

The Ore Bin



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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES**

The Ore Bin

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OREGON'S MINERAL AND METALLURGICAL INDUSTRY IN 1971

Ralph S. Mason*

If 1971 could be labelled the year of "Emergent Environmentalism", then 1972 will almost certainly have to be tagged as the year of "Enforced Environmentalism." Of particular interest to the extractive mineral industry will be the implementation of HB 3013, the Mined Land Reclamation Act, which becomes effective on July 1, 1972. Other environmental regulations originating at state or Federal levels will also have profound effect on the industry.

Despite the lackadaisical state of the economy, mineral production in Oregon chalked up a modest gain, rising to an estimated \$68.4 million. As usual, sand and gravel and stone accounted for most of the production. The value of metals and metallurgical products refined in the state is not included in the canvass by the U.S. Bureau of Mines. If this figure were included, the total would exceed \$700 million.

The Big E

The Environment means many things to many people. To the sand-and-gravel producer Environment will mean conformance to the Mined Land Reclamation Act which goes into effect July 1, 1972, and which will require a permit, a mining plan, a reclamation program and the payment of a small fee. Rules and regulations have not been drawn up but will be published in the Ore Bin later this year. To the hard-rock miner Environment means removal of the requirements for digging location cuts on claims and tightened regulations on solid waste disposal and on air and water pollution. To the mill operator the Big E will mean stricter control of chemical and solid wastes and air and water pollution.

Metallurgical plants have already spent large sums in diminishing environmental problems and millions of dollars more are being spent by

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northwest plants. In the state of Washington, where a mined land reclamation act is two years old, production costs have been upped an estimated one to two cents per yard. The enhancement of the Environment in many sectors is badly needed and long overdue. Just what remedies to apply and to what degree they should be enforced will require much study. Environmental Impact Statements attempt to characterize the effects of a proposed activity. It is suggested that a companion Economic Impact Statement also be prepared to evaluate the effects of environmental controls on industry, jobs, natural resources, and related factors. Enhancement of the environment can only be achieved by massive injections of funds derived from a healthy economy. No matter what course environmental controls take, it is certain that the cost of doing business will be increased.

The Metals

The mining and smelting of nickel ore at the Hanna operation at Riddle in Douglas County continued to be the state's most important metal mining activity. Utilization of some of the vast pile of slag accumulated over the years at the smelter has been growing, and now 3,000 tons a month are processed and sold for a variety of end uses. Sandblasting grit is the most important use for the gray-green glassy material, which is also sold for roofing granules, non-skid coatings, and road sanding material.

Several exploration projects for nickeliferous laterite deposits in southwestern Oregon were conducted during the year. The work follows earlier geochemical stream-sediment sampling conducted by the Oregon Department of Geology and Mineral Industries.

The production of mercury declined almost to the vanishing point as the price per flask moved to lower and lower levels. The old Maury mine east of Prineville in Crook County was explored with the aid of an OME loan by C. F. Taylor. Exploration drilling was also conducted just west of the Horse Heaven mine in Jefferson County, where Ray Whiting had previously produced a few flasks. The Horse Heaven mine closed a number of years ago after a long period of production. Cleanup operations at the Elkhead mine, Douglas County, by Alcona Mining Company accounted for the bulk of the state's liquid metal production, with a total of 31 flasks retorted.

Although gold mining in Oregon extends back 120 years, it reached what must be an all-time low during 1971 when no production was reported by the U.S. Bureau of Mines. Actually tiny amounts were produced from a few seasonal placer and small hard-rock mines. Additional quantities were also recovered by part-time skin divers and recreationists, who spent many days in and under the water collecting "colors."

Interest by mining companies looking for gold prospects continued at a slow pace in the state during the year. The old Bald Mountain mine, Cracker Creek district, Baker County, was explored by Nuclear Development Company, which shipped 13 rail carloads of development ore to Tacoma.

Some of Oregon's Minerals at a Glance
Preliminary Figures for 1971
(in thousands of dollars)

	1970	1971
Antimony	\$ ---	\$ 21
Clays	180	180
Diatomite	5	W
Gem stones	750	750
Gold	9	---
Lime	1,777	1,647
Mercury	112	W
Nickel	W	W
Pumice and volcanic cinders	1,252	1,338
Sand and gravel	25,978	26,803
Silver	6	---
Stone	20,948	20,110
Value of items that cannot be disclosed: Cement, fire clay, copper, talc, and values indicated by symbol "W"	<u>17,084</u>	<u>17,605</u>
Totals	\$68,101	\$68,454

Otherwise most gold activity was by individuals or small partnerships who explored the North Pole Lode, Cracker Creek district, Baker County; the BiMetallic mine, Greenhorn district, Grant County, in northeastern Oregon; and the Humdinger mine and Fall Creek mine in the southwestern part of the state. The Roy prospect adjacent to the Oregon King mine near Ashwood, Jefferson County, was explored with the help of an OME development loan. The Oregon King has produced modest amounts of silver over the years. Although not strictly a mining operation, a considerable quantity of high-grade silver was recovered in the state from old photographic and X-ray film. One of the operators produces pure silver jewelry in addition to the normal silver bars.

Northeastern Oregon and the adjoining area around Cuprum in Idaho saw continuing exploration for copper during the year. Field work ranged from basic geologic mapping to drilling and sampling with most of the work being done by five companies. The Department sparked interest in northeastern Oregon copper a number of years ago when it publicized the results of a limited geochemical sampling program.

In southwestern Oregon copper exploration was conducted at the Rowley mine and at the Lick Creek Copper prospect, both in Jackson County. Duval Corporation employed four men on a stream-sediment sampling program in Douglas, Josephine, and Jackson Counties, with copper as their main objective.

Two tungsten properties, one on Pedro Mountain, Mormon Basin district, and the other on the Little Joe property in the Burnt River district, both in Baker County, were worked in a small way during the year.

Industrial Minerals

Although normal geologic erosional processes annually produce some "new" supplies of sand and gravel, the resource should best be considered to be non-renewable, particularly so in view of the rapidly growing demands for this irreplaceable construction material, and the equally rapid urbanization of areas underlain by potential source beds. Growing numbers of communities are becoming aware that their local supplies of sand and gravel will not last forever and have begun studying how best to preserve their deposits. At the state level several studies have been proposed which would inventory areas underlain by sand and gravel, and identify those areas which (1) are potential sources of aggregate, (2) are aquifers for underground water, and (3) should be left undisturbed as spawning grounds for fish. None of these proposals have received funding. Any effective regional or local long-range planning must necessarily wait until these studies have been completed.

Sand and gravel and crushed stone still are "best buys" in the construction field, with prices rising far less rapidly than most other segments of the economy. As shortages develop in locally deprived areas in the future, this situation will change and prices will rise substantially. Although not

Oregon's Million-Dollar-A-Year Club, 1970*

<u>County</u>	<u>Value</u>	<u>County</u>	<u>Value</u>
Baker	\$ 6,153,000	Linn	\$1,238,000
Benton	1,030,000	Multnomah	7,402,000
Clackamas	11,433,000	Washington	2,276,000
Klamath	2,945,000		

*In addition to the values shown, there was a total of \$21,101,000 which could not be assigned to specific counties. Production from Columbia, Douglas, Gilliam, Harney, Hood River, Jefferson, Malheur, Morrow, and Wheeler Counties was concealed by the U.S. Bureau of Mines 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 \$1,891,000 during the year.

practical at present, the time may come when even used concrete will have to be recycled.

Preliminary figures for 1971 show that Oregon produced 30 million tons of sand and gravel and stone with a value of about \$47 million, a fractional increase over 1970.

Other industrial minerals produced in the state included limestone quarried at Lime in Baker County by Oregon Portland Cement Company; pumice and volcanic cinders quarried by several operators in central Oregon; diatomite mined near Silver Lake in northern Lake County; silica from a quarry near Gold Hill in Jackson County and another east of Roseburg, Douglas County; dimension stone from various small quarries scattered throughout eastern and central Oregon; and soapstone blocks cut out of a stone quarry near Williams in Josephine County. Clay for red-firing brick and tile was dug in various pits throughout the state. Expansible clay for lightweight aggregate and pozzolan was produced at a quarry in Washington County.

Semi-precious gemstones continued their great popularity with a steadily increasing number of rockhounds. Although the activity is almost exclusively based on individual efforts, the value of quartz family stones annually extracted in the state probably exceeds \$750,000. A few commercial gemstone operations are active in the state, but no completely integrated facilities have as yet been developed to cater to both the experienced collector and the casual tourist.

An emery deposit near Sweet Home, Linn County, is being developed by Jerry Gray of the Oregon Emery Company. The deposit was described in the November 1968 issue of the Ore Bin.

