 miles southeast of Heppner in a mountainous region just west of the divide (Arbuckle Mountain) between the Willow Creek and the John Day River drainages. Monocotyledonous leaves were collected and sent to F. H. Knowlton who regarded them, on the basis of additional species collected, as being Eocene in age.

Chaney (1948) in "Ancient Forests of Oregon" pictures layers of fan-type palm-leaf fossils from the Arbuckle Mountain shales. Hogenson (1957), in an open-file report on the ground-water resources of the Umatilla River basin, recounts the collecting of fossil leaves in the Arbuckle Mountain area from shales containing carbonaceous material altered to lignite or bituminous coal. He states: "Plant fossils from several carbonaceous seams were studied by Roland W. Brown of the U.S. Geological Survey. He determined the Eocene age of the formation from these fossil plant identifications." Listed were Sabalites and other warm-climate trees including Magnolia.

Pigg (1961), in a University of Oregon master's thesis, reviewed the occurrences and used the dating of palm-leaf fossils as Eocene in determining the age of lower Tertiary sedimentary rocks in the Pilot Rock and Arbuckle Mountain areas. He mentions the occurrence of palm leaves as much as 4 feet across. Hergert (1961), in a summary of the plant fossils in the Clarno Formation, includes palm (Sabalites) leaves in a list of plants from the Pilot Rock locality.

Clarno area: Eocene palm is best known from the Clarno area, the type locality for the Clarno Formation and also the site of Camp Hancock, Oregon Museum of Science and Industry's famous outdoor laboratory for fossil plant and animal studies.

The Clarno Formation has been well described in the literature (Merriam, 1901; Hodge, 1942; Wilkinson, 1959; and Baldwin, 1964). It is composed almost entirely of andesitic volcanic material - chiefly lavas, mud flows, breccias, and tuffs, including some water-laid sediments. The formation overlies older marine rocks of Paleozoic and Mesozoic age. The Clarno sediments contain abundant silicified plant remains, mainly tropical and subtropical in nature, including palm at a number of localities (Chaney, 1948). The fossils occur in lenses of volcanic ash that accumulated in shallow lake bottoms, either by direct ash falls or by erosion and redeposition of such material. At some localities the plants are in carbonaceous shales associated with coal beds. The type exposures of the Clarno Formation can be seen about 2 miles east of Clarno Bridge in Wheeler County.

Near the type locality are the Clarno nut beds (SE$\frac{1}{4}$ sec. 27, T. 7 S., R. 9 E., Wheeler County), which are world famous among paleobotanists for their well-preserved seeds, nuts, and fruits as well as other plant parts (Scott, 1954). The nuts and other plant remains are enclosed in a bedded volcanic tuff that was laid down in very late Eocene time. A potassium-argon age of 36.4 million years was recently obtained for an overlying welded ash-flow tuff (Swanson and Robinson, 1968).

The lack of stratification within the nut beds, plus the presence of standing Equisetum stems, seems to indicate that the material accumulated by very rapid deposition. Arnold (1952) suggests that the nut beds may have been deposited during a flood.

Many fine collections of plant material have been made from the Clarno nut beds, but the most remarkable is that of Thomas J. Bones of Vancouver, Wash. Mr. Bones describes his work:

"I first visited the Clarno nut and seed beds in 1942 and discovered that finding specimens there was a real challenge to the collector. At first I could find only some of the larger nuts, but later discovered that by careful working, seeds even the size of poppy seeds could be found. The larger seeds and nuts are worked out in the field as a hard rock mining operation, by digging and breaking. The smaller seeds are obtained from matrix material that is brought home, broken down, screened and looked over with a magnifying glass."

"Walnut, grape, magnolia, moonseed, palm, pistacia, elder and water lily are some familiar plant seeds found that continue to grow on earth. Many of the hundreds of seeds found at Clarno represent plant species now extinct. Dr. Richard A. Scott, USGS, has worked on identification of this Clarno material."

Although most of the original Thomas J. Bones collection has been permanently located in Washington, D.C. in the National Museum of the Smithsonian Institute since 1961, Mr. Bones has continued collecting and has accumulated many more equally noteworthy specimens since that time.

Among the fossil plants found by Mr. Bones in the Clarno Formation are wood, leaves, leaf fronds, and seeds representing at least eight different genera of palms. Other collectors have found palm in the Clarno area, including trunks and root masses. One of the largest of these specimens is a jasperized stump of typically rounded appearance that is 3 to 4 feet in diameter and estimated to weigh 2 tons. For many years it was on display in Antelope and was considered by its owner to be a meteorite. Later it proved to be one of the largest fossil palm stumps ever found in Oregon or, indeed, anywhere (Richard Rice, oral communication, April 1969).

Other areas: As geologic mapping in Oregon has increased, the presence of many additional areas occupied by rocks of the Clarno or equivalent age in central and eastern Oregon has become evident. The occurrence of fossil palm wood at some of these localities is proving to be a factor in age determination. Recently such a determination was made for the Dooley Rhyolite of the Ironside Mountain area of eastern Oregon by W. D. Lowry ("Geology of the Ironside Mountain quadrangle, Oregon," State of Oregon Department of Geology and Mineral Industries Bulletin, in manuscript form) (figure 7).

Other localities, as yet not noted in the literature, contain fragmented fossil palm wood of presumed Eocene age spread over areas of many square miles in eastern Oregon. In some places the palm wood has been eroded from Clarno-age rocks and transported to areas of younger formations, as in the Jamieson-Huntington region. Pieces of silicified wood, fossil "bog" containing palm wood and root chips, portions of palm leaves, and other palm debris have been collected from various places by rock hunters.

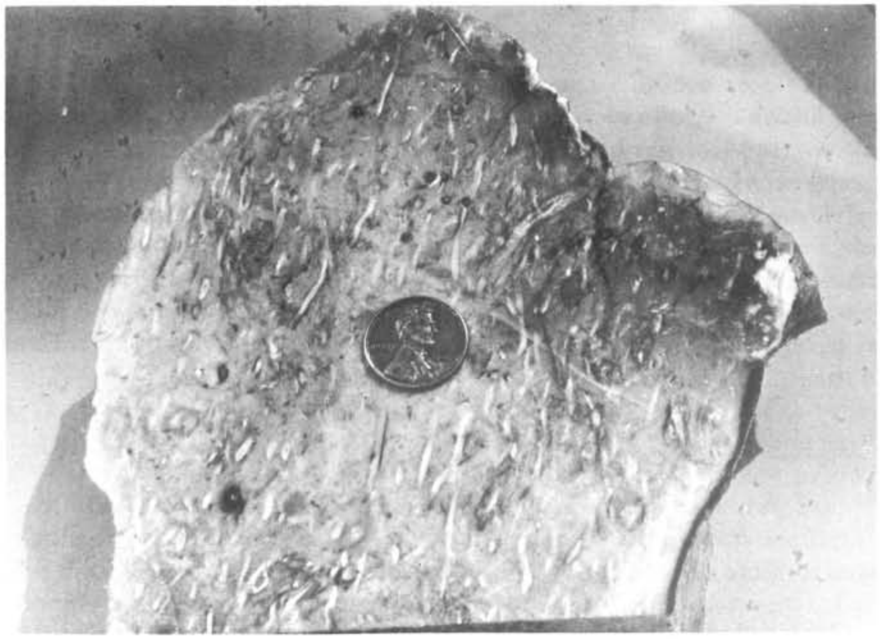

Figure 7. Longitudinal view of fossil palm wood from the Ironside Mountain quadrangle, Baker County, Oregon.

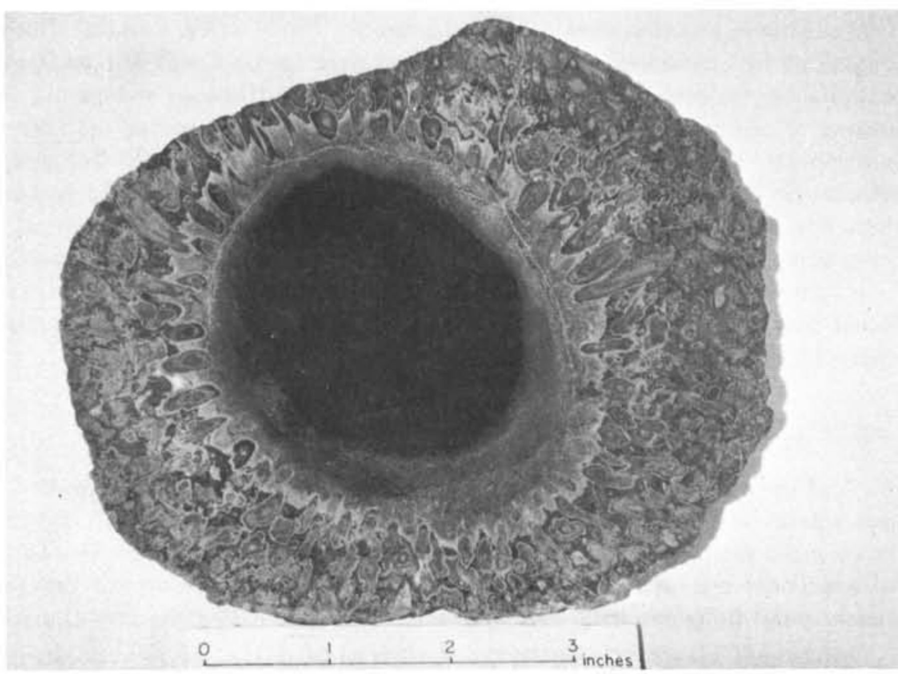

Figure 8. Cross section of an entire fossil palm trunk (about 3 inches in diameter) surrounded by a thick layer of roots. Dark mineral impurities in silica obscure typical "eye" pattern of trunk. Specimen found in Sams Valley near Medford, Oregon (Richard Rice collection).

Much is float, and in most occurrences the original source of the material is not known. Whole sections of palm wood have been seldom reported from rock-hunter localities of eastern Oregon.

West of the Cascades in the Medford area, palm wood occurs in areas mapped by Wells and Peck (1961) as late Eocene nonmarine sedimentary rocks, equivalent in age to the Clarno Formation east of the Cascades. Complete sections of petrified palm wood have been found (figure 8). The presence of palm is to be expected in other western Oregon Eocene localities as an associated species with other warm-climate and subtropical fossil plants.

Oligocene

As yet, fossil palm wood and leaves have not been noted with certainty from the John Day Formation of central Oregon, which contains an abundant flora of temperate-climate species. The palm-wood specimens thus far reported from the John Day have occurred as float and are considered to represent reworked material of Eocene age.

West of the Cascades, palm-leaf fragments are reported from two localities in Oligocene rocks. One is in the Eagle Creek flora of the Columbia Gorge area, described by Chaney (1920). The other is in the Rujada flora (Chaney, oral communication, February 1969). The Rujada* flora, described by Lakhanpal (1958), is situated near Layng Creek Ranger Station about 23 miles east of Cottage Grove. Here, in tuffaceous sediments, are leaves of temperate species as well as palm, catalpa, avocado, and other subtropical and warm-temperate trees. The presence of these relict species of warmer Eocene times is thought to be due to the relatively mild and uniform coastal climate of Oligocene time which enabled them to carry on long after their extinction elsewhere under less favorable climatic conditions.

In spite of the wealth of tropical and subtropical woods in the Sweet Home petrified forest near Holley, no palm has as yet been encountered there by the writer (Gregory, 1968).

General distribution

The accompanying map (figure 9) shows some of the localities in Oregon where fossil palm has been found as leaves, fruits, or wood. Probably many more such localities can be added to the map in the future as additional specimens are reported. Most of the occurrences shown on the map represent fossil palm material that was found in place. That is, it was enclosed

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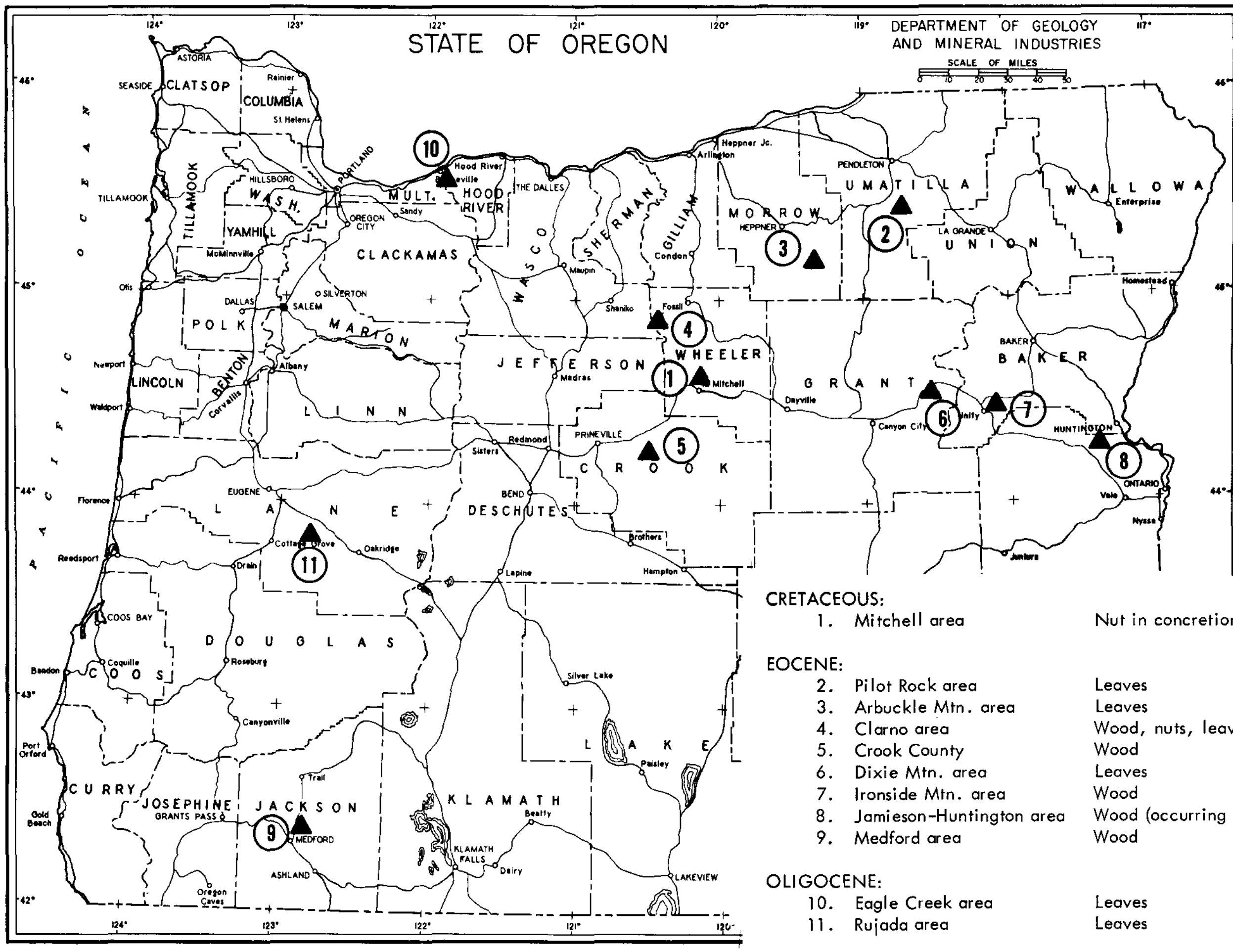
* The name "Rujada," which is so often mispronounced, is made up from the initials of two loggers, R. Upton and J. Anderson, together with the initials of the Department of Agriculture. It is correctly pronounced Rue-jade-ah.



CRETACEOUS:

1.	Mitchell area	Nut in concretion

EOCENE:

2.	Pilot Rock area	Leaves
3.	Arbuckle Mtn. area	Leaves
4.	Clarno area	Wood, nuts, leaves and leaf stems
5.	Crook County	Wood
6.	Dixie Mtn. area	Leaves
7.	Ironside Mtn. area	Wood
8.	Jamieson-Huntington area	Wood (occurring as float)
9.	Medford area	Wood

OLIGOCENE:

10.	Eagle Creek area	Leaves
11.	Rujada area	Leaves

Figure 9. Some fossil palm localities in Oregon.

in or intimately associated with the geologic formation in which it was originally buried before petrification. Fossil palm fragments occurring as float have less geologic significance.

Suggestions for the Rock Hunter

Reports of palm-wood occurrences from both east and west of the Cascades are frequent. However, many specimens, when examined under magnification, show no cellular structure and are actually various forms of orbicular agate and jasper or oolitic material. Others do prove to be palm, but the locations for all are a closely held secret of the finders, palm wood being one of the rock hunter's materials that has developed a certain desirability and "mystique" of its own. Prized varieties of palm wood for jewelry making include an ivory-colored jasp-agate with snow-white "eyes," as well as jet-black palm wood also with white "eyes." More commonly it is found in soft, blue-gray shades. Occasionally, a specimen of a deep, rich maroon color is found.

Hobbyists who wish to determine whether or not a specimen is palm wood can generally do so with a 10 X lens. After orienting the specimen to get a possible transverse or cross-section view, they should look for scattered "eyes" all with a similar pattern and each having two (rarely three) tiny, solid-looking dots (vessels) on one side. A longitudinal cut through an eye will show it as a lengthwise line or tube. If, instead, it appears as a short line or is ball shaped, the specimen is more probably one of Oregon's ubiquitous oolites rather than the sought-after palm.

Acknowledgments

Grateful appreciation is expressed to members of the State of Oregon Department of Geology and Mineral Industries for photographic work and for valuable assistance in preparing the manuscript for publication. Gratitude is extended also to Thomas Bones, Jim De Mastus, Dwight McCorkle, Richard Rice, Fred Roner, and the many others, including members of the Gregory family, who provided information, specimens, collecting privileges, and field assistance.

Selected References

Andrews, Henry N., 1961, Studies in Paleobotany: New York, John Wiley & Sons, Inc.

Arnold, Chester A., 1947, An Introduction to Paleobotany: New York, McGraw-Hill Book Co.

Arnold, Chester A., 1952, Fossil Osmundaceae from the Eocene of Oregon: Stuttgart, Palaeontographica 92 (B).

Axelrod, D. I., 1950, The Anaverde flora of southern California: Carnegie Inst. Washington Pub. 590.

Baldwin, E. M., 1964, Geology of Oregon: Eugene, Ore., Univ. Oregon Coop. Book Store.

Berry, E. W., 1916, Lower Eocene floras of southeastern North America: U.S. Geol. Survey Prof. Paper 91.

_________, 1924, The middle and upper Eocene floras of southeastern North America: U.S. Geol. Survey Prof. Paper 92.

_________, 1929, A palm nut of Attalea from upper Eocene of Florida: Washington Acad. Sci. Jour., v. 19, p. 252-255.

_________, 1930, Revision of the lower Eocene Wilcox flora of the southeastern states: U.S. Geol. Survey Prof. Paper 156.

Brown, R. W., 1934, The recognizable species of the Green River flora: U.S. Geol. Survey Prof. Paper 185-C.

_________, 1956, Palmlike plants from the Dolores Formation (Triassic) of southwestern Colorado: U.S. Geol. Survey Prof. Paper 274-H.

Chaney, R. W., 1920, Flora of the Eagle Creek Formation (Washington and Oregon): Chicago Univ. Walker Museum Contr., v. 2, no. 5.

_________, 1948, Ancient forests of Oregon: Eugene, Ore., Oregon State Sys. Higher Educ., Condon Lecture.

Corner, E. J., 1966, The natural history of palms: Berkeley, Calif., Univ. Calif. Press.

Gregory, Irene, 1968, The fossil woods near Holley in the Sweet Home petrified forest, Linn County, Oregon: The ORE BIN, v. 30, no. 4, April, 1968.

Hergert, H. L., 1961, Plant fossils in the Clarno Formation, Oregon: The ORE BIN, v. 23, no. 6, p. 55-62.

Hogenson, G. M., 1957, Geology and ground-water resources of the Umatilla River basin area, Oregon: U.S. Geol. Survey open-file rept., p. 19-21.

Hodge, E. T., 1942, Geology of north-central Oregon: Oregon State College Studies in Geol. No. 4.

Hollick, Arthur, 1936, Tertiary floras of Alaska: U.S. Geol. Survey Prof. Paper 182.

Knowlton, F. H., 1918, Geology and paleontology of Raton Mesa and other regions in Colorado and New Mexico: U.S. Geol. Survey Prof. Paper 101.

_________, 1919, Catalogue of the Mesozoic and Cenozoic plants of North America: U.S. Geol. Survey Bull. 696.

_________, 1930, Flora of the Denver and associated formations of Colorado: U.S. Geol. Survey Prof. Paper 155.

Ladd, Harry S., and Brown, R. W., 1956, Fossils lift the veil of time: National Geographic, v. CIX, no. 3, March 1956.

Lakhanpal, Rajendra N., 1958, The Rujada flora of west central Oregon: Univ. Calif. Pub. in Geol. Sci. No. 35.

LaMotte, R. S., 1952, Supplement to the catalogue of the Cenozoic plants of North America through 1950: Geol. Soc. America Mem. 51.

Lowry, W. D., Geology of the Ironside Mountain quadrangle, Oregon: State of Oregon Dept. Geology and Mineral Ind. Bull., unpublished.

Mendenhall, W. C., 1907, A coal prospect of Willow Creek, Morrow County, Oregon: U.S. Geol. Survey Bull. 341-C.

Merriam, J. C., 1901, A contribution to the geology of the John Day basin: Univ. Calif. Dept. Geol. Bull., v. 2, no. 9, p. 269-314.

Pigg, John Henry, 1961, Lower Tertiary rocks in the Pilot Rock and Heppner areas, Oregon: Univ. Oregon master's thesis.

Reid, E. M., and M.E. J. Chandler, 1933, The London Clay flora: London, British Museum Nat. Hist.

Potbury, Susan S., 1935, The La Porte flora of Plumas County, California: Carnegie Inst. Washington Pub. 465.

Scott, Richard A., 1954, Fossil fruits and seeds from the Eocene Clarno Formation of Oregon: Stuttgart, Palaeontographica 96 (B).

Sargent, C. S., 1922, Trees of North America: New York, Houghton Mifflin Co.

Swanson, D. A., and Robinson, P. T., 1968, Base of the John Day Formation in and near the Horse Heaven mining district, north-central Oregon: U.S. Geol. Survey Prof. Paper 600-D, p. 154-161.

Tomlinson, P. B., 1961, Anatomy of the Monocotyledons: Oxford, Clarendon Press.

Wells, F. G., and Peck, Dallas, 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geol. Survey Map I-325.

Wilkinson, W. D., Ed., 1959, Field guidebook; geologic trips along Oregon highways: Oregon Dept. Geol. and Mineral Ind. Bull. 50.

Wolfe, J. A., Hopkins, D.M., and Leopold, E.B., 1966, Tertiary stratigraphy and paleobotany of the Cook Inlet region, Alaska: U. S. Geol. Survey Prof. Paper 398-A.

Wolfe, J. A., 1966, Tertiary plants from the Cook Inlet region, Alaska: U. S. Geol. Survey Prof. Paper 398-B.

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BIBLIOGRAPHY OF N.A. GEOLOGY FOR 1965 PUBLISHED

The U.S. Geological Survey has recently issued Bulletin 1235, "Bibliography of North American Geology, 1965." The 1144-page publication is sold for $4.75 by the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402.

* * * * *

DeWEESE APPOINTED TO GOVERNING BOARD

Governor Tom McCall appointed R. W. deWeese, vice president of ESCO Corporation, to the Governing Board of the Department of Geology and Mineral Industries April 17, 1969. DeWeese replaces former chairman of the Board, Frank C. McColloch, whose term expired in March. Mr. deWeese has been associated with both the metals and mining industries for a number of years. He has worked with the American Mining Congress in developing a planned usage for our mineral deposits so that the exploitation of these resources will be balanced with preservation of the natural environment. During his 28-year tenure with ESCO, he has been directly involved with phosphate mining in Florida, copper mining in the southwest, taconite development in the Mesabi iron range in Michigan, and surface mining for coal in the central states.

Mr. deWeese has also contributed much of his time to civic activities, locally and state-wide; he is a director of Portland Public Schools, District No. 1, President of Portland Chamber of Commerce, and technical counselor for Oregon State University. He also serves as a director on the boards of several Oregon companies in addition to his regular duties with ESCO. His wide background of experience in both industry and public affairs will provide the Department with much valuable counsel in establishing its future policies and actions.

Members of the Governing Board are: Fayette I. Bristol, chairman, Rogue River; Harold C. Banta, Baker; and R. W. deWeese, Portland.

* * * * *

NININGER METEORITE AWARD OPEN TO QUALIFIED STUDENT

An award of $1000 is given annually by Dr. and Mrs. H. H. Nininger (1) to generate interest in meteorites among the greatest number of student scientists and (2) to generate within the student scientist the ability to interpret logically and objectively his and other's experimental methods, data, and hypotheses, and to learn by writing. Paper must be written specifically for the Nininger prize and must be received not later than September 1, 1969. Undergraduate and graduate students are eligible. For information regarding the requirements for the paper, write to Dr. Carleton B. Moore, Director, Center for Meteorite Studies, Arizona State University, Tempe, Arizona 85281.

The $1000 may be awarded as a single or divided prize. The papers will be judged by a national panel of scientists engaged in meteorite investigations. Nininger awards have been given annually since 1962 to recipients at colleges and universities all over the United States.

* * * * *

GEOCHEMICAL ANALYSES TO BE RELEASED

On June 20, 1969 the results of all analyses of stream sediments on more than 3000 streams in southwestern Oregon will be released for public inspection at the State of Oregon Department of Geology and Mineral Industry's offices in Portland, Baker, and Grants Pass. These samples were collected during the summer months from 1963 to 1967 as a part of a state-wide mineral-evaluation program. Semiquantitative chemical analyses were made for copper, zinc, molybdenum, and mercury in the Department's laboratory in Portland by R.G. Bowen. This information has been available on open file since the inception of the program.

New information to be released at the same time consists of semiquantitative spectrographic analyses for 30 elements by the U.S. Geological Survey. The Survey's analyses were made at the Denver laboratories under the supervision of Jerry Motooka. The samples were scanned for the following elements: iron, magnesium, calcium, titanium, manganese, silver, arsenic, gold, boron, barium, beryllium, bismuth, cadmium, cobalt, chromium, copper, lanthanum, molybdenum, niobium, nickel, lead, antimony, scandium, tin, strontium, vanadium, tungsten, yttrium, zinc, and zirconium

In addition to being available for inspection at the Department's offices, these data, tabulated on approximately 400 pages, will be duplicated and mailed to any interested person for $25.00. All orders with payments received by June 6 will be mailed on June 20.

A bulletin containing all of the above information, together with maps, discussion of geology, geochemistry, analytical techniques, anomalies, and mineral deposits in the region where the samples were collected is now being prepared for publication. The analytical data are being released early, because it is the Department's policy to make such information available as soon as possible after it has been compiled.

* * * * *

MYRTLE POINT AREA IN COOS COUNTY MAPPED

"Geologic map of the Myrtle Point area, Coos County, Oregon," by Ewart M. Baldwin has been published by the U.S. Geological Survey under the Mineral Investigations Field Studies Map series. The map, designated as MF-302, is in color at a scale of 1:48,000 on a 22- by 27-inch sheet. It is available for 50 cents from the U.S. Geological Survey, Federal Center, Denver, Colo. 80225.

The map area lies at the southern end of the Coos Bay coal field and is a southward extension of the Coos Bay structural basin. Lower to middle Eocene Umpqua Formation, middle Eocene Tyee Formation, and upper Eocene Coaledo Formation overlie pre-Tertiary rocks of the Klamath Mountains. A total of about 20,000 feet of Tertiary sediments is represented.

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AVAILABLE PUBLICATIONS

(Please include remittance with order. Postage free. All sales are final and no material is returnable. Upon request, a complete list of the Department's publications, including those no longer in print, will be mailed.)

BULLETINS

2.	Progress report on Coos Bay coal field, 1938: Libbey	$ 0.15
8.	Feasibility of steel plant in lower Columbia River area, rev. 1940: Miller	0.40
26.	Soil: Its origin, destruction, preservation, 1944: Twenhofel	0.45
33.	Bibliography (1st supplement) of geology and mineral resources of Oregon, 1947: Allen	1.00
35.	Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1963: Baldwin	3.00
36.	(1st vol.) Five papers on Western Oregon Tertiary foraminifera, 1947: Cushman, Stewart, and Stewart	1.00
	(2nd vol.) Two papers on Western Oregon and Washington Tertiary foraminifera, 1949: Cushman, Stewart, and Stewart; and one paper on mollusca and microfauna, Wildcat coast section, Humboldt County, Calif., 1949: Stewart and Stewart	1.25
37.	Geology of the Albany quadrangle, Oregon, 1953: Allison	0.75
46.	Ferruginous bauxite deposits, Salem Hills, Marion County, Oregon, 1956: Corcoran and Libbey	1.25
49.	Lode mines, Granite mining dist., Grant County, Ore., 1959: Koch . .	1.00
52.	Chromite in southwestern Oregon, 1961: Ramp	3.50
53.	Bibliography (3rd supplement) of the geology and mineral resources of Oregon, 1962: Steere and Owen	1.50
56.	Fourteenth biennial report of the State Geologist, 1963-64	Free
57.	Lunar Geological Field Conference guide book, 1965: Peterson and Groh, editors	3.50
58.	Geology of the Suplee-Izee area, Oregon, 1965: Dickinson and Vigrass .	5.00
60.	Engineering geology of the Tualatin Valley region, Oregon, 1967: Schlicker and Deacon	5.00
61.	Gold and silver in Oregon, 1968: Brooks and Ramp	5.00
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63.	Sixteenth Biennial Report of the State Geologist, 1966-1968	Free

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Preliminary geologic map of Sumpter quadrangle, 1941: Pardee and others . . .	0.40
Geologic map of the St. Helens quadrangle, 1945: Wilkinson, Lowry & Baldwin .	0.35
Geologic map of Kerby quadrangle, Oregon, 1948: Wells, Hotz, and Cater . .	0.80
Geologic map of Albany quadrangle, Oregon, 1953: Allison (also in Bull. 37) .	0.50
Geologic map of Galice quadrangle, Oregon, 1953: Wells and Walker	1.00
Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts	0.75
Geologic map of Bend quadrangle, and reconnaissance geologic map of central portion, High Cascade Mountains, Oregon, 1957: Williams.	1.00
GMS-1 - Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka	1.50
GMS-2 - Geologic map, Mitchell Butte quad., Oregon, 1962: Corcoran et al. .	1.50
GMS-3 - Preliminary geologic map, Durkee quad., Oregon, 1967: Prostka . .	1.50
Geologic map of Oregon west of 121st meridian: (over the counter) . . . . . . folded in envelope, $2.15; rolled in map tube, $2.50	2.00
Gravity maps of Oregon, onshore and offshore, 1967: [Sold only in set]: flat . . folded in envelope, $2.25; rolled in map tube, $2.50	2.00

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18.	Radioactive minerals the prospectors should know (2nd rev.), 1955: White and Schafer	0.30
19.	Brick and tile industry in Oregon, 1949: Allen and Mason	0.20
20.	Glazes from Oregon volcanic glass, 1950: Charles W.F. Jacobs	0.20
21.	Lightweight aggregate industry in Oregon, 1951: R. S. Mason	0.25
23.	Oregon King Mine, Jefferson County, 1962: F.W. Libbey and R.E. Corcoran	1.00
24.	The Almeda Mine, Josephine County, Oregon, 1967: F.W. Libbey	2.00

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THE GEOLOGY OF CEDAR BUTTE NORTHERN COAST RANGE OF OREGON

By
Dennis O. Nelson* and Gerald B. Shearer**

The following article on the Cedar Butte area in Oregon's northern Coast Range was written originally as a term paper by the authors at the time they were undergraduate students in geology under Dr. Paul Hammond at Portland State University. Although their period of field work was brief and their mapping of a reconnaissance nature, the authors were able to extract enough information to write a report which has considerable merit as a basis for further study.

The northern Coast Range has received little attention geologically, and mapping has been limited to the broad, generalized picture. And yet, here is a region right at Portland's back door that begs to be studied. Its complex history of Tertiary volcanism, marine deposition, folding, and faulting offers many areas for research in stratigraphy, petrology, paleontology, and structure.

A further inducement is the abundance of outcrops in the Tillamook Burn. This rugged area of some 550 square miles, including Cedar Butte, was once covered by a nearly impenetrable forest. In 1933, 1939, and again in 1945 devastating fires swept across the region, destroying the timber and leaving behind a desolate terrain of scorched soils and barren rock. A new forest is springing up as the result of the State Department of Forestry's rehabilitation program. But opportunely for the geologist, the rocks are still fairly well exposed in most places, and numerous logging roads, built for salvage and reforestation purposes, make the area easily accessible.

It is hoped that this paper by Nelson and Shearer will encourage others to select localities for geologic research in this much neglected portion of the Coast Range. - Editor

Introduction

Cedar Butte is situated in the Tillamook Highlands, a mountainous region in the northern Coast Range of Oregon (figure 1). The butte rises to 2907

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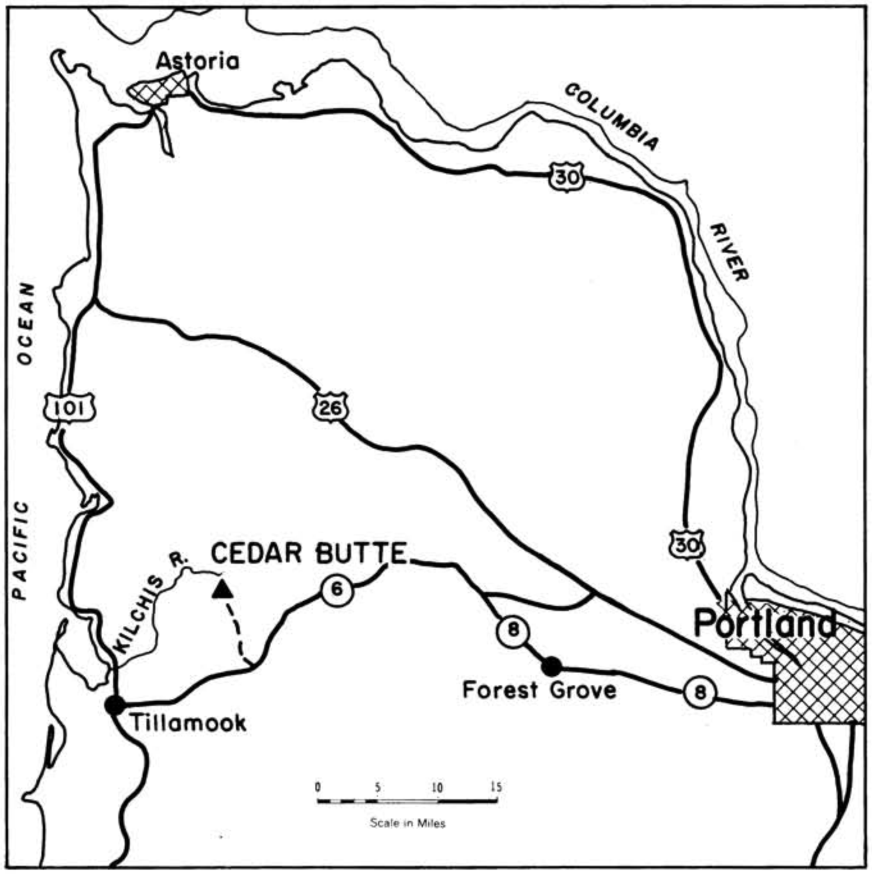

Figure 1. Index map of northwestern Oregon showing location of Cedar Butte.

feet above sea level in the NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 10, T. 1 N., R. 8 W., Tillamook County (figure 2). The area is readily accessible by car in good weather and is reached by way of Oregon Highway 6 (Wilson River Highway) and logging roads.

The purpose of this paper is to describe the various rock units found in the Cedar Butte area, to present specific data to supplement the more general knowledge concerning the igneous and sedimentary rocks of the northern Coast Range, and if possible to stimulate further interest so that more detailed work might be done by others.

Because of limited time, we restricted the area of study to approximately 15 square miles within the 15-minute Enright quadrangle. A detailed geologic map (plate 1) was made of the immediate vicinity of Cedar Butte. The emphasis was on field relationships, supplemented by limited petrographic studies of some units. Field work for this report was done in the fall of 1966 and spring of 1967, while we were undergraduates at Portland

State University.

We were first introduced to the Cedar Butte area during a collecting trip to the "augite locality" (figure 3). Our study of the "augite" crystals indicated that they are probably members of the diopside-hedenbergite compositional series. They occur in a thick unit of crystal vitric tuff which is highly weathered and very friable (figure 4). Single crystals can be found at the surface, and more can be obtained with only minor digging, using a rock hammer. Because of the friable state of the tuff, individual crystals can be removed easily and without being damaged. Both single and twinned crystals can be found, almost all perfectly euhedral and generally showing no visible alteration.

The crystals occur throughout the unit, but the best location for collecting is on the south side of Cedar Butte (see plate 1). Roads leading to Cedar Butte are shown on the 15-minute Enright quadrangle and State Forest maps of the area, both of which are readily available. It is suggested that anyone planning to collect in this area should carry one of these maps, since the maze of winding roads can be confusing. Additional information can be obtained from the State Forestry Headquarters at Forest Grove.

Regional Geology

The northern Coast Range in Oregon has been mapped on a regional basis by Warren, Norbisrath, and Grivetti (1945); Wells and Peck (1961); and Snavely and Wagner (1964). The following discussion of the regional geology is summarized chiefly from Snavely and Wagner (1964).

The northern Coast Range is part of an anticlinorium extending northward from the Klamath Mountains to the Columbia River in western Oregon. Minor anticlines trending east-west and northwest lie across the regional grain. The faults follow northeasterly and northwesterly trends. The stratigraphy consists of the Eocene Tillamook Volcanic Series overlain by Eocene to early Miocene eugeosynclinal sediments which, in turn, are overlain by Miocene basalt flows.

Uplift and erosion of rocks in the northern Coast Range have produced the Tillamook Highlands, a topographically rugged region underlain primarily by the Tillamook Volcanic Series (figure 5). From early Eocene time to possibly late Eocene this region was a center of volcanism, largely submarine, where basaltic pillow lavas and breccias, along with some interbedded sediments, accumulated to an estimated thickness of 20,000 feet. Tuffaceous marine sediments were deposited around the margins of the volcanic center. They interfinger with the lavas and thicken away from the locus of volcanic activity. Rocks overlying the Tillamook Volcanic Series on the margins of the Tillamook Highlands are mapped as undifferentiated marine tuffaceous siltstone and sandstone of late Eocene to middle Miocene age. They include also basalt and andesite flows, breccia, and pyroclastic rocks of late Eocene age south of the Tillamook Highlands.

Description of the Units

The stratigraphic sequence consists of tuffaceous shales and volcanic sandstones overlain unconformably by volcanic rocks, dominantly pillow basalts and submarine breccias. Capping these rocks is a series of basalt flows fed by a number of small dikes.

To avoid confusion in the literature, the formations have not been named and will be referred to in more general lithologic terms. The units are described below, from oldest to youngest (see table 1).

Olivine basalt porphyry

Although not exposed in the mapped area, olivine basalt porphyry occurs as xenoliths in several of the described units. This rock apparently underlies the lowest exposed sequence in the area.

The material is greenish black, amygdaloidal, holocrystalline, fine grained allotriomorphic granular and porphyritic, having 35 percent phenocrysts whose average size is 2.5mm. Of these phenocrysts, 15 percent are augite and 85 percent are Mg-olivine. The groundmass is composed of 20 percent plagioclase, probably labradorite (An_{60}); 30 percent augite (40 percent Ca)*; 40 percent titaniferous(?) magnetite; and 10 percent alteration minerals of which 5 percent are antigorite and 5 percent calcite.

Tuffaceous shale and volcanic sandstone

The oldest unit exposed within the map area is a sequence of interbedded, sparsely fossiliferous, tuffaceous, siliceous shale and volcanic sandstone. Thin layers of ash can readily be found throughout the entire formation. The base is not exposed, but the unit is at least 250 feet thick and is probably very much thicker. It strikes northwest with a moderate northerly dip. The best section within the mapped area crops out along the south fork of the Kilchis River (plate 1). Similar sediments crop out along Cedar Butte road south of the mapped area (figures 6 and 7).

The shale members of this formation are dark gray, weathering to light brown. The rock is extremely fine grained, and is composed primarily of silt- and clay-size particles with a few small subangular sand grains firmly bound by a siliceous cement. Minerals recognized are quartz, feldspar, and a small amount of authigenetic mica. The shale exhibits good bedding-plane fracture.

Of special significance is the fact that fossil leaves of conifers and deciduous trees are present in this shale. These indicate a temperate climate and a shallow-water environment of deposition.

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* Value estimated from 2V.

Figure 2. (Top) View of the top of Cedar Butte from its south flank. The "augite" locality is to the left of the photograph.

Figure 3. (Bottom) "Augite" locality on the southwest side of Cedar Butte. Part of the butte is visible in the background. Crystal-bearing vitric tuff unit dips northeasterly. Attitude of the beds is assumed to represent initial dips or cross-bedding.

Table 1. Stratigraphic column of the Cedar Butte area.

Lithologic Name	Thickness (feet)	Description
Basalt flows	400+	Dense, black amygdaloidal basalt flows capping Cedar Butte; cliff former.
(Disconformity [?])		
Upper submarine breccia	100-150	Fine-grained, dark, massive breccia containing pillows and stringers of basalt; cliff former.
Interlayered basalt flows and breccias	300-325	Interlayered thin-bedded dark, massive fine-grained olivine basalt and dark, massive submarine breccias; cliff former.
Crystal vitric tuff	100-400	Green-black to red-brown massive, fine- to medium-grained crystal vitric tuff; contains pyroxene crystals.
(Disconformity)		
Palagonitic pillow breccia	320-450	Interstratified palagonitic pillow breccia and lensoidal masses of basalt; breccia composed of basalt pillows in red-brown tuffaceous matrix.
Lower submarine breccia	100	Gray-brown, massive submarine breccia composed of fragmented volcanic rocks in a fine-grained matrix; contains moderately to well-developed pillows; cliff former.
(Angular unconformity)		
Tuffaceous shale and interbedded volcanic sandstone	250+	Dark-gray to light-brown fine-grained tuffaceous siliceous shale, containing fossil leaves and exhibiting good bedding-plane fracture; interbedded with gray to red-brown volcanic sandstone; cliff former.

Figure 4. (Top) Weathered vitric tuff at "augite" locality shows abundance of crystals in talus; scale is compared to a dime.

Figure 5. (Bottom) Rugged topography typical of the Tillamook Burn region is illustrated by this view looking northwest down the Kilchis River from the Cedar Butte area.

Interstratified with the shales are beds 1 to 3 feet thick of coarse-grained sandstone(?), consisting of angular fragments of shale, pyroxene, and dark glass, cemented with silica.

The volcanic sandstone members are composed of ferruginous, argillaceous, silty wacke of a gray to grayish-brown color, weathering to dark reddish brown. Thicknesses of beds range from 5 to 60 feet. The sandstone is massive, fine to medium grained, and poorly sorted. It is composed of subangular grains of quartz, plagioclase, lithic fragments, and clay firmly bound together with a siliceous cement. The sandstone members are prominent cliff formers.

No microfossils were observed when representative samples of this sedimentary sequence were disaggregated and studied under a binocular microscope to determine mineralogical composition.

Lower submarine breccia

The tuffaceous shale and volcanic sandstone is overlain unconformably by massive cliff-forming submarine breccia, which has a uniform thickness of about 100 feet. It is grayish brown, composed of angular fragments of poorly sorted volcanic rocks in a fine- to medium-grained matrix consisting of quartz, zeolites, minor olivine, and unidentified accessory or alteration minerals firmly cemented with silica.

An outcrop along the north fork of the Kilchis River contained a pelecypod, possibly a Unio(?).

The submarine origin of the breccia is suggested by moderately to well-developed pillow structures. Massive, fine-grained breccia exposed on slopes south of Cedar Butte has the appearance of pavement (figure 8).