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QUICKSILVER MAP PUBLISHED

The Department has issued Miscellaneous Paper 15, "Quicksilver Deposits in Oregon," by Howard C. Brooks. The publication consists of a map showing distribution of all known mines and prospects in the State, with a numerical listing giving locations by county. On the reverse side is a summary of the economics of quicksilver, mineralogy of deposits, prospecting guides, and geology of the main districts where mercury mineralization occurs. Trends in Oregon production over the years are shown graphically, and the annual production from individual mines between 1882 and 1970 is tabulated.

The publication is designed to replace the out-of-print map by Francis Frederick (1945) and to update the information in the out-of-print Bulletin 55, "Quicksilver Deposits in Oregon," by Brooks (1963).

Miscellaneous Paper 15, on a sheet 22 by 36 inches, comes folded in an envelope. It can be purchased from the Department's offices in Portland, Baker, and Grants Pass. The price is \$1.00.

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OIL AND GAS EXPLORATION IN 1971

Vernon C. Newton, Jr.*

Oregon, along with Washington and Idaho, is still without commercial discoveries of oil and gas. A total of 181 wildcats has been drilled in the state since the early 1900's, but only 26 of the onshore holes and 8 offshore holes have penetrated deeper than 4000 feet. Texaco's wildcat "Federal No. 1," drilled in central Oregon this past fall, drew considerable attention from the rest of the oil industry, but the hole was abandoned at the 8000-foot level.

Onshore activity

Texaco began drilling the "Federal No. 1" approximately in the center of its 250,000 acre lease block in Crook County in August. The drilling contractor was released in December, so it is presumed that Texaco does not plan any more exploration on its 400-square mile lease block in the near future. It is probable that additional drilling was discouraged by environmentalists asking for delay in issuance of drilling permits by the U.S. Bureau of Land Management.

The Oregon Environmental Council asked in October that the Texaco drilling be halted until an impact statement could be filed, which it claimed was required under the 1970 National Environmental Policy Act. The Regional Director of the U.S. Bureau of Land Management and his staff, after making an environmental analysis of the drilling, determined that an impact statement was not required because the operation did not involve a "major Federal action" significantly affecting the quality of the human environment (U.S. Bureau of Land Management News Release, November 13, 1971).

The U.S. Department of the Interior has announced that after April 1, 1972, a public notice will be required for each application to drill on Federal lands. If substantial objections are raised during that period, a review will be made and an impact statement prepared.

Geologic mapping indicates that the area explored by Texaco has marine sediments at depth. Northeast-striking marine sandstone and conglomerate beds of the Bernard Ranch Formation of Late Cretaceous (Cenomanian) age crop out 12 miles east of the Texaco well site. Older Mesozoic and Paleozoic marine rocks lie at the east of the Cretaceous exposures, and Tertiary volcanics overlie them to the west (Dickinson and Vigrass, 1965).

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

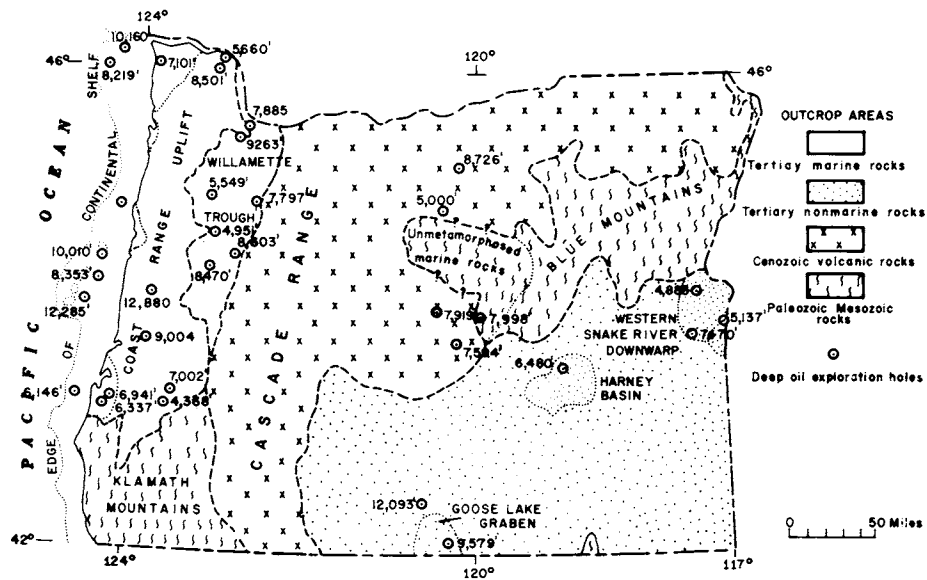
Cretaceous marine and nonmarine sedimentary units have been mapped 40 miles north of the Texaco location near the town of Mitchell. These rocks are dated as Albian-Cenomanian by Oles and Enlows (in press), so they are in part older than the Bernard Ranch Formation. Mapping by Swanson (1968) shows the location of the Texaco "Federal No. 1" well to be on an anti-clinal structure, with the Eocene Clarno Formation exposed at the crest and Miocene basalt covering the flanks.

Standard Oil Company of California made a surprise move early in 1971 by leasing several hundred square miles of land in eastern Oregon and western Idaho which is covered by young volcanics and the subsurface geology uncharted. Standard also picked up some acreage at the southeast corner of the Texaco land block. Amoco Production Company (formerly Pan American Petroleum Corp.) applied in September for leases on Federal lands adjoining the northwest portion of Texaco's leases and for another several hundred square miles of leases in the western Snake River Basin where many gas shows have been found in past drilling. Processing of the leases by the U.S. Department of Interior has been delayed because of environmental considerations.

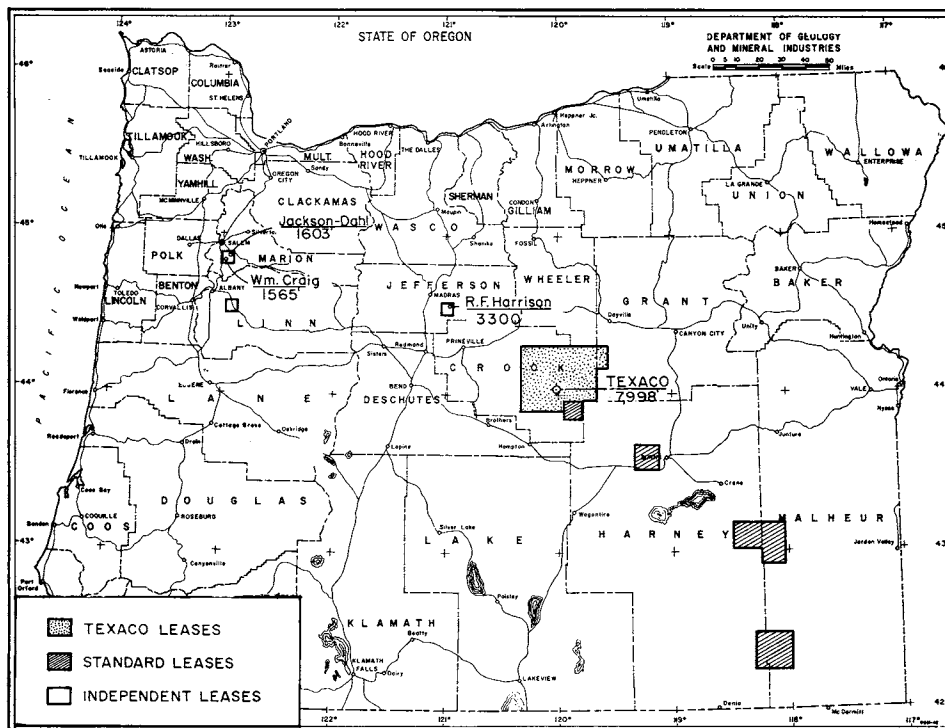
News of the relinquishment of leases in Columbia, Washington, Coos, and Lane Counties by Mobil Oil Company was discouraging. Mobil had done no drilling on the leases but conducted field studies for several years in western Oregon.

Wildcatters accounted for an estimated 20,000 acres of oil and gas leases in Oregon in 1971.

Active Drilling Permits - 1971					
Operator	Permit No.	Unique well No.	Location	Depth	Status
R. F. Harrison	60-D	031-00002	SW $\frac{1}{4}$ sec. 18, T12S., R15E. Jefferson Co.	3300'TD	No new hole drilled Plugged and abandoned 8-9-71
Wm. Craig-Producers Oil & Gas	61	047-20001	NW $\frac{1}{4}$ sec. 24, T9S., R4W. Marion County	1565'TD	Plugged and abandoned 3-19-71
Jackson-Dahl	62	047-20002	NE $\frac{1}{4}$ sec. 24, T9S., R4W. Marion County	1603'TD	Plugged and abandoned 6-29-71
Texaco, Inc.	63	013-20001	SW $\frac{1}{4}$ sec. 31, T17S., R23E. Crook County	7998'TD	Plugged and abandoned 11-22-71



Major rock types and deep exploratory wells (after Wagner and Newton, 1969).



Oil exploration in 1971 showing location of lease areas.

Offshore activity

Although two companies maintained geophysical exploration permits for work along the Oregon Coast, no work is believed to have been done in 1971. Eleven major oil companies conducted exploration studies off the Oregon Coast in the period 1961-1967. No oil or gas was discovered in that time and all the leases were dropped by 1969. The moratorium following the Santa Barbara blow-out reportedly resulted in cancellation of the drilling of at least one more deep test off the Oregon Coast in 1969, a very unfortunate situation when one considers that all the machinery of nominations and lease sales have to be gone through in order to make that same test in the future.

Active Offshore Geophysical Permits 1971

Texaco, Inc.	Expires April 1972	Federal OCS lands
Standard Oil Co.	Expires August 1973	State submerged lands

The search for oil and gas will go on in Oregon for some time yet with a deep test drilling every two or three years until a discovery is made or until geologists are satisfied that little possibility exists for a commercial discovery. The continental shelf off the Oregon Coast has by no means been sufficiently explored. The Federal government offered less than half of the OCS shelf lands in the 1964 lease sale so that some promising structures have yet to be tested. For example, no leases were offered between Reedsport and Coos Bay, where one of the thickest sections of Tertiary marine rocks is known to exist (Braislin, Hastings and Snively, 1971).

Environmental considerations

Concern for the environment has temporarily slowed development in offshore areas but dwindling energy resources in the United States will eventually take precedence. Norway, Denmark, Holland, and Britain have been pleased with discoveries made in the North Sea, and for the first time in history they have the prospect of producing adequate domestic supplies of petroleum. Improved technology has narrowed the risk of spills while subsea installations hold promise of maintaining aesthetic quality during the period of production.

Many citizens fortunate enough to live in natural surroundings characteristic of the Pacific Northwest are reluctant to encourage industrial or mineral development for fear of degrading the natural setting. Some carry this philosophy too far, however; very few of those who would like to eliminate or curtail industry and mining would be willing to relinquish the modern conveniences that result from these enterprises.

Petroleum is an example of an essential commodity finding varied use in heating, transportation, synthetic rubber, fabrics, plastics, detergents, medicines, and sundry other uses. Residents of the Pacific Northwest used 300 billion cubic feet of natural gas and 170 million barrels of liquid petroleum in 1970 (Independent Petroleum Assoc. of Amer. statistics for 1971). Oregonians accounted for more than 30 percent of this. The market value of oil and gas used in Oregon in 1970 amounted to an estimated \$340 million.

The entire amount of petroleum products consumed by Oregonians had to be imported from Canada, Venezuela, Alaska, Wyoming, and New Mexico. Looking at the petroleum business from the viewpoint of internal economics, it is apparent that if oil and gas were found in quantities large enough just to supply Oregon, the economic impact would be considerable.

Too often, critics of the industry use examples of outdated methods in pointing to hazards of developing this resource. Sizeable spills from producing wells are minimal with an incidence of approximately 1 in 3,000 wells. After all the publicity and upset resulting from the Santa Barbara blowout, the effects of spillage on the ecology was found to be very light (Jones and others, 1969), and the beaches and harbor were cleaned within 45 days after the blowout occurred (USGS, 1969b). The unusual circumstances at Santa Barbara are unlikely to occur again (USGS 1969a). Drilling on land is not subject to the distributing effect of oil floating on water, but onshore spills are quickly absorbed in sediments. Also, crude oils have much less toxicity to plants and animals than refined oils (Jones and others, 1969).

It is not the intent here, however, to approve any type of development but to say that properly planned operations should be adaptable to most environments. Producing wells are closed fluid systems and should cause no pollution except by accident or through negligence. In most cases, problems with aesthetics or interference with other uses can be minimized.

The type of rock, geologic structure, and hydrodynamic conditions necessary for accumulation of petroleum are unique occurrences. We cannot choose where they will be, but if such an occurrence were found in Oregon we would be indeed fortunate.

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OREGON ACADEMY OF SCIENCE TO MEET AT PSU

The Oregon Academy of Science will hold its annual meeting at Portland State University on Friday and Saturday, February 25 and 26, 1972. Friday afternoon and evening will be devoted to a symposium "Sea, Science, and Society" to be held in the Smith Memorial Center ballroom. Saturday morning will be given to meetings of the individual science sections. Nine papers on sedimentation and volcanism in western Oregon will be presented at the Geology Section. The public is cordially invited.

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AIME HONORS FAY LIBBEY

The Oregon Section of AIME dedicated its December 16, 1971 annual meeting in honor of Fay W. Libbey, director of the Oregon State Department of Geology and Mineral Industries from 1944 to 1954. Mr. Libbey has been a member of the Oregon Section since 1936. He served as its chairman in 1942 and was a director of the board of National AIME for 3 years. Recollections of his mining experiences in Canada and Arizona prior to his coming to Oregon were read at the December meeting and were greatly enjoyed by the mining group.

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GEOHERMAL ACTIVITY IN 1971

Richard G. Bowen*

The Geysers field in Sonoma County, California, continues to be the only site of electric power production from geothermal resources in the United States. Two new turbine-generator units were brought into production during the year, increasing the installed capacity from 82 to 192 megawatts. Two other plants, each of 110 megawatt capacity, are under construction at the field by Pacific Gas and Electric Company; one is scheduled for completion in the fall of 1972 and the other a year later.

In another development at The Geysers field, the Northern California Power Agency, an 11-city combine, has committed \$60,000 for a feasibility study for a projected \$35 million, 220-megawatt power plant on a portion of the field under lease to Signal Oil Company.

Eleven new wells were drilled at The Geysers field during the year: eight by Union Oil Company and its partners, Magma Power and Thermal Power Companies; two by Pacific Energy Corporation, which took over the operation of Geothermal Resources International, and one by Signal Oil Company. This new drilling has extended the boundaries of the field to an area covering about 9 by 2 miles. One new well, the most northern drilled, has the largest capacity of the field with a flow of 386,000 pounds per hour, sufficient for a plant of over 19 megawatts.

Outside of The Geysers area, four other wells were drilled during the year. Near Clear Lake, 8 miles north of The Geysers, a shallow well drilled by Magma Power showed elevated bottom-hole temperatures but failed to produce any fluid. Plans are being made to deepen that well. Near Mono Lake, in eastern California two wells were drilled, one by Mono Power and another by Geothermal Resources International; both wells failed to find temperatures high enough to be of economic interest. In New Mexico a well drilled to extend the steam zone found in 1970 on Baca Ranch near Los Alamos was not successful.

During 1971 work progressed on implementing the Federal geothermal leasing act. As a part of the pre-leasing requirements, 1.7 million acres of land were designated by the U.S. Geological Survey as known geothermal resource areas (KGRA's) and the Federal land included will be subject to competitive leasing. In the northwest, the KGRA classification covered 84,000 acres in Oregon, 17,000 acres in Washington, and 21,000 acres in Idaho.

The USGS report lists an additional 97 million acres of land as having prospective value. The Federal land in this category does not require

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competitive leasing and can be leased by the first qualified person making the necessary deposit. Oregon and Idaho each have about 15 million acres and Washington about 6 million acres that are considered to be of prospective value.

Both of the above categories are subject to continual modification as knowledge of geothermal exploration increases.

The Interior Department has issued rules and regulations concerning the leasing, exploration, drilling, and production activities for geothermal resources on Federal lands. Also, in compliance with the National Environmental Policy Act of 1969, an Environmental Impact Statement for the Geothermal Leasing Program has been prepared and public hearings will be held in Reno, Sacramento, and Portland regarding the implementation of the law. After the period of time allotted for public comment, these rules, with any necessary modifications, will be accepted; then applications may be filed for leasing public lands. Because the Federal government is such a large landowner in the western states--about 55 percent of Oregon and 85 percent of Nevada, for example, are owned by various Federal agencies--any major exploration effort must await the promulgation of these regulations. It appears that it will be early 1972 before the first leases will be made available, over one year after President Nixon signed the act into law.

During the past year, articles on geothermal power have appeared in many widely circulated publications; newspapers in particular have published many feature stories. There have been several announcements of joint exploration efforts by utilities and other companies. In Oregon, Pacific Power and Light Company and Weyerhaeuser Company announced the formation of a joint venture to explore and develop geothermal resources on Weyerhaeuser's extensive land holdings in southern Oregon. Eugene Water and Electric Board, according to a recent press release, is considering giving financial support to studies of geothermal sources by the University of Oregon Department of Geology and is exploring joint venture possibilities.

Other cooperative ventures include the agreement between San Diego Gas and Electric Company and Magma Power Company to explore and develop geothermal energy resources in the Imperial Valley area. If hot water is found, they plan to build a "Magamax" type power plant, utilizing an intermediate low-boiling-point fluid to transfer the energy from the hot water to the turbine-generator, the first installation of this type in the United States. Also in the Salton Sea-Imperial Valley area several groups, including the U.S. Bureau of Reclamation, Union Oil Company, Standard Oil of California, Southern California Edison Company, and the University of California, are making a serious effort toward a multipurpose development of the hot waters found there. Another result of collective action was the formation of the Mono Power Company by Getty Oil Company and Southern California Edison.