Palagonitic pillow breccia

The submarine breccia is overlain conformably by 320 to 450 feet of interstratified palagonitic pillow breccia and lensoidal masses of basalt. The breccia consists of whole or fragmented pillows of fine-grained basalt, set in a yellow to reddish-brown tuffaceous matrix and containing blebs of sideromelane partly altered to palagonite. Xenoliths of olivine basalt porphyry occur throughout the unit.

This unit was apparently formed by the flowing of basaltic lava into water.

Crystal vitric tuff

Overlying the palagonitic pillow breccia with a disconformity is a crystal-vitric tuff (figures 3 and 9). It is greenish black, weathering to reddish brown, massive, fine to medium grained, poorly sorted, and is composed of pyroxene crystals, glass, and iron-bearing clay.

Studies of optical properties and crystal morphology gave ambiguous results as to the identity of the crystals. X-ray diffraction was employed and all the peaks on the resulting graph indicated that the mineral was in the diopside-hedenbergite solid solution series. The following lattice planes were identified for the mineral: (220), ($\bar{2}$21), (310), ($\bar{3}$11), (1$\bar{3}$1), ($\bar{5}$31), and ($\bar{2}$23). It should be noted that all of the members of the diopside-hedenbergite series have similar diffraction patterns with respect to the major peaks. Mineral analysis performed by the State of Oregon Department of Geology and Mineral Industries gave the following average:

SiO_2	50.0%
Al_2O_3	7.0
Fe_2O_3	6.5
CaO	19.5
MgO	17.5
	100.5%

Comparison of these average analyses with those given by Deer, Howie, and Zussman (1965, v. 2, p. 47-55) indicates that the mineral may be a variety of salite, a member of the diopside-hedenbergite compositional series.

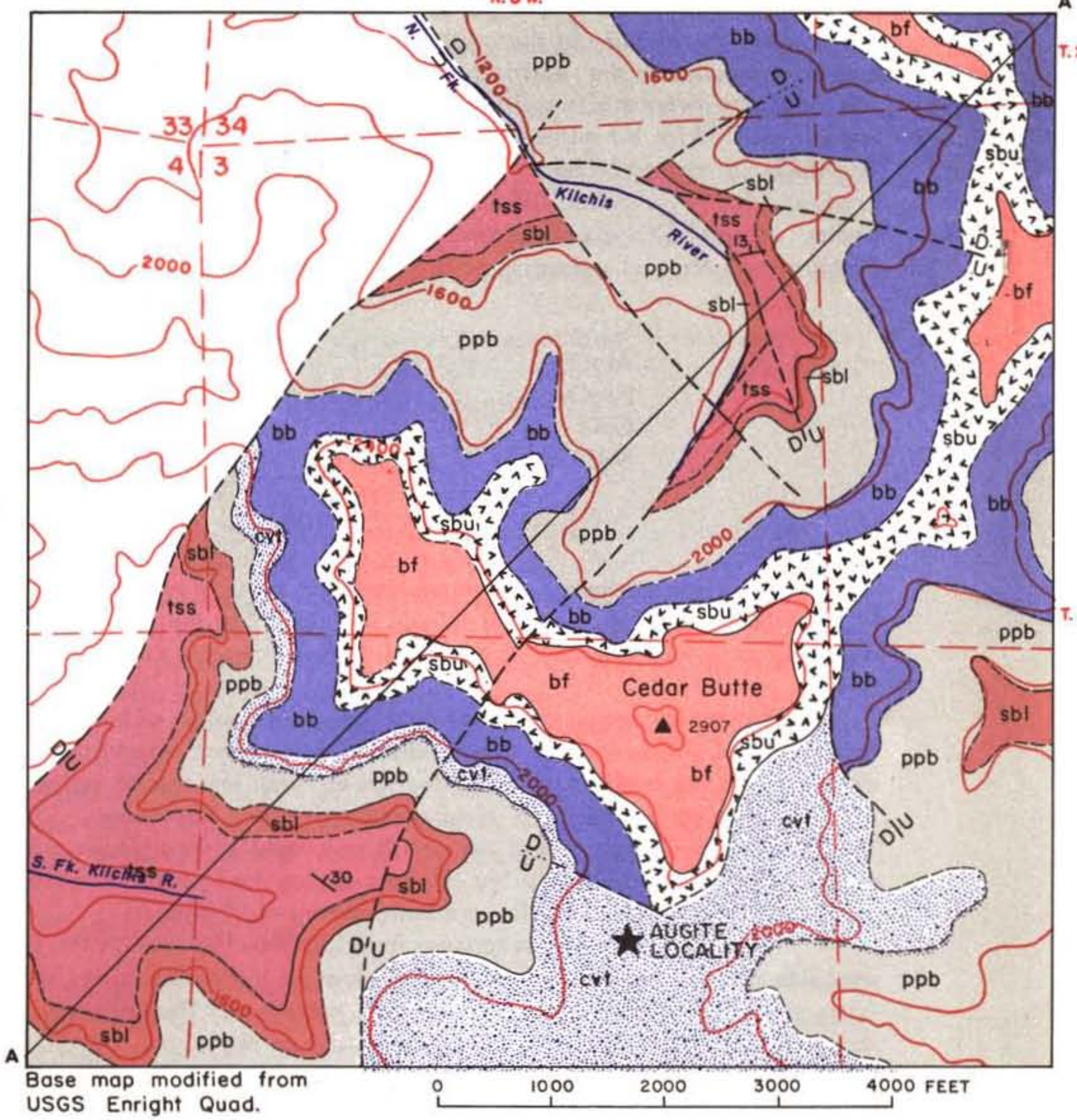
The glass is opaque to transparent, being composed of both black tachylyte and yellow-orange sideromelane. Subsequent alteration of the sideromelane has resulted in the formation of minor amounts of palagonite(?). The concentration of glass is approximately 50 percent.

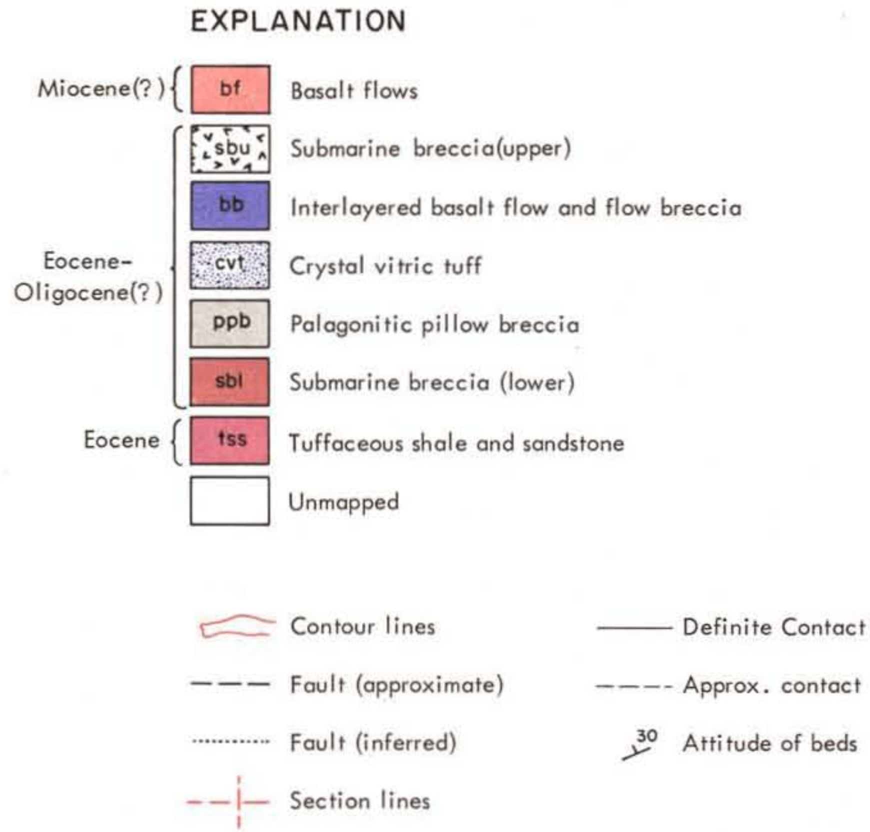
The remaining portion of the unit is composed of ferruginous clay and minor amounts of secondary silica released during the hydration of the sideromelane. The silica and clay are both cementing agents.

The unit has a thickness ranging from less than 100 feet on the southwest side of Cedar Butte to more than 400 feet on the eastern side, where fairly steep easterly dips in cross beds were measured. The unit contains laminar bedding and xenoliths of olivine basalt porphyry.

The very thin-bedded character, the size, and areal extent, suggest an airborne deposit into shallow water. Pelecypods are reported to have been found in the unit, supporting the belief that the unit was deposited in water (R. E. Corcoran, personal communication). The advancement of a basaltic ash flow into water has also been suggested (P. E. Hammond and R. E. Corcoran, personal communications). Ash-flow tuffs, however, generally consist of unsorted pyroclastic debris that would include vesiculated rock fragments. Ross and Smith (1960, p. 18) report that generally in subaerial ash flows the most important criterion for recognition of ash-flow tuffs is the presence of these pyroclastic rock fragments. The absence of such debris and the moderate degree of sorting suggest to the present authors that the unit was not an ash-flow tuff.

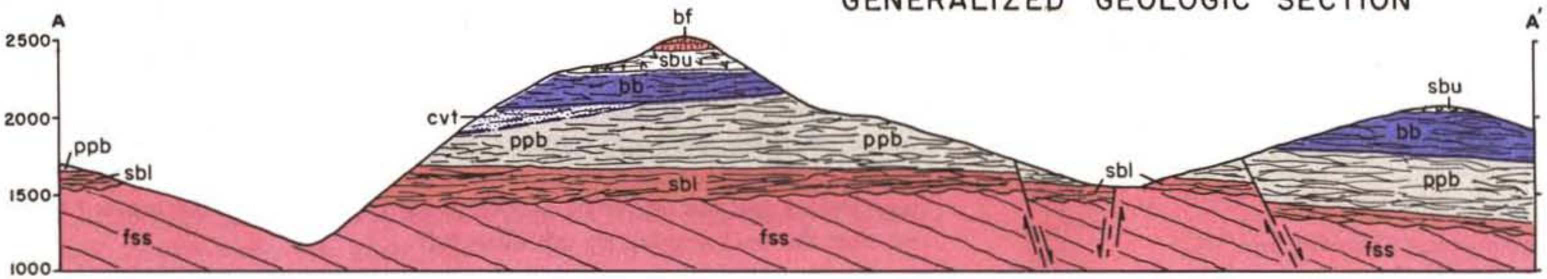
Plate 1 GEOLOGIC MAP OF CEDAR BUTTE





Index map showing approximate location of area of study.

GENERALIZED GEOLOGIC SECTION



Interlayered basalt flows and flow breccias

Overlying the crystal-vitric tuff is a sequence of interlayered basalt flows and submarine flow breccias 300 to 325 feet thick. The basalt flows are olivine basalt, very dark, massive, fine grained, and composed of plagioclase, pyroxene, lesser olivine, and interstitial glass. Individual flows are about 8 to 10 feet thick and have irregular columnar and vertical jointing.

The flow breccias are dark brown to black, massive, and fine grained. They contain angular fragments of basalt, ranging in size from one to four centimeters and similar in composition to the flows. Minor alteration has resulted in the formation of zeolites. The flow breccias range in thickness from 15 to 100 feet.

The basalts of this sequence are massive, hypocrystalline, aphanitic, with a trachytic to pilotaxitic texture, and are composed of plagioclase, pigeonite, olivine, magnetite, glass, and chlorite. Of the rock, 40 to 45 percent is plagioclase, occurring both as phenocrysts and microlites. The phenocrysts, most of which are albite twinned, are zoned, ranging from An_{75} at the core to An_{50} at the rims. The microlites are all albite twinned and have a composition of An_{50}.

The pyroxene, making up 30 to 35 percent of the rock, occurs both as phenocrysts and in the groundmass. Some crystals are twinned, and minor zoning is present. A large portion of the pyroxene shows alteration to chlorite. Interference figures gave a positive 2V of approximately 15 to 20 degrees and it is probably pigeonite (18 percent Ca). Olivine occurs in the groundmass and as phenocrysts, making up 10 to 15 percent of the rock. Optical properties indicate the olivine is Mg-rich. Alteration to serpentine with subsequent magnetite dust is common. Minor amounts of glass (3 to 5 percent) occur as irregular veins and between grains of pyroxene, olivine, and plagioclase, suggesting rapid cooling after prolonged crystallization. Opaque minerals compose 5 to 8 percent of the rock. Alteration minerals, consisting of chlorite and iddingsite(?), constitute 5 percent of the rock.

Upper submarine breccia

Conformably overlying the basalt flow and flow-breccia sequence is a fine-grained, dark, massive breccia containing pillows and stringers of basalt with well-developed columnar jointing. The rock is well indurated and consists of 50 percent lithic fragments, 25 percent glass, 15 percent magnetite, 5 percent pyroxene, and 5 percent olivine bound by a siliceous cement. The unit ranges from 100 to 150 feet in thickness and forms cliffs exposed near the summit of Cedar Butte.

Basalt flows capping Cedar Butte

Amygdaloidal basalt flows overlie the breccia with a depositional contact. They are dense and black, with poorly developed primary jointing and intensive fracturing. The units have an exposed thickness of more than 400 feet, with the individual flows ranging from 60 to 100 feet. They form a resistant cap on Cedar Butte, and weather to form steep cliffs.

Microscopically, the basalt is hypidiomorphic granular, and has a composition of 50 percent plagioclase, 25 percent augite, 7 percent magnetite, and 18 percent alteration minerals, primarily chlorite and an unidentified mineraloid. The plagioclase is highly zoned and ranges from An_{40} in the rims to An_{70} in the cores of the phenocrysts. The microlites have a composition of An_{40}. The pyroxene, occurring primarily in the groundmass, is lime-rich augite (47 percent Ca)*.

Basaltic dikes

The rocks of the Cedar Butte area are cut by several dikes of basaltic composition (not mapped) (figure 9). In general, these intrusive bodies trend northwesterly and dip steeply northeast, and are probably small feeder dikes to the overlying cap rocks.

The specimen of dike rock studied in this section is a porphyritic olivine basalt. It is holocrystalline, fine to medium grained, hypidiomorphic granular, pilotaxitic and porphyritic. It contains augite, 40 to 45 percent; labradorite, 35 to 40 percent; Mg-olivine, 8 to 10 percent; magnetite, 5 percent; and alteration minerals, 3 to 5 percent. The plagioclase phenocrysts have a composition of An_{64}. The microlites are only slightly less calcic, having a composition of An_{56}. The pyroxene has a positive 2V of 56° and is probably augite (45 percent Ca)*. A greater percentage of the pyroxene occurs in the groundmass, and many crystals are twinned along the b-axis parallel to (010)*. The olivine is generally euhedral and occurs only as phenocrysts. Optical properties indicate a Mg-rich variety. Alteration has resulted in the formation of serpentine and magnetite. Magnetite occurs as both a primary and a secondary mineral.

Composition of the Basalts

Determining whether a particular flow is a tholeiitic or an alkali-olivine basalt by means of petrographic data alone may yield results somewhat less than satisfactory, but such a study may serve, at least, to indicate compositional varieties.

Probably the most reliable petrographic criteria for establishing the

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* 2V and twinning data obtained from measurements on the universal stage.

Figure 6. (Top) Thick sedimentary series below the volcanics is exposed along the road to Cedar Butte.

Figure 7. (Bottom) Close-up view of weathered shale and sandstone of figure 6.

various types of basalts are modal percentage and mode of occurrence of the olivine, and the Ca-content of the pyroxenes (Wilkinson, 1967).

In an alkali-olivine basalt, olivine percentage is high, with olivine generally occurring both as phenocrysts and in the groundmass. Coexisting pyroxene is usually Ca-rich (Ca percentage $>$45). In a tholeiitic basalt, olivine percentages are low and the mineral generally occurs only as phenocrysts. Pyroxene in such a basalt would be Ca-poor (Wilkinson, 1967).

The previously mentioned data for the basaltic rocks described earlier are listed in table 2.

Table 2. Data for compositional character of basalts of the Cedar Butte area.

Unit	Vol. % olivine	Mode of occur. of olivine	% Ca in pyroxene
1	30	P & G	~ 40
2	23	P & G	~ 18
3	8-10	P	~ 45
4	0	-	~ 47

P = Occurs as phenocrysts
G= Occurs in the groundmass

Unit 1. Olivine basalt porphyry; oldest unit, probably underlying mapped area.
Unit 2. Basalt from the basalt flow - flow breccia sequence.
Unit 3. Basalt from dike intruding unit 2.
Unit 4. Basalt from youngest flows capping Cedar Butte.

From the data presented, no confident conclusions can be drawn. The results are somewhat ambiguous and sometimes conflicting. Unit 1, however, does seem to approximate the characteristics of an alkali-olivine basalt, while the modal percent and mode of occurrence of olivine in units 3 and 4 may indicate a tholeiitic character similar to that of Columbia River Basalt.

More reliable results could be obtained through wider and more systematic sampling, and detailed chemical and petrographic analysis. It is hoped that in the near future such a study will be undertaken.

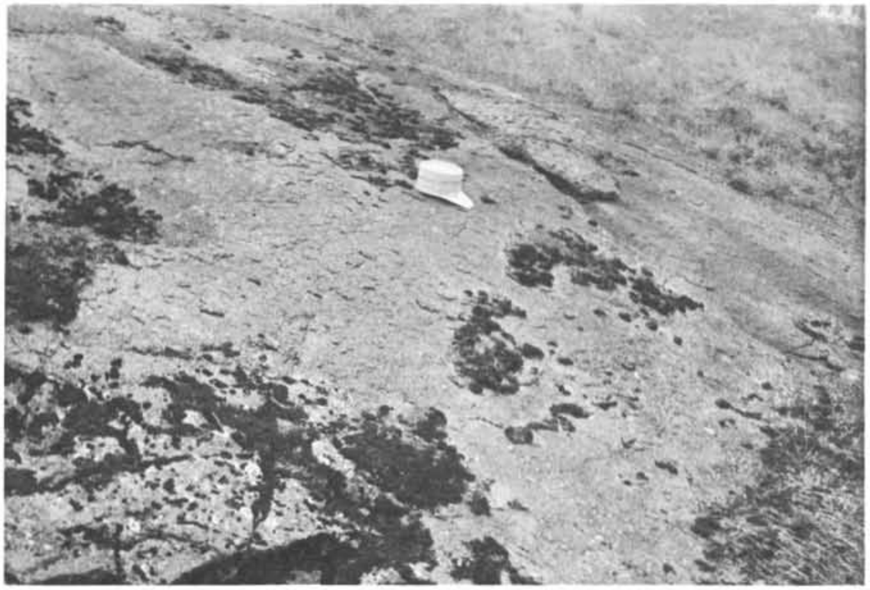

Figure 8. (Top) Fine-grained volcanic breccia forms massive pavement-like outcrops south of the mapped area.

Figure 9. (Bottom) Small basalt dike which marks minor offset in the vitric tuff bed was probably one of the feeders for the basalt cap on Cedar Butte.

Structural Geology

The most significant structural feature of the Cedar Butte area is the angular unconformity between the older sedimentary sequence and the overlying volcanic rocks. The older sedimentary sequence strikes northwesterly and dips variably to the northeast. The younger volcanic rocks are nearly horizontal or are dipping gently to the west-northwest (plate 1).

The rocks are complexly faulted in both northeast and northwest directions. The faults in general are high-angle normal ones with small to moderate displacement; some strike-slip movements were also interpreted. Mapping was on too small a scale to detect the large-scale regional folding noted by Snavely and Wagner (1964).

Summary and Conclusions

Cedar Butte, located in the northern Coast Range of Oregon, consists of a sequence of basalt flows, basaltic pillow lavas and submarine breccias, unconformably overlying sparsely fossiliferous tuffaceous shales and volcanic sandstones. The leaf fossils within the sedimentary rocks indicate a temperate climate and a shallow-water environment of deposition. The sedimentary rocks appear to have been derived from volcanic rocks. Later volcanism is indicated by basalt flows, flow breccias, and a crystal-vitric tuff. Pillow lavas, pillow palagonite breccias, palagonitic breccias, and submarine breccias indicate the volcanism was dominated by submarine activity. It is probable that the sedimentary sequence is part of the Tillamook Volcanic Series of middle to late Eocene age.

The presence of the angular unconformity between the Eocene sedimentary sequence and the younger volcanic sequence, and the possible tholeiitic character of the younger basalts suggest to the authors that these basalts may be related to the Columbia River Basalt of Miocene age.

Acknowledgments

We wish to express our appreciation to Dr. Paul E. Hammond and to other members of the Department of Geology at Portland State University for their helpful suggestions during the preparation of this report.

References Cited

Deer, W. A., Howie, R. A., and Zussman, J., 1965, Rock-forming Minerals, vol. 2, Chain Silicates: New York, John Wiley & Sons.

Ross, Clarence S., and Smith, Robert C., 1960, Ash flow tuffs: their origin, geologic relations and identification: U.S. Geol. Survey Prof. Paper 366.

Snavely, P.D., Jr., and Wagner, H.C., 1963, Tertiary geologic history of western Oregon and Washington: Washington Div. Mines and Geology Rept. Invest. 22.

__________________, 1964, Geologic sketch of northwestern Oregon: U.S. Geol. Survey Bull. 1181-M.

Warren, W.C., Norbisrath, Hans, and Grivetti, R.M., 1945, Geology of northwest Oregon west of Willamette River and north of latitude 45°15': U.S. Geol. Survey Map OM 42.

Wells, F.G., and Peck, D. L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geol. Survey Map I-325.

Wilkinson, J. F. G., 1967, The petrography of basalts, in Hess, H. J., and Poldervaart, A., eds., Basalts: the Poldervaart Treatise on Rocks of Basaltic Composition: Interscience Publishers, v. 1, p. 163-214.

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DATE OF MARMES MAN CONFIRMED

Ancient human remains at the Marmes rockshelter site in the southeastern part of Washington are now established as about 10,000 years old, according to scientists of the U.S. Geological Survey and Washington State University. Confirmation of the dating was announced recently by Dr. Meyer Rubin, head of the U.S. Geological Survey Radiocarbon Dating Laboratory in Washington, D.C., and by Professor Roald Fryxell of Washington State University's Laboratory of Anthropology.

Samples of bone from skulls, charcoal from firepits, and residue from decayed vegetation that grew at the excavation site were analyzed. Age of the specimens was determined by using the radiocarbon method. An additional check was provided by Dr. Minze Stuiver, head of Yale University's Radiocarbon Laboratory, who analyzed samples of shells from freshwater molluscs which lived in the nearby Palouse River shortly after the occupation of the Marmes site, and also shells discarded on the floor of the site.

The Marmes site has attracted international attention since the discovery of skull remains in 1965, not only because of the great age of the human skeletal remains, but also because of the unique sequence of these remains, artifacts, fossil animal bones, and geological record from the site, ranging in age from the 10,000-year-old skeletons in the lowest layer to remains of an individual who died only 2000 years ago. Hopes of preserving the site were set back in February, 1969, when a protective levee failed to save it from water backing up behind Lower Monumental Dam on the Snake River in Washington.

The dating of the Marmes site corresponds fairly closely with that assigned to the Fort Rock sandals (9050 B.P.) in northwestern Lake County, Oregon. The sandals, discovered about 30 years ago by Dr. Luther Cressman, head of the Department of Anthropology at the University of Oregon, represent the oldest known artifacts in North America.

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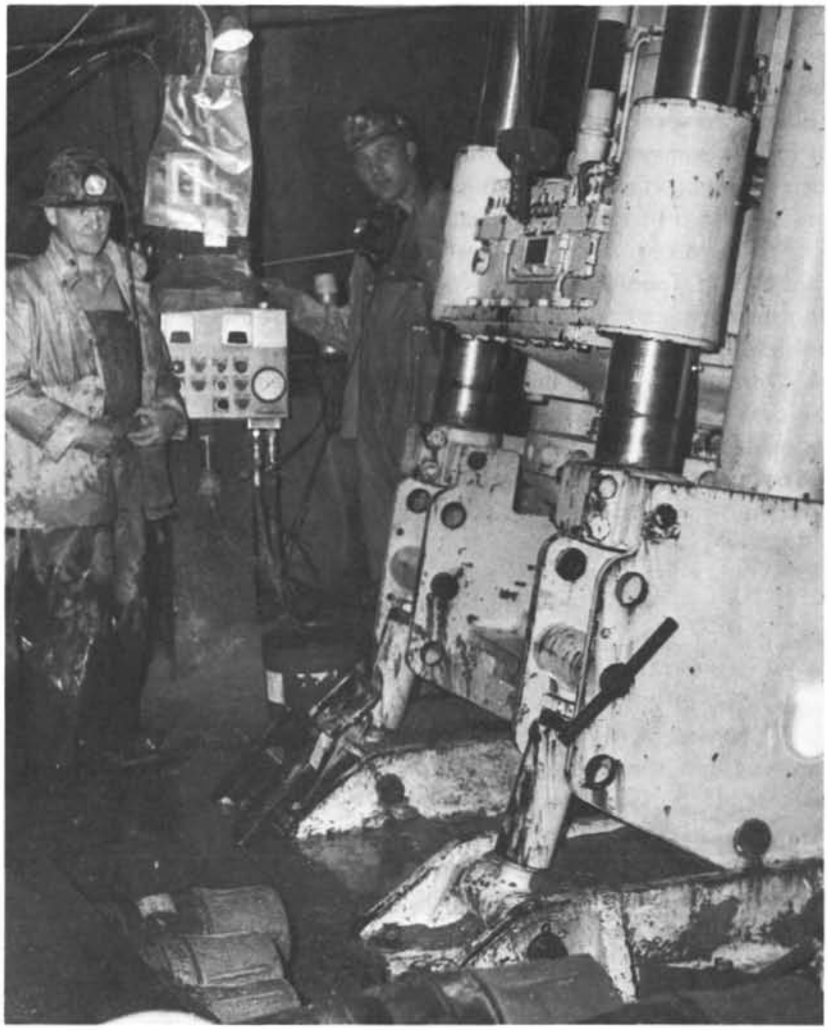

OMEGA MINES USES BORING MACHINE

Pictured above is the raise boring machine used recently by Omega Mines in the drilling of a 4-foot-diameter interconnection between levels on the company's property at Bourne, Baker County, Oregon. Ted Corcoran (left) is superintendent of the mine; Alf Madson (right) is operator of the equipment.

Machines of this type first drill a pilot hole between levels and then, with the reamer bit attached, enlarge the hole from the bottom up. The raise now completed by Omega was bored over a distance of 150 feet for the dual purpose of enhancing subsurface ventilation and providing an emergency alternate escapeway for safety purposes. (Continued on page 132)

Insofar as is known, this is the first time a raise has been bored by a machine of this type and size in any mine in Oregon. This particular project represents only part of Omega's continuing program of developing and appraising ore reserves on their extensive holdings in the Bourne area. Plans for the summer include a massive diamond-drilling effort from both surface and subsurface locations and the driving of a considerable footage of new workings in the form of both drifts and crosscuts.

The more noteworthy properties now part of Omega's holdings include the old E & E, Tabor Fraction, North Pole, Golconda, and Columbia mines. During the fore part of the century these properties were operated as individual mines under separate ownership and management; however, all properties overlie portions of the outcrop of what is believed to be the longest and widest continuous gold-bearing shear zone in Oregon. Omega's program for exploring and developing this lode therefore rates as a truly major project of far-reaching significance. (Photograph by Jerry Herman, courtesy of the Democrat-Herald, Baker, Oregon.)

* * * * *

MINERALS YEARBOOK AVAILABLE

The U.S. Bureau of Mines has issued its MINERALS YEARBOOK for 1967. The four-volume statistical publication is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Volumes I and II (under one cover), priced at $6.25, summarize all metals, minerals, and fuels; Volume III, at $5.25, contains the domestic area reports; and Volume IV, at $5.25, has the international area reports. All of the volumes are clothbound.

* * * * *

WILLAMETTE VALLEY SOILS DESCRIBED

"Geomorphology and soils, Willamette Valley, Oregon," by C. A. Balster and R. B. Parsons, has been published as Special Report 265 by the Oregon State University Agricultural Experiment Station in cooperation with the Soil Conservation Service of the U.S. Department of Agriculture. The 31-page publication, including a geomorphic-soils map, is available from the Agricultural Experiment Station, Oregon State University, Corvallis, Oregon 97331. There is no charge for single-copy orders.

The report demonstrates the time sequence of landscape development and establishes the relation of the soils of the valley to the geomorphic units.

* * * * *

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DISTRIBUTION OF HEAVY MINERALS IN THE SIXES RIVER, CURRY COUNTY, OREGON

Sam Boggs, Jr.*

Introduction

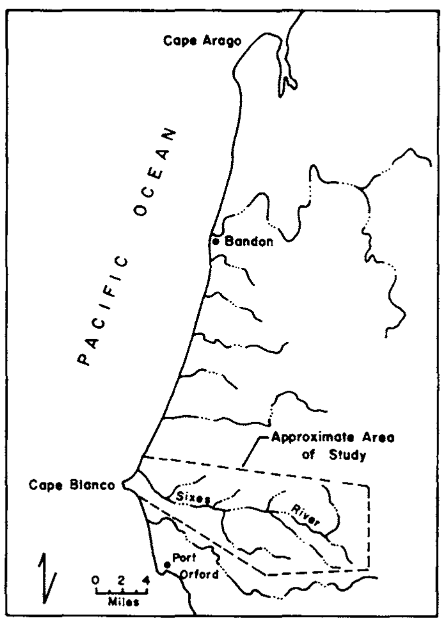


Figure 1. Index map of a portion of the southern Oregon coast showing area of study.

An investigation of heavy minerals and heavy metals in coastal streams of southwestern Oregon was begun in 1967 in conjunction with the Heavy Metals Program conducted by the U.S. Geological Survey. A part of this research involved study of the origin and distribution of heavy minerals in the drainage basin of the Sixes River, located north and east of Cape Blanco (see figure 1). The Sixes River is a short, moderately high-gradient stream that drains a diverse terrane of igneous, sedimentary, and metamorphic rocks ranging in age from Jurassic to Holocene (Wells and Peck, 1961).

The surface detritus that composes the bars and the stream bed of the river is mainly gravel with an interstitial sand content, at most localities, ranging from about 15 to 30 percent. Small "patches" of sand occupy the more protected parts of the bars and the stream bed at many places along its course, but sand-size material becomes dominant only in the extreme lowermost part of the Sixes estuary. This paper reports the results of a study of the size and composition of the sand-size heavy minerals contained interstitially in the surface gravels of the Sixes River and its tributaries.

---

* Assistant Professor of Geology, University of Oregon, Eugene, Oregon.

Methods

Samples were collected at 75 localities (figure 2) situated along the river and the beach extending about 1 mile north and south of the river, and three or more samples were taken at most localities in order to evaluate local variations in heavy mineral content. Each sample, of about 2 kilograms size, was collected at a depth of 12 to 18 inches below the surface. The samples were dried and sieved through a 2.0 mm sieve to separate the sand-size material from the gravel. Approximately 100 grams of the sand-size material was split from the bulk sample with a microsplitter and separated in tetrabromoethane (sp. gvty. 2.96) into light and heavy fractions. The heavy fraction was washed in acetone, weighed, and sieved through a $\frac{1}{2}$ Φ set of sieves ranging in size from -0.5 Φ (1.41 mm) to 4.5 Φ (0.044 mm). Magnetite was removed from each $\frac{1}{2}$ Φ size group of the heavy fraction and weighed. Mean size of total heavy minerals (including magnetite) and of magnetite alone was computed statistically by computer methods. About 135 samples were analyzed to determine the content and size of total heavy minerals and magnetite, and about 80 samples were analyzed petrographically.

Petrographic analysis was made of the 80 to 120 mesh (0.177 mm - 0.125 mm) size fraction of the heavy minerals from which magnetite had been removed. Preliminary examination of several size fractions showed that this size fraction offered the best compromise between minimum amount of rock fragment contaminants, a sufficiently large number of grains to make an adequate analysis, and a grain size that could be readily studied in grain mounts. Grains were cleaned in an ultrasonic tank and mounted in AROCHLOR 4465 (Monsanto Chemical Co.), which has an index of refraction of 1.660 - 1.665. The relatively high refractive index of AROCHLOR greatly facilitates identification of certain minerals such as the amphiboles. Two samples from each of 29 selected localities, and single samples from 21 other localities were examined petrographically. The point counting procedure consisted of first counting 300 grains to establish the relative percentage of rock fragments, "cloudy" grains, opaque grains, and non-opaque grains. Counting then continued, with only non-opaque grains being counted, until a total of at least 200 non-opaque grains had been identified and counted. "Cloudy" grains are those grains that are too badly altered for identification; in most cases they appear to be single grains, but some are probably rock fragments.

Distribution of Heavy Minerals

Total heavy minerals

The distribution of heavy minerals in the Sixes River and its tributaries is summarized in figure 2, which shows the average percent of total heavy minerals (including magnetite) in the sand-size fraction of the samples at each sample locality. The values shown are the averages of two to three samples in most cases; however, a few are single-sample values. Average heavy mineral content of the sand-size material ranges from about 1 percent to 6 percent; most of the samples contain 2 to 5 percent heavy minerals.

The Sixes River drains a diverse geologic terrane with a variety of igneous, sedimentary, and metamorphic rocks exposed throughout the drainage basin. This heterogeneity of source rocks and consequent mixing of heavy minerals in the various tributaries and the main stream leads to a poorly defined concentration gradient

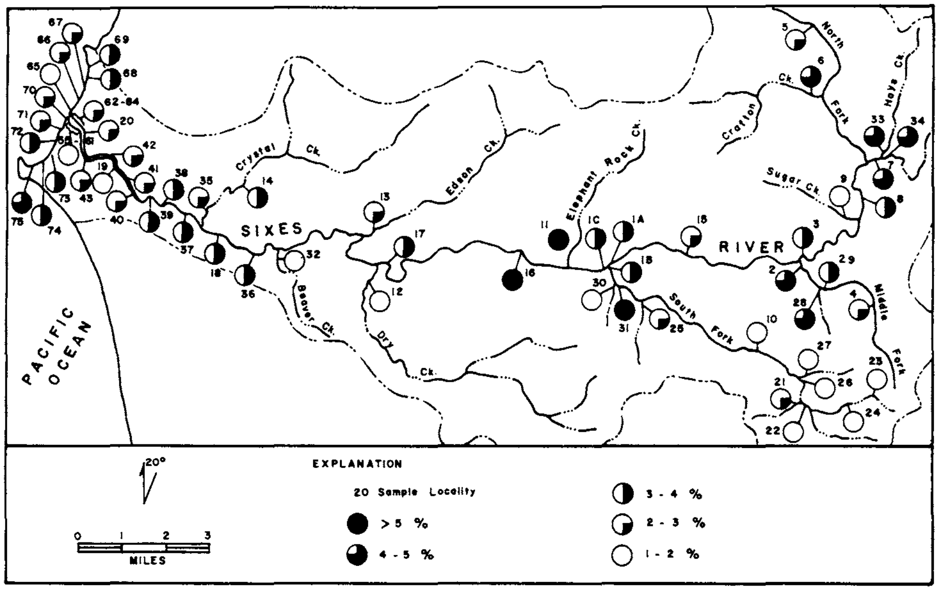


Figure 2. Concentration of total heavy minerals in the sand-size fraction of surface gravels in the Sixes River drainage basin.

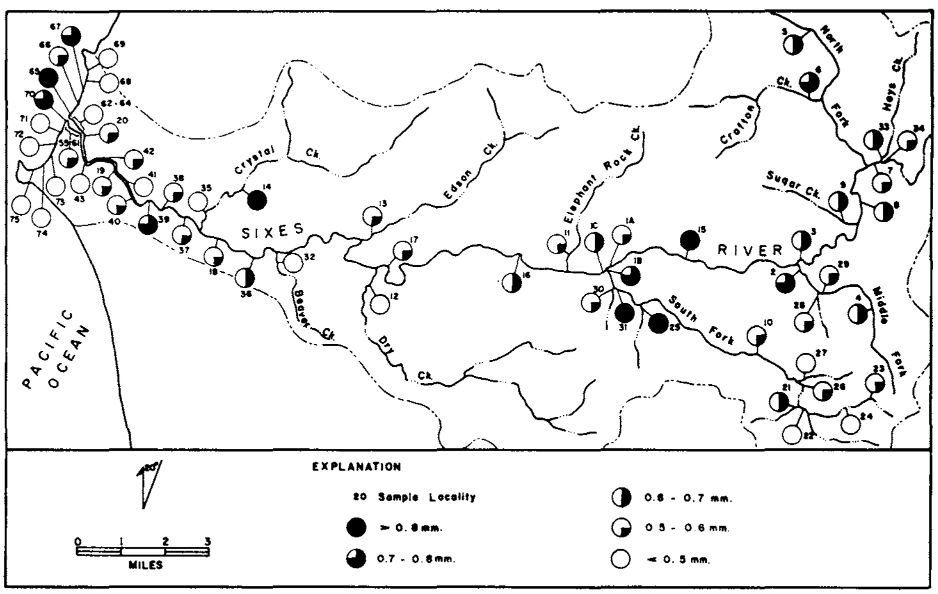


Figure 3. Average mean size of total heavy minerals in the sand-size fraction of surface gravels in the Sixes River drainage basin.

within the basin; however, highest heavy mineral concentrations are generally in the upper, or eastern, portion of the drainage system. Note that the heavy mineral content of certain tributaries, notably Dry Creek, Beaver Creek, Sugar Creek, and the extreme headwaters of South Fork, are particularly impoverished in heavy minerals. The heavy mineral content of deposits in the main Sixes channel appears to decrease gradually, but not uniformly, downstream. With the exception of the tributaries mentioned above, most samples from the upstream portion of the drainage system contain 3 to 6 percent heavy minerals in the sand-size fraction of the gravel; those in the middle reach of the Sixes contain 3 to 4 percent, and those from the lowermost 3 to 4 miles of the main channel contain 1 to 3 percent heavy minerals. With minor exception, samples from the beach also have comparatively low heavy mineral content (1 to 4 percent) relative to samples from the headwaters of the drainage basin.

Pétrographic analysis shows that a large percentage (more than 50 percent in many cases) of the heavy grains in the stream samples are rock fragments, and the percentage of rock fragments increases with increasing size of the grains. The general decrease in content of heavy grains in the main Sixes channel in the downstream direction may be due both to breakdown of some of the heavy rock fragments into constituent grains (thereby reducing the mass of the heavy grains), and to "dilution" of the heavy mineral content of lower Sixes sediments because downstream tributaries furnish less heavy minerals to the main channel than do upstream tributaries.

Figure 3 shows the average mean size of total heavy minerals in the sand-size fraction of the samples. The values are the averages of the mean sizes of two to three samples from most sample localities. Average mean size of the heavy grains ranges from less than 0.5 mm to more than 0.8 mm. The average mean size of the heavy minerals in the upper portion of the drainage system, particularly in parts of South Fork, Middle Fork, and North Fork and its tributaries, is generally larger than in the lower portion of the basin. However, average mean size of heavy minerals in samples even from the lowermost portion of the Sixes estuary is quite large, ranging up to 0.6 mm. This large mean size is mainly due to the abundance of rock fragments in the heavy fraction, as indicated above.

Magnetic heavy minerals

Magnetic grains were removed from each size fraction of the heavy minerals by passing a magnet over the grains; all grains were removed which adhered to the magnet while held a very short distance above, but not in contact with, the grains. Two to three passes were made over the grains to insure complete removal. The magnetic grains in the finer size fractions (less than about 0.125 mm) are mainly magnetite and ilmenite. In the coarser fractions, however, many of the magnetic grains are rock fragments which contain enough magnetite to cause them to be attracted to the magnet. No practical way was found to prevent inclusion of the rock fragments during the process of removing the magnetite. The data which follow with regard to concentration and size of magnetite necessarily include these magnetic rock fragments. Because the amount of rock fragments increases with increasing size of the grains, these fragments have a pronounced effect on the apparent size and concentration of magnetite, and it must be realized in studying these data that both the concentration and size of the magnetic grains, exclusive of rock fragments, are probably less than the figures shown.

Figure 4 shows the average magnetite concentration at each sample locality. Average values range from less than one-tenth percent to more than seven-tenths

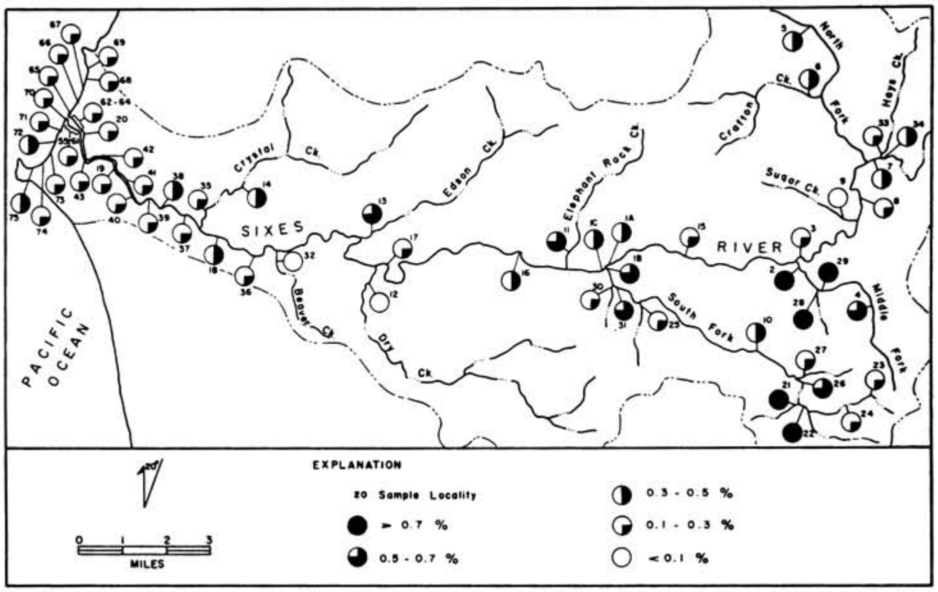


Figure 4. Concentration of magnetic heavy minerals in the sand-size fraction of surface gravels in the Sixes River drainage basin.

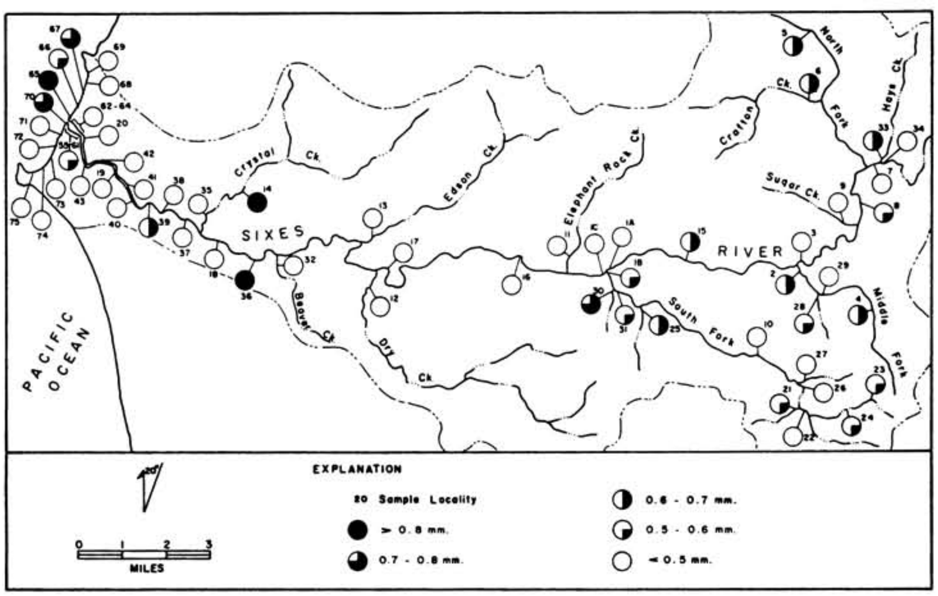


Figure 5. Average mean size of magnetic heavy minerals in the sand-size fraction of surface gravels in the Sixes River drainage basin.