In California, legislation at the State level to regulate and supervise the exploration and production of geothermal resources has been in effect

since 1968. In Oregon the 1971 Legislature passed the necessary law to authorize the State Department of Geology and Mineral Industries to regulate geothermal activities in Oregon. Several of the other states are studying the California and Oregon regulations prior to preparing their own.

During 1971 several meetings and symposia were held to present papers and stimulate discussion of geothermal developments. In February, at the meeting of the Geological Society of America's Cordilleran Section in Riverside, California, several papers were presented concerning the geothermal phenomena of the Imperial Valley and a field trip was made into the area. In May the West Coast Oil Scouts at their meeting in Los Angeles presented a seminar and panel discussion on geothermal resources.

On May 21 in Olympia the Washington State Department of Natural Resources held the first Northwest Conference on Geothermal Power. This meeting brought together people from electrical utilities, government agencies, petroleum companies, mining firms, and members of the interested public. As the result of a post-conference meeting, a Steering Committee was formed to organize a Geothermal Resources Council covering the western states. The committee included representatives of the geothermal development industry, equipment suppliers, public and private electric power companies, energy suppliers, universities, concerned governmental agencies, environmental organizations, and the general public. The Steering Committee held two organizational meetings and set up committees to cover such areas as Exploration and Drilling, Resource Utilization, Regulation, Environment, Economics, and Education and Information.

The Geothermal Resources Council is sponsoring a 3-day meeting in El Centro, California February 16, 17 and 18, 1972. This will be the largest conference on geothermal resources yet held in the United States. The program of this meeting is given below.

GEO THERMAL RESOURCES COUNCIL EL CENTRO CONFERENCE

WEDNESDAY, FEBRUARY 16

Morning session at Imperial Valley Country Club

8:00 Welcoming addresses:

Richard Bowen, Chairman, Geothermal Resources Council
James G. Stearns, Director, California Department of Conservation
Bert L. Cole, Commissioner of Public Lands, Washington

9:20 "Worldwide Review of Geothermal Exploration and Development" by

James Koenig, Executive Officer, California Div. of Mines and Geology

10:25 "Federal Geothermal Leasing and Operating Regulations and Environmental Impact Statements" by Reid Stone, Geothermal Coordinator, U.S. Dept. of the Interior

11:10 "U.S.G.S. Research in Geothermal Resources: by Patrick Muffler, Coordinator, U.S.G.S. Geothermal Resources Program

12:30 Luncheon speaker: Hamilton Hess, Sierra Club
"Environmental Priorities, Human Needs, and Geothermal Power"

Afternoon session at Imperial Valley College

2:20 "Welcome to Imperial Valley College" by Buck Paoli, Dean of Instruction
2:35 "Dry Steam Power Plants" by David Barton, Pacific Gas and Electric Co.
3:10 "Flashed Steam Power Plants" by Jorge Guiza L., Jefe del Departamento de Recursos Geotermicos, Comision Federal de Electricidad, Mexico
3:45 "Geology of the Imperial Valley" by Robert Rex, Univ. of Calif., Riverside
4:20 "Review and Discussion of Geothermal Exploration Techniques" by James B. Combs, University of California, Riverside

Evening activities

7:30 No-host cocktail party
8:30 Banquet at Holiday Inn, El Centro. Speaker: Joseph Aidlin, Aidlin, Martin, and Mamakos. "Review of Some of the Legal Problems in Geothermal Development"

THURSDAY, FEBRUARY 17

"Overviews of the Western United States in Respect to Geothermal Exploration and Development"

Morning session at Imperial Valley Country Club - 7:30 to 11:30

California: Lawrence Axtell, Division of Oil and Gas
Bureau of Reclamation - Imperial Valley Project: R. T. Littleton, Regional Geol.
Arizona: John Harshbarger, University of Arizona
Oregon: Richard Bowen, Department of Geology and Mineral Industries
Washington: Vaughn Livingston, Division of Mines and Geology
New Mexico: Kelly Summers, Bureau of Mines and Mineral Resources
Wyoming: Edward Decker, University of Wyoming
Idaho: Mont Warner, Boise State College
Utah: William Hewitt, Geological and Mineral Survey

Afternoon session at Imperial Valley College - 2:30 to 4:00

Nevada: Larry Garside, Bureau of Mines and Geology
Montana: Cliff Balster, Bureau of Mines
Colorado: Richard Pearl, Colorado Geological Survey
Hawaii: Representative, University of Hawaii
Alaska: Tentative

Evening: Geothermal Resources Council, Executive Committee Meeting - 8:00p.m.

FRIDAY, FEBRUARY 18

Field trip to Cerro Prieto Steam Field, Mexico - 7:30 a.m. to 5:00 p.m.

At Cerro Prieto the Comision Federal de Electricidad is developing the first flashed steam geothermal power plant in North America. A 75,000 kw plant is under construction and is expected to be on line in 1972.

* * *

Registration for the conference is \$10. For further information and pre-registration form contact Sam Dermengian, Citrus College, Azusa, California 91702. Phone: (213) 335-0521

FIELD WORK IN OREGON DURING 1971

During the 1971 field season at least 116 geologic field studies were conducted in the State of Oregon. Listed below are the studies about which this Department is aware. For convenience, the state is subdivided into six sections, and the studies are grouped according to location. Also, a section dealing with water-resource studies is included in the list.

The list is probably not complete, and the Department would appreciate receiving information about other studies in progress in this state. Resumes received thus far have been of immeasurable help, and the Department expresses its gratitude for these contributions.

Regional Studies

Northwestern Oregon

1. Recent sedimentation in Tillamook Bay: Gennaro Avolio, graduate student, PSU
2. Limestone west of Dallas: Sam Boggs, Ewart Baldwin, Bill Orr, professors of geology, UO
3. Nodules within the Oligo-Miocene shales: Sam Boggs, professor of geology, UO
4. Boundary of the High Cascades and the Western Cascades: Richard Bowen, DOGAMI
5. Nestucca Formation: Arden Callender, graduate student, PSU
6. Ground water study, with emphasis on pollution: Roger Dickinson, graduate student, UO
7. Western Cascades, mapping between Detroit and Eugene: Andrew Duncan and Jaroslav Lexa, Postdoctoral residents, UO
8. Cascade volcanoes, thermal surveillance: J. D. Friedman, USGS, Washington, D.C.
9. Surf transformation near Newport: Mike Gaughan, oceanography, OSU
10. Yaquina Formation, stratigraphy and sedimentary petrology: Clinton Goodwin, OSU
11. Mollusca of the Keasey Formation: Carole S. Hickman, Adjunct Research Associate, Swarthmore College, Swarthmore, Pennsylvania
12. Coastal geology with emphasis on landforms: Ernest Lund, professor, UO
13. Tertiary calcareous plankton: Daniel McKeel and Jere H. Lipps, UCal, Davis, California
14. Eocene geology and inferred early Tertiary rifting: Robert McWilliams, professor, Miami U, Hamilton, Ohio
15. Environmental geology of the Lake Oswego area: Roger A. Redfern, graduate student, PSU

16. Petrology of the Mt. Hebo intrusive: Joe Rohleder, graduate student, UO
17. Eocene stratigraphy west of Salem: Herb Schlicker, DOGAMI; Robert Deacon, Shannon and Wilson; John Beaulieu, DOGAMI
18. Geologic hazards of Clatsop and Tillamook Counties: Herb Schlicker, DOGAMI; Robert Deacon, Shannon and Wilson; John Beaulieu, DOGAMI; Gordon Olcott, DOGAMI
19. Late Quaternary geology of the Mt. Jefferson area: William E. Scott, graduate student, UW
20. Coastal geology, remapping of Hebo quadrangle: Parke Snively and Norman MacLeod, U.S.G.S., Menlo Park, California
21. Columbia River Basalt: Donald Swanson and Thomas Wright, U.S.G.S., Menlo Park, California
22. Beach processes in Tillamook Bay: Tom Terrick, oceanography, OSU
23. Geologic map of the Columbia River Gorge: Aaron C. Waters, professor of geology, UCal, Santa Cruz
24. Seismic behavior of the Portland area: Paul White, graduate student, PSU
25. Portland Hills Silt: Cheryl Wilgus, graduate student, PSU

Southwestern Oregon

1. Cenozoic molluscan faunas: Warren O. Addicott, U.S.G.S., Menlo Park, California
2. Oligocene fossils: John M. Armentrout, graduate student, UW
3. Plio-Pleistocene megafossils: John M. Armentrout, graduate student, UW
4. Drill evaluation program: Donald Baggs, graduate student, PSU
5. Mapping of the Ivers Peak, Camas Valley, Sitkum and Tyee quadrangles: Ewart Baldwin, professor of geology, UO
6. Lower Cenozoic geology: Ewart Baldwin, professor of geology, UO
7. Sedimentary processes: Sam Boggs, professor, UO
8. Heavy mineral concentrations: K. C. Bowman, graduate student, oceanography, OSU
9. Mapping of the Langlois quadrangle: Michael Brownfield, graduate student, UO
10. Glacial and neo-glacial geology of the Mountain Lakes area: Gary Carver, graduate student, UW
11. Black sands: H. E. Clifton, U.S.G.S., Menlo Park, California
12. Tectonic history of the Josephine peridotite: Henry Dick, graduate student, Yale University
13. Crater Lake National Park: Jack H. Hyde, geology instructor, Tacoma Community College
14. Mapping of the northeast quarter of the Bone Mountain quadrangle: Nils Johannesen, graduate student, UO

15. Estuaries of the Sixes and Rogue Rivers: Charles Jones, graduate student, UO
16. Bone Mountain quadrangle, southeastern quarter: Richard Kent, graduate student, PSU
17. Josephine peridotite: Robert A. Loney, U.S.G.S., Menlo Park, Cal.
18. Geology of Mt. McLoughlin: Leroy Maynard, graduate student, UO
19. Kalmiopsis Wilderness: Len Ramp, DOGAMI
20. Tiller area: Len Ramp, DOGAMI; and Dr. M. A. Kays, UO
21. Nickel prospects: Len Ramp, DOGAMI
22. Microfossils from well cuttings: Weldon Rau, paleontologist, Washington Division of Mines and Geology
23. Mapping of southwest quarter of Bone Mountain quadrangle: John Rud, graduate student, UO
24. Detection of chromite: Gerald Shearer, graduate student, Ohio State U.
25. Geochemistry of High Cascades volcanoes: Terry Steinborn, graduate student, UO
26. Coarse sediment in the Elk River: Fred Swanson, graduate student, UO
27. Southcentral Bone Mountain quadrangle: William Utterback, graduate student, OSU

North-central Oregon

1. Columbia River Group, deep resistivity soundings: L. A. Anderson, U.S.G.S.
2. Canyon Mountain Complex: Dr. Hans Ave Lallement, assistant professor, Rice U., Houston, Texas
3. Zeolites in the John Day Formation: Donald Baggs, graduate student, PSU
4. Heat flow: Richard Bowen, DOGAMI
5. Clarno Formation: Harold Enlows, professor of geology, OSU
6. Flat-topped volcanic landforms: Brian Gannon, graduate student, PSU
7. Cretaceous mudstones, clay mineralogy, and sedimentary petrology: (Mrs.) Clara Jarman, graduate student, UO
8. Canyon Mountain Complex: Robert A. Loney, U.S.G.S., Menlo Park
9. Clarno flora: J. William Schopf, professor of geology, UCLA
10. Deschutes Formation (Dalles and Madras Formations of authors): Don Stensland, instructor of geology, Coos Bay Community College
11. High Cascades geology between Three Sisters and Mt. Bachelor: Ed Taylor, professor, OSU
12. Ultramafic rocks of the Canyon Mountain Complex: Thomas P. Thayer, U.S.G.S., Washington, D.C.
13. Radioactive materials disposal site: Vernon C. Newton, DOGAMI
14. Metolius Springs: Norm Peterson, DOGAMI, Grants Pass Field Office
15. Columbia River Group: T. L. Wright, U.S.G.S.

South-central Oregon

1. Trace elements in obsidian: Marv Beeson, Paul Hammond, professors of geology, and Al Waible, graduate student, PSU
2. Newberry Caldera: Robert Beyer, graduate student, UO
3. Crust and geochemistry of Klamath Mountains: A. H. Lachenbruch U.S.G.S., Menlo Park
4. Geothermal prospects and induced earth currents: William MacFarland, graduate student in oceanography, OSU
5. Alkali Lake Basin, chemical waste disposal: Vernon C. Newton, DOGAMI
6. Pliocene ignimbrites: Don Parker, Ph.D. candidate, OSU
7. Mineral resources of Klamath and Lake Counties: Norm Peterson, DOGAMI, Grants Pass Field Office
8. Geothermal ground noise: Norm Peterson, DOGAMI, Grants Pass Field Office
9. Geothermal resources: Norm Peterson, DOGAMI, Grants Pass Field Office
10. Silica deposits: H. E. Reed, Assistant Manager, Raw Materials Research, Burlington Northern, Seattle
11. Geothermal ground noise: Gerald W. Thorsen, Washington Division of Mines and Geology
12. Geomorphology of the Warner Valley: David Weide, professor, UCLA
13. Geothermal prospects and microseisms: Robert Whitsett, oceanography, OSU

Northeastern Oregon

1. Pliocene diatoms in the Durkee Basin: George W. Andrews, U.S.G.S. Washington, D.C.
2. French Gulch and Lost Basin quadrangles: Roger P. Ashley, U.S.G.S. Menlo Park, California
3. Drill evaluation program: Don Baggs, graduate student, PSU
4. Geologic reconnaissance: John Beaulieu, DOGAMI
5. Alpine glaciation: Elton Bentley, graduate student, UO
6. Huntington quadrangle: Howard Brooks, DOGAMI, Grants Pass Field Office
7. Martin Bridge Formation: Jeffrey C. Brown, graduate student, WSU
8. Canyon Creek quicksilver area: Al Edwards, graduate student, UO
9. Columbia River Group: M. J. Grolier, U.S.G.S.
10. Trace elements in banded rhyolites: Gary Hallock, graduate student, PSU
11. Origin of copper deposits near Keating: Ray Hammitt, graduate student, UO

12. Mineralization north of Huntington: Tom Henricksen, Ph.D. candidate, OSU
13. Pre-Tertiary structure: Robert Lawrence, professor, OSU
14. Cenozoic rocks of the Baker AMS sheet: James R. McIntyre, Southern Oregon College, Ashland, Oregon
15. Seven Devils Volcanics: John M. Morganti, graduate student, WSU
16. Geology near Dale: Robert Olsen, Master's student, UO
17. Geochemical stream sampling: Allen Preisler, DOGAMI
18. Pliocene zeolites: Richard A. Sheppard, and A. J. Gude, III, U.S.G.S., Federal Center Building, Denver, Colorado
19. Geologic mapping: Bill Taubeneck, professor, OSU
20. Mineral potential of the Eagle Cap Wilderness: E. T. Tuck and A. B. McMahon, U.S. Bureau of Mines, Spokane, Washington
21. Pre-Tertiary geology: Tracy Vallier, professor of geology, Indiana State U., Terre Haute, Indiana
22. State geologic map project: George W. Walker, U.S.G.S., Menlo Park, California
23. Eagle Cap Wilderness: A. E. Weissenborn, U.S.G.S., Spokane, Wn.
24. Greenhorn Mountain district, Greg Wheeler, graduate student, UW
25. Pre-Tertiary geology of the Snake River area: David L. White, graduate student, Indiana State U., Terre Haute, Indiana
26. Eocene flora: J. A. Wolfe, U.S.G.S.

Southeastern Oregon

1. Isotope analysis of thermal waters: Richard Bowen, DOGAMI
2. Geologic mapping adjacent to Nevada, R. C. Greene, U.S.G.S.
3. Pueblo Mountains: Jerry L. Harold, graduate student, OSU
4. Zeolitic tuff: W. L. Rice, U.S. Bureau of Mines, Spokane, Wash.
5. Diamond Craters: Lawrence C. Rowan, U.S.G.S., Menlo Park, Ca.

Water Resource Studies

1. Ground water of the Corvallis-Albany area: F. Frank, U.S.G.S., Portland
2. Ground water in the dune-sand area north of Coos Bay: J. Robison, U.S.G.S., Portland
3. Ground water of part of the Klamath River basin: A. Leonard, U.S.G.S., Portland
4. Ground water in northern Clackamas County: A. Leonard, U.S.G.S., Portland
5. Movement of radionuclides in the Columbia River estuary: D. Hubbell and J. Glenn, U.S.G.S., Portland

AVAILABLE PUBLICATIONS

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BULLETINS

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GEOLOGIC MAPS

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for compiling this information will be appreciated.

SEDIMENTARY PETROLOGY OF WHISKY RUN TERRACE SANDS, CAPE ARAGO, OREGON*

Carmen J. Rottman

Introduction

Plio-Pleistocene marine terraces are found intermittently along the entire western coast of the United States. Some of the best exposures of these wave- and surf-cut terraces and the overlying deposits of sand are those between Coos Bay and Bandon, Oregon (see Figure 1). Diller (1902) first described the four coastal terraces in this region and later examined the composition of the overlying sands (1914). Griggs (1945) investigated the heavy mineral content of black sand deposits within the terrace sands. Baldwin (1945) presented a chronology of Plio-Pleistocene geology and terrace formation. With the exception of these studies, there has been little work on the overall physical nature of the sands lying on the terrace surfaces. Hence, the present study defines the sands of the lowest surface with regard to grain size, grain shape, and heavy mineral composition and utilizes these variables to determine the probable sediment source and environment of deposition.