TABLE 1.

Percent Composition of the 0.177–0.125 mm. heavy mineral fraction of sand-size detritus from Sixes River gravel.

Sample Number	Sample Locality	Total Sample: Rock Fragments	Total Sample: "Cloudy" Grains	Total Sample: Opaque Minerals	Total Sample: Nonopaque Minerals	Total Sample: Magnetic Minerals	Total Sample: Non-Magnetic Minerals	Nonopaque Fraction: Augite-Diopside	"Titan" Augite	Enstatite	Hypersthene	Green Hbl.	Blu-Gn Hbl. + Actinolite	Red-Bn Hbl.	Glaucophane	Epidote	Clinozoisite-Zoisite	Pink Garnet	Clear Garnet	Zircon	Barite	Staurolite	Sphene	Other
SR-10	1A	46	16	19	19	10.6	89.4	35.5	4.0	2.5	2.0	9.5	5.5	2.5	11.5	12.0	1.5	3.5	2.0	3.5	–	–	1.5	3.0
SR-14A	1A	39	15	11	35	35.7	64.3	53.0	–	1.0	0.5	31.0	3.5	3.0	–	1.0	–	0.5	–	2.0	–	–	–	3.5
SR-11	1B	45	6	22	27	20.7	79.3	40.5	3.5	3.0	1.5	6.5	6.0	2.5	6.0	4.5	0.5	5.5	4.0	6.0	4.5	–	1.5	3.0
SR-13A	1B	46	2	27	25	21.3	78.7	65.0	0.5	2.0	1.0	10.0	3.5	4.0	tr.	5.5	0.5	1.5	1.5	1.5	–	–	1.0	2.5
SR-28A	15	58	8	17	17	20.6	79.4	39.0	5.0	1.0	1.0	11.0	6.5	5.0	8.5	8.0	–	7.0	2.5	3.5	2.0	–	–	0.5
SR-29A	15	59	4	13	24	13.7	86.3	37.0	3.5	4.5	–	14.5	9.5	2.5	7.5	13.5	–	1.0	1.5	1.0	2.5	–	1.0	0.5
SR-33A	16	55	9	12	24	10.9	89.1	37.0	7.5	5.0	1.0	23.0	10.0	1.5	3.0	2.0	0.5	2.0	1.5	–	5.0	–	–	0.5
SR-35A	16	51	1	10	38	19.6	80.4	57.0	3.0	5.5	–	15.0	6.0	3.0	2.0	1.5	1.0	1.0	1.0	0.5	1.0	–	1.0	1.0
SR-36A	17	58	8	12	22	18.4	81.6	49.5	2.0	2.0	0.5	17.0	5.0	1.5	1.5	6.0	1.5	1.5	1.5	0.5	2.5	–	–	6.5
SR-39A	17	51	5	20	24	17.1	82.9	54.5	3.5	2.5	–	14.0	7.5	3.0	1.5	4.0	1.0	1.0	0.5	2.5	2.0	–	0.5	2.0
SR-42A	18	39	5	29	27	21.6	78.4	54.5	4.5	1.0	1.0	11.0	5.5	1.5	2.0	3.5	2.5	2.5	2.0	5.0	–	–	0.5	3.0
SR-46A	18	29	9	30	32	17.2	82.8	56.5	3.5	2.5	–	13.5	4.5	2.0	1.5	4.5	2.5	3.5	2.0	2.5	–	–	0.5	1.5
SR-47A	18	38	8	21	33	14.1	85.9	52.0	5.5	1.5	–	19.5	3.0	2.5	2.5	5.0	–	3.0	2.0	0.5	–	–	–	3.0
SR-49A	19	37	3	29	31	17.7	82.3	48.0	3.5	3.5	0.5	14.0	7.5	3.5	2.5	8.0	1.5	2.0	1.5	0.5	–	–	2.0	1.5
SR-51A	19	39	10	25	26	16.5	83.5	40.5	5.0	6.0	2.0	20.0	9.5	3.5	5.0	2.0	1.0	1.0	–	2.0	–	–	0.5	1.5
SR-53A	20	56	5	8	31	7.7	92.3	54.5	4.0	4.5	–	15.0	5.5	3.0	3.0	6.0	1.0	0.5	1.0	–	–	–	1.0	1.5
SR-56A	20	18	16	34	32	16.7	85.3	48.0	2.5	3.0	0.5	16.0	8.0	3.5	2.0	4.0	3.0	2.5	2.0	2.5	–	–	–	2.5
SRX-1A	14	41	12	29	18	12.6	87.4	22.5	15.5	2.0	1.0	2.5	8.5	2.5	1.5	15.5	3.0	2.5	2.5	8.0	5.0	–	3.0	4.5
SRX-4A	14	33	3	42	22	15.5	84.5	24.5	13.0	4.5	3.0	1.5	9.5	1.5	2.0	18.0	0.5	2.5	1.0	11.5	4.5	–	1.0	3.0
SRE-1A	13	29	14	21	36	16.2	83.8	67.0	19.0	4.5	1.0	0.5	5.5	–	0.5	0.5	–	–	–	–	–	–	–	1.5
SRE-4A	13	23	2	14	61	15.5	84.5	63.5	26.0	2.5	–	1.0	3.5	1.0	–	2.0	–	–	–	–	–	–	–	0.5

TABLE 1, CONTINUED

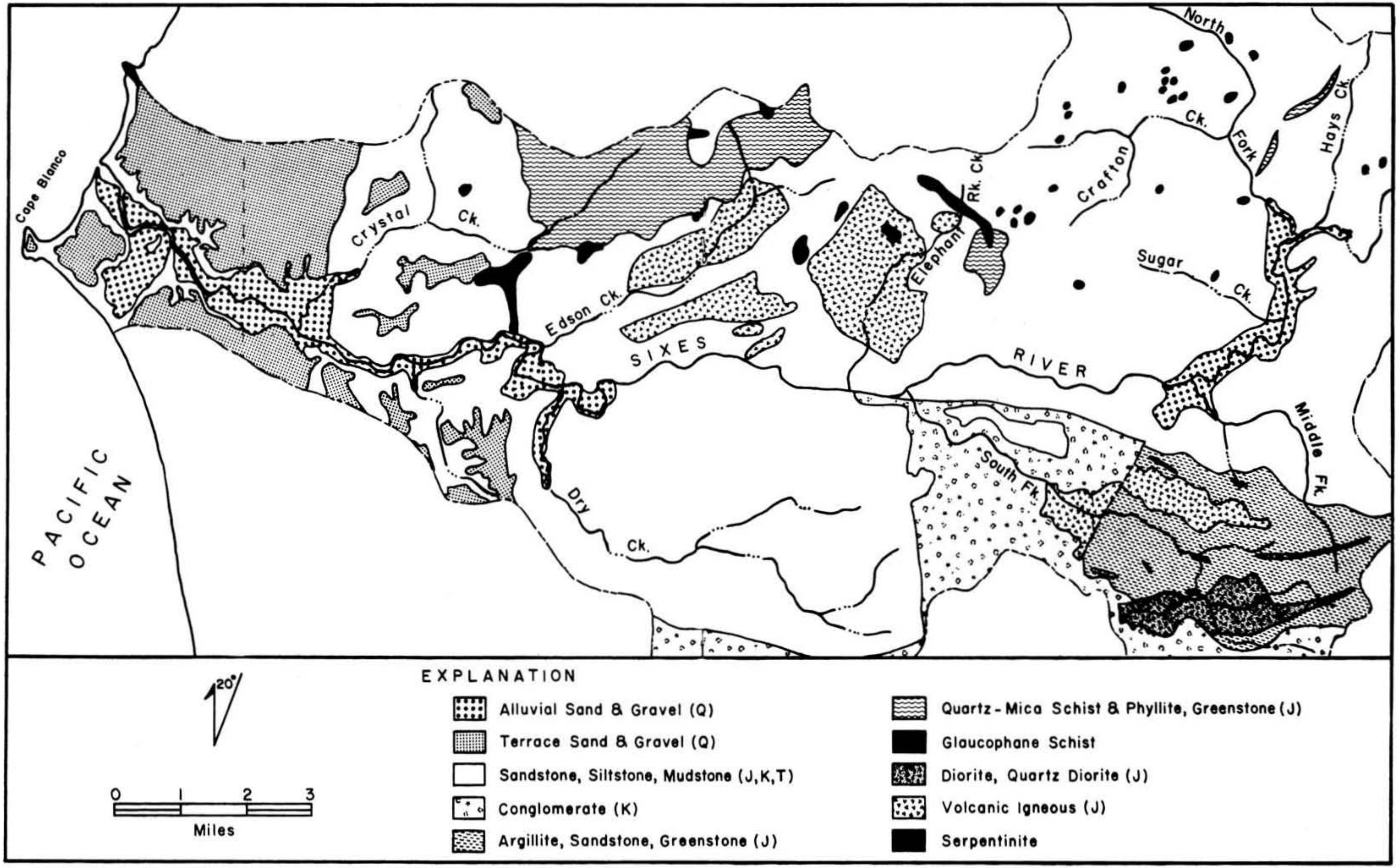
Sample Number	Sample Locality	Total Sample				Total Sample		Nonopaque Fraction																
		Rock Fragments	"Cloudy" Grains	Opaque Minerals	Nonopaque Minerals	Magnetic Minerals	Non-Magnetic Minerals	Augite-Diopside	"Titan" Augite	Enstatite	Hypersthene	Green Hbl.	Blu-Gn Hbl. + Actinolite	Red-Bn Hbl.	Glaucophane	Epidote	Clinozoisite-Zoisite	Pink Garnet	Clear Garnet	Zircon	Barite	Staurolite	Sphene	Other
SRD-2A	12	51	6	21	22	4.8	95.2	69.0	–	1.5	–	4.0	4.0	2.5	–	7.0	1.5	1.0	1.5	2.5	–	–	0.5	5.0
SRD-3A		62	14	9	15	1.7	98.3	71.5	–	1.0	–	7.0	3.0	2.5	–	8.0	2.0	1.5	1.5	1.5	–	–	–	0.5
SRER-3A	11	41	7	19	33	22.6	77.4	62.0	1.5	7.5	–	11.5	7.0	2.5	1.0	3.0	1.5	–	–	–	–	–	–	1.5
SRER-4A		44	18	18	20	18.7	81.3	55.0	3.0	8.0	–	13.0	19.0	2.0	–	–	–	–	–	1.0	1.0	–	–	–
SRS-2A	10	27	12	13	48	31.5	68.5	15.5	–	–	0.5	63.5	1.0	18.5	·	0.5	–	–	–	tr.	–	–	0.5	–
SRS-3A		37	2	11	50	26.4	73.6	12.5	·	1.5	–	63.5	1.5	18.0	–	1.5	0.5	–	0.5	–	–	–	–	0.5
SRM-4A	2	43	13	18	26	21.2	78.8	67.5	1.0	1.5	–	7.0	4.0	5.0	–	6.0	1.5	0.5	3.5	1.5	–	–	–	0.5
SRM-5A		32	2	30	36	18.6	81.4	58.0	1.0	1.0	0.5	17.5	2.0	5.0	·	5.0	0.5	1.5	2.0	3.0	–	–	1.5	1.5
SRM-11A	4	40	7	16	37	16.3	83.7	68.5	–	0.5	–	11.0	4.5	6.0	–	5.5	0.5	–	2.5	–	–	–	–	1.0
SRM-13A		34	17	8	41	14.2	85.8	56.0	–	–	–	25.0	3.0	11.5	–	1.0	–	–	–	0.5	–	–	–	0.5
SRN-1A	3	35	11	36	18	15.1	84.9	16.5	3.5	1.5	0.5	8.0	13.5	1.0	8.0	12.5	0.5	6.0	4.0	16.0	5.5	·	1.5	1.5
SRN-6A		42	7	25	26	14.0	86.0	16.0	3.5	1.0	–	13.0	13.5	4.0	8.5	16.5	3.0	3.5	3.0	6.5	4.0	·	1.5	2.5
SRN-8A	5	33	14	29	23	9.8	90.2	19.5	7.0	0.5	0.5	1.0	12.5	–	12.0	17.0	-	6.0	4.0	6.0	9.5	–	3.5	1.0
SRN-9A		25	4	47	23	10.2	89.8	15.5	3.5	2.5	0.5	4.0	7.5	0.5	11.5	16.5	1.0	7.0	3.5	4.0	13.0	–	6.5	3.0
SRN-12A	8	41	11	27	21	12.7	87.3	17.5	5.5	0.5	0.5	8.0	18.0	2.0	9.0	14.5	3.0	4.0	4.5	5.0	4.5	–	1.5	2.0
SRN-14A		40	9	30	21	12.6	87.4	12.5	5.0	0.5	1.5	11.5	8.0	0.5	7.0	15.5	2.0	8.0	7.0	10.5	7.0	–	1.0	2.5
SRSU-1A	9	51	8	26	14	5.4	94.6	14.5	3.5	1.5	3.0	2.0	13.5	–	13.5	14.5	3.5	9.0	8.0	5.0	2.0	0.5	1.5	1.5
SRSU-3A		48	21	18	13	9.4	90.6	8.0	7.0	1.0	–	3.0	14.0	0.5	7.0	18.0	2.5	10.0	11.5	9.5	0.5	–	3.0	4.5
SRH-2A	7	33	8	43	16	10.4	89.6	17.5	1.0	3.5	0.5	13.0	10.0	3.0	4.0	17.0	1.0	7.0	5.0	5.5	2.0	–	1.0	8.5
SRH-3A		45	28	18	9	12.8	87.2	12.5	–	2.0	1.0	14.0	20.5	4.5	8.0	14.5	3.0	6.5	3.0	4.5	2.0	–	1.0	3.0

TABLE 1, CONTINUED

Sample Number	Sample Locality	Total Sample: Rock Fragments	"Cloudy" Grains	Opaque Minerals	Nonopaque Minerals	Total Sample: Magnetic Minerals	Non-Magnetic Minerals	Nonopaque Fraction: Augite-Diopside	"Titan" Augite	Enstatite	Hypersthene	Green Hbl.	Blu-Gn Hbl. + Actinolite	Red-Bn Hbl.	Glaucophane	Epidote	Clinozoisite-Zoisite	Pink Garnet	Clear Garnet	Zircon	Barite	Staurolite	Sphene	Other
SRC-1A	6	45	17	15	23	13.4	86.6	11.0	0.5	0.5	–	26.0	21.5	1.0	12.0	8.0	1.5	6.0	0.5	4.0	3.5	--	2.5	1.5
SRC-2A		41	15	16	28	12.7	87.3	19.5	3.0	2.0	-	16.0	13.5	1.0	10.5	14.5	1.5	3.0	1.5	3.0	7.5	–	–	3.5
68-31	36	38	7	18	37	18.8	81.2	55.0	5.0	6.0	–	12.0	4.5	3.0	1.5	5.0	1.0	1.0	1.0	1.0	–	-	0.5	3.5
68-32		39	7	17	37	14.2	85.8	57.5	3.0	4.0	–	12.0	5.0	1.0	3.0	6.0	0.5	1.0	1.5	2.0	1.5	–	0.5	1.5
68-34	37	38	9	15	38	12.9	87.1	51.0	5.0	4.0	0.5	14.5	2.5	4.0	4.5	6.5	2.0	1.5	–	0.5	1.5	–	0.5	1.5
68-35		38	11	18	33	17.5	82.5	48.5	6.5	5.5	–	16.5	3.5	2.5	2.5	5.5	–	2.0	2.0	1.5	–	–	1.0	2.5
68-38	38	32	8	28	32	21.2	78.8	40.5	7.0	4.5	–	17.0	5.5	3.0	1.5	9.0	0.5	3.0	2.5	4.5	–	–	1.0	0.5
68-39		36	10	17	37	14.1	85.9	48.0	9.5	6.5	0.5	14.0	5.0	2.0	4.0	5.5	1.0	2.0	1.0	–	–	–	–	1.0
68-40	39	34	6	27	33	17.7	82.3	51.0	6.5	7.0	1.0	12.5	2.0	3.0	2.0	6.0	0.5	3.0	1.5	1.0	–	–	0.5	2.5
68-42		37	6	19	38	9.2	90.8	48.0	1.5	5.0	–	18.5	6.0	3.0	6.0	5.5	1.0	1.0	0.5	1.0	1.0	–	–	1.5
68-43	40	38	8	16	38	12.6	87.4	44.5	6.0	5.0	–	21.0	5.0	2.5	5.0	6.0	–	3.0	1.0	0.5	–	–	0.5	–
68-45		48	8	12	32	9.4	90.6	44.0	2.0	5.5	1.5	20.5	8.0	3.5	3.5	3.5	0.5	2.0	1.5	0.5	1.0	–	0.5	2.0
68-46	41	42	8	17	33	9.5	90.5	50.0	5.5	7.0	1.5	15.5	5.5	0.5	2.5	7.5	1.0	0.5	1.5	–	0.5	–	–	1.5
68-48		37	7	22	34	20.3	79.7	47.0	6.5	5.0	–	16.5	3.0	0.5	2.5	6.5	–	4.5	3.0	3.0	0.5	–	–	1.5
68-49	42	47	6	15	32	13.1	86.9	44.5	7.0	2.5	0.5	19.5	7.5	1.0	3.5	7.0	0.5	0.5	1.0	0.5	–	–	0.5	4.5
68-50		43	8	18	31	14.9	85.1	48.5	5.0	6.0	0.5	17.5	6.0	1.5	3.5	4.0	1.0	1.5	1.0	1.0	0.5	–	1.5	1.0
68-52	43	46	2	25	27	16.6	83.4	44.5	4.0	3.5	–	11.5	8.0	2.0	6.0	9.0	2.0	2.0	1.5	2.0	0.5	–	0.5	3.0
68-54		41	5	29	25	21.3	78.7	41.5	7.5	3.0	1.0	15.5	5.5	1.5	3.0	9.0	1.5	1.0	2.5	3.0	1.0	–	1.0	2.5
68-55	55	45	11	11	33	6.5	93.5	51	3.5	5.0	1.5	17.5	8.5	2.0	3.0	6.0	–	0.5	--	–	0.5	–	–	0.5
68-56	61	42	5	24	29	17.6	82.4	40.0	5.5	5.5	1.0	17.0	6.0	2.5	3.0	9.0	1.0	3.0	1.0	1.5	0.5	–	1.0	2.5

TABLE 1, CONTINUED

Sample Number	Sample Locality	Total Sample: Rock Fragments	"Cloudy" Grains	Opaque Minerals	Nonopaque Minerals	Total Sample: Magnetic Minerals	Non-Magnetic Minerals	Nonopaque Fraction: Augite-Diopside	"Titan" Augite	Enstatite	Hypersthene	Green Hbl.	Blu-Gn Hbl. + Actinolite	Red-Bn Hbl.	Glaucophane	Epidote	Clinozoisite-Zoisite	Pink Garnet	Clear Garnet	Zircon	Barite	Staurolite	Sphene	Other
68-57		32	2	35	31	21.3	78.7	47.5	4.0	6.5	1.5	8.0	5.0	2.0	2.0	9.5	1.0	2.5	2.0	4.5	0.5	–	0.5	3.0
68-58		31	2	35	32	20.8	79.2	45.0	5.0	3.0	0.5	15.0	5.0	1.0	5.0	8.0	1.5	4.5	2.0	1.0	–	–	1.0	2.5
68-59	55-61	32	3	28	37	15.6	84.4	45.5	3.0	4.0	1.5	14.5	7.0	1.0	0.5	10.0	2.5	4.0	2.5	2.0	1.0	–	1.0	–
68-60		44	4	18	34	8.9	91.1	25.5	0.5	2.0	3.5	18.0	6.0	3.0	–	16.5	5.0	5.5	8.0	3.5	–	–	1.5	2.5
68-61		53	4	9	34	4.2	95.8	32.0	2.5	2.0	2.5	22.5	13.0	2.0	1.5	11.0	2.5	2.5	3.5	–	1.0	–	0.5	1.0
68-62		41	3	22	34	8.6	91.4	27.5	1.0	2.0	4.0	18.5	8.5	2.5	2.0	12.0	2.0	8.5	7.0	2.0	–	–	1.0	1.0
68-63	62-64	38	4	25	33	14.0	86.0	45.5	4.5	2.0	1.0	10.0	6.0	2.0	4.0	11.0	1.0	3.5	2.5	1.5	3.0	–	1.0	1.5
68-64		45	3	17	35	8.9	91.1	31.5	1.5	0.5	5.0	14.5	5.0	1.5	2.5	18.0	2.5	8.0	5.0	1.5	–	–	1.5	1.5
68-65		53	1	11	35	<1.0>	99.0	29.0	2.0	3.0	6.0	24.0	7.0	4.0	1.0	10.0	2.0	1.0	5.0	–	1.0	–	2.0	3.0
68-66		53	3	13	31	5.6	94.4	28.0	2.0	0.5	5.0	25.0	4.5	1.0	1.0	17.5	0.5	5.5	5.5	–	0.5	–	2.0	1.0
68-67		50	5	11	34	8.5	91.5	22.5	1.0	1.5	5.0	22.5	6.0	1.5	1.0	20.5	1.5	5.0	6.5	1.5	–	–	1.0	3.0
68-68		53	3	7	37	4.9	95.1	23.0	1.5	1.5	3.0	24.0	7.0	2.5	1.5	16.0	3.5	6.5	3.0	–	0.5	1.0	1.0	4.5
68-69		51	4	7	38	2.7	97.3	23.0	–	1.0	4.5	28.0	8.5	5.0	1.5	17.5	–	4.0	3.0	1.0	–	0.5	–	2.0
68-70		51	3	9	37	1.1	98.9	23.5	1.5	1.0	5.5	28.5	7.0	1.5	1.0	15.5	2.0	5.0	3.0	–	–	1.5	0.5	3.0
68-71		56	3	5	36	2.3	97.7	18.5	2.0	2.0	5.0	30.0	11.5	3.5	1.0	15.5	1.0	3.5	2.0	–	1.0	–	0.5	3.0
68-72		51	4	15	30	4.9	95.1	20.0	1.5	2.0	5.0	20.0	4.0	4.5	1.0	22.0	1.5	6.5	6.0	1.0	0.5	1.5	2.0	1.0
68-73		54	4	6	36	2.4	97.6	19.5	–	2.5	5.5	24.5	9.0	3.5	1.0	14.5	1.0	3.0	8.5	0.5	0.5	1.5	1.5	2.5
68-74		58	5	6	31	3.5	96.5	23.5	0.5	1.0	6.0	24.5	6.0	3.0	1.5	17.5	1.0	9.0	3.5	1.0	0.5	–	1.0	0.5
68-75		51	4	11	34	3.8	96.2	22.5	0.5	1.0	4.5	21.0	8.0	4.0	1.5	15.5	1.0	5.5	9.0	1.5	–	2.0	1.0	1.5


Cape Blanco
PACIFIC OCEAN
Crystal Ck.
Edson Ck.
SIXES RIVER
Dry Ck.
Elephant Rk. Ck.
Crafton
Sugar Ck.
North Fork Ck.
Hays Ck.
Middle Fk.
South Fk.
20°
0 1 2 3
Miles
EXPLANATION
Alluvial Sand & Gravel (Q)
Terrace Sand & Gravel (Q)
Sandstone, Siltstone, Mudstone (J,K,T)
Conglomerate (K)
Argillite, Sandstone, Greenstone (J)
Quartz-Mica Schist & Phyllite, Greenstone (J)
Glaucophane Schist
Diorite, Quartz Diorite (J)
Volcanic Igneous (J)
Serpentinite

percent of the sand-size material. In general, there is fair correlation between magnetite content and total heavy mineral content; that is, most samples that have a high total heavy mineral content also have a high magnetite content. A close comparison of figures 2 and 4, however, reveals some discrepancies. Although the distribution of magnetite in the drainage basin does not exhibit a particularly strong trend, certain parts of South Fork, Middle Fork, Elephant Rock Creek, and Edson Creek appear to have the highest magnetite concentrations (ranging from about five-tenths percent to more than seven-tenths percent of the sand-size fraction). Magnetite content decreases slightly in the downstream direction and the content of magnetite in the sand-size fraction of most samples from the lower part of the Sixes channel, the estuary, and the beach is less than three-tenths percent.

Figure 5 shows the grain-size distribution of magnetite within the Sixes drainage basin. The average mean size of magnetite exceeds 0.8 mm at a few localities, but at most localities is less than 0.5 mm. With the exception of Crystal Creek, average mean size is somewhat larger in that part of the drainage system upstream from the junction with South Fork than in the downstream portion of the basin. Otherwise, no particular pattern of size distribution is apparent. A comparison of the average mean size of magnetite with the average mean size of total heavy minerals in individual samples shows that the mean size of magnetite is slightly smaller in most cases than the mean size of total heavy minerals. This is consistent with the principle of hydraulic equivalency by which smaller, heavier grains (in this case magnetite) would be expected to be deposited together with larger, lighter grains (nonmagnetic heavy minerals).

Non-magnetic heavy minerals

The data obtained by analysis of the 0.177 mm - 0.125 mm size fraction is summarized in table 1. This table shows that magnetic opaque grains (removed prior to petrographic analysis) compose about 1 percent to more than 35 percent of the total heavy minerals in this size fraction, although the majority of samples contain between 3 to 20 percent. Some samples from the extreme lower portion of the Sixes estuary, and all samples from the beach have markedly lower magnetite content than most of the other river samples. Nonmagnetic opaque minerals range in abundance from about 5 percent to 47 percent of the nonmagnetic fraction. The areal distribution of these nonmagnetic opaque grains is quite random, but like the magnetic opaque grains, the beach samples contain significantly less nonmagnetic opaque grains than do most of the river samples. No attempt has been made to identify the nonmagnetic opaque grains, but they are probably mainly ilmenite and chromite.

Table 1 shows that the percentage of rock fragments in the 0.177 mm - 0.125 mm size fraction of the heavy minerals ranges from 18 percent to 62 percent. At first it was thought that the extremely high content of rock fragments might be due to improper separations, but study of the non-opaque fraction of the heavy minerals shows that there is very little contamination with light minerals such as quartz and feldspar; therefore, the rock fragments must contain enough heavy grains to increase their specific gravity above 2.96. Although no quantitative counts were made of rock fragments in the progressively coarser size fractions, the content of rock fragments in these coarser sizes must be significantly higher than that in the 0.177 mm - 0.125 mm fraction. The extremely high rock-fragment content of the heavy mineral fraction of Sixes River samples appears to be due to the very fine grain size of many of the source rocks and to the proximity of the sample sites to the source rocks from which the grains were derived; that is, the rock fragments have not undergone adequate weathering, transportation, and reworking to cause them to break down into their constituent heavy mineral grains.

Figure 6 is a generalized rock-type map of the Sixes River drainage basin which shows the major types of source rocks in the basin. This map, compiled mainly from work by Baldwin (Baldwin and Boggs, 1969) and Lent (1969), provides a reference framework for relating the heavy minerals from given sample sites to the probable source rocks of these minerals. The major rock types include sandstone, siltstone, and mudstone of the Otter Point Formation (Jurassic), Rocky Point Formation (Cretaceous), and Umpqua Formation (Tertiary); conglomerate mainly in the Humbug Mountain Conglomerate (Cretaceous); argillite, sandstone, and greenstone in the Galice Formation (Jurassic); quartz-mica schist and phyllite, and greenstone in the Colebrooke Schist (Jurassic); glaucophane schist and serpentinite which occur in scattered "pods" that are difficult to relate to specific formations; diorite and quartz diorite (Jurassic) intruded into the Galice Formation and Humbug Mountain Conglomerate; and volcanic rock of various compositions which belongs to the Galice Formation and the Otter Point Formation. Note that the metamorphic rocks of the Colebrooke Schist and the serpentinite and glaucophane schist bodies all occur on the north side of the Sixes River, whereas intrusive igneous rocks and argillite are confined to the south side of the river mainly in the headwaters of South Fork. Other rock types are scattered throughout various parts of the basin.

The composition of the non-opaque heavy minerals is given in table 1, and the distribution of these minerals within the Sixes River basin is shown graphically in figure 7. The dominant mineral species in the basin is clinopyroxene, which predominates at almost every locality. The ratio of clinopyroxene to other heavy minerals is particularly high in such tributaries as Edson Creek, Elephant Rock Creek, Dry Creek, and Middle Fork, and clinopyroxene is clearly the dominant mineral in essentially all samples from the main Sixes channel. The clinopyroxene is mainly colorless to pale green augite and diopside, but in some tributaries, particularly Edson Creek and Crystal Creek, there is abundant moderate- to deep-brown clinopyroxene with pale, purplish-brown pleochroism. This is called "titanaugite" in table 1, although it was not positively identified optically as titanaugite. Minor amounts of "titanaugite" are found in most of the samples.

Orthopyroxene, which is not particularly common in the Sixes drainage, consists mainly of enstatite. Except in some samples from the lower part of the Sixes estuary, hypersthene rarely occurs in amounts exceeding about 2 percent, and was not found at all in many samples. Some samples from the lower part of the estuary contain 3 to 5 percent hypersthene, much of which is distinctly different from the hypersthene found in other parts of the river. Samples from the beach also contain higher hypersthene content, averaging about 5 percent; much of this also differs in appearance from the Sixes hypersthene and is probably from a different source. Hypersthene brought into the river from the beach probably accounts for the higher hypersthene content of the lower part of the estuary.

Amphibole is the second most-abundant type of heavy mineral in the Sixes drainage. Green, blue-green, and red-brown amphibole and glaucophane are all reasonably common. As shown by figure 7, green and red-brown hornblende together are generally more abundant than blue-green hornblende. However, in some tributaries such as Crafton Creek, Hays Creek, and Sugar Creek, which drain schist bodies (see figure 6) blue-green hornblende exceeds green and red-brown hornblende. Only at one locality in the headwaters of South Fork does amphibole exceed pyroxene in

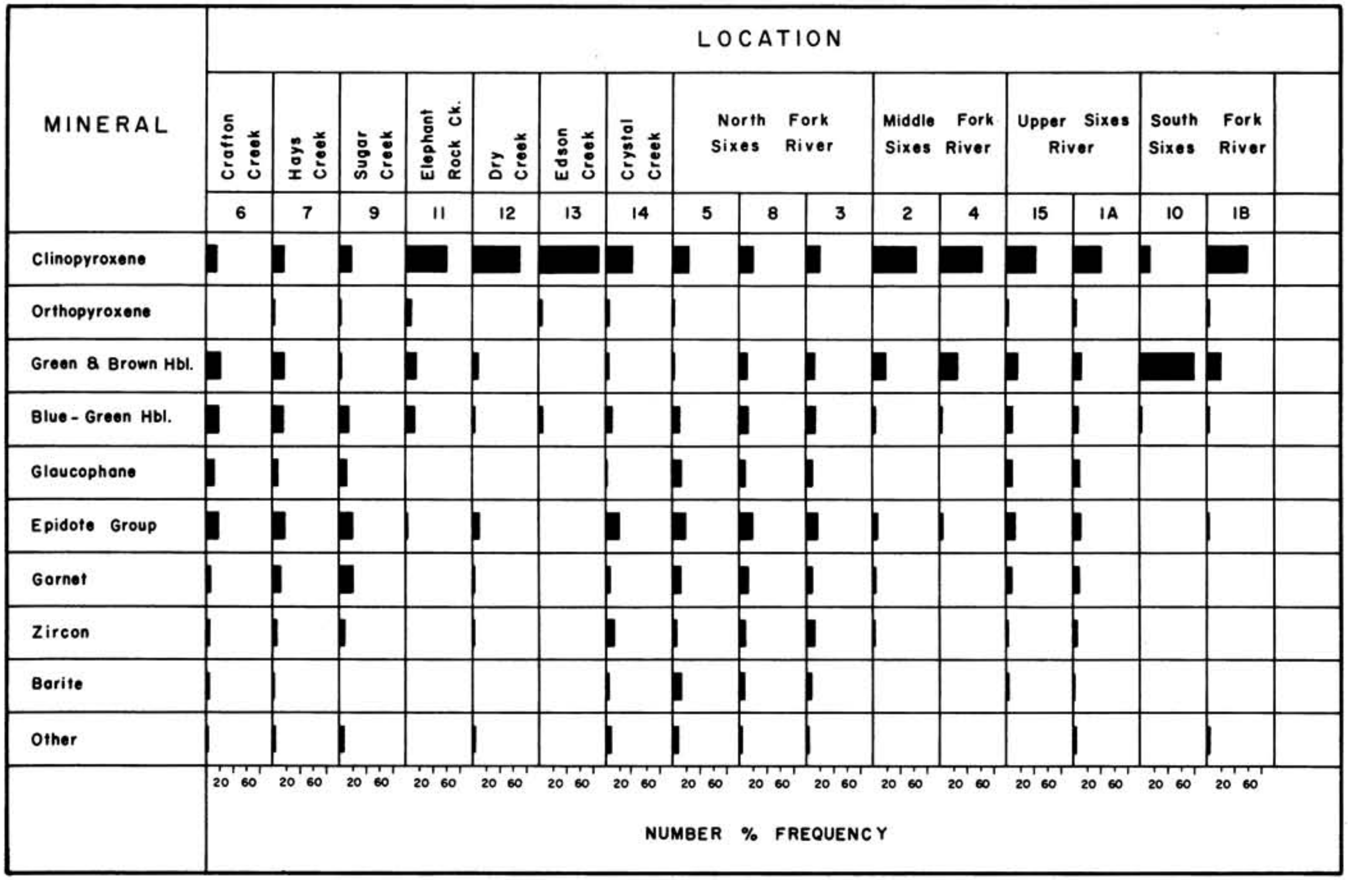


Figure 7. Composition of non-opaque heavy minerals in the 0.177 - 0.125 mm size fraction. Values less than about 3 percent are not shown.

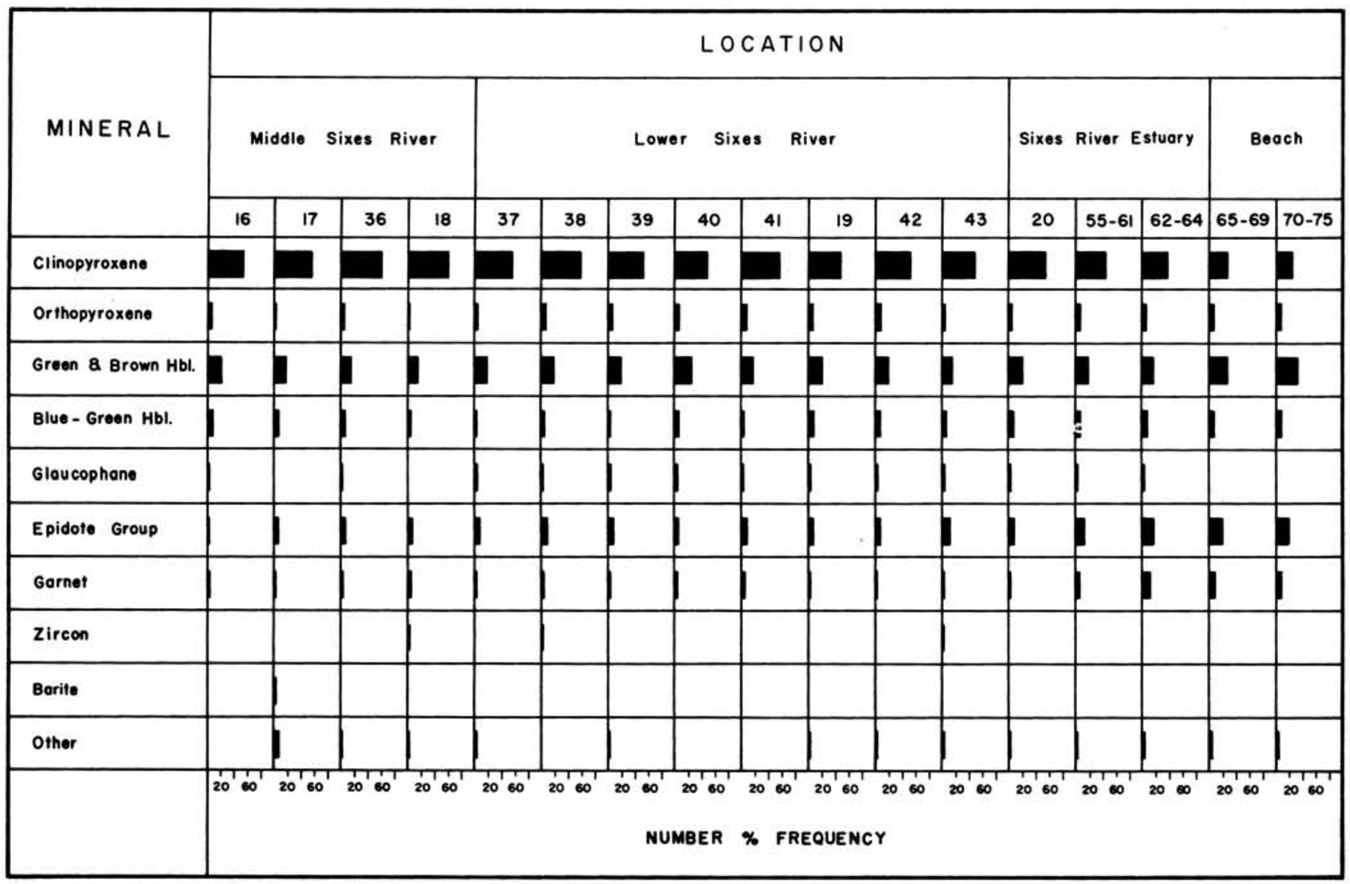


Figure 7, continued.

abundance. This locality is only a few miles downstream from a small quartz diorite stock. Analyses of samples from this intrusive by E. H. Lund (Baldwin and Boggs, 1969) show that the quartz diorite contains about 11 percent hornblende and about 2 percent accessory heavy minerals including magnetite, sphene, and apatite.

Glaucophane, together with epidote (including some clinozoisite and zoisite), garnet, and zircon are common constituents of the main Sixes channel and of most of the tributaries which drain the north slope of the Sixes basin. The rock-type map (figure 6) shows that numerous small bodies of blue schist are exposed in the middle and upper portions of the basin along the north slope. R. L. Lent (1969) analyzed a number of samples from these blue-schist bodies, and reports high percentages of glaucophane and epidote, as well as some garnet. A portion of the Colebrooke Schist thrust plate, exposed within the Sixes basin, strongly influences the heavy mineral assemblages in Edson Creek and Crystal Creek in particular. Lent reports some glaucophane in the basal part of the Colebrooke Schist, together with epidote, clinozoisite, zoisite, and other heavy minerals. The strong influence of the metamorphic bodies on the heavy mineral assemblages of the various tributaries is evident by comparing the mineral assemblages from the tributaries which drain the north slope of the basin with those which drain the south slope. Metamorphic rocks are not present in the south-slope drainage, and the southern tributaries, notably South Fork, Middle Fork, and Dry Creek all have heavy mineral assemblages which are devoid of glaucophane and impoverished in epidote, clinozoisite-zoisite, garnet, and zircon.

Samples from North Fork, in particular, and from a few other localities contain an unusual heavy mineral with abundant bubble inclusions. This mineral, which composes about 4 to 13 percent of the heavy minerals in the 0.177 - 0.125 mm size fracion in samples from North Fork, could not be positively identified in grain mounts. Dr. Adolph Pabst (University of California) kindly offered to make a single crystal x-ray analysis of the mineral. Dr. Pabst reports that the crystals are orthorhombic, biaxial positive, 2V 40° ± 10° (not measured directly), cell dimensions: a = 7.147 Å, b = 8.872 Å, c = 5.450 Å, and he identifies the mineral as barite.

Barite is not a particularly common detrital mineral, and its abundance in the stream sediments of the North Fork drainage is surprising. It is a common gangue mineral in metalliferous hydrothermal veins, and it occurs as vein or cavity fillings in various types of rocks; however, the ultimate source of barite in the North Fork drainage is not known at this time. In addition to its occurrence in North Fork, small amounts of barite were found in many samples from the main Sixes channel, but abundance decreased sharply downstream from North Fork. This is probably due mainly to "dilution" in the lower part of the stream, but decrease in abundance downstream might be the result of mechanical destruction of the relatively soft (3 -3.5 hardness) barite grains.

A few other minerals such as sphene, sillimanite, and biotite were identified in trace amounts in a number of samples, and some grains in certain samples could not be identified due to alteration of the grains or inability to measure optical properties. In figure 7 these unidentified grains and the minor heavy mineral species are all included in the "other" category.

Figure 7 shows that the non-opaque heavy mineral composition of samples from the middle and lower reaches of the main Sixes channel, excluding the estuary, is reasonably constant and reflects the mixing of heavy mineral suites from the various upstream tributaries. A distinct change in relative abundance of the various mineral species is evident, however, in samples from the extreme lower portion of the Sixes estuary, and particularly in samples collected along a stretch of the beach about 1 mile north and south of the mouth of the Sixes River. The ratio of total amphibole to total pyroxene increases slightly in the lower part of the estuary, and increases markedly on the beach to the point where amphibole equals or exceeds pyroxene. Also, the proportion of both epidote minerals and garnet increases in the lower part of the estuary and on the beach. There are also marked differences in appearance of certain heavy minerals; some of the green hornblende from the lower estuary and the beach is very highly colored and almost opaque. No such hornblende was found in any sample from the remainder of the Sixes drainage. As mentioned in a preceding section, hypersthene from the lower estuary and beach differs from that in the upper portion of the Sixes; it is generally more elongated and euhedral, and the pleochroism tends to be much stronger. A mineral tentatively identified as staurolite was found in many beach samples, but did not occur in any samples from the river.

These data indicate that the heavy mineral suite on the beach and in the lower portion of the estuary has been affected by mixing of some heavy minerals from a source other than the Sixes River. The fact that the heavy mineral assemblage of the lower portion of the estuary closely resembles that of the beach suggests that heavy minerals are being transported from the beach up the estuary a short distance and deposited along with other heavy minerals moving down the Sixes River. This is further substantiated by the fact that many heavy mineral grains from the beach and from the lower estuary are moderately well rounded. Most heavy mineral grains of this size from other samples within the Sixes basin, however, are angular to subangular; even heavy minerals from tributaries such as Dry Creek which drain only sandstone terrane (grains obviously polycyclic) are generally quite angular. In fact, the only moderately well-rounded heavy mineral grains found in any sample, exclusive of those from the lower estuary and beach, came from samples collected in Crystal Creek. The headwaters of Crystal Creek are incised into the Colebrooke Schist, and these rounded grains may be second-cycle grains derived from the Colebrooke. Small patches of marine terrace sand are also preserved within the Crystal Creek drainage, however, and these may possibly have furnished the rounded grains, many of which are zircon.

Summary

Surface detritus of the Sixes River consists mainly of gravel with an interstitial sand content of approximately 15 to 30 percent at most localities studied. The total content of heavy minerals in the sand-size fraction of the gravel ranges from about 1 percent to 6 percent, and magnetic heavy grains make up about one-tenth to seven-tenths percent of the sand-size material. Rock fragments are extremely abundant constituents of the sand-size detritus and compose more than 50 percent of many samples. The high percentage of rock fragments in both the total heavy mineral fraction and the magnetic heavy fraction results in a comparatively large mean size for these grains at most localities. The mean size of the total heavy grains and the magnetic heavy grains in the sand-size fraction of the gravel which the Sixes River furnishes to the ocean is almost one-half millimeter.

Study of the 0.177 - 0.125 mm size fraction of the non-opaque heavy minerals shows that clinopyroxene is the most abundant heavy mineral species in the Sixes River drainage basin, and is followed in abundance by monoclinic amphiboles; these include green and red-brown hornblende, blue-green hornblende, and glaucophane. Orthopyroxene (mainly enstatite), epidote, garnet, and zircon are common in many of the tributaries and in the main Sixes channel. Barite occurs in moderate abundance in some tributaries, particularly North Fork.