Setting

The lower member of the upper Eocene Coaledo Formation crops out along the coast south of Coos Bay from Sunset Bay State Park to Cape Arago State Park (see Figure 1). During the Holocene, the steeply dipping, inter-bedded sandstones and shales of this unit have been carved into vertical cliffs, jutting promontories, and a sea-level bench by the continuous action of the surf. Capping the prominent cliffs is a thin layer of limonitized sand, deposited on a terrace surface formed during an earlier stand of the sea (see Figure 2). This terrace surface, known as the Whisky Run Terrace, probably originated in a manner very similar to that which is forming the present coastal scenery.

*Paper is based on a portion of Mrs. Rottman's doctoral dissertation, University of Oregon, 1970.

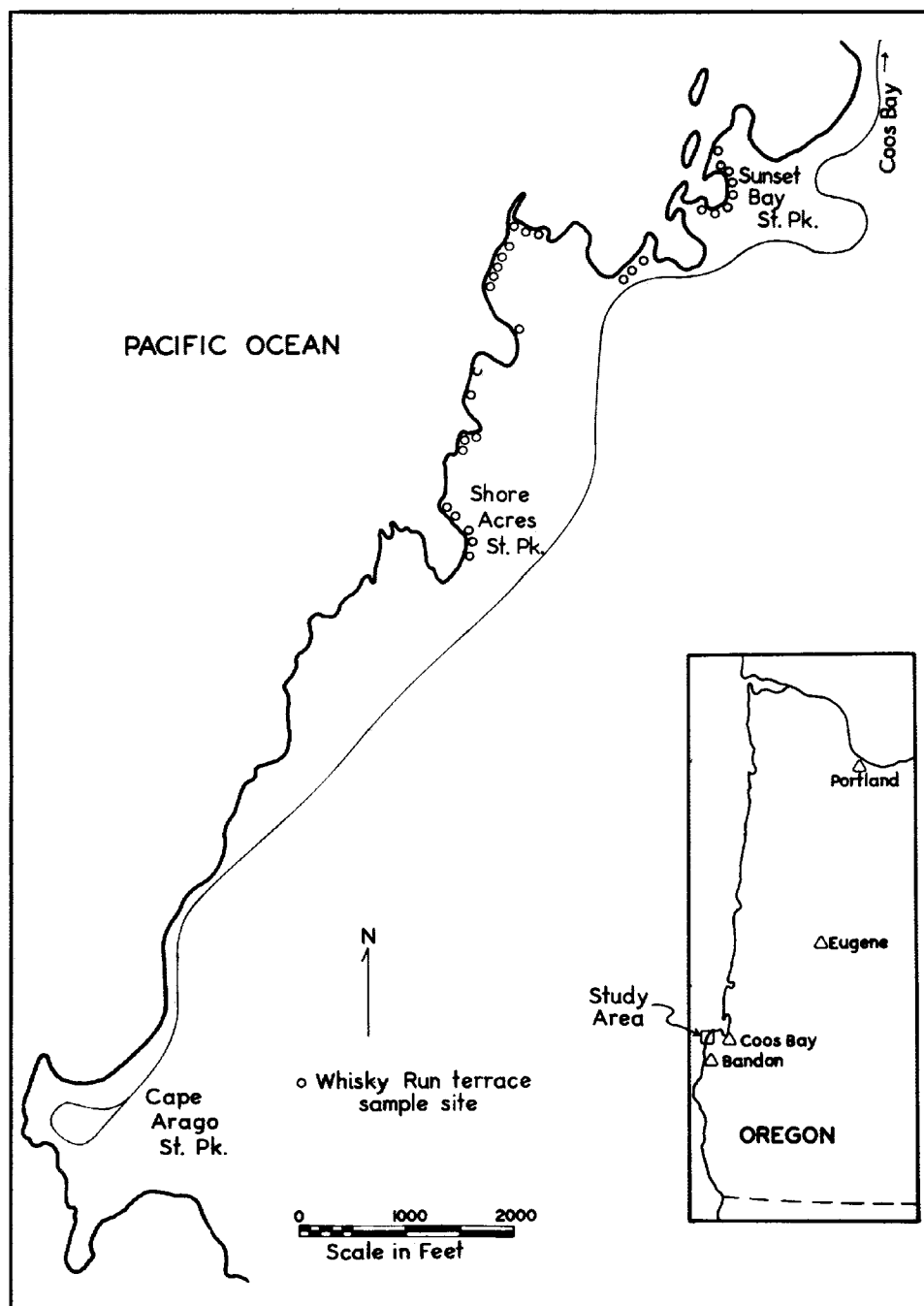


Figure 1. Map of Cape Arago study area with western Oregon reference map.

Method of Study

As part of a more comprehensive study (Rottmann, 1970), 30 samples of the Whisky Run terrace sands were gathered by channeling the rim of the seacliff at selected sites from Shore Acres State Park to Sunset Bay State Park (see Figure 1). Standard procedures of sedimentary petrology were used to prepare the sediment samples for size, shape, and composition analysis. These procedures included chemical disaggregation, combined washing and decantation, and size sieving through a standard sieve series.¹

After sieving, sized fractions of the samples were given additional preparation for shape analysis and heavy mineral analysis. Measurement of quartz-grain shape, limited to $1.5\phi^2$ (0.35mm) size fractions, was carried out by the method designed by Boggs (1967) (see Figure 3). Heavy mineral separates, obtained by gravity separation of 2.5ϕ (0.177mm) and 3.5ϕ (0.088mm) size fractions, were studied and identified under a petrographic microscope.

Raw data for size, shape, and composition measurements were programmed for statistical analysis on the University of Oregon Statistical Laboratory and Computing Center IBM System 360 computer. The refined data thus obtained was reprogrammed by the method of Wahlstedt and Davis (1968) to determine interdependence of the several different parameters measured.

Discussion

Grain size

Table 1 shows the average values and ranges of values for phi mean, phi standard deviation, and skewness.³ These three grain size parameters were determined by two different statistical methods (Inman, 1952; Griffiths, 1967) for comparative purposes. The sediments are in the medium to very fine sand grades and range from well to moderately sorted.

Visher (1969) has defined a series of environmental sand types, based on the relative proportions of sand deposited under traction, saltation, or suspension conditions. When the grain size distributions for all terrace sand samples are analyzed by Visher's method, they fit into the beach and wave zone categories.

¹For detail on specific procedures see Rottmann (1970) or consult any handbook of sedimentary petrology, for example Müller, 1967.

²The Greek letter ϕ (phi) is standard notation for grain size units. A phi unit equals the negative \log_2 of the size in millimeters (Krumbein, 1938).

³Mean - measure of average size; standard deviation - measure of uniformity of sorting; skewness - measure of asymmetry with respect to the mean.



Figure 2. Thin layer of Whisky Run terrace sand lying unconformably on steeply dipping Lower Coaledo bedrock, south side of Shore Acres State Park.

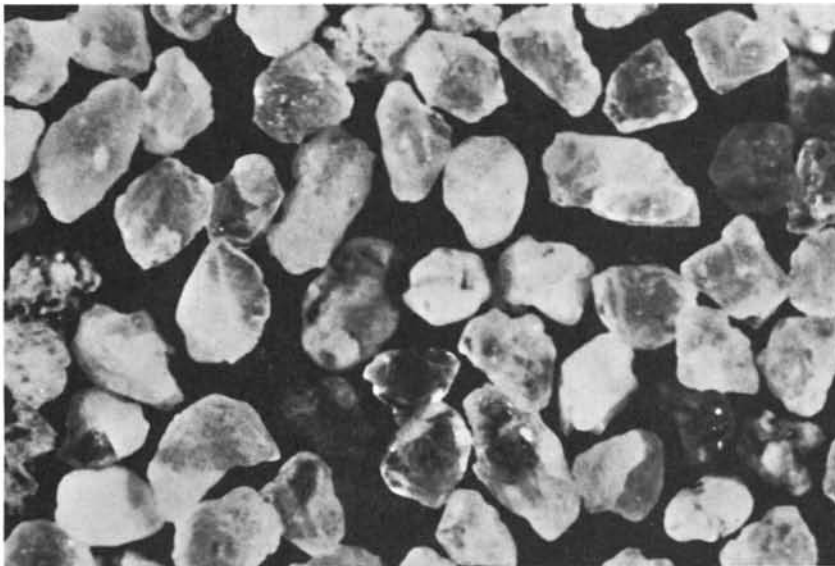


Figure 3. Photograph of quartz grains (white and clear) prepared for roundness and sphericity measurement by method of Boggs (1967); grains are 1.5 ϕ (0.35 mm) across the shorter projected diameter.