Hornblende increases in abundance at the expense of clinopyroxene in the lower part of the Sixes estuary, and some new types (colors) of hornblende appear. Hypersthene is uncommon throughout most of the Sixes drainage, but increases in abundance in the lower part of the estuary and on the beach. These changes in mineral composition in the lower estuary, accompanied by marked increase in roundness of heavy mineral grains, indicate that some of the heavy minerals have their source outside the Sixes River drainage basin, and were brought into the lower part of the estuary from the beach.

Source rocks which furnish heavy minerals to the Sixes River and its tributaries include sandstone, siltstone, and mudstone of the Otter Point Formation (Jurassic), Rocky Point Formation (Cretaceous), and Umpqua Formation (Tertiary); the Humbug Mountain Conglomerate (Cretaceous); argillite, sandstone, and greenstone in the Galice Formation (Jurassic); quartz-mica schist and phyllite and greenstone in the Colebrooke Schist (Jurassic); glaucophane schist and serpentinite; and volcanic igneous rock of various compositions (Jurassic).

Acknowledgments

The research reported in this paper was supported by U.S. Geological Survey Contract No. 14-08-001-11058 through the Office of Marine Geology and Hydrology, Menlo Park, Cal., and the information contained herein is drawn largely from unpublished U.S. Geological Survey Technical Report No. 2, 1969 (Baldwin and Boggs). I wish particularly to thank Ewart M. Baldwin and Robert L. Lent for permission to use unpublished material from their geologic maps of the Sixes River area, and Adolph Pabst for x-ray analysis of a mineral from the North Fork drainage which could not be identified in grain mounts. Several students participated in various phases of the research. Richard Robertson and Saleem Farooqui assisted with field mapping and sampling, Charles Jones, Carmen Rottman, William Eaton, Charles Price, and Mary Gable assisted with laboratory analyses, and Richard Stewart, Carmen Rottman, and Fred Swanson programmed data for computer analysis.

References

Baldwin, E. M., 1945, Some revisions of the late Cenozoic stratigraphy of the southern Oregon coast: Jour. Geology, v. 52, no. 1, p. 35-46.

Baldwin, E. M., and Boggs, Sam, Jr., 1969, Study of heavy metals and heavy minerals of the southern Oregon coast: U.S. Geol. Survey, Technical Report No. 2, Contract No. 14-08-001-11058 (unpublished).

Boggs, Sam, Jr., and Baldwin, E. M., Distribution of gold in the Sixes River, southwestern Oregon: A preliminary report: U.S. Geol. Survey Circular (in press).

Koch, J. C., 1966, Late Mesozoic stratigraphy and tectonic history, Port Orford-Gold Beach area, southwestern Oregon coast: Am. Assoc. Petroleum Geologists Bull., v. 50, no. 1, p. 25-71.

Lent, R. L., 1969, Geology of the southern half of the Langlois quadrangle, Oregon: Univ. Oregon doctoral dissertation (unpub.), 189 p.

Wells, F. G., and Peck, D. L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geol. Survey Map I-325, prepared in coop. with State of Oregon Department of Geology and Mineral Industries.

* * * * *

INTERIOR URGES NATIONAL MINERALS POLICY

Hollis M. Dole, Assistant Secretary of the Interior for Mineral Resources, spoke before the Wyoming Mining Association at its convention on June 20 and urged its support for a National Minerals Policy. The following paragraphs are quoted from his address:

On July 9 hearings will begin on S. 719, a bill to establish a National Minerals Policy. This bill, introduced by Senator Allott of Colorado and amongst others cosponsored by Senators Hansen and McGee is, in my opinion, one of the most important bills in Congress with which your Association should be interested. It is not only important to the Wyoming Mining Association and its members, it is important to all the people of Wyoming, and to all the people of the U.S.

The hearings on this bill are important because they provide a forum calling the attention of all the people of the country to the tremendous quantity of mineral raw materials that will be needed in the coming years. You know that to provide this requirement will take years of searching, billions in investment with a high risk factor, and many years of mining effort. You know this -- but unfortunately the man in the street doesn't. He buys his metal in the form of fabricated goods from the store, in accord with his requirements, never realizing that the metal he uses today may have taken many years to get to him.

All forecasts on mineral needs for the future indicate that our industry will be hard pressed to furnish the basic materials that go into the color TV's, cars, air conditioners, boats and the thousands of other items we accept as necessary today and the many new items of tomorrow that will be added to our descendants' everyday living needs. The hearings on S. 719 will be the opportunity to reveal the basic character of the mineral industry, because effort today is needed to prevent constraints on tomorrow's affluence. Unless the man in the street recognizes that his future is at stake in the minerals industry, he will continue to underestimate your requirements. The result will be ever-increasing restraints on exploration and mining, a greater dependence on overseas sources of supply with its accompanying erosion of national security and a continuing decline in the number and calibre of students studying earth sciences in our universities. Perhaps the latter is the most important problem, for it is going to take keen and imaginative minds to provide for the future. If you think getting a man on the Moon is glamorous, look at what is being currently planned or is on the drawing boards for the mineral industry; nuclear stimulation for gas, nuclear fracturing followed by leaching for copper, in situ retorting of oil shale, combustion drive for oils liquefaction and gassification of coal, offshore mining, offshore drilling in thousands of feet of water, rapid excavation underground, use of nuclear explosives to open new gas and oil fields in the West, mine mouth power generation, recovery of uranium from mine wastes, and new methods of determining open pit mine stability; and Wyoming can take pride in the fact that it is to be the site for several of these experiments.

So I urge you, join with me in giving wholehearted support and full testimony at the hearings to be held on our National Minerals Policy. If you can't attend, submit written statements, for I warn you, if due significance isn't given to the real value of our mineral industry today -- the minerals shortages could well become a social problem of the future. (American Mining Congress Memorandum, June 23, 1969.)

* * * * *

ASSESSMENT WORK DEADLINE NEARS

Assessment work on claims located on the Public Domain must be completed by the end of the assessment year, which is September 1st. At least $100 worth of labor and supplies must be expended on each located claim each assessment year. The work must be of benefit to the claim. Where several claims in a group either side-line or end-line each other, all of the assessment work may be done on one claim, provided that the work is of benefit to all of the claims. Immediately upon completion of the work a Proof of Labor affidavit should be completed and filed at the County Court House for the county in which the claim is located. Mining claimants having claims located on O & C lands or power sites which are administered by the U.S. Bureau of Land Management must send a copy of the affidavit to the Bureau's Oregon State Office, P. O. Box 3965, Portland, Oregon 97208.

* * * * *

MINERAL AND WATER RESOURCES OF OREGON PUBLISHED

"Mineral and Water Resources of Oregon," prepared by the U.S. Geological Survey in cooperation with the State of Oregon Department of Geology and other agencies, is expected to be available by the end of this month and will sell for $1.50. It can be obtained from the Department's offices in Portland, Baker, and Grants Pass.

The 462-page book contains two sections. Section 1, Geology and Mineral resources, describes the geology of Oregon and presents information on the known and potential mineral resources. Section 2, Water Resources and Development, deals with quantity, quality, and distribution of surface and ground water and with its utilization. The report is one of a series of state mineral and water resource summaries prepared for use of the U.S. Senate Committee on Interior and Insular Affairs, and now made available to the public. The Oregon report was commissioned by Senator Mark O. Hatfield. A. E. Weissenborn, U.S. Geological Survey, Spokane, Wash., was in charge of assembling, organizing, and editing the contents. Many authors, including geologists and engineers with the Department, contributed to the report, which is being issued as Department Bulletin 64.

* * * * *

ANDESITE PROCEEDINGS PRINTED

"Proceedings of the Andesite Conference," edited by Dr. A. R. McBirney, Head of the Department of Geology at the University of Oregon, has been published by the State of Oregon Department of Geology and Mineral Industries as Bulletin 65, and will soon be available for distribution at $2.00 per copy. The 200-page bulletin contains a group of papers representative of the topics and views discussed at the Andesite Conference held July 1968 in Bend, Oregon. The bulletin can be purchased from the Department's offices in Portland, Baker, and Grants Pass. A companion volume, Bulletin 62, "Andesite Conference Guidebook," containing geologic maps and photographs, is also available and sells for $3.50.

* * * * *

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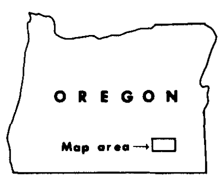
LAVA-TUBE CAVES IN THE SADDLE BUTTE AREA OF MALHEUR COUNTY, OREGON

by

Robert F. Ciesiel* and Norman S. Wagner**

Introduction



During the summer of 1967 the authors participated in a search for caves in an area of geologically young basalts situated in the Saddle Butte area north of the Burns junction in Malheur County. The project was initiated by the Vale District of the U.S. Bureau of Land Management as a result of a widely quoted press report concerning the alleged existence in this area of a cave 40 or more miles long. Although no single cave was found that even approached the dimensions reported in the press article, the evidence for there having existed a string of closely interrelated lava tubes extending for nearly 8.5 miles was considered worthy of detailed mapping and description.

The authors were aided on this project by several staff members of the BLM and two locally resident seasonal employees, all of whom had a great deal of first-hand familiarity with the terrain in the project area. Excellent aerial photographic coverage was available for the entire area and a helicopter was provided for scouting throughout the more inaccessible regions. Under the circumstances, the screening for potential cave entryways can be rated as quite comprehensive. Before preparing this report, however, the writers did revisit some portions of the area independently in 1969 to gather details not secured previously.

Results of Mapping

All caves encountered during the course of this investigation were explored to their ends and were mapped with a compass (Brünton) and tape survey and rod measurements to the roof. Exceptions were a few very short caves and two that were deemed too dangerous. The longest cave mapped proved to be 3620 feet by traverse distance from the portal to the face, while the second and third longest measured 1750 and 1550 feet respectively. Of special interest, however, is the fact that this group of caves clearly represents uncollapsed sections of what had once been a continuous chain

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** Geologist, State of Oregon Department of Geology and Mineral Industries.

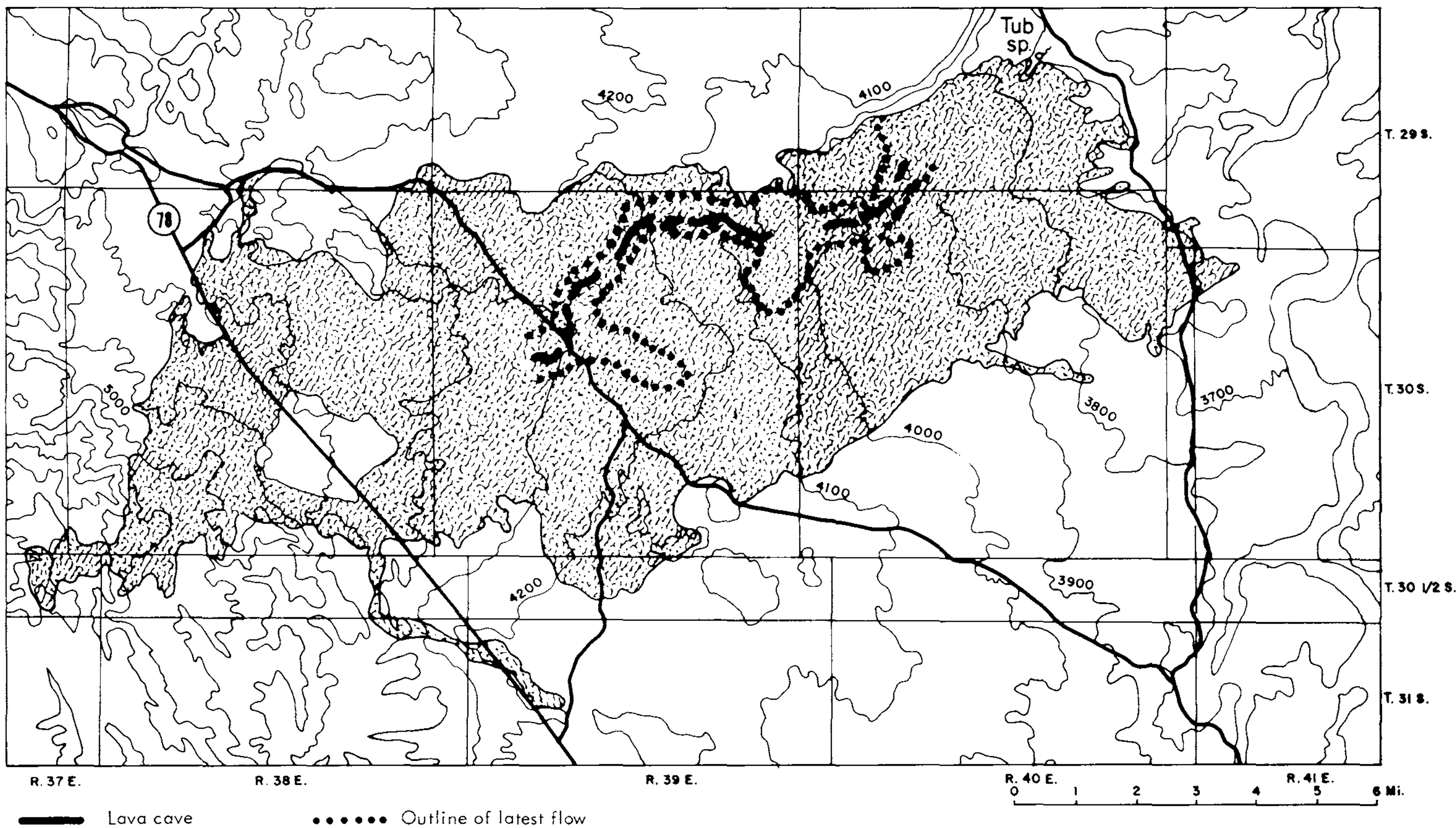
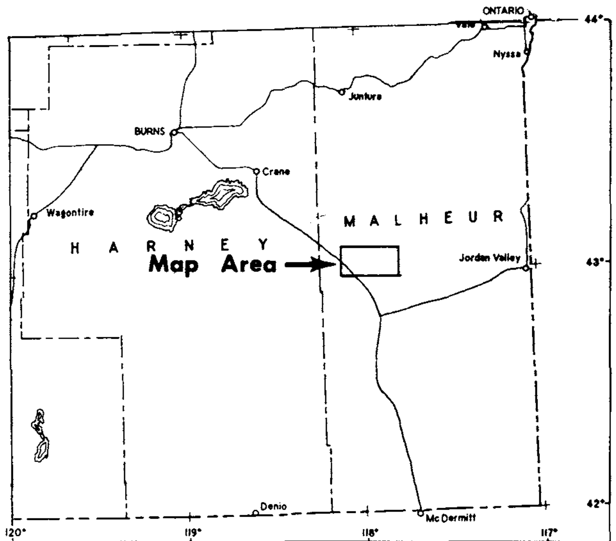


Figure 1. Map of the Saddle Butte area lava field showing the general outline of the youngest lava flow and its chain of tubes and collapse trenches.



Index map for figure 1.

of superimposed and coalescing lava tubes traceable over a distance of 8.5 miles. The portal and face of each open cave are aligned with conspicuous surface trenches marking collapsed portions of the original tube, while the few observable discontinuities are recognized as uncollapsed tube sections for which no accessible entryway presently exists.

Like old, abandoned mine workings, some of the caves are more dangerous than others, but all have a potential for collapse at any unpredictable time. Consequently, frequent reference is made in this report to the hazards of spelunking in this area.

Location and Access

The lava field in which this chain of tubes is developed occupies an area of about 82 square miles in western Malheur County. It is named for Saddle Butte, a prominent topographic feature situated in the northeast corner of T. 29 S., R. 39 E., a short distance north of the mapped area shown in figure 1. Elevations of the lava surface range from around 3700 feet at the eastern end to 5000 feet at the western. The climate in this region is semiarid and vegetation is scarce.

Oregon State Highway 78 crosses the western end of the lava field, and side roads lead into other portions, as indicated in figure 1. A complication confronting any visitor not aquainted with the area is the low relief and lack of distinctive topographic landmarks. It is very easy to become confused, and even lost, in the wide-open expanse of the lava field, hence off-the-road exploration should be undertaken only by persons equipped with adequate vehicles, food supplies, water, and either maps or aerial photographs, or both.

Access to most of the still-open caves and their adjoining collapsed trenches is mainly by rough side trails not suitable for travel in vehicles other than trucks or four-wheel-drive units. Otherwise, these features can be reached only by hiking, horseback, or helicopter.

As pointed out earlier, none of the caves can be considered safe to enter because of their thin, highly fractured, and unstable roof capping. Unlike solution caverns in massive limestones, which can be developed into relatively safe tourist attractions, the accessible caves in this particular lava-tube complex represent natural hazards totally unsuitable as sites for family outings or for needless entry by anyone under any circumstances. Indeed, it is a coincidence that some of the presently accessible tube sections are still bridged by roof segments, and that collapse has not occurred before now, since a roof fall can be triggered by a sonic boom, the hoof beats of wild horses galloping over the lava flow, the seismic vibrations of a distant earthquake, or any one of many other causative factors. Thus, despite their interest as geologic features, these caves are not recommended as sites for public visitation. Rather, they are recommended as places to avoid.

General Setting

Emplacement of the lava field occurred during late Pleistocene to recent time, according to geologic mapping by the U.S. Geological Survey (Walker and Repenning, 1966). The basalt making up the lava field is characterized by clear, fresh olivine and abundant titanaugite and, except in a few places, by flow surfaces only scantily modified by erosion. Over wide areas the soil covering is generally as sparse as the vegetation it supports.

The land surface in the area occupied by this lava field slopes eastward with minimal relief; however, aerial photographs indicate that the most recent flow, and the one in which the lava-tube chain developed, was confined to a relatively narrow, serpentinous course having an over-all direction toward the northeast. In effect, therefore, the youngest outpouring of molten lava flowed like a river across its previously emplaced neighbors in a narrow channelway. This channel probably marked the trace of a shallow erosional gully which existed on the old land surface before any of the older companion flows were erupted. The approximate bounds of this "river of lava" in the cave area, as taken from aerial photographs and including local impoundments, is indicated in figure 1. How the differences in vegetative covering and soil development serve to make this boundary conspicuous when viewed from a high altitude is illustrated by figure 2, which represents a portion of one standard aerial photograph.

Figure 2 also illustrates the appearance of collapse trenches as seen from the air and the extent to which such collapse has taken place in comparison with the length of land-surface segments still bridged. Therefore, since aerial photographs covering other sections of the trench-tube chain show a similar ratio of collapse versus bridging, there are two conclusions which are strikingly evident. One is that it is only a matter of time until all remaining bridges break down to form one continuous long trench. The second is that, because of this propensity to collapse, these bridges and their underlying caves are doubly hazardous, in that it would be just as bad to be walking or driving over the top of a cave as it would to be inside it when the roof fell in.

Origin of Lava Tubes

Lava tubes can be compared to the empty cavity in a cocoon after the moth has hatched and departed. In other words, they mark the place in the body of a lava flow from which a highly liquid core has drained after the rest of the surrounding lava has cooled and solidified enough to stand rigid. This does not happen in the case of all lava flows; instead, it occurs only in those in which there is a fairly rapid cooling and solidification along the sides and top, but also sufficient depth or thickness to insulate the interior lava and thus retain a state of liquidity in the innermost, lower portions. Even then this inner-zone lava will eventually cool to become solid rock if the physical conditions do not permit drain-out of the liquid core. This entails the existence of a slope down which to flow and some form of unobstructed place at the down-hill end at which to vent.

Because these conditions prevail, or are likely to prevail, in the many types

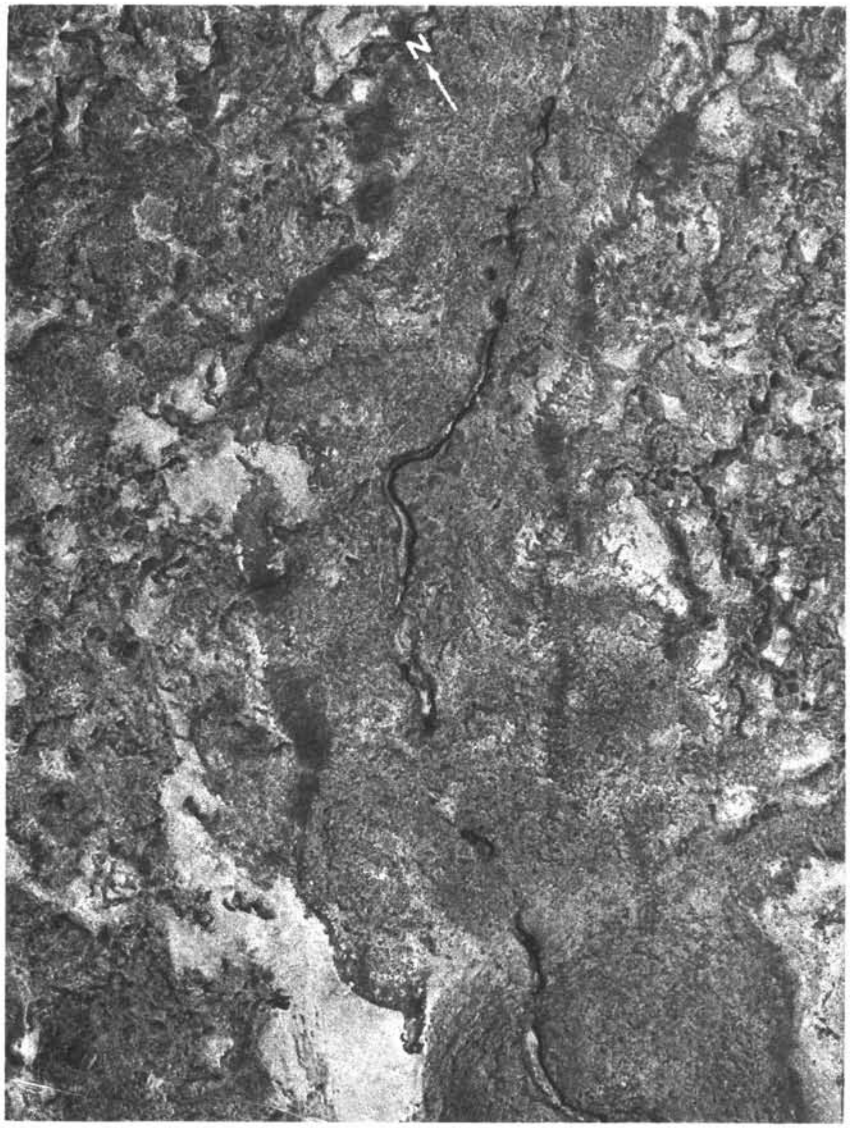


Figure 2. Aerial photograph of part of the Saddle Butte lava field showing the difference in appearance between the older lava surface and the youngest flow. The prominent worm-like lines in the youngest lava are trenches formed by collapse of the shallow 8.5-mile tube near its southwestern end. Scale is 1 inch = 1430 feet.

of terrain over which basaltic lavas can be erupted, lava tubes or other voids within the body of a congealed flow are not uncommon. For the most part, however, the area over which ideal gradient and vent conditions can occur is more likely to be localized than extensive; hence, the length of the essentially continuous chain of tubes and related collapse sections of the Saddle Butte lava field is unusual.

In some instances lava tubes contain a great deal of ornamentation comparable to the stalactite and stalagmite formations found in caves in limestone; however, when it occurs in lava tubes, this ornamentation is composed of lava rock and not calcite, and it is formed by molten lava dripping from the roofs and sides of the tubes or squeezing out into the tube from crevices during the final stages of solidification of the tube walls. Converging and diverging lateral branches constitute another characteristic commonly found in connection with lava tubes, and it is not unprecedented to find tubes developed one above another.

Lava Tubes and Trenches in the Saddle Butte Area

Few of the characteristics described above are found in the Saddle Butte area tubes. For example, the picturesque ornamentation such as lava cicles hanging from the roof, drip accumulations on the floor, and fan-like sheets extruded from joints are almost totally lacking, and even where present they are poorly developed. Also lacking in any of the accessible tubes is evidence of splits with lateral converging and diverging branches. Present, however, at the portal of the 40-Mile Cave (figures 3 and 5) is a fine example of one tube above another. Here, entrance to the longer, lowermost tube is achieved by entering the upper tube through a small collapsed hole and thence by walking on the rubble-covered shell separating the tubes for a distance of 200 feet to a point where both merge and where descent can be made into the lowermost tube. A similar superpositioning of two tubes is also indicated at the far end of this cave, where the last third of the lowermost tube underlies a well-developed surface trench which represents the remains of the now collapsed upper tube.

The natural floors of the Saddle Butte area tubes are extensively obscured, either by accumulations of rock which have dropped from the top roof shell, or by a layer of clayish silt which represents soil carried into the tube by rain and snow water entering through crevices which extend between the tube ceiling and the surface. The rubble from natural stoping occurs frequently in the form of large, steep-sided piles involving scores to hundreds of tons of blocky rock. In contrast, the washed-in soil occurs in the form of a fairly thin, level, and widely distributed floor covering which, interestingly enough, often exhibits a well-developed pattern of five-sided shrinkage cracks similar to those commonly observable on sun-baked surface clays. Where observable, though, the natural floor in all of the tubes slopes consistently eastward in conformity with the slope of the overlying land surface. This suggests that a fairly uniform gradient prevailed throughout the entire 8.5-mile distance over which the lava tubes formed.

Only at intervals, and for relatively short distances, do any of the tubes exhibit their original lining of comparatively homogeneous, solidified lava in the form of an unbroken shell. Instead, the top section of this lining is lacking more frequently than not. This is due to caving primarily; however, the tendency for caving is due in turn to the fact that the overhead arch of lining is very thin and poorly developed in the first place -- too thin, that is, to offer substantial support for the covering of overlying rock for any prolonged period of time. This lack of a thick, strong lining in the roof section accounts for the fact that so much of the original tube has

(Above) This large, wide-open cave entrance was caused by massive collapse of an adjoining section of the tube. The thin shell of rock still bridging the cave is characteristic of all remaining lava tubes in the area.

(Below) Typical view of a cave entrance taken from inside. Note the size of the blocks of rock that have fallen in the past and the size of those ready to fall in the future.

already collapsed into trenches.

Without doubt, many factors contributed to the lack of development of a substantially thick lining in the arching top section of these particular tubes. The most significant is evidence indicating that the tubes carried no sustained flow of molten lava from a replenishing source over any prolonged period of time. Instead, during much of their later history they carried only a partial load, as is indicated by horizontal bulges on the side walls of some of the tubes at various midway heights between the floor and the top. In other words, these bulges represent local thickenings of the side wall and they indicate where the level of the stream of draining lava stood during different periods of the drainage cycle. Had the tubes run more nearly to capacity over a longer period of time, more of the molten material would have splattered onto the ceiling and thereby contributed to the build-up of a thicker lining in the topmost portion. Such a thicker lining could have contributed to the support needed for the preservation of a greater amount of the original tube than exists. Since the few remaining intact sections lack the support needed to counteract the steady pull of gravity on their thin, highly fractured shells of overlying basalt, eventual total collapse is inevitable. Indeed, two major rock falls can be reported as having taken place between the time the caves were mapped in 1967 and re-examined in 1969.

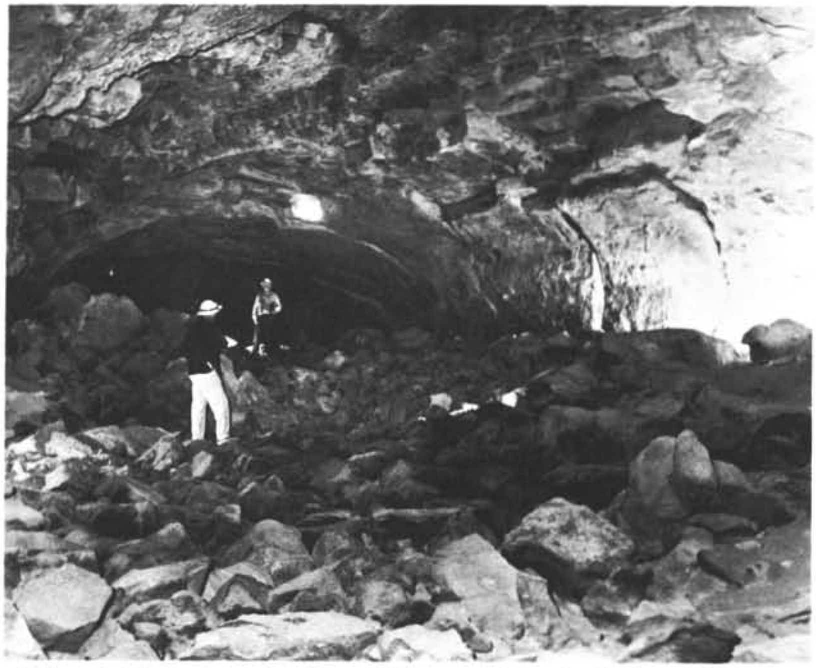
The surface trenches formed as a result of bygone collapses are for the most part abrupt, steep-sided channels ranging from 20 to 80 feet wide and from 10 to 20 or more feet deep. All are bottomed with a jagged jumble of broken blocks of what was once surface basalt. Soil washed or blown in over the years has accumulated in sufficient amounts in a few trenches to modify the harshness of the scene by supporting some grass and brush; however, in most trenches soil is very scarce, or absent. The inescapable conclusion is, therefore, that most of the collapsing is comparatively recent in age and that some of it is very new. That more trenches can be expected to develop in the future as a consequence of collapsing is a conclusion rendered virtually certain by the character of the remaining roof structures and the weakening effects constantly being generated by natural stoping.

Descriptions of Individual Caves

The six major caves in the Saddle Butte lava field are described individually in the following paragraphs. For convenience, these descriptions begin with the Coyote Trap Cave, shown on the southwestern corner of figure 3, and continue thereafter in the order of their succession as shown on the map. Included also are maps of the Tire Tube, 40-Mile, and Owyhee River Caves.

Coyote Trap Cave

Entrance to this cave consists of a very narrow, irregularly shaped passageway leading downward on a sloping course through the nested blocks of the collapsed margin for a distance of about 20 feet. From this point a compass bearing confirms that the still intact remnant of the tube leads to and terminates against collapse rubble located an estimated distance of 150 feet to the northwest. Beyond this no detailed measurements were made, since the main cave was considered too dangerous to enter due to the fact that stoping has progressed to a level so near the surface of the ground that the remaining roof is obviously very thin and fragile.



(Above) Natural stoping is well illustrated by the fallen rock on the floor and the jagged, fractured roof overhead. Note the thinness of the lava lining of the tube arch visible in the background. This is the condition of Tire Tube Cave some 100 to 200 feet beyond the entrance.

(Below) This scene is in 40-Mile Cave and is one of the few places where one can relax in comparative safety. The natural tube lining of fairly homogeneous lava is still well preserved, providing support to the overlying bridge of fractured basalt.

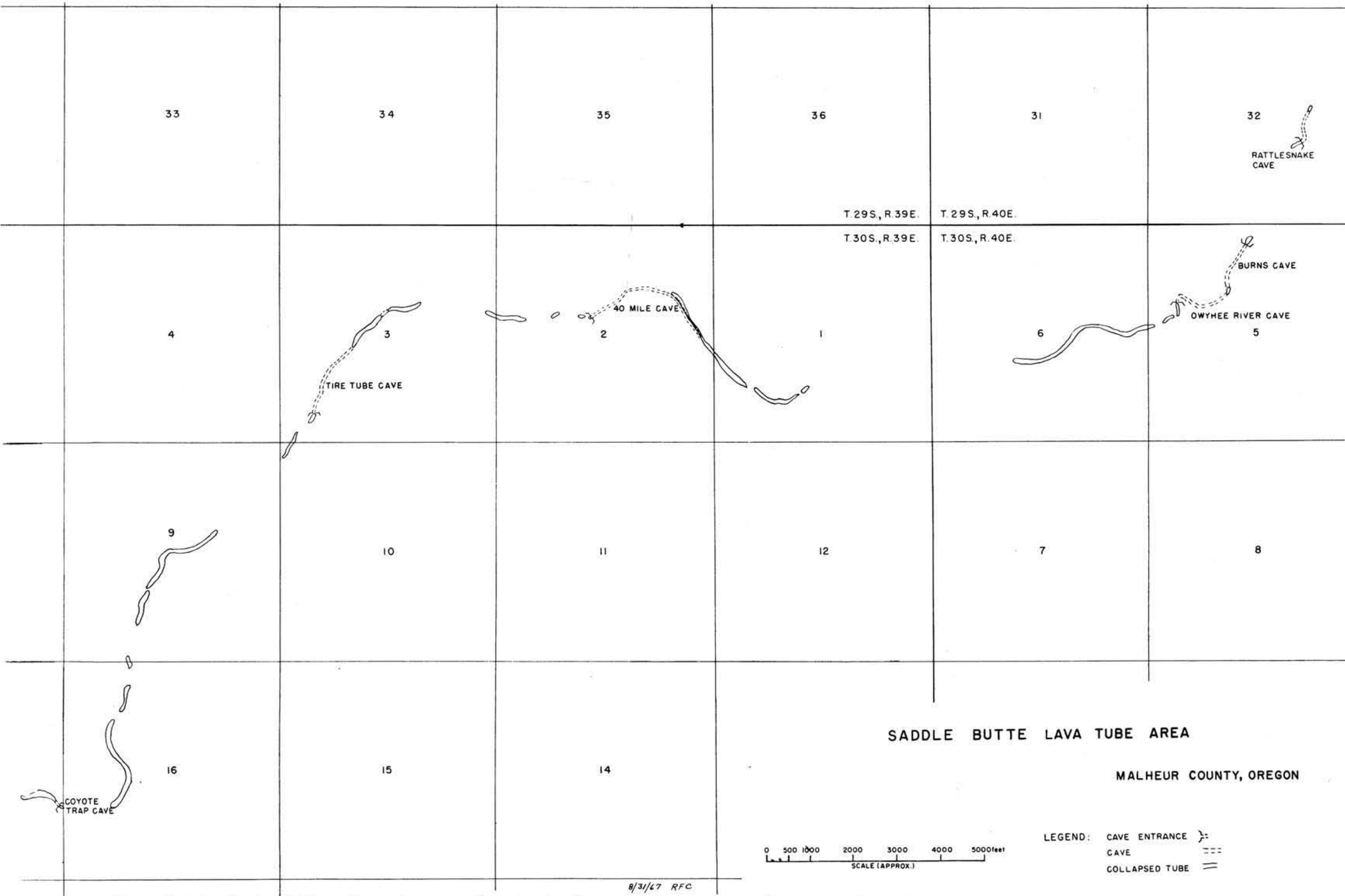


Figure 3. Map showing the interrelation between collapsed and still-intact sections of the Saddle Butte area lava tube, as expressed by prominent surface trenches and presently accessible caves. Discontinuities represent tube sections with no visible entryway.

The forms resembling ghosts in this picture are the real flesh-and-blood individuals who made this time exposure possible by walking back and forth and playing lights on the walls and ceiling of a section of the 40-Mile tube.

Tire Tube Cave

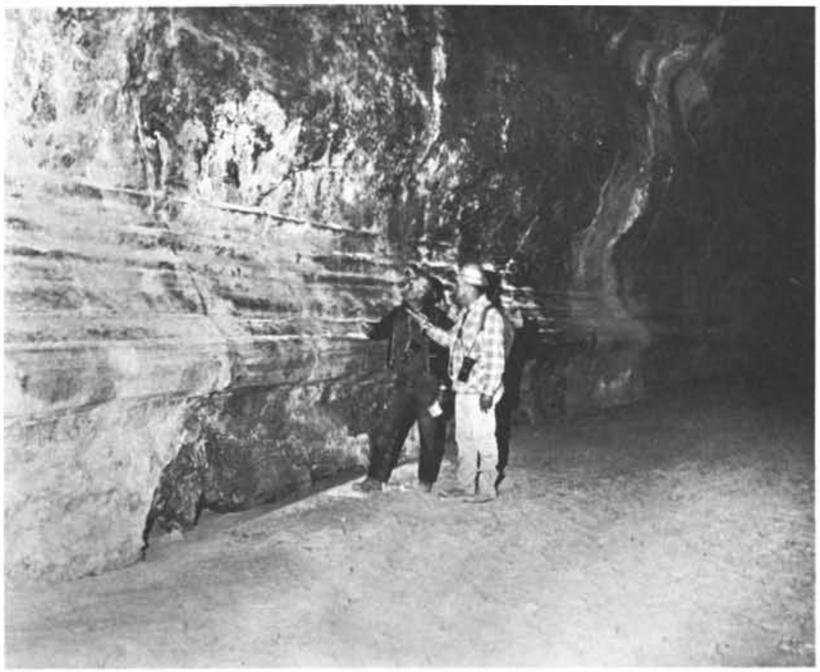
A local collapse of the side wall constitutes the entrance to this cave, the first several hundred feet of which consists of blocky rubble under foot and rough, jagged, highly fractured rock above. In fact, it was in this cave at a distance of about 250 feet from the entrance that one of the major post-1967 rock falls was noted. Therefore, since the area directly in front of this recent fall measures approximately 50 feet wide by 23 feet high, with nothing but interwedged blocks of fractured rock in the roof, no re-examination was made in 1969. The 1967 notes show, however, that this tube had a measured traverse distance of 1705 feet to the face and that it tapered fairly consistently from the portal to the end. The last third is floored with silt introduced through crevices at the end. Because this silt leaves only the narrow upper portion of the tube open, the mapped width in plan view appears to decrease (figure 4). Of interest in the cave are the shrinkage cracks in the silt. Although developed in total darkness, these are in all respects similar in appearance to the cracks commonly found on the surface of sun-baked mud flats.

40-Mile Cave

This cave is referred to as the "40-Mile Cave" because of the press reports in which it was described as being that long. However, the measured distance between the entrance and the face on its easternmost extension is 3620 feet. This tube is reported to extend an additional 1200 feet to the westward, according to a speleologist who supposedly entered this portion of the tube by crawling for a distance of approximately 50 feet through a narrow, crooked opening in places only 15 inches high. In any event, two ladders are needed for access into this cave -- one to descend through a small hole in the roof to the floor of an upper tube, and another to descend from the floor level of the upper tube to the floor level of the lower tube at the place where the two tubes merge.

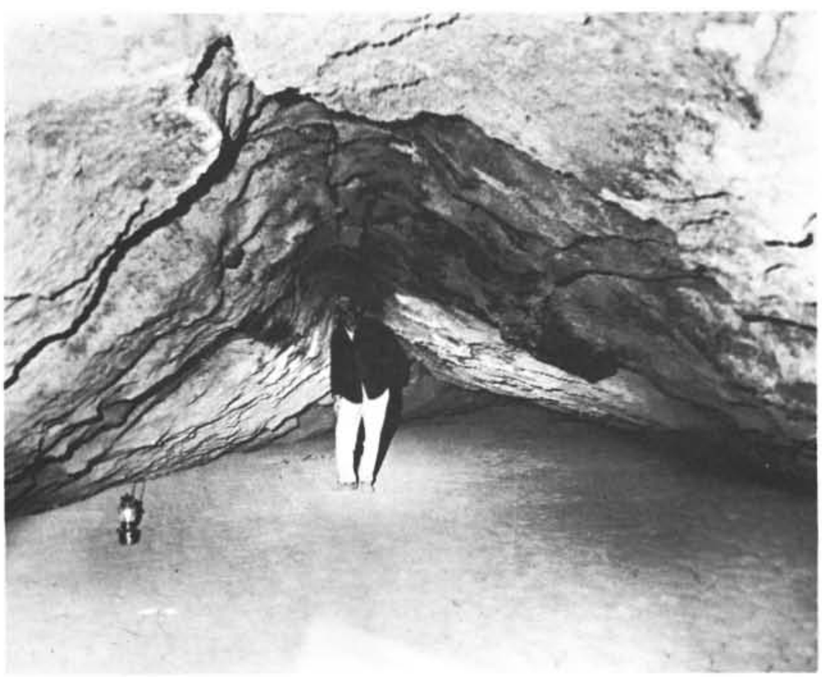
Except for stoping conditions in the vicinity of the entrance and at three places where the top arch of the lower tube has been breached by caving between the entrance and the end (figure 5), this is probably the best preserved of any of the Saddle Butte area caves. It is also one of the most impressive, in that cross-sectional tube dimensions in the open, nonsilted half nearest the entrance exhibit sustained widths of 40 and 60 feet by heights of 35 to 47 feet over a long distance.

Towards its end, this cave is progressively filled with silt to the point where the silt merges with the back or ceiling, thereby ending the cave. However, as is indicated on figure 3, the survey of its configuration indicates that the last several hundred feet of this cave closely parallel and apparently underlie a well-defined collapse trench on the surface. The Brunton survey is sufficiently accurate to show that this tube relates intimately with the one represented by the surface trench. But whether the 40-Mile Cave underlies or is laterally offset in relation to the trench is a question which would require a more precise survey inside the cave and the establishment of a picket line on the surface for a positive determination. On the basis of the present data, however, a small lateral offset is believed probable because of the relatively sound, fracture-free nature of the arched lining in the portion of the 40-Mile Cave paralleling the surface trench. In either case, the 40-Mile Cave and its upper companion segment are functional links in the 8.5-mile chain of tubes and relating trenches.



(Above) Horizontal ridges on the side walls of one of the better preserved sections of 40-Mile Cave show that the level of the stream of outflowing molten lava was both low and relatively stationary at times during the final drain-out stage of this tube's history.

(Below) Some caves like the Tire Tube Cave shown here are completely blocked by silt washed in from the land surface through open cracks and crevices in the roof. Other caves have merely a thin layer of silt on the floor near the crevices.



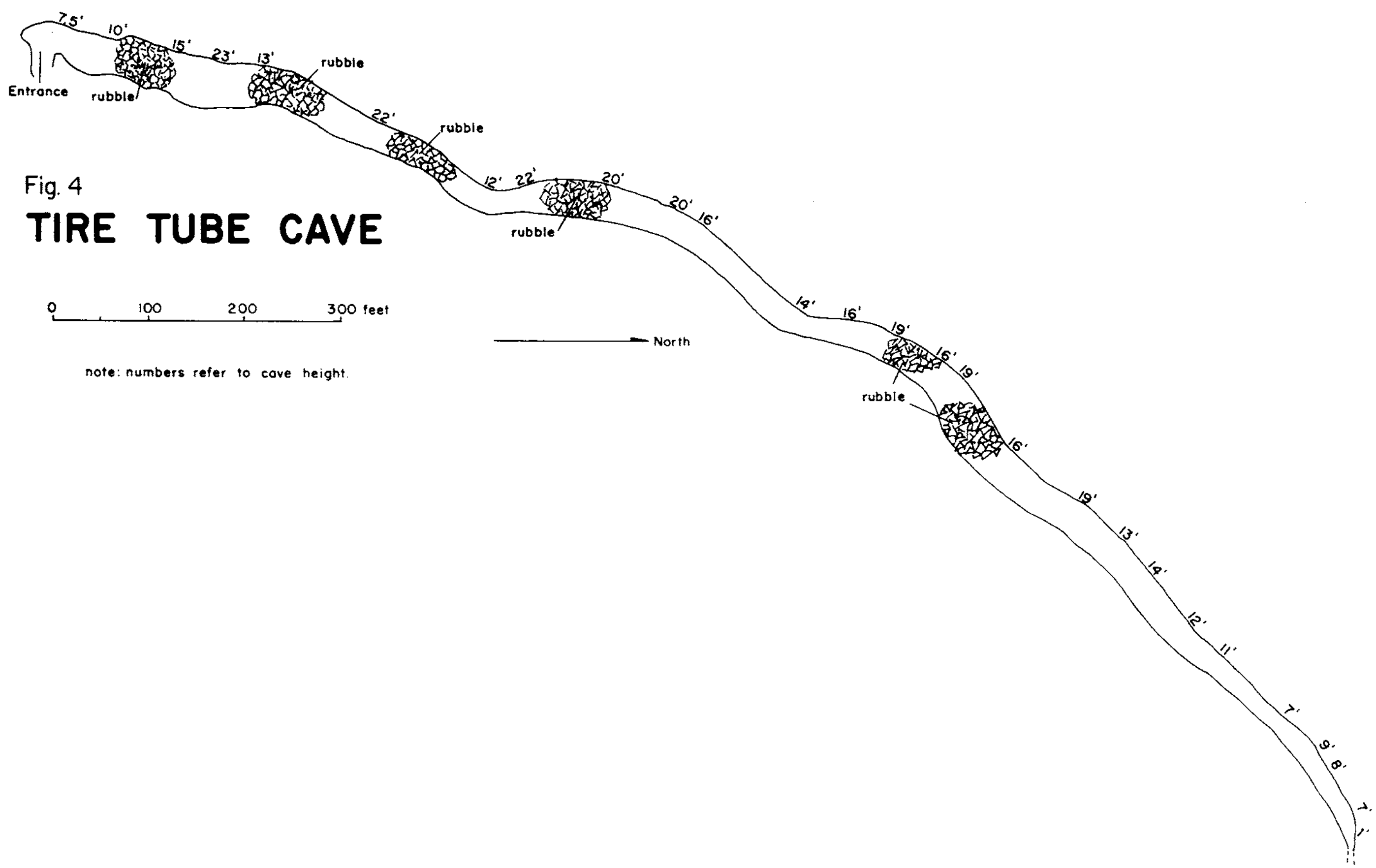


Fig. 4

TIRE TUBE CAVE

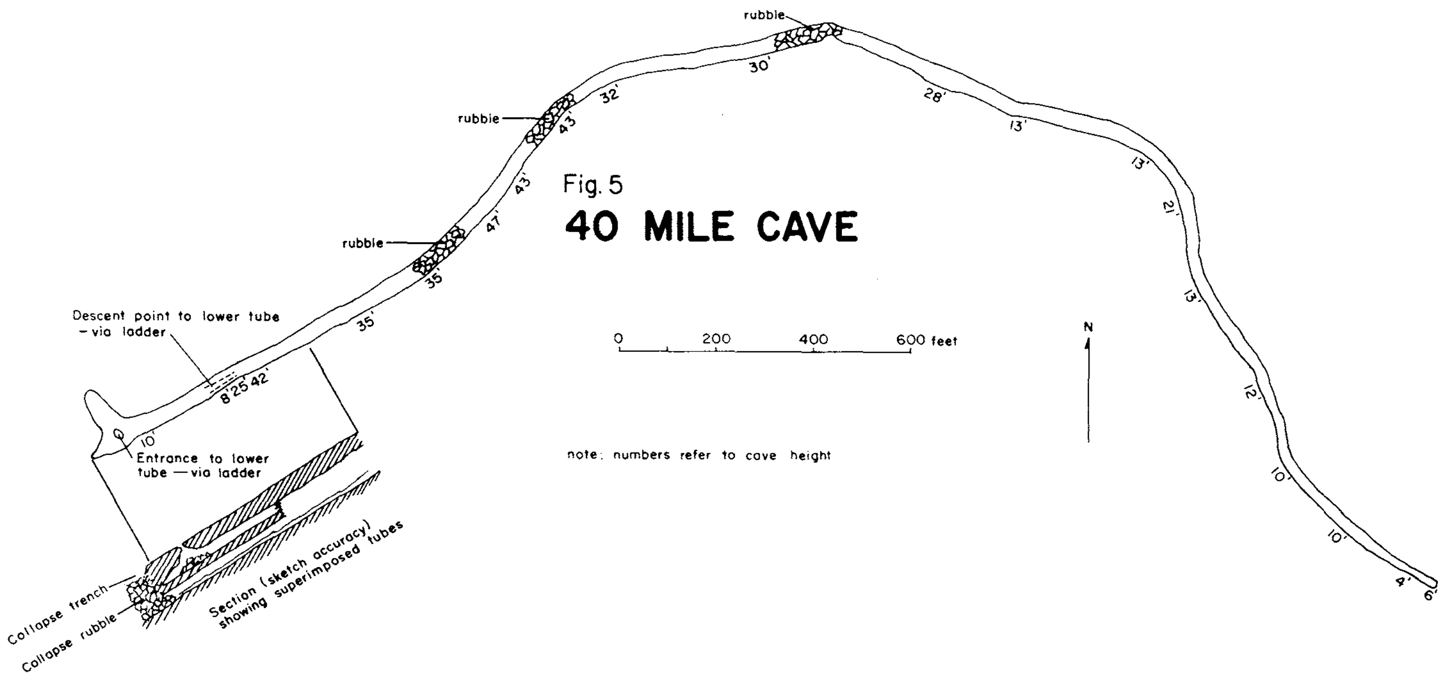
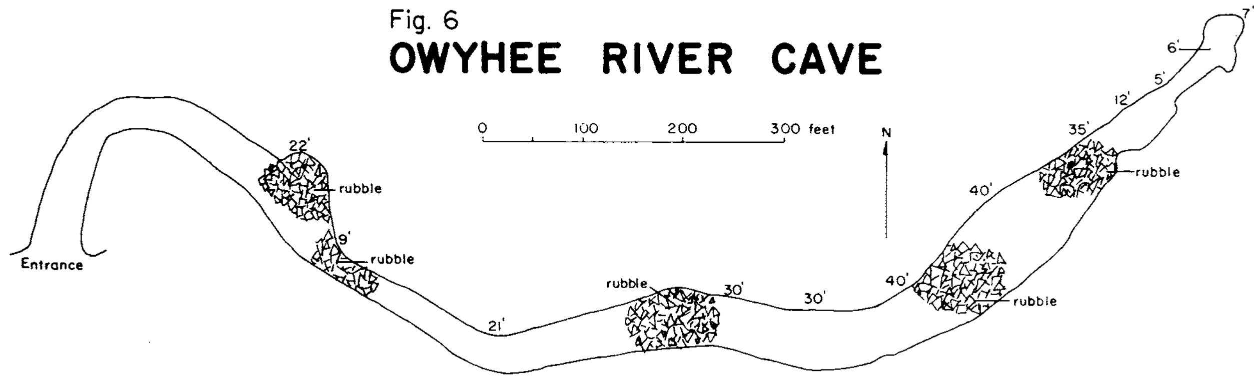


Fig. 5
40 MILE CAVE

Fig. 6
OWYHEE RIVER CAVE



note: numbers refer to cave height.

Owyhee River Cave

Entrance into the open end of this cave exists as a result of a massive collapse of part of the original tube. Distance to the back is 1550 feet by a circuitous course. Cross-sectional dimensions vary greatly to a maximum width of 85 feet by a height of 40 feet at a point near the end. Crevices in the floor, together with a drum-like sound produced by footsteps at places in this cave, suggest the possibility of there being an underlying tube.

Although the original tube cross-section is intact and nicely preserved in parts of this cave, much of the presently existing height is due to stoping, which in places must leave the ceiling practically at grass-root level. Indeed, there are five such places (figure 6) where the accumulated rubble on the floor assumes frightening proportions from the standpoint of the amount of material that has fallen and the size of many of the slabs. Moreover, the instability of the roof is such that it was at one of these places where the second large post-1967 rock fall took place.

Evidence in the form of a note on an old, yellowed paper cached in a bottle at the very end of this cave indicates that it was visited and explored prior to the turn of the century and again 10 years later. At least, in two different sets of handwriting this note reads "Arego Harrison, February 6, 1897" and "George P. Buckley and W. H. Gripe, June 6, 1906." Who Buckley and Gripe were is not known, but the name Arego Harrison is recognized as that of a sheep-camp tender working in the area at the time indicated on the note. How much the stoping has progressed between the time these notes were written and now would be interesting to know; however, in view of the unstable conditions currently observable, there is little room to doubt that the tonnage of rock in the various rubble piles on the floor is today many times greater than it was when Harrison, Buckley, and Gripe made their visits.

Burns Cave

This cave begins with a narrow, tortuous passageway between slumped and interwedged blocks of rock on the margin of a collapse trench. Beyond that, the still-remaining section of intact tube extends southward to a small but definitive collapse area which is all that keeps it and the previously described Owyhee River Cave from joining end to end as one continuous tube (figure 3). This was established by entering the cave the distance needed to confirm the bearing of the course of the main tube as recorded by a previous survey party on a plaque left at the entrance. Otherwise, no time was spent examining this cave for the reason that it seemed a needless risk; hence, no map showing configuration details is available in this instance.

Rattlesnake Cave

Found from a cruising helicopter and named after the guardian of its entrance, this cave measures only 882 feet in length and exhibits no features or dimensions differing materially from those observable in the other caves. For this reason the survey consisted of the center-line traverse only, with no height or width measurements. It is to be noted, however, that while the tube terminates against a collapse in the way the other caves do, there is at the end a small dog hole which angles upward through the rubble to the surface, where it emerges on the lower flank of a pressure ridge. This "exit," if it can be called that, is thus similar in its basic make-up to the entrances to the Burns and Coyote Trap Caves.

How much farther the lava-tube chain extends to the north and northeast from the collapse barrier which terminates forward progress in the Rattlesnake Cave can only be surmised, since no collapse trenches are to be seen on the aerial photographs beyond this point. There are, however, in places where the tube course can logically be projected, some patterns which can be interpreted as evidence of incipient subsidence. If this can be accepted as sufficient grounds for surmising that the tube does indeed continue northward on a winding course which could very likely lead to the Tub Springs area, if not to Tub Springs itself, then the total length of the original tube system may possibly be 1.5 to 2 miles longer than mapped.

Conclusion

The chain of tubes and collapse trenches traceable for 8.5 miles in the Saddle Butte lava field was originally one continuous tube, or a closely interrelated system of individual tubes functioning as a unit. This feature formed near the surface of the parent lava flow without producing a strong reinforcing lining. Therefore, the thin, fractured, and poorly supported roof has collapsed over long distances. The potential for further collapse is too great to warrant developing as a tourist attraction the few short cave sections that are still fairly safe to enter.

Reference

Walker, G. W., and Repenning, C. A., 1966, Reconnaissance geologic map of the west half of the Jordan Valley quadrangle, Malheur County, Oregon: U.S. Geol. Survey Misc. Geol. Invest. Map I-457.

* * * * *

GEOLOGIC MAP OF OREGON FOR SALE BY DEPARTMENT

A small, multicolored map of Oregon on a scale of 1:2,000,000 has just been published by the U.S. Geological Survey. The map shows the various types and ages of rocks, the major faults, and a few geographic features. It was prepared by George W. Walker and Philip B. King and appeared originally in black and white patterns at a smaller scale in Oregon's Mineral and Water Resources report (Department Bulletin 64) compiled for the Committee on Interior and Insular Affairs. The colored version, Map I-595, is on a sheet 11 by 20 inches. It is for sale by the Department at its Portland, Baker, and Grants Pass offices for 25 cents.

* * * * *

GROUND WATER IN COLUMBIA RIVER BASALT DESCRIBED

"Effect of tectonic structure on the occurrence of ground water in the basalt of the Columbia River Group of The Dalles area, Oregon and Washington," by R. C. Newcomb has been published as Professional Paper 383-C by the U.S. Geological Survey. The report discusses the geology and hydrology of a 620-square-mile area covering both sides of the Columbia River between lat. 45°30' and 45°45' and long. 120°45' and 121°30'. The report includes a geologic map at the 1:62,500 scale, cross sections, and photographs. It is for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington D.C., 20402 for $1.25.

* * * * *

TECTONIC MAP OF NORTH AMERICA PUBLISHED

"Tectonic Map of North America," on a scale of 1:5,000,000 (1 inch = 80 miles), has been compiled by the U.S. Geological Survey in collaboration with other national geological surveys, and with the assistance of various individuals. The multicolored map, printed on two sheets, each 40 by 65 inches, is available from the U. S. Geological Survey, Federal Center, Denver, Colorado 80225, at $5.00 per set.

A separately published companion to the map is Professional Paper 628, "The Tectonics of North America," designed to aid in the use and understanding of the map. This 95-page report can be purchased from the Superintendent of Documents, Washington, D.C. 20402, at $1.00 per copy.

* * * * *

EARTHQUAKE FELT IN HAINES-POWDER AREA

A slight earthquake was felt at both North Powder and Haines in Baker County on August 14, 1969, according to the Record-Courier and the Democrat-Herald of Baker, Oregon. It was the first quake experienced by residents in that area in many years. The tremor was confirmed at the Blue Mountain Seismological Observatory as having occurred at 7:37 a.m., with a magnitude of 3.5 and centering 3½ miles south of North Powder. Larry Jaksha, chief of the station, said that the tremor persisted about 3 or 4 minutes on the instruments, but that it was localized possibly about 10 seconds.

* * * * *

HORSE HEAVEN EXPLORATION GETS OME LOAN

The partners in the Horse Heaven Mining Co., Al Franco, Milton Roumm, and Dr. Charles Fine of Seattle and Ray Whiting, Jr. of Reno have received an OME loan of $24,000 to explore for mercury in a new area just west of the old Horse Heaven mine in Jefferson County. Proceeds of the loan will be used for shaft sinking, drifting, and long-hole drilling. Ray Whiting, who has been exploring the region around the Horse Heaven for the past 3 years, has shipped 17 flasks of mercury from the new site.

* * * * *

JOHN DAY GEOLOGY BOOKLET AVAILABLE

A booklet, "The geologic setting of the John Day Country, Grant County, Oregon," has just been issued by the U.S. Geological Survey. The 23-page booklet, illustrated with photographs and diagrams, was prepared by the Survey in cooperation with the Oregon Department of Geology and Mineral Industries, the Oregon State Highway Department, and the Grant County Planning Commission. The booklet is obtainable from these agencies free of charge.

The information for the booklet was supplied by Dr. T. P. Thayer, who is an authority on the geology of this region. Designed especially for visitors touring the area, the publication is written in nontechnical style. It contains a summary of the geologic history of the area and a road log of the John Day "loop," which begins near Mount Vernon and makes a circuit through Picture Gorge, Kimberly, Monument, Long Creek, and back, with stops at points of special geologic interest.

* * * * *

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SAWTOOTH RIDGE: A NORTHEAST OREGON VOLCANIC CRATER

Peter V. Patterson*

Introduction

Sawtooth Ridge lies about 20 miles northeast of Baker, Oregon in sections 10 and 11, T. 7 S., R. 42 E. (figure 1). The structure in its entirety is shown on the U.S. Geological Survey $7\frac{1}{2}$-minute topographic quadrangle preliminary map Keating NE (1968) (plate 1). It consists of a shield portion

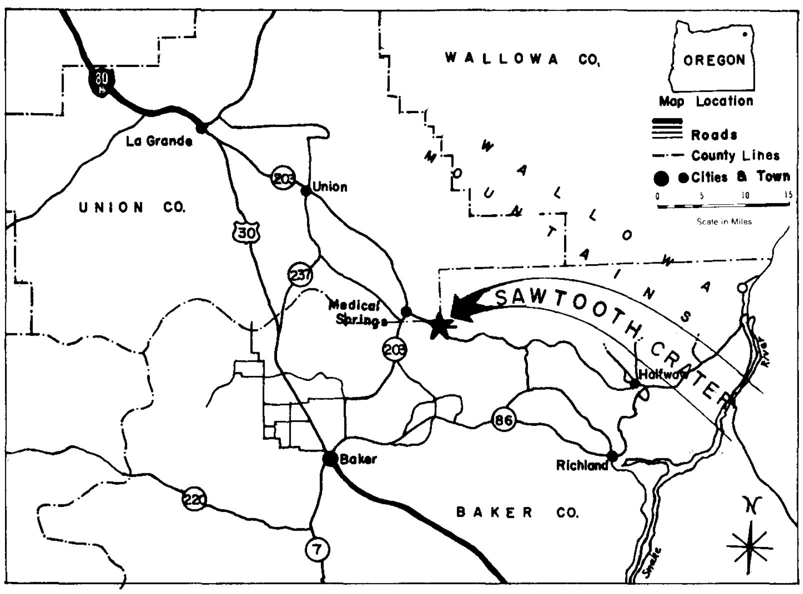


Figure 1. Location map of Sawtooth Ridge.

* Geologist, Watershed Planning Staff, Soil Conservation Service, Portland, Oregon

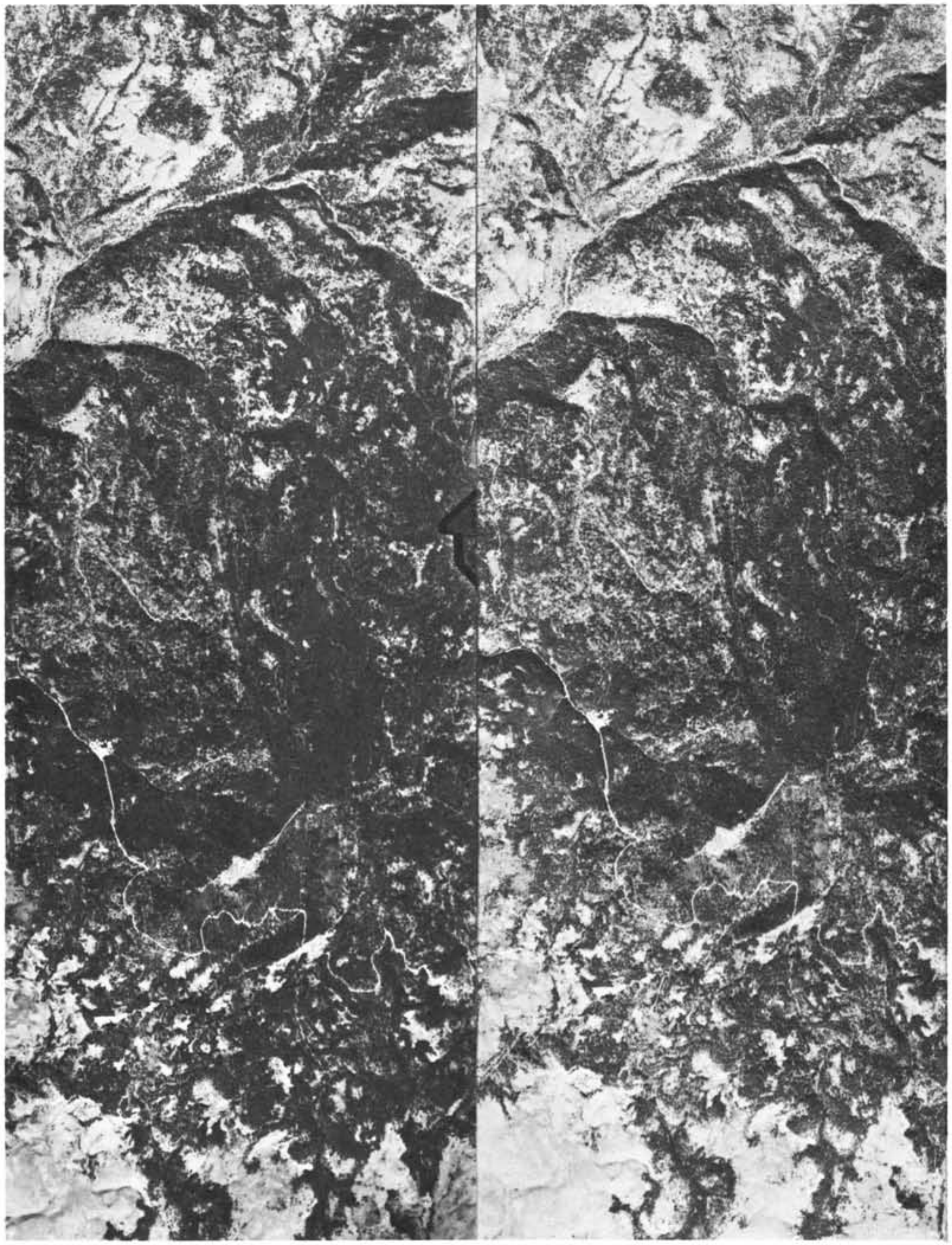


Figure 2. Stereographic plates of crater and surrounding area
Scale: 1" = approximately 4000'.

approximately 3 miles in diameter, with a central crater separated by two radial dikes extending from the source spine. The average crater diameter is approximately 5000 feet. It is located on the southwestern margin of the Wallowa Mountains and can be reached by a U.S. Forest Service road from Medical Springs.

The geology of this area has been described by James Gilluly (1937), N. S. Wagner (1958), R. L. Bateman (1961), and H. J. Prostka (1962). Bateman recognized the shield nature of this feature and developed the detailed stratigraphic sequence for the area. The purpose of this paper is to describe the crater structure and to show its relationship to the surrounding geology. Structures of this magnitude and degree of preservation are relatively rare, particularly in this area of Oregon (figure 2).

Stratigraphic Sequence Underlying the Crater

The area of interest is located on the southwest flank of the Wallowa Mountains uplift. The albite granites which are exposed farther to the east are assumed to form the deeper part of the geologic "basement" beneath the crater. Overlying this unit are the pre-Tertiary volcanics and sediments of the Clover Creek Greenstone (Ptcg). These rocks are exposed along Big Creek approximately 2 miles northwest of the crater and also along the upper reaches of Clover Creek about 1 mile to the southeast (plate 2). At greater distances they almost circumscribe the structure. As described by Prostka (1962), these rocks consist of "basaltic to rhyolitic volcanic flows, coarse- to fine-grained volcanic wackes, sandstones, tuff, and subordinate amounts of chert, conglomerate, and limestone, all of which have been slightly to moderately metamorphosed."

Overlying the pre-Tertiary rocks are several hundred feet of sequential flows of olivine basalt (Tob) which have been assigned to the upper Miocene by fossil-leaf dating. These basalts form a broad plateau which dips gently away from the Wallowa uplift. The rock is grayish-brown and the flows range from 30 to 100 feet in thickness, with well-developed columnar jointing.

Description of the Crater

The Sawtooth shield and crater overlie the olivine basalts and the Clover Creek group (figure 3). The shield consists of discontinuous flows of platy andesite (Taif) which range in thickness from 20 to 50 feet. As described by Bateman (1961) "the flows of platy andesite surrounding Sawtooth Ridge have a gentle dip away from their source. Felted texture is most common and results in the platy fracture which is most common in most outcrops." Generally the dip of the plate surfaces increases to 30° to 40° in or near the crater rim. No tuffaceous or pyroclastic beds were observed within or on the andesites of the shield.

Figure 3. Profile view of the crater, looking east from Oregon State Highway 203.

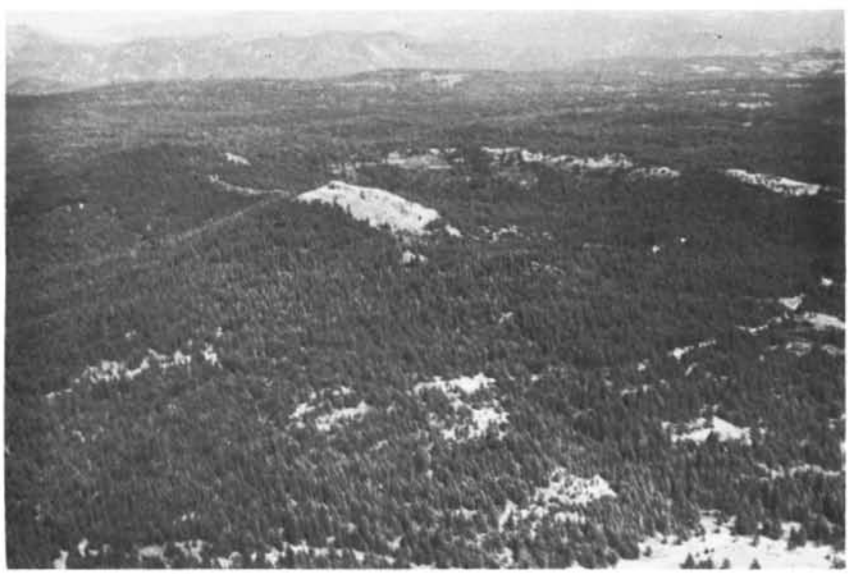


Figure 4. Oblique aerial view to the northeast, showing the central spire, radial dikes, and the southeast rim.

The Sawtooth Crater is roughly circular in shape and covers 650 acres within the rim (figures 4 and 5). The rim circumference is approximately 19,000 feet. The height of the rim above the crater floor ranges from 100 to 400 feet, with the central spire rising to an elevation of 420 feet above the floor. Two radial dikes (figure 6) extend northeast and southwest from the spire and divide the crater into two equal basins along this axis. The northeast dike is the better preserved and is probably the origin of the name "Sawtooth Ridge." This feature rises 300 feet from the crater floor, the last 70 feet being a vertical wall. Breaching has occurred in each basin. Considerable rim erosion has taken place in the northwest basin, whereas the southeast basin has breached to form a narrow andesite-bound defile with resulting excellent rim profile preservation. The radial dikes extend from the central spire to the rim and terminate in what appears to be rim horns or secondary plugs. No extension of the dikes was apparent beyond the rim termination.

Three rock units were observed within the crater proper. The rim cap, central spire, and radial dikes are composed of platy andesite (Taif) like that in the shield section. This material is best exposed in the central spire, the northeast dike, and the southeast rim, which is almost completely capped by this resistant material. The central spire and dikes are characterized by steeply dipping to vertical platy joints (figures 7 and 8). The plates range in thickness from $\frac{1}{4}$ to 2 inches and separate rapidly on subaerial exposure.

Two outcrops of pyroclastic ejecta (Tp) are located within the crater (plate 1). The area on the floor immediately south of the central spire shows definite bedding planes dipping steeply away from the spire. Extensions of this outcrop were found in three backhoe exploration pits farther to the south and west where the angle of dip was significantly less. The second outcrop is located high on the north rim immediately beneath the platy andesite. Unfortunately, no bedding planes were evident at this location. The presence of a pyroclastic fraction was observed in backhoe pits well up the south rim, significantly above the crater floor. These rocks consist of sand- to pebble-sized pumice, cinders, and andesite fragments. Embedded within this material are numerous 2- to 6-inch scoria bombs. The individual grains are angular to subrounded. Gross color has the appearance of "salt and pepper" owing to the light pumice and the darker cinders and andesite. These pyroclastics are moderately to well cemented with some zones having a welded appearance. The lateral extent of this unit is obscured by the colluvial aprons; however, the presence of the outcrop along the rim above the crater floor seems to indicate lateral subrim extension. This is consistent with the conical emplacement of pyroclastics and lava flows during the build-up of a composite volcanic cone.

The lower interior slopes and the floor are mantled with colluvial aprons of platy andesite, pyroclastics, and their developing soil profile of clayey silt (Qcd).

Figure 5. Oblique aerial photograph showing rim curvature, dike, and central plug.

Figure 6. Northeast radial dike as seen from the central plug. Maximum relief above talus apron is approximately 70 feet.

Figure 7. Platy andesite of the northeast dike.

Figure 8. Platy andesite of the central plug.

Formation of the Crater

Most crater formation can be ascribed to one or a combination of the following four processes: impact, explosion, collapse, or differential erosion. In the case of the Sawtooth structure, the existence of the massive central plug and the well-defined radial dikes would preclude impact and explosion as modes of formation. Although the collapse theory can by no means be ruled out, the presence of the plug and dikes and the absence of precollapse ejecta surrounding or downwind from the crater seem to discount this origin.

The author feels that the observed geologic conditions are probably most consistent with the differential erosion process of crater formation. The presence of less resistant pyroclastic deposits, both on the crater floor and immediately underlying the platy andesite high on the northeast rim, provides the necessary erosional unit. It is recognized that their lateral extent is limited; however, a circular or conical type of deposition extending generally outward from a central vent is a reasonable explanation. With this initial structure, normal erosional processes would result in the present form once the protective andesite shield had been breached.

Summary

The objective of this report has been to locate and describe a well-defined crater structure in the Miocene lavas of northeastern Oregon. The preliminary reconnaissance indicates that the structure is erosional; however, the theory for a collapse origin cannot be positively discarded without further detailed investigations. The general geomorphic form is similar to previously described structures in south-central and southeastern Oregon.

The existence of such a well-defined feature in this particular part of the state is relatively unknown. Further investigation of the crater is anticipated; this should add considerably to knowledge of the origin and emplacement of the late Cenozoic lavas in northeastern Oregon.

References

Wagner, N.S., 1958, Important rock units of northeastern Oregon: The ORE BIN, vol. 20, no. 7, p. 63-67.

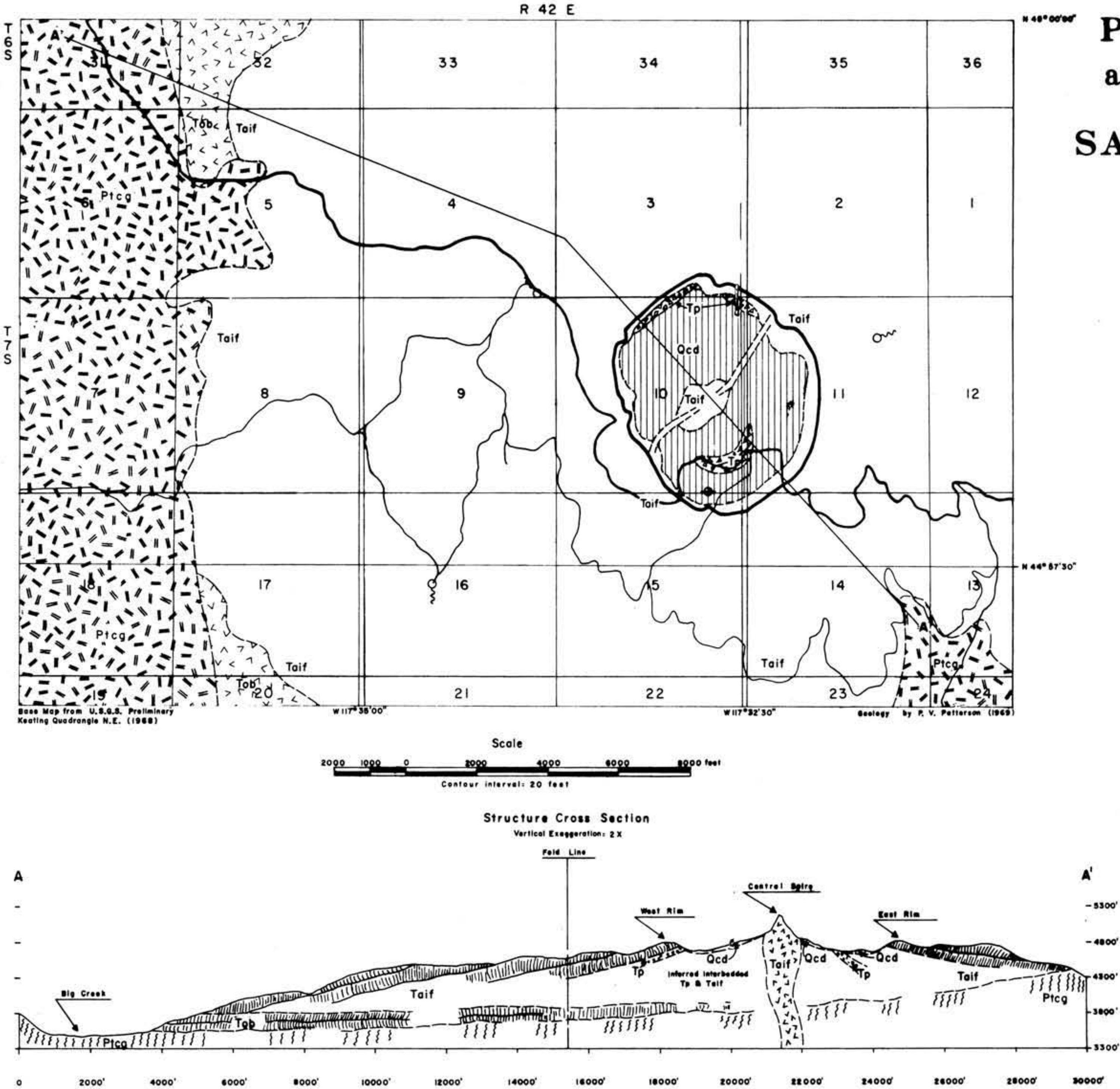
Bateman, R. L., 1961, Observations concerning Tertiary geology of northeastern Oregon: unpublished report.

Prostka, H. J., 1962, Geology of the Sparta quadrangle: Oregon Dept. Geology and Mineral Industries map GMS-1.

Gilluly, James, 1937, Geology and mineral resources of the Baker quadrangle, Oregon: U.S. Geol. Survey Bull. 879.

* * * * *

Plate 1. Geologic Map and Structure Section of SAWTOOTH CRATER Baker County, Oregon



LEGEND

Cenozoic

Qcd — Colluvial debris. Includes andesite talus, pyroclastic float and associated soil mantle

Taif — Andesite intrusives and flows. Includes the central plug, radial dikes and surrounding shield flows. Structure predominantly platy.

Tp — Pyroclastic debris. Beds of sand to pebble size pumice, andesite cinders, and associated ejecta. Generally dipping away from the central plug.

Pre-Tertiary

Tob — Olivine basalt. Flow on flow of vesicular, columnar, jointed basalt

Ptcg — Clover Creek Greenstone, (after Gilluly - Baker Quadrangle). Altered flows, pyroclastics and sediments forming the local basement.

Approximate formation contact.

Topographic rim of crater

Attitude of flows and pyroclastic beds.

Horizontal bed

Trace of structure section

Springs

Major / Minor — Access Roads

Map Area — OREGON

WORM-BORED POPLAR FROM THE EOCENE OF OREGON

By Irene Gregory*

That faithful, true-to-life detail may be retained during the process of petrification is shown by the photographs on the opposite page. The beautifully preserved and undisturbed chips of wood filling this worm burrow were formed in a poplar tree living about 40 million years ago during the Eocene in Oregon. The specimen (much enlarged) is of the genus Populus in the willow family (Salicaceae).

The worm tunnel was made by an insect larva of the flat-headed borer type of today. Its strong mandibles enabled it to carve out from the living poplar wood the typical crescent-shaped chips pictured "floating" in the clear chalcedony that was deposited in the borrow during petrification by silica-bearing ground waters.

The process of petrification of wood is not yet well understood, but, by this means, original cell structure is retained through some mineral (commonly silica) infiltrating the plant tissues. The nearly perfect preservation of detail that can result provides one of our most accurate tools for fossil-wood research.

In the specimen illustrated, structural features appear as clearly as in living wood, and minute anatomical details are retained in even the smallest chips carved out by the borer.

Some of the typical anatomical features of poplar wood preserved in this fossil specimen include growth rings delineated by somewhat larger vessels at the beginning of each ring; vessels small and in short radial rows of two to several; rays fine and close; and parenchyma limited to terminal.

As with many Tertiary woods of the Pacific Northwest, the over-all aspect of this specimen more clearly resembles Asiatic Populus of today than it does our living North American members of this genus. The living forests of Asia seem to have retained their Tertiary character, not only in the kinds of trees present but also in the anatomy and general aspect of their woods.

The specimen pictured is one of an assemblage of silicified Eocene woods occurring in an outcrop of the Clarno Formation in Crook County, Oregon. Woods from this area are being collected and studied by the author.

Selected References

Pearson, R. S., and Brown, H. P., 1932, Commercial timbers of India: Oxford, England, Oxford University Press.

Sudo, Syoji, 1959, Identification of Japanese hardwoods: Tokyo, Japan, Govt. Forestry Bull. No. 118.

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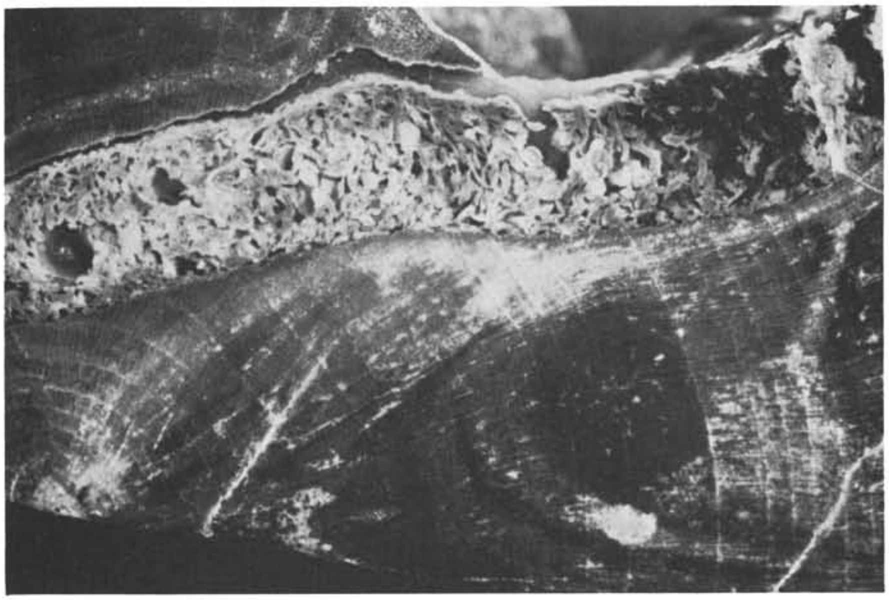
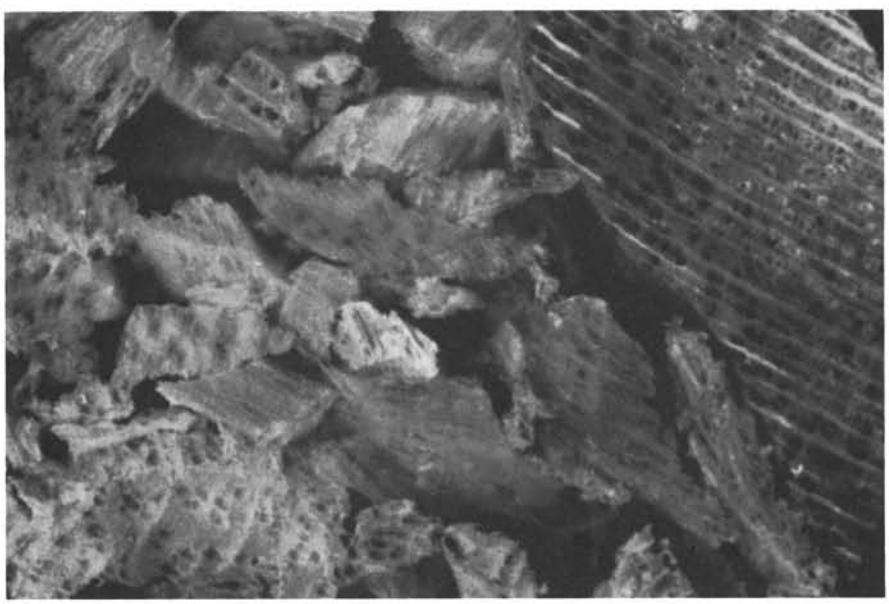
* Authority on fossil woods of Oregon and author of several articles in The ORE BIN.





Photomicrographs of silicified poplar wood showing tunnel and chips made by a wood borer during the Eocene Epoch. Upper picture 2.5 X enlargement; lower picture (portion of upper) 35 X enlargement. (Specimen preparation by Fred Roner and photography by Thomas J. Bones.)

See page opposite for story.

Oblique aerial view looking west across the Willamette River in the vicinity of Oregon City, showing the present valley of the Tualatin River on the left and the former route through Lake Oswego on the upper right. (Delano Photographics)

GEOMORPHOLOGY OF THE LAKE OSWEGO AREA, OREGON

Roger B. Parsons*

Baldwin (1957) has reported drainage changes of the Willamette and Tualatin Rivers near Lake Oswego, Oregon, and indicated that the Lake Oswego channel probably was formed during Illinoian time. The channel is considerably younger than Illinoian. Baldwin apparently did not fully consider the sequential geomorphic relations in establishing the Pleistocene chronology of the Lake Oswego area.

The purpose of this paper is to show how geomorphology may lead to a better understanding of the genesis of the Lake Oswego area and to provide an explanation for a seemingly unusual soil occurrence along the Tualatin River.

Regional Geomorphology

Geomorphic surfaces recently have been studied and mapped in the Willamette and the Tualatin River valleys (Balster and Parsons, 1968). The surfaces were mapped on high-altitude aerial photographs and visually traced throughout approximately 3000 square miles of the study area. Surfaces of particular interest in the Lake Oswego area, from oldest to youngest, are Senecal, Champoeg, Winkle, Ingram, and Horseshoe. Soils have been related to the geomorphology and can be arrayed in a developmental sequence with decreasing horizonation as one progresses to successively younger surfaces. However, Chehalis soils occur on both Winkle and Ingram surfaces.

Steep, active slopes in the Willamette Valley were mapped as the Looney unit typified by Looney Butte in Marion County. Areas of Looney cannot be placed in a chronological sequence and soils exhibit a wide range of development. Dolph and Eola surfaces (figure 1) are primarily remnants of once-extensive middle Pleistocene landscapes. Areas of these surfaces occur on Petes Mountain and south of the Tualatin Valley. Soils on Dolph and Eola surfaces are generally red, strongly acid, and have well-differentiated horizons. Since Dolph and Eola surfaces predate the Lake Oswego

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sequence, they are included in this discussion to complete the local geomorphology.

The Senecal surface constitutes the modified main valley floor as typified along Senecal Creek in Marion County. Deposits associated with the Senecal surface are Linn Gravel, Willamette Silts, and strata recently named Diamond Hill, Wyatt, Malpass, and Greenback (Balster and Parsons, in press). The Diamond Hill paleosol may be correlative to the well-known Troutdale Formation in the northern Willamette Valley. Soils that occur on the Senecal surface are in the Willamette, Woodburn, Amity, Concord, Holcomb, and Dayton series (Parsons, Simonson, and Balster, 1968). Dayton soils have been shown to be derived from the contrasting Greenback and Malpass deposits (Parsons and Balster, 1967).

The Champoeg surface is a lower lying modification of the Senecal surface and consists primarily of small, pediment-like landforms and deposits of sand and gravel. An area near Champoeg Park, about 2 miles southwest of Newberg, serves as the type locality. The base level to which the Champoeg surface was developing was stable for only a short time during the late Pleistocene (Balster and Parsons, 1968). Champoeg surface is not readily identified in the Willamette Valley south of Salem.

The Winkle surface occurs throughout the Willamette Valley and is the oldest surface obviously associated with present drainage systems. An area south of Winkle Butte in Benton County is the type locality. Soils developed on the Winkle surface have been dated (Reckendorf and Parsons, 1966) by C^{14} methods at 5,250 ± 270 years B.P.* Wood from deeper sediments beneath the Winkle surface has yielded a date of 10,850 ± 240 years B.P. (Balster and Parsons, 1968). The Winkle surface consists of terraces, abandoned lake beds, wind gaps, and the flood plain of the Tualatin River. In several localities, strata largely composed of pumice have been observed within soil profiles. The pumice is probably from Mount Mazama, since the ages for the Winkle surface are approximately correlative to dates for the Mazama eruption.

The Ingram surface is the high flood plain of the Willamette and most tributary rivers. Ingram Island in Benton County provides the name and type locality for the surface. The bar and swale topography of the Ingram surface, with point bars and oxbow lakes, is typical of recent flood plains. In general, the bars are not flooded, but swales may be inundated depending on the severity of flooding, the presence of log jams, dams, and other factors. This recent alluvium has been dated at approximately 555 years (Balster and Parsons, 1968). Direct correlation of surfaces suggests a possible maximum age for Ingram alluvium of 3,290 ± 120 years B.P. (Balster and Parsons, 1968). A study is presently being conducted on Ingram and Winkle surfaces in Lane County which should provide useful information about soil-geomorphic relationships on the high flood plain and low terraces.