Table 1. Average grain size distribution values for Whisky Run terrace sands (30 samples).*

Inman Statistics		
	Average	Range
Phi Mean Size	2.371	1.895 - 3.201
Phi Standard Deviation	0.482	0.306 - 0.846
Skewness	0.082	-0.141 - 0.398
Moment Statistics		
	Average	Range
Phi Mean Size	2.3388	1.9184-2.8220
Phi Standard Deviation	0.5892	0.3685-1.0180
Skewness	0.7664	0.2932-1.1001

*See footnote 3 for definition of terms

Table 2. Heavy mineral composition of Whisky Run terrace sands.*

2.5 ϕ Separates		3.5 ϕ Separates	
Mineral	Percent	Mineral	Percent
Clinopyroxenes	21.6	Blue-green hornblende	21.9
Blue-green hornblende	19.4	Magnetite	17.2
Brown hornblende	14.2	Brown hornblende	16.0
Other amphiboles	12.6	Other amphiboles	14.0
Clear garnet	9.3	Clinopyroxenes	10.6
Hypersthene	5.5	Hypersthene	4.8
Magnetite	5.2	Clear garnet	4.7
Pink garnet	3.9	Epidote	2.6
Epidote	3.7	Clinozoisite	1.5
Biotite	1.3	Zircon	1.3
Minor constituents	3.3	Pink garnet	1.1
(glaucophane, enstatite,		Glaucophane	1.0
zircon, clinozoisite, olivine,		Ilmenite	1.0
sphene, kyanite)		Minor constituents	2.3
		(biotite, enstatite, olivine,	
		sphene, kyanite)	
Total	100.0	Total	100.0

*Averages based on 22 and 17 counts in excess of 100 grains for 2.5 ϕ and 3.5 ϕ , respectively

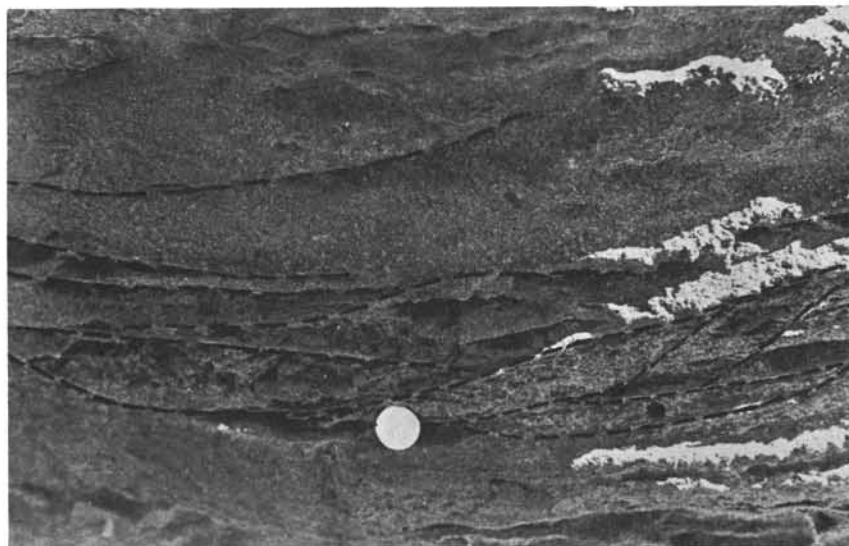


Figure 4. Detail of cross-bedded wave structures in outcrop of Whisky Run terrace sand at Shore Acres State Park; quarter coin for scale.

In addition, Inman and Chamberlain (1956) have shown that Holocene marine sands of similar mean size and sorting are deposited in zones of wave action, i.e., either beach or shallow offshore depositional environments.

These comparisons suggest that these sediments were deposited in a zone of wave action. In particular, the degree of sorting (standard deviation) reflects the winnowing produced by continuous wave action. Figure 4, a close-up of a terrace sand outcrop, shows current structures typically formed in a zone of to-and-fro wave action.

Roundness and sphericity

Figure 5 displays the results of measuring two grain shape parameters: roundness and sphericity.⁴ The values for each sample were computed from a maximum of 100 quartz grains (a total of 2918 grains from 30 samples). The average mean roundness for all samples is 0.478 (subrounded class of the 1953 Powers' scale); average mean sphericity is 0.829.

Because of variation in methods of analysis, little comparative literature exists to relate these measured shape values with those ascribed to particular depositional environments. However, the larger investigation (Rottmann, 1970), which included the present study, does compare

⁴Roundness - particle angularity (i.e., smoothness of grain edges); sphericity - approximation of particle shape to shape of a perfect geometric sphere.

roundness and sphericity of Coaledo bedrock, Whisky Run terrace sand, and modern beach sand from the same area. Application of multi-variate analysis to the data of the same study indicates that the coastal outcrop of the Coaledo sandstones is and was the major sediment source for both the modern beach sands and the Whisky Run terrace sands of the Cape Arago area. The quartz grains of the terrace sediment are the most spherical of the three sediments, but are less rounded than those of the modern beach sand.

The relatively higher sphericity of the terrace sands suggests that the sands were transported only a short distance from the sediment source before final deposition. Several authors (Pettijohn and Lundahl, 1943; Russell and Taylor, 1937) have described naturally occurring reductions in sand grain sphericity as the distance from sediment source increases. MacCarthy (1933) has shown that longshore drift, which is mainly a suspension transport mechanism, carries grains of lower sphericity for greater distances. Because more spherical grains settle first from suspension transport (Krumbein, 1942), higher sphericity values are measured closer to the sediment source.

On the basis of the identification of the sediment source (Coaledo sandstones) and the greater roundness of quartz grains from the modern beach sands relative to those of either the Coaledo source or the terrace, Rottmann (1970) concludes that a measurable increase in grain roundness does occur in the zone of surf action (i.e., the beach). This conclusion suggests that the terrace sand is not a product of the beach depositional environment.

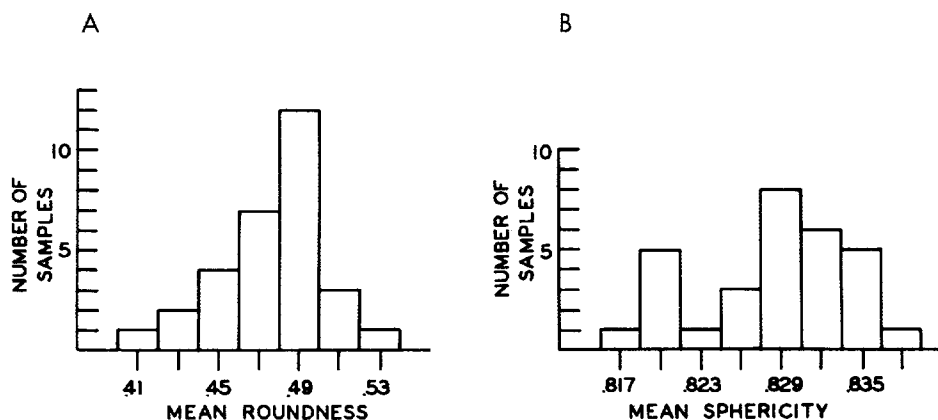


Figure 5. A. Mean roundness of 1.5Ø (0.35 mm) quartz grains from 30 terrace sand samples.

B. Mean sphericity of 1.5Ø (0.35 mm) quartz grains from 30 terrace sand samples.

Heavy minerals

Clinopyroxenes in the 2.5 ϕ separates and blue-green hornblende in the 3.5 ϕ separates are the most common heavy minerals (Specific gravity >2.96) in these terrace sands. Other commonly occurring heavies include brown hornblende, magnetite, garnet, hypersthene, and epidote. Table 2 lists the percentages of all heavy mineral species; the relative proportions of the major heavy mineral species are given in Figure 6.

This heavy mineralogy is very similar to that of the recent southern Oregon shelf sediments (Kulm, and others, 1968) and to that of the lower Coaledo (Rottmann, 1970). However, the latter does not contain glauco-phane and kyanite, two minor minerals of the terrace sands. This similarity of mineralogy is additional evidence that the Coaledo was the probable major source of terrace sediment. Yet, the presence of additional minerals indicates one or more additional sources. The exposure to shelf currents of either an offshore or an open beach depositional environment would account for the minor occurrence of these minerals.