The Horseshoe surface includes the present stream channels and annual

*Before present

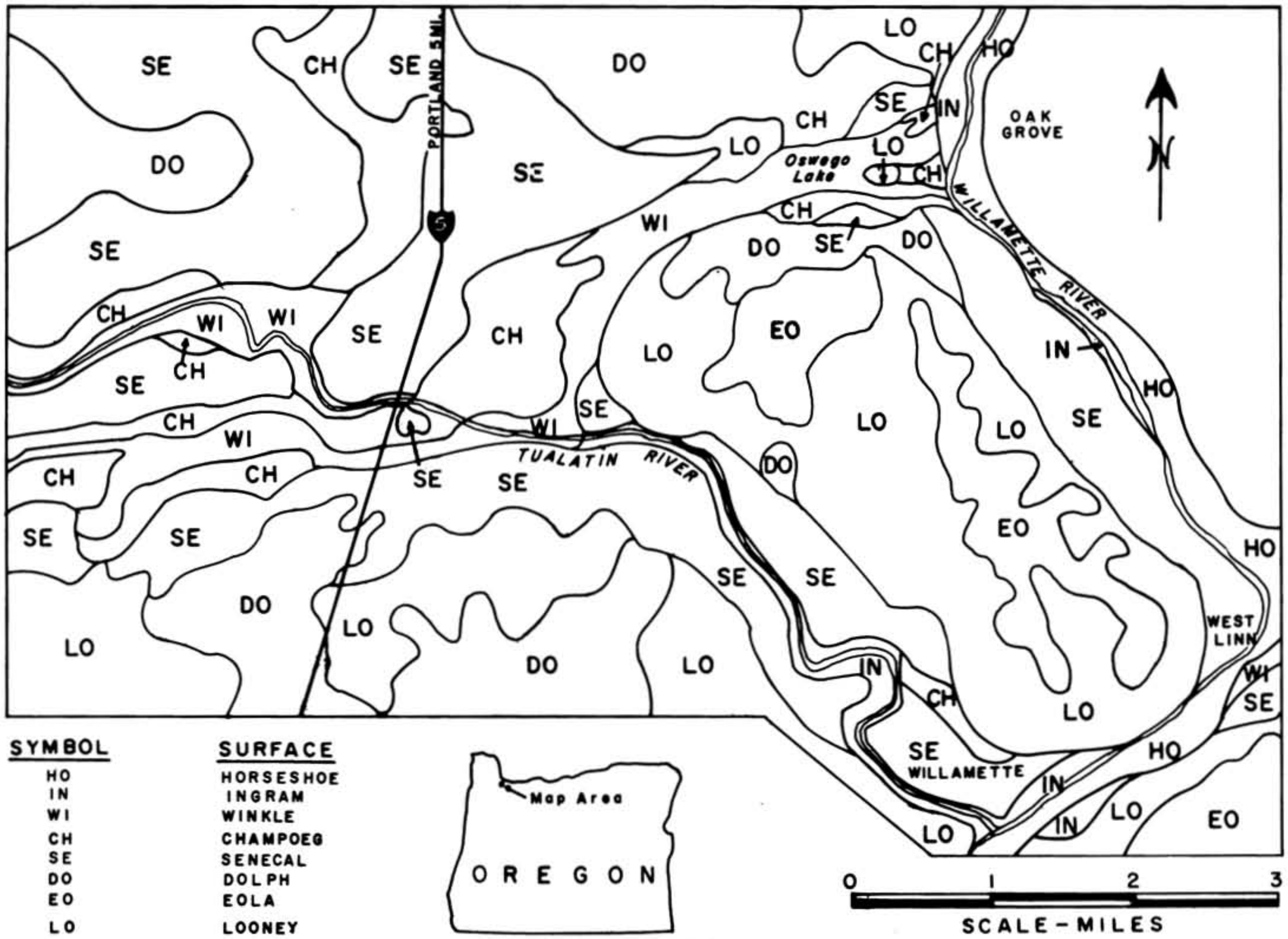

Figure 1. Geomorphic map of the Lake Oswego area.

flood plains and is believed to be post-settlement in age (Balster and Parsons, 1968). Horseshoe Island in the Willamette River in Benton County serves as the type locality. Sediments associated with the Horseshoe surface are primarily coarse-textured. Organic accumulation and weak structural development are the only evidences of soil formation.

Since in most localities the Winkle surface is a terrace, a question arises as to why the Winkle surface is a flood plain along the Tualatin River. Chehalis soils are generally encountered on the Ingram surface and lack the development of soils that occur on the older Winkle surface. However, Chehalis is the well-drained soil series on the Winkle surface along the Tualatin River.

Lake Oswego Geomorphology

The Lake Oswego valley between the Portland Hills and Petes Mountain had developed by the time the Senecal surface was formed. Small remnants of the Senecal surface are preserved along the edge of the Lake Oswego valley (figure 1) and truncate the older Dolph and Eola geomorphic surfaces.

Geomorphic relations may substantiate Baldwin's (1957) interpretation that the post-Troutdale (Senecal) drainage of the ancestral Willamette River flowed through the area presently occupied by the town of Willamette along the present lower reaches of the Tualatin River and joined the Tualatin River near the town of Tualatin at the west end of Lake Oswego. However, an alternative is that the Tualatin, during stages of development of the Senecal surface, flowed along its present course, joined the Willamette River at the town of Willamette, and the combined rivers then cut the rock-floored Senecal in the vicinity of West Linn and Oregon City. Subsequent uplift in the Petes Mountain area could have displaced the Tualatin River northward to the Champoeg-Winkle channel through Lake Oswego. Post-Senecal uplift of the Parrot-Chehalem Mountain area is suggested by bedding in Willamette Silts that gradually dips to the south in the vicinity of St. Paul. The Senecal surface rises gradually between Salem and Newberg and may have been caused by continued deformation along a structural trend across the valley from Oregon City to Chehalem Mountain (Balster and Parsons, 1968). Tectonic activity in the area has been described in some detail by Schlicker and Deacon (1967).

The flood event that eroded the present Oswego channel (Schlicker and Deacon, 1967) and truncated Willamette Silts on Senecal surface deposited the torrentially cross-bedded Portland Sands (Baldwin, 1957). This sand (and gravel) is associated with the Champoeg geomorphic surface. It is possible that the bedrock-floored Senecal surface in the vicinity of West Linn was completely scoured of Pleistocene alluvium during the flood torrent (Baldwin, 1957) which brought in the Portland Sands during the Champoeg episode.

The ancestral Tualatin River remained in its Champoeg channel and re-excavated Lake Oswego throughout the Winkle episode. The Winkle-age Tualatin channel effectively removed the Portland Sands, the lacustrine sand described by Schlicker and Deacon (1967). Then some mechanism, perhaps uplift of the area to the north or even backwater from the Columbia River, diverted the Tualatin from its Winkle-age Lake Oswego channel. A new Tualatin channel incised the Senecal surface, northwest of the town of Willamette, and was apparently the easiest course to the Willamette River. Baldwin (1957) suggests that plugging of the Lake Oswego channel by Portland Sands was probably responsible for the diversion of the Tualatin River. However, if the torrentially cross-bedded Portland Sands are a deposit related to the constructional Champoeg surface in the area, then the Winkle-age ancestral Tualatin River was able to make a course through the Portland Sands and Lake Oswego. Baldwin (1957) apparently did not consider the geomorphic development that occurred between the time the Portland Sands were deposited and the development of the present lower Tualatin channel, or in other words, the Winkle episode.

The Ingram surface has developed upstream on the Tualatin River to about the NW$\frac{1}{4}$ section 20, T. 2 S., R. 1 E., or about 4 miles upstream from its confluence with the Willamette River. The remainder of the present-day Tualatin flood plain is Winkle surface which is deeply incised by the meandering Tualatin channel. The channel is comparatively straight on the lower reaches of the Tualatin River where the Ingram surface has developed. The Tualatin River above Section 20 has a hanging valley. Horseshoe surface, the channel itself, is unable to carry the large volume of flood water. Therefore, the channel quickly fills to overflow and inundates the Winkle surface. Periodic flooding with accompanying sedimentation effectively inhibits soil horizonation. With continual renewal by additional alluvium, particularly alluvium containing considerable quantities of organic matter, soil development is retarded. Hence, Chehalis and other soils lacking B horizons with clay illuviation are encountered on Winkle surface in the Tualatin Valley, whereas more developed soils are commonly found on Winkle throughout the Willamette Valley (Balster and Parsons, 1968).

Summary

Geomorphology provides a means of developing a sequence of events. Study of soils and geomorphology in the Tualatin Valley indicates that the abandonment of the Lake Oswego channel was not nearly as long ago as Baldwin suggests but may have been between 3290 and 5250 years ago. Throughout the Willamette Valley, Winkle surfaces now exist as terraces, peat bogs, or wind gaps. Examples of Winkle surfaces in the Willamette Valley area are Richardson Gap in Linn County, Lake Labish in Marion County, typical stream terraces in Benton County, and Lake Oswego in

Clackamas County.

Pleistocene stages in the Lake Oswego area are late Wisconsin and Recent. The Senecal and Champoeg surfaces are late Wisconsin, whereas the Winkle and Ingram surfaces are about 5250 and 555 years old, respectively.

References

Baldwin, E. M., 1957, Drainage changes of the Willamette River at Oregon City and Oswego, Oregon: Northwest Sci., v. 31, no. 3, p. 109-117.

Balster, C. A., and Parsons, R. B., 1968, Geomorphology and soils, Willamette Valley, Oregon: Oregon State Univ. Spec. Rept. 265.

__________________, in press, Late Pleistocene stratigraphy, southern Willamette Valley, Oregon: Northwest Sci.

Parsons, R. B., and Balster, C. A., 1967, Dayton - a depositional planosol, Willamette Valley, Oregon: Soil Sci. Soc. Am. Proc. 31:255-258.

Parsons, R. B., Simonson, G. H., and Balster, C. A., 1968, Pedogenic and geomorphic relationships of associated Aqualfs, Albolls, and Xerolls in western Oregon: Soil Sci. Soc. Am. Proc. 32:556-563.

Reckendorf, F. F., and Parsons, R. B., 1966, Soil development over a hearth in Willamette Valley, Oregon: Northwest Sci., v. 40, no. 2, p. 46-55.

Schlicker, H. G., and Deacon, R. J., 1967, Engineering geology of the Tualatin Valley region, Oregon: State of Oregon Dept. Geology and Mineral Industries Bull. 60.

* * * * *

REYNOLDS METALS ACQUIRES ALCOA PROPERTIES

Reynolds Metals Co. announces that it has acquired from the Aluminum Co. of America bauxite properties in Washington and Oregon, some of which are adjacent to present Reynolds holdings. Counties where property was acquired include Columbia, Washington, and Multnomah in Oregon, and Cowlitz in Washington.

Deposits of high-iron bauxite were discovered by the State of Oregon Department of Geology and Mineral Industries in the Tualatin Hills of Washington County in 1943. After the results of test drillings in this area were published (Department Bulletin 29, "Ferruginous bauxite deposits in northwestern Oregon," by F. W. Libbey and others), Alcoa Mining Co. conducted a long-range exploration and drilling program which led to the acquisition of the properties recently purchased by Reynolds.

* * * * *

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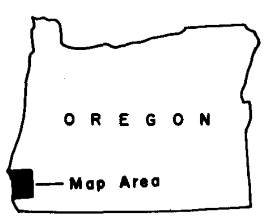
DIORITE INTRUSIONS BETWEEN SIXES AND PISTOL RIVERS, SOUTHWESTERN OREGON

Ernest H. Lund and Ewart M. Baldwin*

Introduction

Many small stocks and irregularly shaped plutons of dioritic composition are present between the Sixes and Pistol Rivers in Curry and Coos Counties in southwestern Oregon. The plutons have been of interest as a possible source of gold. The junior author paid particular attention to the location and shape of these plutons during an investigation of heavy minerals which was supported by a grant for the U.S. Geological Survey (Baldwin and Boggs, 1969). Geologic maps of the Agness quadrangle and the Powers quadrangle are in preparation.



Pioneer work in this part of Oregon was done by Diller (1903), who mapped the 30-minute Port Orford quadrangle. The northern two-thirds of the region discussed in this paper is included in this quadrangle. Difficulties encountered by Diller in mapping such a large, rugged area which had few roads resulted in some striking errors in contacts, a situation that can readily be appreciated by those working there now. Diller included the greenstone and associated small gabbroic intrusions at Rusty Butte and those in the upper part of Elk River with some of the dioritic rock. Dott (1966) mapped in reconnaissance a smaller area showing the headwaters of the South Fork of the Sixes River and the North and South Forks of Elk River. He recognized more diorite than did Diller, but he included without appreciable change many of Diller's contacts. Both show a belt of intrusive rock trending eastward across the forks of Elk River, but no diorite was found in this area by the junior author. Only small, for the most part landslide, blocks of greenstone are present.

Intrusions of altered gabbro are also common, but most appear to be associated with the Galice greenstone and probably represent small dikes

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and plugs that may have acted as feeders. Similar bodies, perhaps even more altered, are in the Colebrooke Schist. Most of these bodies may be readily separated from the younger dioritic intrusions, and they are not shown on figure 1. One large intrusion extending from the north fork of Lobster Creek eastward through Boulder Creek was tentatively mapped with the diorites (figure 1), but petrographic examination shows that it is related to the gabbros.

Burt (1963) mapped the Collier Butte area and shows the intrusion as a diorite plug in serpentine. Koch (1966) mapped the Port Orford and Gold Beach 15-minute quadrangles and described the Pearse Peak pluton. It is the largest and most accessible pluton and therefore serves as a type for correlation. Baldwin (1968) mapped the area that includes Gray Butte and the pluton at Game Lake Lookout.

Most of the intrusive bodies were emplaced during the Nevadan orogeny and correlate with the Pearse Peak pluton both in age and general composition, but several are questionable. Although Pearse Peak yielded K-Ar dates for biotite (Kulp in Koch 1966, p. 53) of 141 ± 7 m.y. and 146 ± 4 m.y., it also yielded an anomalous date based on hornblende of 275 ± 20 m.y. (Koch, 1966). The Saddle Mountain-Lawson Creek pluton yielded a date of 285 ± 25 m.y., also on the basis of K-Ar from hornblende (Koch, 1966, p. 53).

The writers acknowledge the support of field work by the U.S. Geological Survey and advice by H. E. Clifton of the U.S. Geological Survey.

Petrographic Procedure

In the rocks for which a mode was determined, 1000 points were counted. All the rocks examined are hydrothermally altered in varying degree, and the secondary minerals were counted along with the minerals from which they were derived. In some rocks where biotite has been almost completely converted into the secondary minerals chlorite, epidote, and white mica, it appears in the mode though not in the rock in its present state. It is recognized that some secondary minerals draw their components from more than one source mineral and that for some grains the parent mineral is not definitely known. These conditions introduce some error into the determination of the mode, but it is believed that the error is small and that the modes as stated are fair representations of the original rock compositions (table 1).

Pearse Peak and Related Plutons

Pearse Peak pluton (1)*

The rock of the Pearse Peak pluton is a medium gray, medium granitoid,

* Numbers refer to map locality (see figure 1).

Table 1. Modes of quartz diorites (volume percentages).

Locality	Pearse Peak	Benson Creek			Josh Creek		Dixie Creek	Granite Peak	Johnson Creek	Gray Butte	Lawson Creek
	1	2	3	4	5	6	7	8	9	10	11
Andesine	59	60	63	62	64	60	62	55	54	63	57
Quartz	15	13	17	17	13	12	15	15	10	21	21
Orthoclase	4	3.5	2	4	6	3	5	6	2	0	0
Hornblende	15	16	11	10	11	17	10	14	30	10	16
Biotite	7	7	5	6	5	7	7	9	2	5	5
Minor accessories	tr	0.5	2	2	1	1	1	1	2	1	1
(Magnetite, apatite, zircon, sphene)											

1. BPO 67-1B Along Elk River road at the mouth of Platinum Gulch.
2. BP 67-1 Where Rusty Butte logging road meets Benson Creek drainage; edge of pluton at west side of saddle.
3. BP 68-16 Along logging road that skirts north side of Benson Creek west of saddle and BP 67-1 locality.
4. BP 68-33 Logging road that follows south side of Benson Creek. Second saddle west of its crossing at the extreme end of Benson Creek.
5. BP 67-24 At mouth of Josh Creek a few yards above its junction with Benson Creek.
6. BP 67-23 At 1600-foot elevation in upper Josh Creek.
7. BP 67-3 In Dixie Creek a few yards above the junction of Dixie Creek and Benson Creek.
8. BP 68-37 In Granite Creek on north edge of Granite Peak.
9. BP 67-31 In Johnson Creek a short distance below the mouth of Poverty Gulch and above the mouth of a small tributary called Boulder Creek.
10. BCB 67-8 The extreme tip of Gray Butte.
11. BCB 69-1 By waterfall in narrow gorge about 150 yards below prominent forks in upper Lawson Creek. Pluton extends into Saddle Peak.

equigranular, massive quartz diorite. Minerals identifiable in hand specimen are plagioclase, quartz, hornblende, and biotite. Orthoclase, present in minor amount, is not readily distinguishable in hand samples of the Pearse Peak rock.

Significantly abundant minerals, the amounts of which are shown in table 1, are plagioclase (andesine), quartz, hornblende, and biotite. Orthoclase is present but not in essential amounts, and minor accessories include magnetite, apatite, zircon, and sphene.

The plagioclase is distinctly zoned, with some grains showing oscillatory zoning, and its average composition is about medium andesine, perhaps a little on the sodic side of the midpoint in the andesine range. The grains are mainly subhedral but range from anhedral to nearly euhedral. The mineral has been considerably altered to sericite and lesser amounts of zoisite, and alteration is compositionally controlled. The central calcic part of most grains is altered, and the more sodic outer rim is generally clear. In the grains that show oscillatory zoning, bands of alteration reflect the compositional zoning.

Hornblende is mainly in subhedral grains, and shapes range from anhedral to euhedral. It is mostly unaltered and clear, but a few grains have small amounts of chlorite and epidote.

Biotite was derived from hornblende during the late magmatic stage and is closely associated with hornblende. Much of it is fresh, but a considerable amount has been altered to chlorite, epidote, and an unidentified colorless mineral, the optical properties of which suggest prehnite. This colorless mineral occurs in elongate lenses that lie along the cleavage planes of the biotite and appears not so much a product of alteration as something introduced. Its growth has forced apart the folia of biotite to conform to the shape of the mineral lenses. Alteration in most biotite grains is only partial, but some have been completely converted to secondary minerals.

Quartz is anhedral and, like orthoclase, occupies interstices between the earlier-formed hornblende and plagioclase. The mineral is clear except for liquid gas inclusions, which occur in irregular patches and in alignment.

Orthoclase crystallized at about the same time as quartz and is in anhedral grains, the shapes of which are determined by the interstices between the plagioclase and hornblende. Except for small inclusions and possibly incipient kaolinization, the mineral is clear and has not undergone the hydrothermal alteration that affected the plagioclase.

According to the mode of one Pearse Peak sample, the rock is classified as hornblende-biotite quartz diorite. Though it is near granodiorite, there is not quite enough orthoclase to place it in this class.

Benson Creek pluton (2 - 7)

Samples from a quartz diorite intrusion, here referred to as the Benson

Creek pluton, were collected from localities on Benson, Josh, and Dixie Creeks. The rock of this pluton is almost identical to that of the Pearse Peak pluton, both megascopically and microscopically. The minerals and their paragenesis are the same, and the percentages of six samples fall within expected limits of randomly collected samples. Secondary minerals are the same and bear the same relationship to the magmatic minerals as do those in the Pearse Peak rock.

Granite Peak pluton (8)

In hand sample the rock of the Granite Peak pluton closely resembles that of Pearse Peak. One small difference is in the color of the orthoclase, which in the rock of Granite Peak is pale pink and readily identifiable because of its contrast with the gray plagioclase. The most significant difference in the rock is the extent of hydrothermal alteration. The biotite has been almost completely converted to chlorite and epidote, and the plagioclase has been considerably sericitized, except for a thin, clear outer zone in most grains. Hornblende is generally fresh looking, but parts of some grains have altered to chlorite. The orthoclase has not been significantly changed. The rock is cut by small veinlets consisting mainly of quartz, and the presence of these veinlets offers a clue to the reason why this rock is more intensely altered than rock in other plutons of the Pearse Peak type.

Johnson Creek pluton (9)

The rock of the Johnson Creek pluton is similar to that of Pearse Peak in both texture and mineral composition, but certain variations were noted. The most significant difference is in its much higher content of hornblende -- 30 percent in the one sample examined in contrast to a maximum of 17 percent in the other samples of this rock type. It is correspondingly lower in all the other essential minerals. And, in addition, the hornblende has more of a tendency to form euhedral grains than it does in rocks of the other plutons.

Gray Butte and Lawson Creek plutons (10 and 11)

The body in upper Lawson Creek also makes up much of Saddle Mountain and is referred to by Koch (1966) by that name. The writers were unable to map the extent of the pluton, so the shape as shown on figure 1 is approximate. In hand specimen the rock of these plutons is not readily distinguishable from that of Pearse Peak. In thin section, however, certain mineral differences become apparent, the most significant of which is the absence, or near absence, of orthoclase. None was identified with certainty.

Other primary minerals in the rock of the Gray Butte and Lawson

Creek plutons are essentially the same as in the other quartz-diorite intrusions. The secondary hydrothermal minerals are the same in kind and bear the same relationship to the primary magmatic minerals as do the secondary minerals of the other plutons. Notably different is the large amount of epidote and the large size of many of its grains in the rock of both plutons. In the Lawson Creek sample, epidote makes up about 10 percent of the total rock and was derived by the alteration of both andesine and the ferromagnesian minerals. The largest grains of epidote are closely associated with the ferromagnesian minerals, but it is abundantly represented in the plagioclase.

Original biotite has been almost completely converted to secondary minerals. These are mainly chlorite and epidote, but considerable white mica is associated with the chlorite and is presumably of hydrothermal origin.

The plagioclase is badly altered, much of it almost beyond recognition, and the sericite formed from it is unusually coarse grained.

Samples from both plutons have small veinlets. In the Lawson Creek sample, the vein minerals are carbonate, epidote, and quartz; in the Gray Butte sample, the main vein mineral is the colorless mineral, believed to be prehnite, associated with biotite in the other quartz diorite samples.

Iron Mountain pluton (12)

The rock of the Iron Mountain pluton is Pearse Peak type quartz diorite. In hand specimen it resembles the Pearse Peak rock, though it is of somewhat lighter color. A sample (BAg 68-5) from the southern end of the mountain near a mining claim on a large quartz vein was examined, but a mode was not made because the rock has been considerably modified through clastic deformation. The development of mortar structure in which the mineral grains are small and the conversion of all the original ferromagnesial silicates to chlorite and epidote make a meaningful mode difficult to determine.

Most of the plagioclase has been very much altered to coarse-grained sericite, zoisite, and epidote. However, enough of it is sufficiently fresh to reveal its composition as medium andesine. Orthoclase, if present, was not identified.

Miscellaneous Plutons

Sixes River Middle Fork pluton (13)

A rock body of undetermined form and affinities on the Middle Fork of the Sixes River has textural similarity to the Pearse Peak quartz diorite but differs significantly in mineral composition.

The rock, a sample (BP 67-27) of which was collected where the

Middle Fork of the Sixes River crosses an east-trending dike that bisects Salmon Mountain, is composed of 57 percent plagioclase, 18 percent orthoclase, 20 percent hornblende, and 3 percent biotite. Accessories amounting to 2 percent of the rock include quartz, abundant sphene, apatite, and very little magnetite. Accordingly, it is a hornblende syenodiorite.

The plagioclase is medium andesine in anhedral and subhedral grains and is much altered to sericite and zoisite.

Hornblende is mostly subhedral, but ranges from anhedral to euhedral. Most of the grains are more or less poikilitic, with included chlorite and epidote and some plagioclase. Closely associated with hornblende are patches of chlorite and epidote, and the texture of the chlorite indicates it is pseudomorphous after biotite. The chlorite and epidote included in the hornblende grains are believed also to be originally biotite rather than secondary minerals derived from the hornblende, which is fresh looking except for iron oxide stains from weathering.

The orthoclase is anhedral and fills interstices between hornblende and plagioclase. In places it embays plagioclase, and some grains have inclusions of plagioclase and hornblende. It is dusty appearing from kaolinization but has not been hydrothermally altered.

A very small amount of quartz crystallized late, probably at the same time as the orthoclase, and it occupies interstices between plagioclase and hornblende. The presence of essential orthoclase and the lack of essential quartz set this rock apart from the Pearse Peak and related quartz diorites, though conceivably it could be a facies variation.

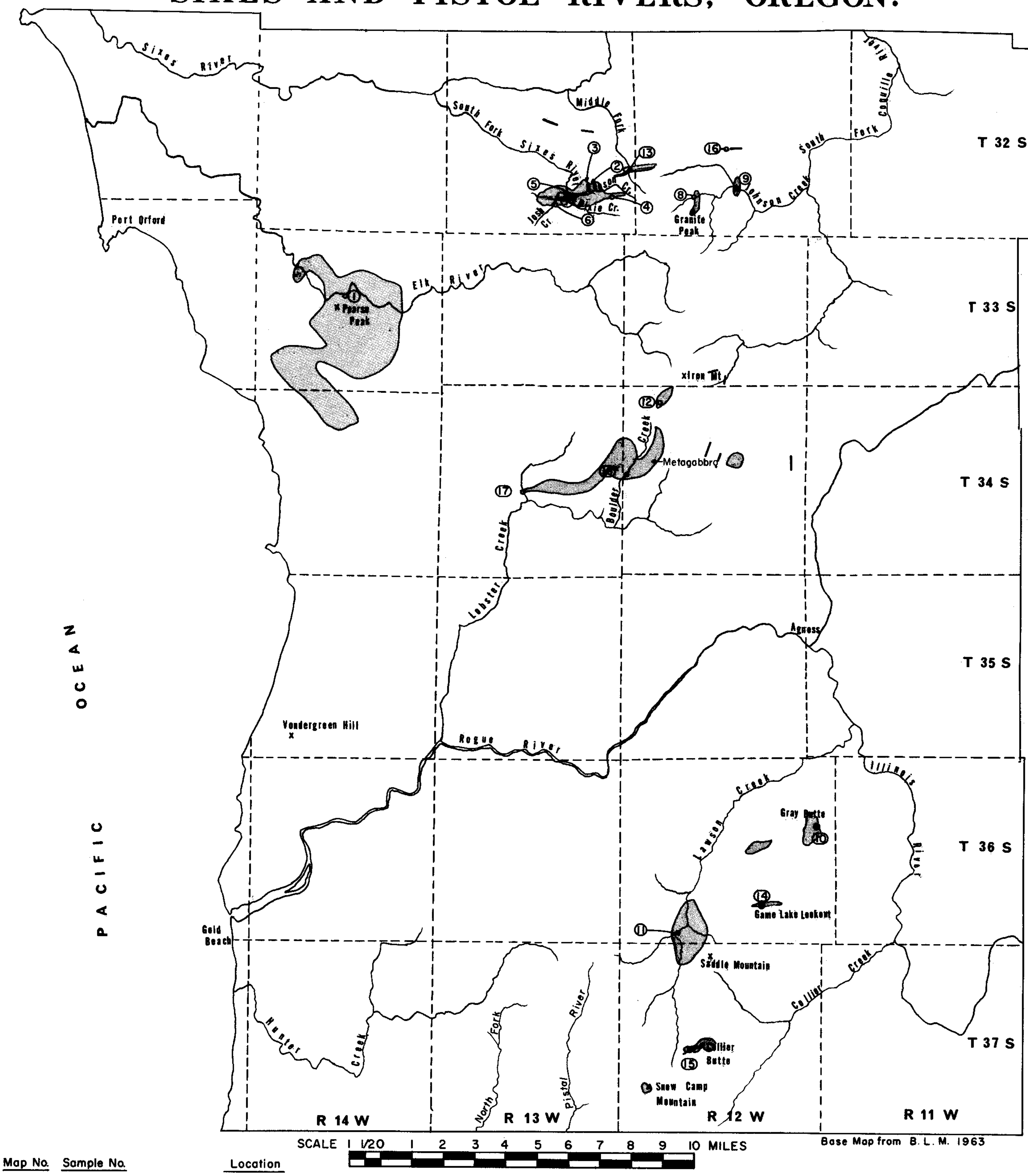
Game Lake Lookout pluton (14)

The rock of the Game Lake pluton is very light colored and has a medium granitoid texture. It was probably originally a massive igneous rock. but cataclastic deformation has imparted to it a trace of gneissic structure. This may not be readily apparent in a freshly broken sample, but the pattern stands out on a weathered surface, especially one with small bits of moss or lichen growing on it. In thin section the cataclastic aspect is apparent in mortar structure, bent muscovite grains and twin lamellae of plagioclase, and broken plagioclase grains.

The mineral composition of the Game Lake rock (BCB 67-1), collected at the site of the former Game Lake Lookout, is 49 percent plagioclase, 38 percent quartz, 12 percent muscovite, and a trace each of orthoclase and biotite. Zircon and apatite are accessories in minute quantities.

The plagioclase is zoned, and its average composition is estimated to be medium oligoclase but on the sodic side of the mid-point in its range. According to the classification of Johannsen (1939), the rock is a tonalite (or quartz diorite). The presence of the varietal mineral muscovite, the virtual absence of ferromagnesian minerals, and the cataclastic texture

FIGURE 1. DIORITE INTRUSIONS BETWEEN SIXES AND PISTOL RIVERS, OREGON.



Map No.	Sample No.	Location
1.	BPO 67-1B	Pearse Peak pluton
2.	BP 67-1	Benson Creek (Benson Cr. pluton)
3.	BP 68-16	Benson Creek (Benson Cr. pluton)
4.	BP 68-33	Benson Creek (Benson Cr. pluton)
5.	BP 67-24	Josh Creek (Benson Cr. pluton)
6.	BP 67-23	Josh Creek (Benson Cr. pluton)
7.	BP 67-3	Dixie Creek (Benson Cr. pluton)
8.	BP 68-37	Granite Peak pluton
9.	BP 67-31	Johnson Creek pluton
10.	BCB 67-8	Gray Butte pluton
11.	BCB 69-1	Lawson Creek pluton
12.	BAg 68-5	Iron Mountain pluton
13.	BP 67-27	Sixes River, Middle Fork pluton
14.	BCB 67-1	Game Lake pluton
15.	BCB 68-2	Collier Butte extension
16.	BP 68-38	Johnson Creek quarry
17.	BAg 67-7	Lobster Creek metagabbro
18.	BAg 69-1	Boulder Creek metagabbro

LEGEND

Location of plutons

Dikes and dike like bodies

mean that the rock could be called either a gneissic muscovite leucotonalite or a muscovite tonalite gneiss. Because the clastic metamorphism has done little to destroy the igneous characteristics of the rock, the writers prefer to call it a tonalite (quartz diorite) rather than tonalite gneiss or quartz diorite gneiss. In a classification such as that of Grout (1932), in which the plagioclase series is divided into three parts and where the first division comes at An_{20}, this rock would be in the granite clan. Under this classification the rock could be called a muscovite sodic leucogranite. Because potash feldspar is the usual feldspar of granites, some readers may take exception to calling a rock that lacks essential potash feldspar a granite.

Collier Butte (extension) (15)

A rock sample (BCB 68-2) from the quarry a mile west of Collier Butte on Game Lake road is a light gray porphyry with plagioclase and quartz phenocrysts in an aphanitic groundmass of plagioclase, quartz, and muscovite. The rock has been sheared, and surfaces with slickensides are common. In thin section some plagioclase grains are seen to be bent and broken, and there is some mortar structure; however, it is not easy to distinguish minerals in the mortar structure from the groundmass minerals.

The plagioclase phenocrysts are of medium andesine composition. The euhedral and subhedral shapes of many grains are still discernable, but the borders of the grains have been encroached upon by groundmass minerals so that boundaries are not distinct planes. The mineral has been sericitized, and much of the sericite is in comparatively large grains.

The quartz phenocrysts show effects of resorption in their much-rounded shapes, and boundaries are irregular because of encroachment of groundmass minerals. The highly undulatory extinction of the quartz probably is another reflection of the stress to which this rock was subjected.

Muscovite is a matrix mineral and occurs in aggregates of small grains rather than in single discrete grains. Much of it has intimately associated chlorite, suggesting original biotite, but none of the biotite remains.

In addition to the sericite and chlorite, zoisite and epidote are secondary minerals present in small amount. Zircon and apatite are accessories in minute quantities.

The composition of the groundmass plagioclase was not determined because of its small grain and altered condition, so an estimate of its anorthite content was not attempted. Based on the composition of the phenocrysts, the rock is classified as porphyritic muscovite dacite. This rock, which may be in an offshoot of the rock body at Collier Butte, is similar to that near Game Lake in its muscovite content and very low content of iron minerals and could well be genetically related, in spite of the textural difference.

Rock in quarry on Johnson Creek road (16)

This rock (BP 68-38), sampled at a small roofing granule quarry at the head of Ragsdale Creek, a short tributary of Johnson Creek, is a light-colored, fine-grained porphyry with plagioclase and some quartz phenocrysts in a groundmass of quartz, plagioclase, and the secondary minerals epidote, zoisite, chlorite, and white mica. Only a trace of original biotite remains, and no hornblende is present. A modal analysis was not made, but the rock is clearly a dacite porphyry.

The plagioclase in the phenocrysts is medium andesine, mostly in subhedral grains but ranging in shape from anhedral to euhedral. Though the general shapes of the grains are still retained, the boundaries are irregular because of encroachment by groundmass minerals. Grains have been altered in varying amounts to sericite, zoisite, and epidote. Some are affected very little, and others are largely destroyed by alteration.

Quartz is not as abundant as plagioclase in the phenocrysts but nearly equal to it in the groundmass. Phenocryst grains are corroded and embayed by the groundmass minerals.

The secondary minerals chlorite, epidote, zoisite, and white mica occur together in aggregates. A cluster may be predominantly one mineral, but generally two or three minerals are together. These minerals, except where clearly embodied in plagioclase grains, are secondary after original ferromagnesian silicates. Some clusters have a trace of biotite, which is a clue to their parent material. These clusters are mainly white mica with lesser amounts of chlorite and other secondary minerals. Aggregates of this combination embody most of the secondary mineral matter outside the plagioclase. A few large clusters composed mostly of epidote may have been derived from hornblende.

Lobster Creek-Boulder Creek metagabbro (17 & 18)

Lying in the drainage area of the North Fork of Lobster Creek and Boulder Creek is a body of rock of mafic composition. The rock (BAg 67-7 collected on the North Fork of Lobster Creek a short distance above the main forks, and BAg 69-1 collected on Boulder Creek, a prominent tributary of the South Fork of Lobster Creek, where road survey line reaches Boulder Creek) in hand specimen has a texture that appears igneous, though its general appearance gives the impression of its having been altered. Olive-green crystals of medium grain size are surrounded by a milky white, granular groundmass.

In thin section the rock is seen to consist largely of secondary minerals. Original monoclinic pyroxene is still present, but much of it has been altered to tremolite. Many grains have been completely converted to tremolite pseudomorphs, and others have been altered in varying amounts. Shapes of tremolite pseudomorphs and partly altered pyroxene grains suggest that the original pyroxene was in euhedral and subhedral grains.

Around the pyroxene and tremolite is zoisite, much of which is in well-developed crystals of the variety with anomalous blue interference color. Associated with the zoisite is a little epidote and probably other secondary minerals not identified. It is very likely that these minerals are secondary after original plagioclase, though none of this mineral remains.

Shear stress, if present during the time the rock was undergoing alteration, did little to impart a planar structure, and in hand specimen there is only a suggestion of mineral grain alignment.

Recrystallization has changed the texture and mineral composition of this rock to such a degree that it should be considered metamorphic. Assuming that zoisite and related minerals represent original plagioclase of calcic composition, the rock is classed as a metagabbro.

Summary and Conclusions

Petrology

Diorite and dacite intrusions lying in the drainage area of the Rogue River and the southern part of the drainage area of the Sixes River in Coos and Curry Counties are of two general types. The most numerous are small diorite plutons that range in size from a few hundred yards to several miles across and are roughly oval to irregular in shape. Dikes or dike-like bodies of dacite are the other type, and they may be apophyses of the larger plutons. The position and age of the intrusions with respect to intruded formations suggest they are epizonal. Textures of the two types are different; the texture of the rock of the plutons is medium granitoid and equigranular, and that of the dikes is porphyritic. Mineralogic similarity between dikes and nearby plutons suggests a genetic relationship between the two types.

The rock of most of the plutons is quartz diorite, and textural and mineralogic similarity between a number of them indicates a common origin. The largest is the Pearse Peak pluton. It was the first to be named and described, and for this reason, and for the reason that its rock is representative of the rock in the several plutons, it is designated as the "type" quartz diorite of this group of related intrusive bodies.

The rocks of three plutons studied differ somewhat from the Pearse Peak type in mineral composition but are like it in texture and general field appearance. One of these is in a pluton on Lawson Creek, and another is at Gray Butte. The rocks of both lack potash feldspar, but otherwise are like the Pearse Peak in mineral paragenesis and texture and are not readily distinguishable from it in the field.

The rock in a small pluton on the Middle Fork of the Sixes River differs significantly from the Pearse Peak in its lack of essential quartz. The other minerals and their paragenesis are the same as the Pearse Peak and the textures are similar. Its affinities are uncertain, but it may be a differentiate of the magma from which the Pearse Peak quartz diorite crystallized. This idea is supported by the proximity of this intrusion to intrusions of the Pearse Peak type.

The rock in the intrusion at Game Lake Lookout is either a quartz diorite or a granite, depending on which classification is used. The sodic oligoclase and the varietal mineral muscovite set this rock apart from the Pearse Peak quartz diorite. A porphyritic rock in a dike-like body west of Collier Butte is similar mineralogically and is probably genetically related to that in the Game Lake Lookout pluton.

An elongate rock body that lies along the drainage divide between the North and South Forks of Lobster Creek and in the drainage area of Boulder Creek is a highly altered gabbro. Some original pyroxene remains, but most of it has been converted to tremolite, and original plagioclase has been completely altered, principally to zoisite. This rock is classified as a metagabbro.

Age and correlation

The intrusive bodies of southwestern Oregon seem to fall into two general groups by rock type: 1) the dioritic intrusions discussed in this paper, and 2) gabbroic intrusions that appear to be associated with the Galice greenstone and the Colebrooke Schist. Diller (1903) included areas of greenstone and sedimentary rocks with gabbro and diorite.

In most instances the two rock types may be distinguished megascopically in the field. However, there are several that need closer inspection. The altered pluton between the North Fork of Lobster Creek and Boulder Creek, although initially mapped with the younger intrusions, appears to be related to the older gabbros. There is a small intrusive body surrounded by serpentine under the Snow Camp Mountain Lookout. This is sheared and somewhat altered and is of questionable age. There is always the possibility that some of the plutonic rock was brought in with the encompassing serpentine. According to Koch (1966, p. 52) several severely deformed quartz diorite bodies are present along the coast near Otter Point and Vondergreen Hill. He concludes that the pluton on the southwestern side of Vondergreen Hill was perhaps dragged upward during intrusion of the ultramafic body. Cataclastic structure in the Game Lake body points to post-intrusive deformation of the body. Diorite float occurs in the North Fork of Rock Creek on the east flank of Iron Mountain. It is similar to that at the south end of the mountain. Small masses are shown on figure 1 that are not discussed.

Most of the dioritic plutons intrude pre-Nevadan formations but nowhere are they definitely known to intrude post-Nevadan formations. Koch (1966) found abundant clasts of Pearse Peak diorite in the basal early Cretaceous Humbug Mountain conglomerate along Elk River. This evidence plus K-Ar dates ranging between 140 and 150 m.y. place the time of intrusion of Pearse Peak and allied plutons within the span of the Nevadan orogeny. K-Ar dates, based on hornblende, of more than 200 million years do not seem tenable, for neither the Pearse Peak nor the Lawson Creek-Saddle Mountain pluton is as internally deformed as one might expect with thrusting, a probable condition for a pre-Mesozoic age. Both are petrographically similar. Although the plutons on the north end of Iron Mountain and on Gray Butte are entirely surrounded by serpentine, and may have been brought in with the ultramafic rock, it is the authors' opinion that these plutons were intruded after emplacement of the serpentine.

References

Baldwin, E. M., 1968, Geology of the Horse Sign Butte blacksand deposit and vicinity, Curry County, Oregon: The ORE BIN, v. 30, no. 3, p. 45-54.

Baldwin, E. M., and Sam Boggs, Jr., 1969, Study of heavy metals and heavy minerals on the southern Oregon coast: U.S. Geol. Survey Rept. no. 2, submitted to Office of Marine Geology and Hydrology, Contract No. 14-08-001-11058, p. 1.

Burt, W. D., 1963, Geology of the Collier Butte area, southwest Oregon: Univ. Wisconsin master's thesis, 93 p., unpub.

Diller, J.S., 1903, Description of the Port Orford quadrangle: U.S. Geol. Survey Geologic Atlas, Port Orford Folio, No. 89.

Dott, R. H., Jr., 1966, Late Jurassic unconformity exposed in southwestern Oregon: The ORE BIN, v. 28, no. 5, p. 85-97.

Grout, F. F., 1932, Petrography and petrology: New York, McGraw-Hill Book Co., 522 p.

Koch, J. G., 1966, Late Mesozoic stratigraphy and tectonic history, Port Orford-Gold Beach area, southwestern Oregon coast: American Assoc. Petroleum Geologists Bull., v. 50, no. 1, p. 25-71.

Johannsen, A. J., 1939, A descriptive petrography of the igneous rocks, Vol. I: Chicago, Univ. Chicago Press, 318 p.

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INTERIOR SUPPORTS MINING LAW OF 1872

Secretary of Interior Walter J. Hickel recently gave full support to the existing Mining Law of 1872. This will necessarily be the stand of the Department of the Interior (which includes the Bureau of Land Management) in the nation-wide controversy over whether the present claim location system should be replaced by a leasing system. This stand completely reverses the position taken by the former Secretary, Mr. Udall.

In a letter to the Public Land Law Review Commission, Secretary Hickel recommended ".... a workable revision of the mining law of 1872 which will enable it to meet our present and future needs. This can be accomplished without sacrificing the best qualities of the old law and stifling needed exploration and development while still insuring appropriate consideration for necessary conservation and multiple use management."

He further recommended "....that a careful study be made of revenues resulting from minerals claims to determine whether the Federal Government should receive any compensation from the minerals extracted from such claims. However, consideration should not be given to revisions which would deter exploration for and development of our mineral resources nor which would render unfeasible or uneconomical the removal of vitally needed minerals from public lands."

His letter then went on to make the following suggestions for improving the Mining Law of 1872:

"1. Revision of the patenting procedures to grant claimants only a patent to subsurface mineral resources with a right to use so much of the surface as is necessary for mining and related activities. Preference should be given to the patentee in any sale of the remaining surface rights.

"2. Provision for realistic increases in the purchase price per acre for mining claims upon patenting. Such increases should adequately reimburse the Federal Government for expenses incurred in issuing the patents. Prices established in 1872 are far from in line with prices of today.

"3. Retention by the United States of surface rights should be accompanied by a provision enabling the Federal Government to exercise a reasonable degree of control over the impact upon the surface and environment as a result of mining and related operations." [State of Alaska Mines Bulletin, vol. 17, no. 10, October 1969, p. 2]

* * * * *

GRANT COUNTY TO PURCHASE FOSSIL COLLECTION

Fossils collected years ago from geologic formations in the area of Dayville by the late Mr. Weatherford, long-time resident of that district, will be enjoyed by visitors to the Grant County Chamber of Commerce. Directors of the organization have voted to purchase the collection. (From the Blue Mountain Eagle, Sept. 11, 1969.)

* * * * *

COPPER BELT RE-EXAMINED

The geological consulting firm of E. P. Sheppard and Associates, Ltd. of Vancouver, B.C., is currently mapping the belt of copper prospects owned by the Oregon Copper Co. in the Lower Powder River and Sparta mining districts of Baker County. An extensive, close-interval geochemical sampling survey is now in progress and a follow-up airborne magnetometer survey is contemplated. The examination is being made for the Baker Mountain Copper, Ltd. (NPL) (formerly Dennis Holding Co.) of Vancouver, B.C. The area under investigation embraces more than 100 claims and includes most of the prospects held under option by the Cyprus Mining Co. during 1967 and 1968. Whether the present examination will include a continuation of the core-drilling program started by Cyprus will be governed by the outcome of the sampling and mapping program now under way.

* * * * *

HEAVY METALS, GOLD PUBLICATIONS ISSUED

"Principal gold-producing districts of the United States," by A.H. Koschmann and M. H. Bergendahl, is a recent Professional Paper (No. 610) of the U.S. Geological Survey. Information on U.S. gold deposits is presented alphabetically by state; 15 pages of the 283-page book are devoted to a discussion of Oregon's gold-producing districts. The book is for sale by the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. Price per copy (cloth bound) is $4.75.

The Survey is also issuing progress reports on its Heavy Metals Program, which began in 1966 in cooperation with the U.S. Bureau of Mines. Field work and topical studies performed in 1968 are summarized in Circulars 621 and 622 respectively. Both circulars are available free of charge from the U.S. Geological Survey, Washington, D.C. 20242.

* * * * *

MOLLUSKS OF THE EUGENE FORMATION DESCRIBED

"The Oligocene marine molluscan fauna of the Eugene Formation in Oregon," by Carole Jean Hickman, has been published as Bulletin 16 by the University of Oregon's Museum of Natural History. A total of 67 species of mollusks are described and figured. In addition, the stratigraphy, paleoecology, and other aspects of the Eugene Formation are discussed. The 112-page bulletin can be obtained from the Museum of Natural History, the University of Oregon, Eugene, Oregon 97403. The price is $2.50.

* * * * *

AVAILABLE PUBLICATIONS

(Please include remittance with order. Postage free. All sales are final and no material is returnable. Upon request, a complete list of the Department's publications, including those no longer in print, will be mailed.)

BULLETINS

2.	Progress report on Coos Bay coal field, 1938: Libbey	$ 0.15
8.	Feasibility of steel plant in lower Columbia River area, rev. 1940: Miller	0.40
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	Vol. 2. Two papers on foraminifera by Cushman, Stewart, and Stewart, and one paper on mollusca and microfauna by Stewart and Stewart, 1949	1.25
37.	Geology of the Albany quadrangle, Oregon, 1953: Allison	0.75
46.	Ferruginous bauxite deposits, Salem Hills, Marion County, Oregon, 1956: Corcoran and Libbey	1.25
49.	Lode mines, Granite mining dist., Grant County, Ore., 1959: Koch . .	1.00
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57.	Lunar Geological Field Conference guide book, 1965: Peterson and Groh, editors	3.50
58.	Geology of the Suplee-Izee area, Oregon, 1965: Dickinson and Vigrass .	5.00
60.	Engineering geology of the Tualatin Valley region, Oregon, 1967: Schlicker and Deacon	5.00
61.	Gold and silver in Oregon, 1968: Brooks and Ramp	5.00
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63.	Sixteenth Biennial Report of the State Geologist, 1966-68	Free
64.	Mineral and water resources of Oregon, 1969	1.50
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GEOLOGIC MAPS

Geologic map of Oregon (12" x 9"), 1969: Walker and King . . .	0.25
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GMS-1: Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka . .	1.50
GMS-2: Geologic map, Mitchell Butte quad., Oregon, 1962: Corcoran et al..	1.50
GMS-3: Preliminary geologic map, Durkee quad., Oregon, 1967: Prostka . .	1.50
Geologic map of Oregon west of 121st meridian: (over the counter) . . . . . folded in envelope, $2.15; rolled in map tube, $2.50	2.00
Gravity maps of Oregon, onshore and offshore, 1967: [Sold only in set]: flat . folded in envelope, $2.25; rolled in map tube, $2.50	2.00

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8.	Available well records of oil & gas exploration in Oregon, rev. '63: Newton	0.50
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CLINOPTILOLITE IN WATER-POLLUTION CONTROL

Basil W. Mercer*

Clinoptilolite is a zeolite mineral which occurs in substantial deposits in the John Day region of Oregon (Fisher, 1962) and in other areas of the western United States (Hay, 1966). Because of its ion-exchange properties and potential low cost, clinoptilolite may find extensive use in the control of water pollution as an agent for the removal of ammonia nitrogen from wastewater. As previously reported, clinoptilolite is highly effective for selectively removing cesium-137 from radioactive wastewaters (Brown, 1962). It is also sufficiently selective for ammonium ion to be of potential value in a rather unusual ion-exchange process which will be subsequently described.

Ammonia as a Pollutant

Early in the developing science of water-pollution control, the presence of ammonia in surface and ground-water supplies was regarded as a strong indication of recent pollution (Babbit and Bauman, 1958). As water-quality science progressed, it became apparent that the presence of ammonia in water has implications far more serious than merely serving as an index of recent pollution (Jones, 1964; Sawyer, 1947; Betz, 1962; and Behrman, 1968). It was demonstrated that:

1. Ammonia can be toxic to fish and aquatic life.
2. Ammonia can contribute to explosive algae growths, thereby promoting eutrophication.
3. Ammonia can restrict wastewater renovation and water reuse.
4. Ammonia can have detrimental effects on disinfection of water supplies.
5. Ammonia can be corrosive to certain metals and materials of construction.

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As a result, the removal of ammonia will become a necessary step in the treatment of municipal, agricultural, and industrial wastewater in many areas of the United States.

More than 90 percent removal of ammonia will be required for municipal sewage treatment plant effluents in some areas which will be involved with very large volumes of wastewater. For example, the City of Detroit, Mich., discharges daily into Lake Erie an average of 687 million gallons of wastewater (U.S. Dept. Interior, 1968) containing an estimated 45 tons of ammonia. The discharge of wastewater from this and other cities in the Lake Erie drainage basin contributes heavily to the accelerated eutrophication of this lake.

Ion Exchange Process

Laboratory and pilot-plant studies on ammonia removal from wastewater by sorption on clinoptilolite have been conducted at the Pacific Northwest Laboratory (Mercer and others, 1969). The clinoptilolite used in these studies was obtained from Hector, Cal. Clinoptilolite and other zeolites, such as mordenite, erionite, and chabazite, exhibit a high affinity for ammonium ion in the presence of other ions commonly found in natural waters (Na^+, Ca^{+2}, and Mg^{+2}). A comparison of the amount of ammonium ion (NH_4^+) adsorbed from a mixed ammonium and calcium solution is shown in figure 1, for Hector clinoptilolite and a conventional ion-exchange resin, IR-120*. The clinoptilolite much prefers the ammonium ion to the calcium ion under these conditions. This selectivity for ammonium ion over calcium ion permits the use of an inexpensive chemical, lime, for regeneration of the clinoptilolite.

In the ammonia-removal process, the clinoptilolite is used in a granular form, normally 20 X 50 mesh, packed in an ion-exchange column. The wastewater is pumped through the bed of granular zeolite until the NH_4^+ sorptive capacity of the zeolite is exhausted. The bed of zeolite is then regenerated or renewed by pumping a lime solution or slurry through the bed. The alkalinity of the lime converts the sorbed NH_4^+ ion to NH_3 which flows out with the waste regenerant solution. The NH_4^+ ion is replaced with Ca^{+2} ion from the lime. The zeolite bed is then ready for service.

This process has a distinct advantage over conventional ion exchange processes in that no liquid waste regenerant requires disposal. The waste regenerant is air stripped to remove the ammonia and is reused after the addition of make-up lime. A photograph of the mobile pilot plant used to demonstrate the process at the Richland, Wash. sewage-treatment plant is shown in figure 2. Using this process, an estimated 480,000 cubic feet of clinoptilolite would be required to treat the wastewater presently discharged from the City of Detroit, Mich.

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* Amberlite IR-120 product of the Rohm & Haas Co., Philadelphia, Penna.

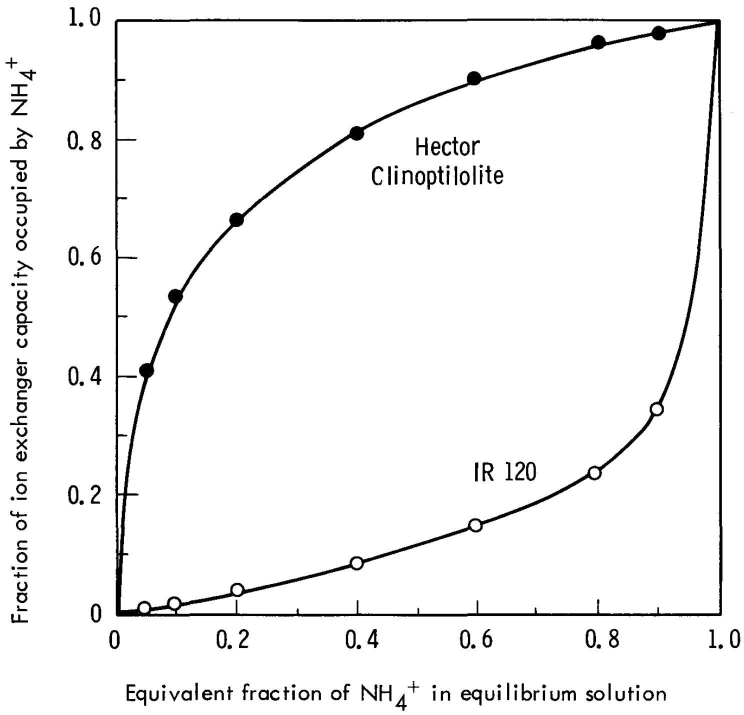

Figure 1. Comparison of the amount of NH_4^+ adsorbed from a mixed ammonium and calcium solution under equilibrium conditions.

Total equilibrium solution normality = 0.1

Clinoptilolite Quality

High resistance to chemical and physical attrition as well as a high percentage of clinoptilolite is required in the granular form of the material used in the ion-exchange beds. The clinoptilolite obtained from Hector, Cal., is contained in an altered tuff with about 15 percent quartz, feldspar, and unaltered glass. The ion-exchange capacity is about 1.7 milliequivalents per gram of zeolite. When crushed, sieved, and thoroughly washed with agitation to remove fines, clay, and other impurities, 20 X 50 mesh Hector clinoptilolite gave a wet attrition test of 3 percent. The wet attrition test determines the amount of fines (less than 100 mesh) generated by 25 grams of the granular zeolite during rapid mixing with 75 milliliters

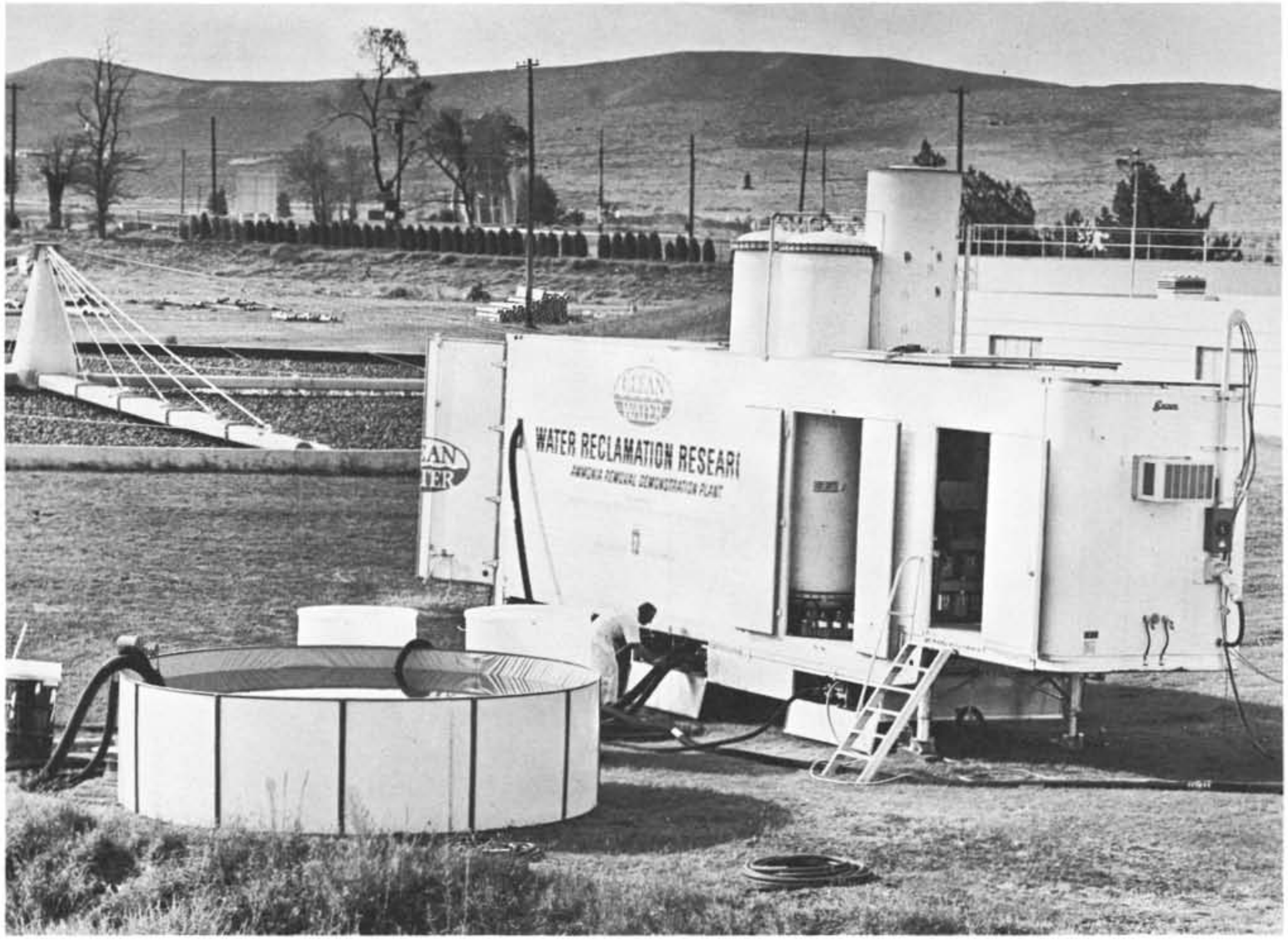

Figure 2. Photograph of mobile pilot plant. (Photograph courtesy Battelle Memorial Institute.)

of water on a paint shaker for 5 minutes. Commercial zeolites, such as erionite and chabazite which are powdered, mixed with clay binder, extruded, and fined, will generally give a wet attrition test of about 6 percent or twice that of the Hector clinoptilolite. Low wet attrition is important because back flushing with fluidization of the ion exchange beds is required after regeneration with lime.

References

Babbitt, H. E., and Bauman, E. R., 1958, Sewerage and Sewage Treatment: New York, John Wiley & Sons.

Behrman, A. S., 1968, Water is Everybody's Business, The Chemistry of Water Purification: Garden City, N.Y., Anchor Books.

Betz Handbook of Industrial Water Conditioning, 1962: Philadelphia, Betz Laboratories.

Brown, R. E., 1962, The use of clinoptilolite: The ORE BIN, v. 24, no. 12, p. 193-197.

Fisher, R. V., 1962, Clinoptilolite tuff from the John Day Formation, eastern Oregon: The ORE BIN, v. 24, no. 12, p. 197-203.

Hay, R. L., 1966, Zeolites and zeolitic reactions in sedimentary rocks: Geol. Soc. America Spec. Paper 85.

Jones, J. R. E., 1964, Fish and River Pollution: London, Butterworths.

Mercer, B. W., and others, 1969, Ammonia removal from wastewater by selective ion exchange: 14th Pac. NW. Industrial Waste Conf. Proc., Oregon State Univ.

Sawyer, C.N., 1947, Fertilization of lakes by agricultural and urban drainage: New Eng. Water Works Assn. Jour., v. 61, no. 2, p. 109-127.

U.S. Dept. Interior Federal Water Pollution Control Admin., 1968, Great Lakes Region, Lake Erie Rept.

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IRONSIDE BULLETIN ON OPEN FILE

"Geology of the Ironside Mountain Quadrangle, Oregon," by Wallace D. Lowry, has been placed on open file in the Department's Portland office. The 79-page bulletin is camera ready for publication, but because funds for this purpose are not available a Xerox copy of the report is now placed in open file in the Department library, where it can be consulted. A color-key proof of the geologic map and the photographic illustrations can also be seen. The Ironside Mountain 30-minute quadrangle spans parts of Grant, Baker, Malheur, and Harney Counties in northeastern Oregon.

* * * * *

MINING POLICY BILL PASSES

A major step toward establishing a much-needed national mining and minerals policy was taken last month with the passage of Senate Bill 719. The measure, which would provide guidelines for orderly development of our mineral resources, was passed in the U.S. Senate on September 5 and sent to the House.

Many in the mining industry feel that such a policy is essential if the U.S. is to continue as the world leader in the mineral industry. While extensive training and research programs have improved the conservation and use of agricultural crops, forests, soils, wildlife, and water resources, no such foresight has been used in the case of mineral resources. The mining industry has been more or less left to fend for itself with little outside support. It has developed practical solutions for many of the problems encountered in exploiting nonrenewable mineral resources and in improving a deteriorating environment. Technical difficulties and costs involved, however, have imposed limitations because they mean the difference between feasibility and infeasibility in the mining industry economic picture in many cases.

Ultimately, the industry will have to turn to lower grade ore deposits and deposits at great depths to satisfy mineral requirements. Such endeavors will, of course, require considerable research. S.719 establishes the policy of fostering such research -- both government-sponsored and private -- to deal with the technological problems of locating and extracting such mineral deposits.

As mineral resource problems increase, the number of mining departments in universities has dwindled -- from 26 in 1962 to only 17 in 1967. The national policy bill also emphasizes the need for technological training as well as strong research and instructional programs. The advantages of publishing and disseminating technical information are also pointed out.

Minerals are critical and essential to the nation's economy and the national mining and minerals policy, S.719, which passed the Senate last month, is the first step in providing guidelines for their wise and efficient use. (Missouri Geological Survey Missouri Mineral Industry News, v. 9, no. 10, October 1969, p. 137.)

* * * * *

ROCK AND MINERAL BOOKLET REPRINTED

"A Description of Some Oregon Rocks and Minerals," by Hollis M. Dole, has just been printed for the fifth time by the Department. This popular 41-page booklet, designated as Miscellaneous Paper 1, was originally published in 1950, and although reprinted three times, the supply has been exhausted since 1963. Miscellaneous Paper 1 is for sale for 40 cents by the Department at its Portland, Baker, and Grants Pass offices.

* * * * *

THE SEMIPRECIOUS GEM INDUSTRY OF OREGON

Professor Leslie L. D. Shaffer*
and
Steve T. Hashimoto, MBA**

Rockhounding, the lively art of searching for, cutting, shaping, and polishing a wide variety of quartz-family semiprecious gemstones, has become the most popular of all recreational activities based on natural resources in the state. More family hours are spent on rockhounding in Oregon than on any other outdoor activity. The following article was suggested to the authors by Ralph S. Mason, mining engineer with the State of Oregon Department of Geology and Mineral Industries, and much of the background information was supplied from the Department's files. Additional material was provided by Jerry Gray, geologist at the U.S. Bureau of Mines, Albany, Oregon. "The Semiprecious gem industry of Oregon" appeared in the Oregon Business Review, publication of the University of Oregon Bureau of Business and Economic Research, v. 28, no. 7, July 1969, 4 pages. (Editor)

Interest in working stones into objects of artistic or utilitarian use is older than the written history of man. Within the general category of stone working there has always been special interest in semiprecious and precious gems. Refining rough material into display quality gem stones was a skill passed on by demonstration even before written instructions were available. The work was surprisingly good even by modern standards, especially in view of the primitive tools which were available.

Rather complete instructions for the working of semiprecious gem material were available about 1800 (Sinkankas, 1962), but the attention of a large number of amateurs did not arise until the advent of the diamond-edge saw and the availability of electric furnaces produced grinding substances -- about 1940. Development of interest has been quite rapid since these technical changes were introduced and especially in the last 15 years.

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* Professor of Management in the College of Business Administration, University of Oregon.

** Graduate student in Management, University of Oregon.

Production Data

The U.S. Bureau of Mines reports that 38 states produced semiprecious gem materials of significant amounts during 1967 (Petkof, 1968). Some believe that Oregon may be first among the states if several factors are considered. The presence of substantial deposits of rough material, the number of persons searching out material, and the number engaged in working rough to finished items, all need to be considered in this judgment. The total value of production for the state during 1967 has been estimated at $1,000,000 (the ORE BIN, 1965). However, it is quite probable that the actual total exceeds the above figure. It is difficult to establish an accurate total dollar value, because much of the collecting of rough material is done by amateurs, both resident and tourist. Also, a large part of the finished stones are never offered for sale.

Other states reporting semiprecious gem production of some value include the following in order of importance: California, Idaho, Arizona, Texas, Wyoming, Colorado, Montana, and Nevada, with each state providing materials exceeding $100,000 in value (Petkof, 1968).

Sources of Gem Material

Gem stones are divided into two general categories: precious and semiprecious. A precious gem stone has beauty, durability, and rarity, whereas a semiprecious gem has only one or two of these qualities (Schlegel, 1957). Examples of precious gems would include diamond, emerald, precious opal, ruby, and sapphire. With the exception of small amounts of precious opal and sapphire, nothing of significance in this category has been found in Oregon (Schrader and others, 1917). However, many varieties of semiprecious gem stones can be located in different areas of Oregon. As noted in table 1, 22 counties in the state have deposits of usable rough material.

In comparison to other minerals produced, gem stones rank only fourth as indicated in table 2. It can be observed, however, that those categories of higher total value include commodities such as sand and gravel, pumice and volcanic cinder, and other bulk items.

There are several reasons why interest in semiprecious gems has developed into a significant activity in the state of Oregon. These include:

1. A great variety of semiprecious material is found in Oregon compared with other states.
2. Regardless of weather conditions, there is always some area in Oregon where raw materials can be obtained.
3. A large part of the raw material is found on public land and access is relatively unrestricted.

Table 1. Principal gem stone localities in Oregon.*

Counties	Gem materials
Baker	Agate, jasper, petrified wood
Benton	Agate
Coos	Fossil wood
Crook	Agate, carnelian, geode, moss agate
Curry	Jade
Deschutes	Agate, carnelian, geode, jasper, moss agate
Douglas	Agate
Grant	Agate, petrified wood
Harney	Agate, obsidian
Jackson	Agate, bloodstone, jasper, petrified wood, rhodonite
Jefferson	Agate, amethyst, geode, opal
Lake	Geode, obsidian
Lane	Agate, petrified wood
Lincoln	Agate, agatized coral, bloodstone, jasper, petrified wood, sagenite, sardonyx
Linn	Agate
Malheur	Agate, geode, jasper, petrified wood
Morrow	Agate, geode
Polk	Agate, jasper, petrified wood
Union	Agate
Wallowa	Agate
Wasco	Agate, amethyst, bloodstone, chalcedony, geode, jade, jasper, opal, quartz, sagenite.

*Petkof, Benjamin, 1965, Gem stones: in Mineral facts and problems: U.S. Bureau of Mines Bull. 630, p. 367.

The expense involved in obtaining semiprecious gem stones is not necessarily great -- it depends upon the degree of interest the collector might have. Lapidary equipment is priced over a wide range. The collecting and finishing of gem stones is an activity that is open to all groups, regardless of age or experience. In addition, the search for gem material can be intellectually stimulating to many persons, since they learn about Oregon's geography, history, and geology. Also, there is always the possibility of discovery of fossils, arrowheads, artifacts, and other unusual items.

Gem Locations

During 1967, the primary locations in Oregon where significant amounts of gem stones were found included sections along the Oregon coast and areas near Lebanon, Prineville, Lakeview, and Nyssa. In these

Table 2. Mineral production in Oregon, 1968.*

Mineral		Quantity	Value (thousands)
Clays	thousand short tons	203	$ 338
Diatomite	short tons	40	3
Gem stones	...	NA	750
Gold	troy ounces	15	**
Lime	thousand short tons	111	2,311
Mercury	76-pound flasks	940	509
Nickel	short tons	16,732	W
Perlite	short tons	W	W
Pumice and volcanic cinder	thousand short tons	850	1,200
Sand, gravel, stone	thousand short tons	40,000	55,440
Silver	troy ounces	W	W
Talc and soapstone	short tons	3	**
Value of items that cannot be disclosed:			
Cement, copper, peat		XX	$77,547

Key: NA = Not available. XX = Not applicable. W = Withheld to avoid disclosing individual company's confidential data. ** = Less than $1000.
* Source: Gray, J.J., Kingston, G.A., McComb, M.A., 1968, Mineral Industry of Oregon in 1968, preliminary annual report: U.S. Bureau of Mines, p. 2.

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locations, the most sought-after semiprecious gem stones include obsidian and cryptocrystalline* varieties of quartz -- thunderegg, moss and plume agate, jasper, and petrified wood (Collins and others, 1968, p. 668). No one knows where all deposits are, and each road-construction project seems to produce its own variety and quantity of interesting material. It is of interest to note that rockhounding has now developed to the point where the state of Oregon, as well as many cities, provides maps showing locations where different types of raw material can be found.

Every year and in increasing numbers individuals search the Oregon beaches as well as the gravel beds of many coastal rivers for gem material. Local collectors report that winter is the best season for obtaining beach agates, because storms are more violent at this time of the year. Also, winter rains assist in exposing agates and other gem materials.

Among the beach gems most prized are the unique agates having various inclusions of colorful mineral matter. These stones are identified under

* Cryptocrystalline refers to crystalline structures consisting of crystals too small to be seen with the microscope.

the general name of sagenite agate. Also beach agates sometimes contain movable bubbles of water (enhydros) and these make interesting cabinet specimens (Dake, H. C., 1962).

Rockhound Meetings

Lebanon, Oregon has become well known for its semiprecious gem materials. In 1965 the Pow-Wow Rockhounds of America held a formal Memorial Day convention there which attracted more than 500 enthusiasts*. In the Lebanon area, many owners of well-known locations charge a fee of $2.00 per day which permits individuals to search for gem stones. Carnelian agate, highly prized for its deep-red color, banded agates, opal, jasper, and petrified wood are found on a large swath of prehistoric river bottom approximately 2 miles south of the city. There are several other productive locations within the Lebanon area - one near Scio, several near Sweet Home and Brownsville, and others on McDowell Creek (Albany Democrat-Herald, 1968).

Perhaps the most outstanding gathering of individuals interested in semiprecious gems occurs in Prineville, Oregon. An estimated 85,000 rockhounds gather annually in this city for a "Pow-Wow." This single event brings in nearly half a million dollars revenue from out-of-state visitors who require food, lodging, gas, and other supplies. Approximately one-half of the gem stones in this area are obtained from private holdings where owners charge a fee. Prices charged at these sites range from 10 to 15 cents per pound of raw materials obtained with a $3.00 minimum per person per day. In addition, the city of Prineville has established several good locations where no fees are charged.

In 1966, the town of Nyssa proclaimed itself "The Thunderegg Capital of Oregon," and conducted a three-day celebration (Thunderegg Days) bringing 3000 visitors and collectors from 42 states (Collins and others, 1967, p. 651). According to Mrs. Kay Brendle, "Many of these out-of-state visitors (including some families composed of up to seven members) stayed in the area for an average of three days bringing in additional income for local businessmen." The festival is now sponsored annually by the Nyssa Chamber of Commerce and the Treasure Valley Gem and Rock Club.

Thunderegg -- Oregon State Rock

The thunderegg is an agate-filled nodule found in parts of central

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* The Pow-Wow Rockhounds of America is a national organization composed of members interested in the earth sciences, rock collecting, lapidary, jewelry making, and archaeology. "Rockhound" has been defined as one who hunts and collects gem stones or minerals as a hobby.

and eastern Oregon, and is Oregon's unique contribution to rockhounding. It became the official state rock on March 5, 1965 (The ORE BIN, 1965, p. 192).

Thundereggs are spherical masses of rock that range in size from less than an inch to several feet in diameter. Most are about the size of a baseball. They have a knobby rind of drab, siliceous rock around either a cavity or a core of agate or crystals. From the outside they appear uninteresting, but when sawed open and polished they may reveal exquisite and colorful designs ranging from five-pointed stars to miniature gardens. They are highly prized by gem collectors who come from every state to search for them. Thundereggs make handsome jewelry, book ends, paper weights, pen stands, and other decorative objects. Each year they contribute thousands of dollars to Oregon's gem-stone industry (The ORE BIN, 1965, p. 192).

The thunderegg may owe its name to a legend of the Indians of central Oregon. The story related that these hard, almost spherical rocks were missiles hurled from the craters of Mount Hood and Mount Jefferson whenever the gods inhabiting the mountains became angry (ibid., p. 196). J. Lewis Renton probably deserves recognition for first putting the term "thunderegg" into print (Renton, 1936, p. 12) and for attributing the name to the Indian legend (The ORE BIN, 1965, p. 192).

Geologists are uncertain about the origin of these spherical objects, and various theories have been advanced to explain the process of their formation. It appears that there may have been at least two separate stages of activity. First, small gas pockets were formed explosively in a semi-solid light-colored lava flow, and second, the pockets were filled at a later time with agate or opal (Ross, 1941, p. 732; Staples, 1965).

Activity and Prices

At the present time in Oregon, there are 54 gem and mineral clubs (Lapidary Journal, 1968, p. 261-262) compared to 40 such organizations in 1957 (Lapidary Journal, 1957, p. 144-146) (see table 3).

Table 3. Gem and mineral clubs in Oregon*

Year	Number of clubs	Year	Number of clubs
1957	40	1963	45
1958	41	1964	49
1959	47	1965	52
1960	47	1966	51
1961	49	1967	54
1962	52	1968	54

* Source: Lapidary Journal, April issues of each year.

This is an indication of the growing interest in Oregon's semiprecious gems. The total number of persons directly involved in this activity in Oregon is unknown, since no survey has been taken. However, it is estimated that some 1900 individuals are actively interested (Northwest Federation of Mineralogical Societies, 1968). In addition, there are about 70 gem-stone retailers, several wholesalers of finished gems, and a fluctuating number of lapidary equipment and supply manufacturers (Lapidary Journal, 1967, p. 194). This would amount to about 2000 individuals in Oregon either interested or actively engaged in this activity. These figures do not include tourists or those enthusiasts who have sophisticated semiprecious gem collections but who are not members of clubs.

Prices for semiprecious gems at any particular time will vary according to several factors including beauty, durability, rarity, and supply and demand. From information obtained in contacting individuals involved in this industry, it was found that raw gem-material prices ranged from free to several dollars per pound or even per square inch of cut material. Unusual and rare items sell for even higher prices. For example, rare plume agate and some limb casts found in central Oregon will sell for as much as $35 per pound.

Polished and mounted gem stones have similar variations. For instance, a plume agate mounted in a necklace can be priced from $3 to $4 up to $15 to $18, depending upon its quality and the location of the retailer. It is apparent that there are no standardized prices for either raw material or finished products.

Prospects

Based upon the increased interest in gem stones indicated by new mineral clubs, larger gem displays in stores, and the volume of inquiries concerning gem locations, it would appear that this activity has considerable attraction and some industrial potential. The data concerning the impact of semiprecious gem stones upon Oregon's economy is incomplete. A more detailed study would provide useful information in this respect, including the following considerations:

1. The precise size and structure of the industry.
2. An analysis of areas open to both fee and free digging.
3. Problems in the administration and control of semiprecious gem locations.
4. A more precise determination of production and valuation of gem stones and gem materials produced annually.
5. The impact upon the state as well as local economies.
6. Possible guidelines and recommendations for future action with regard to growth and development of the industry.

If the income from the sale of lapidary equipment, display fittings, mountings, tools, gem and mineral books, magazines, and living accommodations for vacationing rockhounds are included, it is quite probable that the semiprecious gem-stone "industry" of Oregon is larger than has been estimated. The supply of gem-stone material in Oregon is good, and new locations are continuously being found. There is opportunity for more individuals to make a living from the activity.

Selected References

Albany Democrat-Herald, 1968, Rockhounds from all over attracted to Linn rock beds: Albany Democrat-Herald, March 23, 1968.

Collins, R.P., Gray, J.J., and Kingston, G.A., 1966, The mineral industry of Oregon, 1965: U.S. Bur. Mines Minerals Yearbook, v. III, Area Reports: Domestic.

__________, 1967, The mineral industry of Oregon, 1966: U.S. Bur. Mines Minerals Yearbook, v. III, Area Reports: Domestic.

__________, 1968, The mineral industry of Oregon, 1967: U.S. Bur. Mines Minerals Yearbook, v. III, Area Reports: Domestic.

Dake, H.C., 1962, Northwest Gem Trails: Mentone, Cal., Gembooks.

Gregory, Irene, 1968, The fossil woods near Holley in the Sweet Home Petrified Forest, Linn County, Oregon: The ORE BIN, v. 30, no. 4, p. 57-76.

Lapidary Journal, 1957, Gem and mineral clubs in North America: Lapidary Jour., v. 11, no. 1, p. 144-146.

__________, 1967, Geographical (state and town) index of gem stones and minerals dealers: Lapidary Jour., v. 21, no. 1, p. 194.

__________, 1968, Gem and mineral clubs in North America: Lapidary Jour., v. 22, no. 1, p. 261-262.

Northwest Federation of Mineralogical Societies, 1968 Directory.

The ORE BIN, 1965, Thundereggs: Oregon's state rock: The ORE BIN, v. 27, no. 10, p. 192.

Petkof, Benjamin, 1968, Gem stones: U.S. Bur. Mines Minerals Yearbook, v. I, Metals and Minerals, 1967.

Renton, J. L., 1936, Opal or agate filled "Thunder eggs": The Mineralogist, v. 4, no. 1, p. 12.

Ross, C. S., 1941, Origin and geometric form of chalcedony-filled spherulites from Oregon: American Mineralogist, v. 26, p. 732.

Schlegel, Dorothy M., 1957, Gem stones of the United States: U. S. Geol. Survey Bull. 1042-G, p. 203.

Schrader, F.C., and others, 1917, Useful minerals of the United States: U.S. Geol. Survey Bull. 624, p. 257.

Sinkankas, John, 1962, Gem Cutting: Princeton, N.J., D. Van Nostrand Co., Inc., 2d ed., p. 1.

Staples, L. W., 1965, Origin and history of the thunder egg: The ORE BIN, v. 27, no. 10, p. 195-204.

* * * * *

FRANCIS G. WELLS

Early on the morning of October 20, 1969 Dr. Francis Gerritt Wells, affectionately known to his many friends as "Francois" or "Duke," died of pneumonia in Sarasota, Fla.

Francois was born in Boston, Mass. on February 18, 1898. He was educated as a geologist, first at Massachusetts Institute of Technology, where he received his Bachelor of Science degree in 1922, and later at the University of Minnesota, where he received his doctoral degree in 1928. Dr. Wells worked briefly as a geologist in the eastern United States and, later, in Arkansas, Arizona, Utah, and Alaska. He first came to southwest Oregon in 1930 -- the locale for the greater part of his life's work on the U.S. Geological Survey. Much of his early work in southwest Oregon involved the study of mining districts; this work led to the publication of reports on gold, base metals, mercury, and chromite. During World War II he ably supervised a study of chromite deposits in Oregon and California under the U.S. Geological Survey's Strategic Minerals Program and, at the same time, supervised the geologic mapping of the region from Medford to the coast.

As a result of his many years of work on the geology of Oregon, Francois was selected to direct the Survey's program to prepare a geologic map of the entire state. The western part of this map was published in 1962, shortly before his retirement.

Francois exerted a great influence on the lives of the many geologists who were associated with him, and all will remember his rigorous training camps, his stimulating discussions, and his delightful stories.

- George W. Walker, Menlo Park, Cal.

* * * * *

NORTHWEST OREGON SUBSURFACE STUDY PUBLISHED

"Subsurface Geology of the Lower Columbia and Willamette Basins, Oregon," has been published as the second in the Department's Oil and Gas Investigations series. Author is Vernon C. Newton, Jr., Petroleum Engineer for the Department. In this report Mr. Newton has gathered data from 25 deep exploratory wells in northwestern Oregon basins and has correlated this information with surface mapping. The region selected for the study is underlain by 10,000 to 20,000 feet of Tertiary marine sedimentary and volcanic rocks. Oil and Gas Investigations No. 2 is a 121-page book accompanied by a subsurface geologic map and six sections. The publication can be purchased for $2.00 at the Department's offices in Portland, Baker, and Grants Pass.

* * * * *

BAKER COUNTY GOLD MINE REACTIVATED

Development work conducted by Anthony Brandenthaler of Baker on the old Bald Mountain mine in Baker County resulted in the shipping of one 60-ton carload of gold-bearing quartz ore to the Tacoma smelter during the latter part of October. This is in addition to a carload of mill concentrates scheduled for shipment to the Selby smelter in California in November.

The Bald Mountain mine and its nearby companion, the Ibex, are located in the Cracker Creek district on the western end of the well-known mineralized vein system of the Bourne area. Both mines have a history of productive operation prior to having been closed down by war-time curbs in 1941, and this is the first time that either has been reactivated since. The present output originates from a newly developed ore shoot on a drift at a point about 1500 feet from the portal. Additional shipments of the high-silica quartz ore will be made during the winter if the returns from the present shipment meet current expectations, which preliminary sampling reportedly indicates should be around half an ounce of gold and 17 ounces of silver to the ton. Four men have been employed at the mine and the George Reed Trucking Co. is transporting the ore from the mine to a rail siding at the Chemical Lime plant near Baker.

* * * * *

DEPARTMENT HIRES NEW CARTOGRAPHER

John Newhouse, cartographer for the Department from June 1962 until October 1969, has left this position to go into environmental planning work, a field he is well qualified to follow as a result of his education in geography at Portland State University and his broad experience in map making for the Department. In the seven years he was on the Department staff, John helped to raise the standards of the Department's publications by introducing many new ideas on content, design, and color. He was responsible for the execution of the high-quality geologic maps appearing in The ORE BIN, GMS Map Series, Bulletins, and other Department publications.

Replacing John Newhouse is Steven R. Renoud, who joined the Department staff in August 1969. Steve is a native of Sweet Home, Oregon. He graduated from the Sweet Home High School in 1963 and entered the service that same year. In 1964 he re-enlisted to attend the U.S. Army Engineer's School for Cartography at Fort Belvoir, Va. During the next four years he obtained a wide range of training and experience in cartography with the Army Map Service. One year of this period was spent in Vietnam and another year teaching map drafting to trainees at Fort Lewis. Steve is taking over the job of preparing illustrations and maps for the Department's publications.

* * * * *

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NOTES ON THE HISTORY OF THE SAND AND GRAVEL INDUSTRY IN OREGON

by

Pierre R. Hines*

Introduction

In 1917 George Bellows, American artist (1882-1925), painted a picture of two men loading a wagon with sand on a gravel bar at Monterey, Cal. (figure 1). In those days a team of horses would pull a cubic yard or so of wet sand and gravel in a wagon and haul it directly to the building site.

Figure 1. "The Sand Team," painted in 1917 by George Bellows, hangs in the Brooklyn Museum, Brooklyn, N.Y.

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* Mining engineer, Portland, Oregon

Customarily, the wagon bottom was a layer of 2-by-6's which projected out the rear and could be twisted to dump the load; or, perhaps, the bottom had doors which took care of the dumping operation. If the load was sand to be used in mortar, it was screened by hand, mixed with lime and water, and carried to the masons or plasterers. If the load was sand and gravel for concrete, it was shoveled onto an inclined screen so that the separated components could be measured in the desired proportions. Rough proportions for concrete were usually one part of cement, two parts of sand, and about four parts of gravel. A certain amount of this gravel, measured in wheelbarrow loads, was spread on a mixing platform; then the required wheelbarrow loads of sand were added; and on top of the pile a specified number of sacks of cement was spread. The mass was turned over with straight-edge shovels until uniformly mixed. Water was added as needed and the mixture was transferred by wheelbarrows or buggies to forms, where the concrete mixture was thoroughly tamped. Usually steel re-enforcing rods had previously been placed and secured in the forms. This procedure was typical of the methods used in mixing and placing concrete around the turn of the century.

Development of the Cement Industry in Oregon

Oregon had a small population in the early 1900's so that construction was minimal. An abundance of building materials was readily available, however. The state had immense virgin forests containing the finest of timber and also plenty of good rock for foundation material. No local cement was at first available, so wood construction was usually the principal choice for housing and similar structures. Later, California cement was brought in by ship and became an essential ingredient in masonry construction. In 1916, the first Oregon cement plant began production at Oswego, near Portland.

Increase in sand and gravel production closely parallels the growth of the cement industry, and it follows that construction of the highway system in the United States created a great demand for aggregate and cement in Oregon as well as in other parts of the country. Oregon pioneered in highway construction in 1913-15 in building the Columbia River Highway from Astoria to Hood River. The primary object was to connect western and eastern Oregon with a paved highway and in so doing to take advantage of the scenery of the great Columbia River.

Bonneville Dam on the Columbia, east of Portland, was started in 1933. This was the first of several large, multipurpose dams built throughout the Columbia River system.

Oregon's population swelled during the middle part of the present century, especially after the end of World War II, and need for cement, sand, gravel, and crushed rock increased in a rapidly accelerating curve. Other factors affecting production and use of cement and aggregate in construction, not restricted to Oregon alone but applicable to the country as a whole, are: 1) increased knowledge of how to manufacture high-quality cement, produce better aggregate, and make higher strength concrete at lower cost, and 2) improved highway engineering.

Delivery of ready-mix concrete from a central plant by mixer trucks rather than mixing at individual sites has revolutionized use of concrete in construction on practically all urban jobs*. Production of better aggregate is effected by such factors as: thorough washing of coarse aggregate; increase in the number of sizes made available for mixes; use of vibrating screens which do a more efficient job of screening; and new types of fine grinders which produce a wider range of sizes. The greatest improvement of aggregate is in the sand component. Sand classifiers now meet rigid screen analysis specifications, so that the resulting sand produces a higher strength concrete with less cement.

A central mixing plant which feeds the ready-mix trucks has accurate scale for proportioning the concrete mixture by weight and also has meters for measuring water to obtain the correct water-cement ratio as well as slump control, all of which elements make for better concrete. Certain additives such as air entraining compounds improve freezing resistance and fluidity. Ready-mix is now sold for all important work according to rigid specifications and guarantees. Large producers have their own testing laboratories and technical staffs. The improvements as described were initiated about 1935-40, which is the time also of the beginning of the rapid increase in use of sand and gravel in concrete aggregate.

Historical Outline of Sand and Gravel Operations

1900 - 1920

Uses of sand, gravel, and crushed rock were limited in this period, as has been indicated, and it follows that preparation for application in construction was simple compared to modern practice.

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* Five types of portland cement are now manufactured. They are:

Type I. For use in general concrete construction when the special properties specified for types II, III, IV, and V are not required.

Type II. For use in general concrete construction exposed to moderate sulfate action or where moderate heat of hydration is required.

Type III. For use when high early strength is required.

Type IV. For use when a low heat of hydration is required.

Type V. For use when high sulfate resistance is required. (A.I.M.E., "Industrial Minerals and Rocks," p. 165.)

Early producers of aggregate in the Portland area were: Star Sand Co., Columbia Contract Co., Nickum & Kelly, Diamond O Navigation Co. (Drake O'Reilly), Pacific Bridge Co., Columbia Digger Co., and Hackett Digger Co.

Chris Minsinger, owner of Star Sand Co. (figure 2) and a pioneer in the industry, came to Portland from Pittsburgh, Pa., about 1902. He brought the ladder dredge to the Willamette from the Ohio River -- an innovation in digging river gravel for the local area.

Star Sand Co., Columbia Contract Co., and Nickum & Kelly dug the Willamette River gravel with ladder dredges which were equipped with screening and crushing machinery, and they delivered the crushed products to barges alongside. The barges were towed to the docks and unloaded into bunkers from which the material was trucked to building sites. Some of the other operators used clam-shell dredges, while Pacific Bridge Co. utilized a shovel dredge.

Willamette River gravel at this time was found at shallow depths and was easy digging. The sand component was not considered suitable for concrete, however, and sand from the Columbia River was used instead. Columbia River sand was dug by both clam-shell and suction dredges.

Star Sand, Columbia Contract, and Pacific Bridge Companies had their own rock quarries and produced commercial crushed rock. Star Sand's quarry was at Coffin Rock, a monumental shaft of columnar basalt on deep water at Longview, Wash. Coffin Rock was leveled off just after the end of World War II, and the Weyerhaeuser salt unloading dock and bleach plant were built on the site. Columbia Contract Co. had a quarry on the river at St. Helens and also one for jetty rock at Fisher's Landing just west of Camas, Wash. Their distribution yard was on the east bank of the Willamette River just north of the Hawthorne Bridge (figure 3). Pacific Bridge Co. had a rock quarry on the Columbia River at Corbett, east of Portland; later the operation was moved to the lower Columbia at a location between Scappoose and Linnton where the highway, railroad, and slough converge.

Oregon City, Salem, Albany, and Eugene each had dragline plants on the Willamette River for producing aggregate. Sand and gravel deposits of commercial size are rare on the Oregon coast, owing to the relatively short length of most coastal streams which have their sources in the Coast Range. The Umpqua River is an exception, since it drains a considerable area of the Cascade Mountains. The Umpqua Navigation Co. started to produce sand and gravel from the Umpqua at Gardiner and Reedsport about 1920.

Old placer-mine tailings in the Rogue River drainage area were a source of sand and gravel in southern Oregon.

1920 - 1930

The Federal Highway Act was passed in 1916. It was not until 1920

Figure 2. The Star Sand Co. office and yard in northwest Portland at the turn of the century. (Oregon Historical Society photograph)

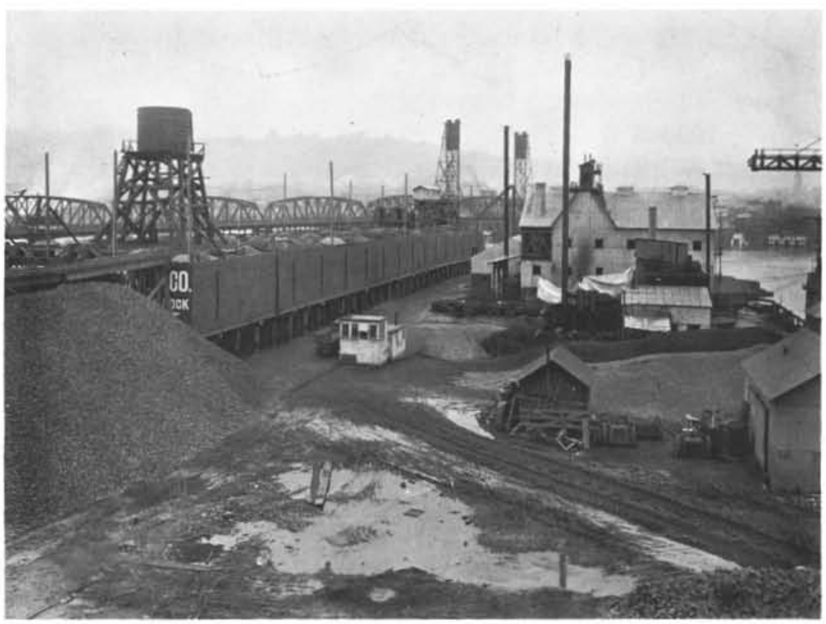


Figure 3. Columbia Contract Co. distribution yard at east end of Hawthorne Bridge about 1920. (Photograph courtesy Miss Grace Kern)

that this act had much influence on Oregon highway construction. Highway engineers encountered many problems, and one was finding adequate construction material. In mountainous areas where no suitable gravel was available, some of the rock cropping out along the highway route had to be used. The State Highway Department designated quarry sites close to each project and let contracts for definite amounts of crushed rock for construction and stockpiles for maintenance. The quantities required would not warrant a single large permanent operation; thus, portable crushing and screening plants were developed at various locations on Oregon highways.

For concrete installations it was usually common practice to haul the sand, gravel, and cement to the construction site and mix them there. Portable mixers were designed for both building structures and highway work. Hoisting towers and chutes were used to place large quantities of concrete for both building structures and dams, all of which required free-flowing concrete and a high water-to-cement ratio. When research proved that better concrete was made with a lower water-to-cement ratio, these older methods were abandoned. Large quantities of coarse gravel up to 3 inches maximum size were used at this time, especially in highway construction.

By 1926 shallow gravel in the Willamette River near Portland was becoming exhausted and digging had become too deep for ladder dredges; consequently, Howard Puariea built a clam-shell dredge equipped with screening and crushing equipment (figure 4). Shore plants and large storage had not previously been needed on the Willamette at Portland.

Also in 1926, John Kiernan, who owned Ross Island and Hard Tack Island, both located on the east side of the Willamette River at Portland, sold them to the Ross Island Sand & Gravel Co., well known in the aggregate business in Portland. It had been previously organized and incorporated by Sneelock & Co. W. G. Brown, Portland civil engineer, made several test borings for the company in the area to a depth of 80 feet and estimated that it contained a probable gravel reserve of 19,500,000 cubic yards, including 6,000,000 cubic yards of sand. This deposit was dug with an electrically driven suction dredge which pumped the material to a sump (figure 5). It was elevated from the sump by means of a clam-shell bucket and delivered to the top of the shore plant on Hard Tack Island which was equipped with crushing and screening machinery, including large bunkers and conveyors. An aerial tram delivered the aggregate to bunkers on McLaughlin Boulevard and to barges on the river.

Willamette River gravel at Portland had not been considered suitable for average concrete, but William Elijah Buell, a civil engineer associated with Schneelock & Co., found that, by removing the contained fine silt, a sand superior to Columbia River sand could be produced. Ross Island installed the required sand wheels and thus produced a satisfactory sand which gave a stronger concrete.

Treatment of the gravel to produce commercial sand by the Ross Island Co. marked a change in the sand and gravel business on the Willamette

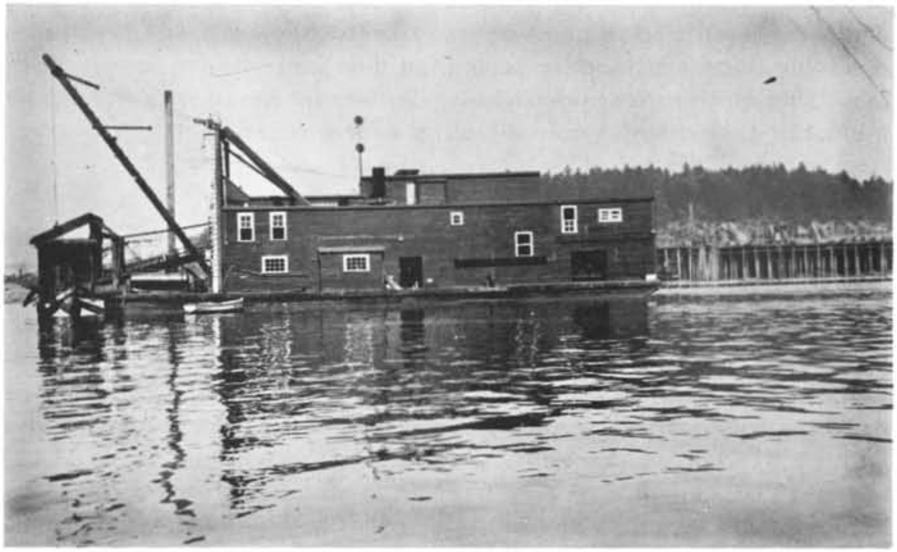


Figure 4. Howard Puariea's first clam-shell dredge, 1926.

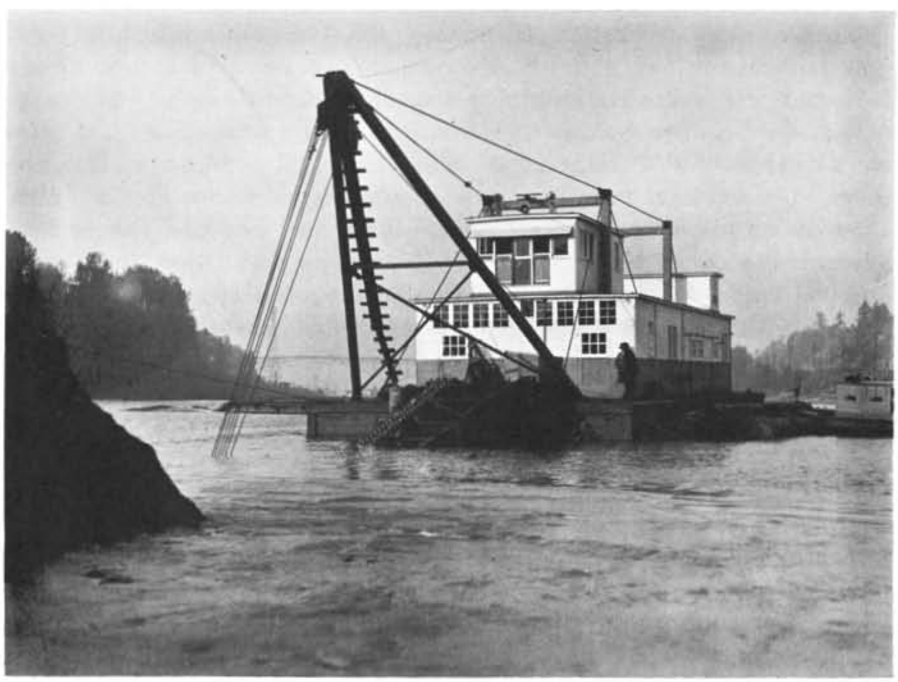


Figure 5. The first Ross Island Sand & Gravel Co. suction dredge, 1927.

River at Portland. Harold Blake was the first manager of the company. He installed a vibrating screen at the Ross Island plant about 1929. Highway engineers questioned its performance, but tests showed that this screen was making a cleaner and sharper separation than the revolving screens then in use. Shortly afterwards the Highway Department issued more rigid screening specifications which only vibrating screens could meet.

1930 - 1940

The 10 years between 1930 and 1940 were years of depression; nevertheless, production curves show that the use of sand, gravel, and crushed rock began to accelerate in 1935.

Work on the Bonneville Dam started on October 7, 1933. This was the beginning of the construction of the great system of dams to develop power, flood control, navigation, and irrigation in the Columbia River basin by the U.S. Government. A number of these dams have been built between Oregon and Washington, and also on the Willamette and its tributaries wholly within Oregon.

J. F. Shea and General Construction Co. had the contract for the south section of the Bonneville Dam. The Big Five Co. had the spillway contract, and used sand and gravel from up the river. General Construction Co. had the subcontract for furnishing 300,000 yards of sand and gravel required for the south section, the power house, and the navigation locks. The gravel plant was built in Portland on the river within the Union Pacific Railroad yards at the foot of N. Portsmouth Avenue. The location was selected for the purpose of obtaining a special intrastate freight rate to the Bonneville Dam site by way of Union Pacific Railroad. Sand and gravel were dug from the Willamette River plus additional sand from the Columbia River, and material from both sources was barged to the Portland plant. Digging equipment was leased from Swigert-Hart Co. and Harold Blake. The gravel plant had a capacity of 2500 yards per day. It had large storage and fast loading equipment; the finished aggregate was shipped directly to the dam site. Harold Blake managed the whole operation and, when the contract was completed, received the plant in payment for his services. This was the start of the combined Pacific Building Materials Co. and the Readymix Concrete Co.

Some time in the 1930's a contractor in San Francisco mounted a concrete mixer on a truck body and patented a transmission by which he could drive the mixer from the truck engine shaft. This idea did not appeal to operators immediately, but eventually it revolutionized the aggregate industry in the United States.

During the late thirties, Porter Yett of Pacific Bridge Co. built a mixing plant at a location on East Water Street, Portland, and began to deliver ready-mix concrete in special trucks. This practice was followed successively by Ross Island Sand & Gravel Co. and Harold Blake of Pacific

Building Materials Co. The Porter Yett plant was one of the most important developments in the history of the sand, gravel, and crushed rock industry in Oregon. It did not change the industry over night, but it was a big step in its evolution.

1940 - 1950

World War II slowed down the increasing rate of rock-products production in Oregon, but did not effectively hinder construction. Shipbuilding plants and housing for shipyard workers, air fields and other adjuncts to defense plants all required concrete, thus greatly increasing demand for construction materials.

During the post-war period, the ready-mix business grew rapidly but selectively. When Coffin Rock at Longview was depleted, Star Sand faded away. Nickum & Kelly went out of business. Diamond O Navigation also closed down after the death of its owner, Drake O'Reilly.

Pacific Building Materials Co. built the Curry Street plant of steel and concrete on the west side of the river convenient to the city core. The plant was designed to produce a large number of sand and gravel sizes and arranged so that the material could be blended to meet a wide range of specifications. The plant could be run the year around, since it had a large storage area. The ready-mix plant had the latest batching equipment, as an outgrowth of large dam construction.

The whole State of Oregon was growing during this period, and even some of the smaller towns had a sand and gravel plant and a ready-mix truck or two.

Those who made the history of the sand, gravel, and crushed rock industry during the first half of the century are listed below. It is to be regretted that the biographies of these men cannot be written here. They were more than producers of sand, gravel, and crushed rock -- they were builders of the Pacific Northwest. All honor to them.

1950 - 1960

Detroit Dam and Lookout Point Dam were built during this period and the aggregate, both coarse and sand size, was made from rock near the dam sites. Although sand and gravel were available locally, the U.S. Corps of Engineers did not find them suitable for a permanent structure because of the presence of hydrous silicates, which may combine with alkalies in the cement and form undesirable compounds. The Vancouver and Longview areas took large amounts of aggregate for industrial construction and most of this was supplied from the Willamette River sand and gravel plants. The gravel at Astoria also required outside sand, since the Astoria gravel was inherently deficient in suitable material.

Pioneer Sand and Gravel Producers in Oregon	
Columbia Contract Co.: Dan Kern Kern & Kibbe Captain Puariea Diamond O Navigation Co.: Drake O'Reilly Eugene Sand & Gravel Co. Pacific Building Materials Co.: Harold Blake Harold Eykelbosch Frank Pennepacker Melvin Erlund Howard Puariea McGeorge Gravel Co. Lewis McGeorge Nickum & Kelly Pacific Bridge Co.: Charles Swigert Phil Hart Porter Yett	Milwaukie Sand & Gravel Co. and predecessors Ross Island Sand & Gravel Co.: Ralph Schneelock Harold Blake Dewey Carpenter W. H. Muirhead Star Sand Co.: Chris Minsinger William Minsinger David Minsinger Salem Sand & Gravel Co. and Oregon Gravel Co.: Mr. Miles Richard Slater James C. Tait Umpqua Sand & Gravel Co.: Howard Hinsdale

Very little sand and gravel was now sold as such, because practically all aggregate was incorporated in concrete or asphalt for highways. Pacific Building Materials Co. and Mason's Supply built lime-slacking plants which also mixed sand and lime for use as plaster. Gypsum wallboard, plywood, and veneer paneling replaced old wood-lath and plaster work in building construction.

1960 - 1970

Concrete is now usually pumped to where it is to be placed, ready-mix trucks delivering it to the pump. Round gravel, as distinguished from angular material from crushers, is preferred for pumping and the balance is crushed for blacktop. Three-inch sizes are no longer required for highway work; minus $1\frac{1}{2}$-inch is now the largest size used in most work except for large dams.

Future supplies

Outside of the Portland area, few of the sand and gravel deposits show signs of exhaustion. The life of some sand and gravel bars has been extended by systematic regulation of the digging, allowing one dug-out portion to fill from stream flow during flood season while another area is

Figure 6. Metcalf gravel pit in east Portland about 1910.

dug out. This, of course, is limited to a certain annual yield.

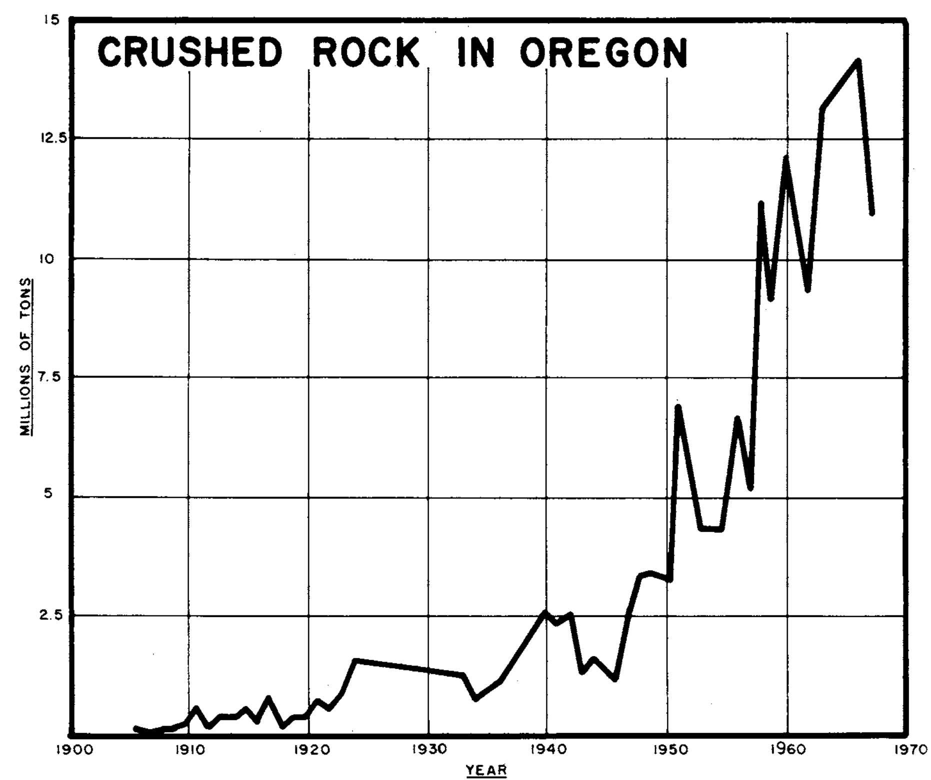
The supply of economic sand and gravel in the Portland area is rapidly becoming depleted. The Willamette River bed from Portland to the Oregon City Falls is now almost exhausted and will not supply the area's needs. Ross Island Co. is using a pump dredge again for the shallow bank work, followed by a clam shell which digs deeper than the suction dredge. Ross Island still has plenty of gravel below the original drilling of 80 feet, but it alone could not supply Portland's requirements. The locks at West Linn are a bottleneck in barging from above the falls -- they take only a 36-by-150-foot barge and the locking time is prohibitive.

Parker-Schramm built a sand and gravel plant at Scappoose near the SP&S Railway years ago. Several companies are now getting ready to take sand and gravel from the Scappoose area. This will not last long at the present rate of demand and further sources are necessary.

The east side of Portland is underlain by good sand and gravel. Small plants along 82nd Avenue and Johnson Creek supplied suburban home construction nearby (figure 6). Portland's growth built up the area but the home dwellers objected to the aggregate plant's operations. The plants then moved eastward, where the cycle was repeated. In a few words, the growth choked the plants which supplied the materials necessary for the growth. The result is that an enormous quantity of sand and gravel is now covered by residential developments.

The accompanying graphs (page 236) show the production of sand, gravel, and crushed rock from 1906 to 1967; they depict better than words how rapid the increase has been. It is estimated that Oregon has produced


OREGON SAND & GRAVEL PRODUCTION
25
20
15
10
5
MILLIONS OF TONS
1900
1910
1920
1930
1940
1950
1960
1970
YEAR


CRUSHED ROCK IN OREGON
15
12.5
10
7.5
5
2.5
MILLIONS OF TONS
1900
1910
1920
1930
1940
1950
1960
1970
YEAR

450,000,000 cubic yards of sand, gravel, and crushed rock in this period. At the present rate of more than 30,000,000 cubic yards a year, it will be necessary to preserve some areas for future needs before they are zoned for other purposes and we are then forced to bring in outside aggregate.

Present open-pit methods of mining rock on a large scale have kept ahead of rising costs of labor and material, but these are still the limiting factors in production of aggregate for concrete. Modern crushing and grinding practice has also progressed so that over-all costs of aggregate are not excessive. The final solution for economical production eventually may be a large-capacity plant making aggregate from rock on either the Willamette or the Columbia Rivers. Oregon has all of the suitable rock needed.

Acknowledgments

The author wishes to express his gratitude to Mr. F. W. Libbey, mining engineer, Portland, for his careful editing of the manuscript, and to the members of the State of Oregon Department of Geology and Mineral Industries for their assistance.

Selected Bibliography

Glenn, J. L., 1962, Gravel deposits in the Willamette Valley between Salem and Oregon City, Oregon: The Ore Bin, v. 24, p. 33-47.

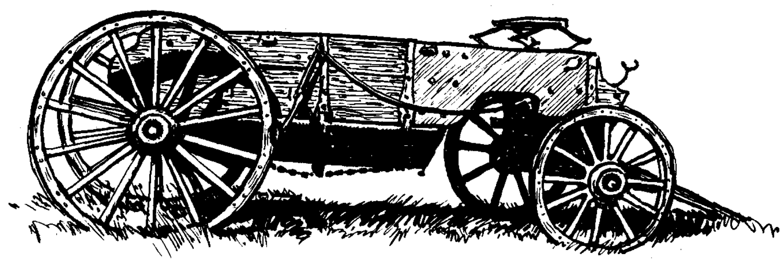
__________, 1965, Late Quaternary sedimentation and geologic history of the northern Willamette Valley, Oregon: Oregon State Univ. doctoral dissertation, 231 p.

Lancaster, S. L., 1915, The Columbia, America's great highway through the Cascade Mtns. to the sea: S. L. Lancaster, Portland, Oregon.

Scott, W. A., 1934, Producing sand and gravel for power house and locks at Bonneville: Pacific Builder & Engineer, December.

Trimble, Donald E., 1963, Geology of Portland, Oregon and adjacent areas: U.S. Geol. Survey Bull. 1119, 119 p.

U.S. Bureau of Mines, 1906-1967, Minerals Yearbooks: U.S. Bur. Mines.

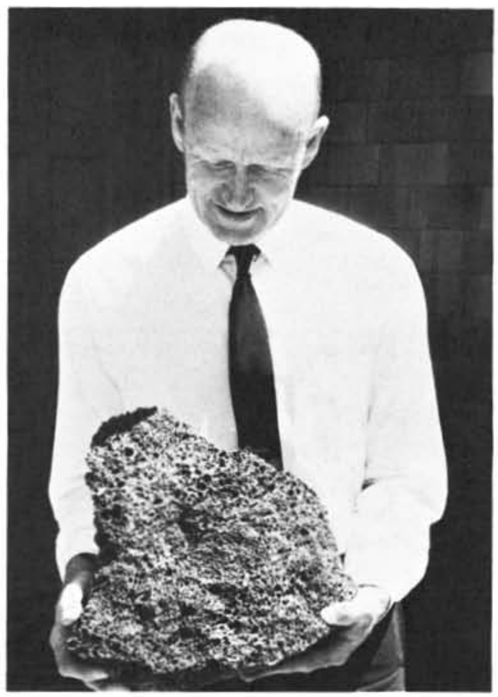


Sketch by Ernest Richardson, The Oregonian

OREGON "MOON ROCK"

When astronauts make their third landing on the moon, after completing the ride into space early in 1970, they are expected to do some drilling into rocky portions of the moon's surface. When they do, they probably will use drills tested and developed by the Martin-Marietta Co. at Denver.

When Martin-Marietta began testing drills to be used on the moon, they called on the State of Oregon Department of Geology and Mineral Industries because of the work the Department has done in past years on the recent volcanic rocks in the Bend area. A special type of lava was needed in order to simulate what the geologists assumed to be the bedrock on the moon.



Norman V. Peterson, district geologist in the Department's Grants Pass office, was able to locate the required rock because he remembered where large blocks of this material had been blasted loose during a construction project and were left lying on the surface. The rock was a vesicular basalt from a relatively young lava flow near Lava Butte, a well-known volcanic peak beside U.S. Highway 97 approximately 10 miles south of Bend. The age of this lava flow was determined by radioactive carbon dating to be 5800 ± 150 years. Approximately 10 tons of the basalt was shipped to Denver in 1966 and an almost equal amount was sent off about May 1 of this year when the supply at Denver had been used up. (Photograph courtesy of Grants Pass Courier.)

THE NORTH POWDER EARTHQUAKE OF AUGUST 14, 1969

by

Richard Couch and Robert Whitsett*

The North Powder earthquake of August 14, 1969 occurred at 07:37 a.m. PDT approximately 4 km southeast of the Thief Valley Reservoir in northeastern Oregon. A magnitude of 3.6 and a depth of focus of 32 km are estimated for the shock. Records list only two other earthquakes for the area between Baker and Union, Oregon -- both of intensity III. Intensities up to V - VI are indicated for the 1969 shock. Consequently, it is the largest earthquake to have occurred in recorded history in this relatively aseismic area (figure 1).

Recording stations

Eight permanent and four temporary seismograph stations recorded the North Powder earthquake. Table 1 lists the P-wave arrival time and initial phase observed at the 12 stations. Only the Baker and Bend, Oregon stations recorded a well-defined first arrival.

Epicenter and origin time

The geographic coordinates of the earthquake are 44° 59'N latitude, 117°45'W longitude. The epicenter, as shown in figure 1, is located approximately 12 km (7.6 miles) south-southeast of North Powder and 4 km (2.4 miles) southeast of the Thief Valley Reservoir. This determination is based on the observed arrival times listed in table 1 and the local travel-time curves prepared for the Pacific Northwest states by Dehlinger, Chiburis, and Collver (1965). The origin time of the earthquake is estimated to be 06 hrs. 37 min. 39.5 sec. PST, August 14, 1969. The seismic wave arrival times at Blue Mountains Seismological Observatory, although well defined, were not used in determining the epicenter.

Depth of focus

The earthquake occurred at a depth of 32 $\pm$ 3 km. Focal depth calculations depend on the seismic velocities of the crustal and subcrustal

* Dept. of Oceanography, Oregon State University, Corvallis, Oregon.

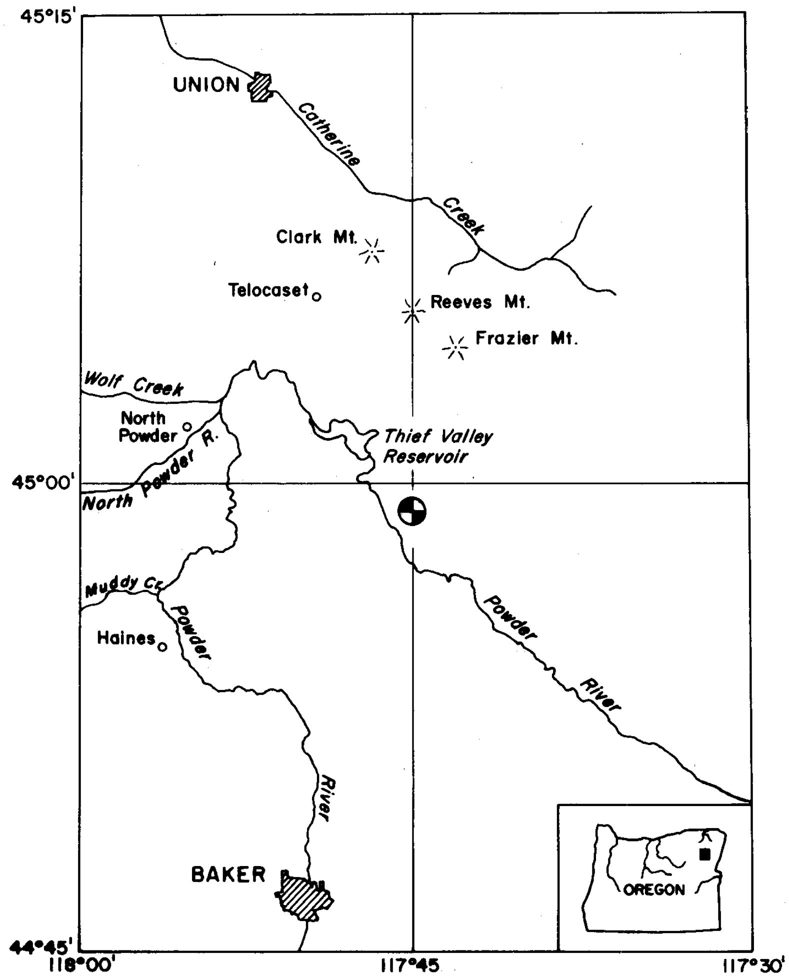


Figure 1. The sectored circle indicates the epicenter of the North Powder earthquake of August 14, 1969.

layers and are quite sensitive to small changes in velocity. A depth of 30.3 km is obtained from calculations using the p-wave travel time to Blue Mountains Seismological Observatory and a crustal structure (Dehlinger, Chiburis, and Collver, 1965; and Dehlinger, Couch, and Gemperle, 1968) consisting of an upper crustal layer 9 km thick with a p-wave velocity of 6.1 km/sec and a lower crustal layer 33 km thick with a p-wave velocity of 6.6 km/sec. French (1970) developed a method of determining earthquake focal depths based on the arrivals of post P_n phases of seismic waves.

A focal depth of 32.0 km is obtained from post P_n arrivals at Pine Mountain Observatory. This depth determination is independent of uncertainties in origin time and the location of the epicenter.

Magnitude

The magnitude of the earthquake is estimated to be 3.6 on the Richter Scale. Magnitudes according to this scale are based on the amplitude of ground motion recorded at seismic stations. Magnitudes are logarithmically scaled and range from 0 or less for the smallest recorded shocks to 8 3/4 for the largest, most destructive earthquakes (Richter, 1958, p. 340). A magnitude estimate of 3.5 was furnished by the Newport Seismological Station at Newport, Wash., and a magnitude estimate of 3.7 was furnished by the Blue Mountains Seismological Observatory at Baker, Ore.

TABLE 1

Station	Location	Time (PST) hr/min/sec	Initial Motion C-Compression D-Dilitation
COR	Corvallis, Oregon	06:38:40.9	--
BMO	Baker, Oregon (Blue Mts. Seis. Obs.)	06:37:47.0	C
HHM	Hungry Horse, Montana	06:38:45.0	--
NEW	Newport, Washington	06:38:30.0	--
NIT	Newport, Washington (Temporary)	06:38:35.0	--
PMT	Bend, Oregon (Pine Mt. Obs.)	06:38:22.2	D
PTD	Portland, Oregon (O. M. S. I.)	06:38:35.2	--
SPO	Spokane, Washington	06:38:26.0	--
BDG	Hanford, Washington (46°14.08', 119°19.05')	06:38:05.5	D
ELT	Hanford, Washington (46°27.90', 119°03.50')	06:38:06.9	D
OTH	Hanford, Washington (46°44.40', 119°13.00')	06:38:10.9	D
MID	Hanford, Washington (46°36.80', 119°45.65')	06:38:12.1	D

Intensity

Estimated intensities on the Modified Mercalli Intensity Scale of 1931 are: Wolf Creek V-VI, Muddy Creek IV-V, North Powder IV, Haines III, Baker II. Intensity estimates are based on the observed or felt effects of the earthquake at these various places. The M.M. scale extends from intensity I, which is not felt, to intensity XII, in which damage is nearly total (Richter, 1958, p. 137). The intensity estimates are based largely on observations as reported by local newspapers. The higher intensities appear to occur in the valleys. This may be attributed to higher population densities in the valleys and also to the surficial material - composed largely of fluviatile deposits - which tends to amplify the ground motion. Undulations of the ground were reported in the Wolf Creek area. The earthquake was reportedly heard before it was felt in the North Powder, Haines, Radium Hot Springs, and Wolf Creek areas.

Source motion

The direction of first motion of the longitudinal wave (P_n) at Pine Mountain Observatory indicated a dilatation and the direction of first motion of the longitudinal wave (p) at Blue Mountains Seismological Observatory indicated a compression. The first motion directions observed at the four Hanford, Wash. stations indicated a dilatation. The first motion directions suggest right lateral faulting along a northwest-southeast trending strike-slip fault or left lateral faulting along a northeast-southwest strike-slip fault. Weak longitudinal wave onsets and motions at Spokane and Newport, Wash., and relatively strong shear wave motions observed at North Powder and Wolf Creek also suggest strike-slip movement. Mapped surface faults in the region trend northwest-southeast. Although the limited data do not permit a definite conclusion regarding fault motion, right lateral motion along a northwest-southeast trending strike-slip fault appears the most likely cause of the North Powder earthquake.

Discussion

The area about North Powder and the Thief Valley Reservoir is relatively aseismic. The area is bordered on the east by a seismically active area along the Snake River and on the north by activity in the vicinity of the Walla Walla River in the Deschutes-Umatilla Plateau. Berg and Baker (1963), in their historical summary of earthquakes in Oregon, list only two shocks for the region about Baker: September 1, 1906 and May 28, 1916. An intensity of III is listed for these two earthquakes, whereas an intensity of approximately V-VI is assigned the August, 1969 earthquake. The earthquake history of this region is too short to calculate an average seismic energy release rate.

The earthquake occurred in the vicinity of the Blue Mountain uplift, an area of glacial and fluviatile deposits. These deposits are mostly of Pleistocene and Holocene age and are concentrated in the numerous valleys of the region. These deposits which are not well consolidated tend to enhance ground vibrations due to seismic waves. Their occurrence may partially explain the relatively high intensities associated with an earthquake 32 km deep.

It is unlikely that changes in the heat source of Radium Hot Springs or levels of the Thief Valley Reservoir are the cause of the earthquake. The focal depth of the earthquake, in this relatively aseismic area, suggests a regional rather than local cause and the method of faulting suggests a subcrustal tectonic cause rather than isostatic adjustment due to load removal by erosion.

The agreement in focal depth of the earthquake, determined from the compressional wave travel-time to Blue Mountains Seismological Observatory and independently by the method of French (1970), indicates that the depth beneath the surface of the Mohorovicic discontinuity - the interface between the Earth's crust and mantle - near Baker, Ore. is approximately 42 km as previously depicted by Dehlinger, Couch, and Gemperle (1968), and Thiruvathukal (1968).

Acknowledgments

The following people supplied arrival-time data and are gratefully acknowledged: F. Brecken, Oregon Museum of Science and Industry, Portland, Ore.; L. Jaksha and D. Newsome, Blue Mountains Seismological Observatory, Baker, Ore.; A. Travis, Newport Seismological Observatory, Newport, Wash.; Robert Bechtold, NASA, Houston, Texas; M. Castner, Mt. St. Michels Seismological Observatory; A. M. Pitt, Regional Center for Earthquake Research, Menlo Park, Cal. We thank Dr. William French, Gulf Research, Pittsburg, Pa., for introducing us to a new method of determining earthquake focal depth and Stephen Johnson, Oregon State University, for technical assistance.

References

Berg, J. W., Jr. and C. D. Baker, 1963, Oregon Earthquakes, 1841 through 1958: Seismol. Soc. Am. Bull., vol. 53, no. 1, p. 95-108.

Dehlinger, P., E. F. Chiburis and M. M. Collver, 1965, Local travel-time curves and their geologic implications for the Pacific Northwest states: Seismol. Soc. Am. Bull., vol. 55, no. 3, p. 587-607.

Dehlinger, P., R. W. Couch and M. Gemperle, 1968, Continental and oceanic structure from the Oregon coast westward across the Juan de Fuca Ridge: Can. J. of Earth Sciences, vol. 5, p. 1079-1090.

French, W. F., 1970, Earthquake waves following the P_n phase and their

indications of focal depth and crustal structures in the Pacific Northwest states: Oregon State Univ. doctoral dissertation, 175 p.
Richter, C. F., 1958, Elementary Seismology: San Francisco, W. H. Freeman & Co., 768 p.
Thiruvathukal, J. V., 1968, Regional gravity of Oregon: Oregon State Univ. doctoral dissertation, 92 p.
The Record-Courier, Baker, Oregon, Thursday, August 21, 1969 and Thursday, August 14, 1969.
Democrat-Herald, Baker, Oregon, Friday, August 15, 1969.

* * * * *

INTERIOR SUPPORTS MINING LAW OF 1872

Secretary of the Interior Walter J. Hickel has given full support to the existing Mining Law of 1872, completely reversing the position taken by former Interior Secretary Stewart Udall. Hickel has recommended the following changes for improving the law without sacrificing its basic concepts:

1. Revision of the patenting procedures to grant claimants only a patent to subsurface mineral resources with a right to use so much of the surface as is necessary for mining and related activities. The patentee would have preference in any sale of the remaining surface rights.
2. Provisions for realistic increases in the purchase price per acre for mining claims upon patenting. Such increases should adequately reimburse the federal government for expenses incurred in issuing the patents. Prices established in 1872 are far from in line with prices today.
3. Retention by the United States of surface rights should be accompanied by a provision enabling the federal government to exercise a reasonable degree of control over the impact upon the surface and environment as a result of mining and related operations.
4. Elimination of the distinction between lode and placer claims. Countless problems have been caused by this needless distinction and it is generally agreed that it serves no useful purpose.
5. Establishment of a means to clear the public land of stale and abandoned mining claims. The present system is ineffective and extremely expensive. As a result, very slow progress has been made in clearing public land of questionable claims which adversely affect both the mining industry and the public interest.
6. Elimination of local laws and customs for the regulation of claims locations and the establishment of clear and modern federal requirements applied uniformly which recognize the technological development made in the mining industry. These regulations should require claim locations to conform to the lines of public survey.

7. Elimination of extralateral rights. Amend existing laws to provide that mining claims include only minerals within the vertical extensions of claim boundaries.

8. Establishment of a system of prediscovery claims subject to reasonable requirements for time of development. This should provide necessary protection for one engaging in exploration with reasonable diligence and intending to develop any workable deposits found.

* * * * *

DOTHAN (?) FOSSILS DISCOVERED

By Len Ramp

While we were mapping in the Kalmiopsis Wilderness Area* of Curry County in September 1968, Vernon Newton and I discovered fossils unexpectedly in an area mapped as Dothan Formation by Wells and Peck (1961) on their Geologic Map of Oregon West of the 121st Meridian. Because of the lack of diagnostic fossils in the Dothan Formation, we were quite excited about our find, and spent considerable time breaking rock to get a representative collection.

The fossils were in loose boulders of a dark gray to black, limy argillite which was brownish on weathered surfaces. The boulders are along the east bank of the Chetco River about 1000 feet upstream from the mouth of Boulder Creek in sec. 7, T. 38 S., R. 11 W., and they appear to have originated from a rock slide. Similar rocks are exposed in place along the river banks nearby.

The fossils have been examined by Dr. R. W. Imlay, U.S. Geological Survey, Washington, D.C. and by Dr. D. L. Jones, U.S. Geological Survey, Menlo Park, Cal. Both men agree that the fossils appear to be Buchia piochii (Gabb). This small clam indicates a latest Jurassic (Tithonian) age for the rocks in which it occurs. If the beds on the Chetco River are indeed part of the Dothan Formation, then the Dothan is appreciably younger than the Late Jurassic Galice (Oxfordian-Kimmeridgian). The age relationship between the Galice and Dothan Formations has been a controversial matter ever since the two units were described by Diller in 1907. Diller (1914) believed that the Dothan was the younger and that the eastward-dipping Dothan-Galice section, with the Dothan on the west, was overturned. Subsequent authors -- Taliaferro (1942), Wells and Walker (1953), Irwin (1964), Dott (1965), and Baldwin (1969) -- have discussed the problem with conflicting views. None of them, however, had the benefit of adequate

* Part of a study concerning the geology and mineral resources of the Upper Chetco River to be published by the Department.

fossil evidence for the age of the Dothan. What is needed now is more detailed mapping within the formation to trace out these sedimentary rocks along the Chetco River and make sure that they are equivalent to similar-appearing rocks at the type locality of the Dothan Formation along Cow Creek in Douglas County, 35 miles to the northeast. Of course, the discovery of Buchia piochii (Gabb) in the type locality would be the best proof.

References

Baldwin, E. M., 1969, Thrust faulting along the lower Rogue River, Klamath Mountains, Oregon: Geol. Soc. America Bull., v. 80, no. 10, p. 2047-2052.

Diller, J. S., 1907, The Mesozoic sediments of southwestern Oregon: Am. Jour. Sci. 4th Ser., v. 23, p. 401-421.

__________, 1914, Mineral resources of southwestern Oregon: U.S. Geol. Survey Bull. 546.

Dott, R. H., Jr., 1965, Mesozoic-Cenozoic tectonic history of the southwestern Oregon coast in relation to Cordilleran orogenesis: Jour. Geophys. Research, v. 70, p. 4687-4707.

Irwin, W. P., 1964, Late Mesozoic orogenies in the ultramafic belts of northwestern California and southwestern Oregon, in Geological Survey Research, 1964: U.S. Geol. Survey Prof. Paper 501-C, p. C1-C9.

Taliaferro, N. L., 1942, Geologic history and correlation of the Jurassic of southwestern Oregon and California: Geol. Soc. America Bull., v. 53, p. 71-112.

Wells, F. G., and Peck, D.L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geol. Survey Map I-325.

Wells, F.G., and Walker, G. W., 1953, Geologic map of the Galice quadrangle, Oregon: Oregon Dept. Geology and Mineral Industries Map Series.

* * * * *

FOSSIL WOOD ON EXHIBIT

The Department has a new exhibit in its "loan case" at the Portland office. It consists of a group of beautifully polished fossil woods that was collected and identified by Mrs. Irene Gregory, authority on fossil woods in Oregon. The wood specimens are from a wide variety of localities in the state, including Sweet Home, Clarno, Greenhorn Mountains, and many other areas. Most of the specimens are cut and polished to reveal identifiable woodgrain. In addition, there are agate limb casts and features such as bark, knots, insect eggs, and replacement crystals. At least 28 genera of Late Cretaceous and Tertiary woods are represented in this fine exhibit.

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INDEX TO THE ORE BIN

Volume 31, 1969

AVAILABLE PUBLICATIONS

(Please include remittance with order. Postage free. All sales are final and no material is returnable. Upon request, a complete list of the Department's publications, including those no longer in print, will be mailed.)

BULLETINS

2.	Progress report on Coos Bay coal field, 1938: Libbey	$ 0.15
8.	Feasibility of steel plant in lower Columbia River area, rev. 1940: Miller	0.40
26.	Soil: Its origin, destruction, preservation, 1944: Twenhofel	0.45
27.	Geology and coal resources of Coos Bay quad., 1944: Allen and Baldwin .	1.00
33.	Bibliography (1st supplement) of geology and mineral resources of Oregon, 1947: Allen	1.00
35.	Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1963: Baldwin .	3.00
36.	Vol. 1. Five papers on western Oregon Tertiary foraminifera, 1947: Cushman, Stewart, and Stewart	1.00
	Vol. 2. Two papers on foraminifera by Cushman, Stewart, and Stewart, and one paper on mollusca and microfauna by Stewart and Stewart, 1949	1.25
37.	Geology of the Albany quadrangle, Oregon, 1953: Allison	0.75
46.	Ferruginous bauxite deposits, Salem Hills, Marion County, Oregon, 1956: Corcoran and Libbey	1.25
49.	Lode mines, Granite mining dist., Grant County, Ore., 1959: Koch . .	1.00
52.	Chromite in southwestern Oregon, 1961: Ramp	3.50
53.	Bibliography (3rd supplement) of the geology and mineral resources of Oregon, 1962: Steere and Owen	1.50
56.	Fourteenth biennial report of the State Geologist, 1963-64	Free
57.	Lunar Geological Field Conference guide book, 1965: Peterson and Groh, editors	3.50
58.	Geology of the Suplee-Izee area, Oregon, 1965: Dickinson and Vigrass .	5.00
60.	Engineering geology of the Tualatin Valley region, Oregon, 1967: Schlicker and Deacon	5.00
61.	Gold and silver in Oregon, 1968: Brooks and Ramp	5.00
62.	Andesite Conference Guidebook, 1968: Dole, editor	3.50
63.	Sixteenth Biennial Report of the State Geologist, 1966-68	Free
64.	Mineral and water resources of Oregon, 1969	1.50
65.	Proceedings of the Andesite Conference, 1969: McBirney, editor . . .	2.00

GEOLOGIC MAPS

Geologic map of Oregon (12" x 9"), 1969: Walker and King . . .	0.25
Preliminary geologic map of Sumpter quadrangle, 1941: Pardee and others . .	0.40
Geologic map of Albany quadrangle, Oregon, 1953: Allison (also in Bull. 37) .	0.50
Geologic map of Galice quadrangle, Oregon, 1953: Wells and Walker. . . .	1.00
Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts . . .	0.75
Geologic map of Bend quadrangle, and reconnaissance geologic map of central portion, High Cascade Mountains, Oregon, 1957: Williams. . .	1.00
GMS-1: Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka . .	1.50
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