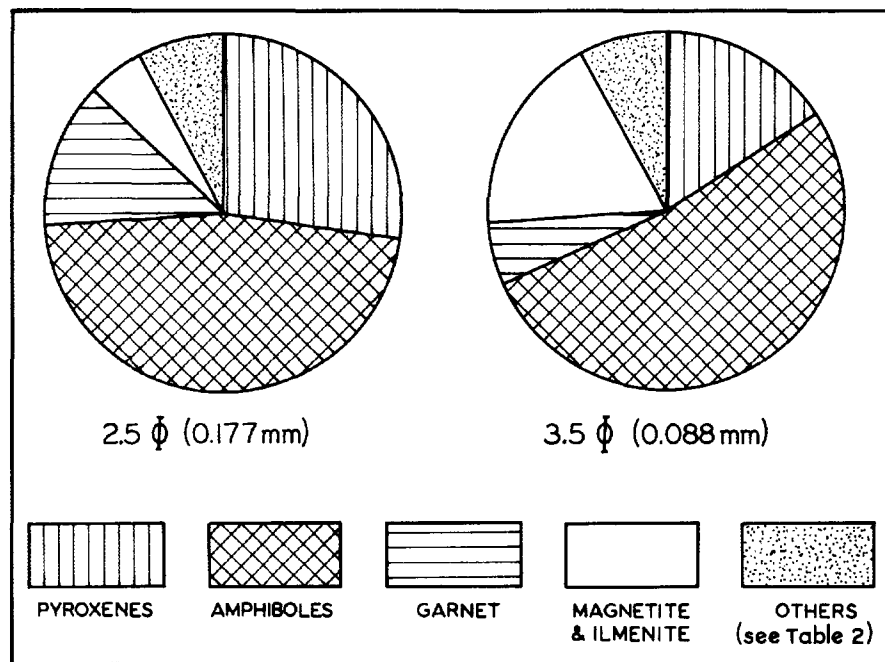


Figure 6. Heavy mineral composition of 2.5 ϕ (0.177 mm) and 3.5 ϕ (0.088 mm) size fractions of the Whisky Run terrace sand.

Summary and Conclusions

The Whisky Run terrace sands are of medium to very fine grain size, moderately well sorted, subrounded, of relatively high sphericity; they contain a heavy mineral assemblage similar to that of other Tertiary and Holocene deposits of southwestern Oregon. Multivariate analysis of the size, shape, and composition variables reveals that all samples of these sands are very uniform in these properties.

Comparison of the measured grain size parameters of these sands with those given in the literature indicates that the depositional environment was a zone of wave action. The heavy mineralogy shows a definite affinity with that of the bedrock cliffs. The roundness of quartz grains from the terrace sands indicates that the depositional site was not a beach at the foot of the cliffs; the sphericity suggests that the site was not a great distance from the sediment supply. Hence, it is postulated that the Whisky Run terrace sands were deposited in a shelf environment just seaward of the surf zone and that the Eocene Coaledo provided the major sediment supply to that site.

Acknowledgments

The writer wishes to thank Dr. Sam Boggs, Jr., for serving as advisor to the doctoral program which included this study. Dr. Boggs and Dr. E. M. Baldwin, both of the University of Oregon Geology Department, are acknowledged for their critical reading of the manuscript. The University of Oregon Geology Department provided financial aid for the duration of the study. I particularly want to thank my husband, Warren, for valuable assistance both in the field and in drafting and photographing the figures.

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SOUTH-CENTRAL OREGON LAKE STUDY PUBLISHED

"Hydrology and geochemistry of Abert, Summer, and Goose Lakes, and other closed-basin lakes in south-central Oregon" is the title of Professional Paper 502-B recently issued by the U.S. Geological Survey. Authors are Kenneth N. Phillips and A. S. Van Denburgh, who have brought together all of the available data on variations of water level, area, volume, and chemical character of the lakes. The 86-page report is illustrated by maps, diagrams, and photographs. For sale by Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price is \$1.75.

* * * * *

A FOSSIL PINE FOREST IN THE BLUE MOUNTAINS OF OREGON

Irene Gregory*

Introduction

A petrified wood deposit in the Blue Mountains of northeastern Oregon appears to be the fossilized *in situ* remains of a pure stand of Western White Pine (*Pinus monticola* Dougl.) of probable Eocene age. Intensive search produced no additional species in the collecting area.

The fossil pine forest is in the Burnt River drainage basin at elevations between 4200 and 5000 feet. The wood occurs over a wide area both in place as low stumps and as scattered logs and chunks. Growing among the fossil material is a living forest of another species of pine, representing a difference in age of as much as 40 million years.

Geologic Relationships

The Burnt River fossil pine wood area is included in the geologic mapping of the Canyon City AMS quadrangle by Brown and Thayer (1966), who show the bedrock units in the vicinity of the wood locality to consist of the Clarno Formation of Eocene age overlain by the Strawberry Volcanics of Miocene-Pliocene age.

Because the locality appeared to be situated near the contact of these two formations of widely differing ages, a more detailed geologic survey was needed to determine the host rocks for the fossil wood. Howard Brooks, geologist at the Oregon Department of Geology and Mineral Industries field office in Baker, who was mapping Tertiary rocks in adjacent areas, kindly offered to investigate the locality. He reported as follows (written communication, November 26, 1971):

"The slope on which the pine wood occurs is underlain chiefly by a gently dipping sequence of interlayered andesitic tuff breccias and tuffs that were at least partly waterlaid. Wood fragments up to 2 feet in diameter were found entirely as float, but the absence of any nearby exposures of younger rock units or gravels seemingly precludes the possibility of a source other than the underlying breccias and tuffs.

"Pardee and others (1941) in mapping the Sumpter quadrangle included the andesite tuff breccias of this region in the lower

*Mrs. James M. Gregory is a fossil-wood anatomist, Hillsboro, Oregon.

Tertiary section. Brown and Thayer (1966) also regarded the andesite tuff breccias as lower Tertiary in age and mapped them as part of the Clarno Formation.

"James McIntyre and I found fossil wood and leaves in Clarno lithologies at several locations in this and adjacent areas. Dr. Jack Wolfe (written communication, July 22, 1971) assigned Clarno dates to the fossil leaf collections. Some of the fossil wood collections are being sent to you for identification."*

Prior to the present study, pine was not commonly recognized as a component of the Eocene forests of Oregon. The writer has found it to be in abundance not only in the Burnt River locality but also in nearly every Clarno wood locality investigated. It occurs in association with both subtropical and temperate types of fossil wood. Pines should thus be considered one of the typical Eocene trees of Oregon.

Description of the Pine Deposit

Wood

The fossil wood deposit represents a dense, unmixed stand of Pinus monticola; such pure stands are also a characteristic growth habit of the living P. monticola. Petrified trunks up to 5 feet in diameter, branches of many sizes, and the typical slender twigs of this species--all the component woody parts of complete trees including bark--are present. Although d.b.h. (diameter breast high--that is, measured at 4½ feet above the ground) has been measured at a record of 8 feet in living specimens, more normally this is 2½ to 3½ feet. Most of the fossil trunk specimens are also 2 to 3 feet in diameter (Figures 1 and 2). Since none show tapering, they may be assumed to represent the middle portions of the tree, which in mature living specimens range from 150 to 180 feet in height. No root-wood has been observed; it presumably remains buried at depth in growth position. Any associated understory of shrubs or herbs of the time has been destroyed or is still buried; this is true also of cones and needles, which have not been found at this locality.

Bark

Fossil bark eroded from exposed trunk sections litters the area as in living pine forests, and some still adheres to the fossil trunks. The bark is often found broken into the peculiar small, square blocks that are

*All of the wood collections from the Clarno localities sent by Mr. Brooks were found to contain pine.



Figure 1. Exhumed trunks of Pinus monticola in Burnt River area.



Figure 2. Gross structure of the pine wood is well preserved in this specimen. See pick for scale.

characteristic of living P. monticola after it reaches a trunk size of approximately 12 inches in diameter. Growth patterns of bark are quite constant within a genus, and some have characteristics unique to the species, as in P. monticola (Figure 3). Distinct microscopic structure of bark, particularly when combined with wood structure, can also be an important feature in identification (Chang, 1954).

Pitch (?)

Of frequent occurrence in the soil zone around the fossil stumps are masses of silicified material that look like pine pitch. Since none of the specimens found thus far are attached to the fossil wood, this identification is uncertain. However, Dr. Lloyd S. Staples, who examined some of the samples, suggested that although the material was completely silicified and lacked residual matter, it would be entirely possible for masses of pitch to become silicified in an environment so highly charged with silica (oral communication, November 29, 1971).

Methods of Identification

Pine is one of the few fossil woods that can be readily identified in the field by means of a hand lens. For more precise microscopic identification as to species, the wood must be exceedingly well preserved and be examined in thin-section views of transverse, tangential, and radial cuts. Much of the wood at the Burnt River locality is replaced by opaque jaspers with scattered pyrite, which obscure the minute details of structure. But some of the highly silicified specimens exhibit very well-preserved, anatomical details of cell structure. These have made it possible to identify this wood as to species, rather than to genus only, as is the case with most fossil woods.

Botanical Classification

Pines and other needle-trees are conifers. They belong to one of the main divisions of plants called Gymnosperms, meaning that they have exposed seeds which are usually borne in cones, as is denoted by their order name, Coniferales. Because of the comparative ease with which their wood is worked, they are classified also as "softwoods" in contrast to "hardwoods," a term which has come to include all dicotyledonous trees such as oak or maple; these belong to the other main plant division, Angiosperms, that have seeds enclosed in a fruit and bear true flowers. Each type of wood has its own structure; that of a typical softwood is shown in Figure 4, which is a diagram of the transverse view of white pine (P. monticola).

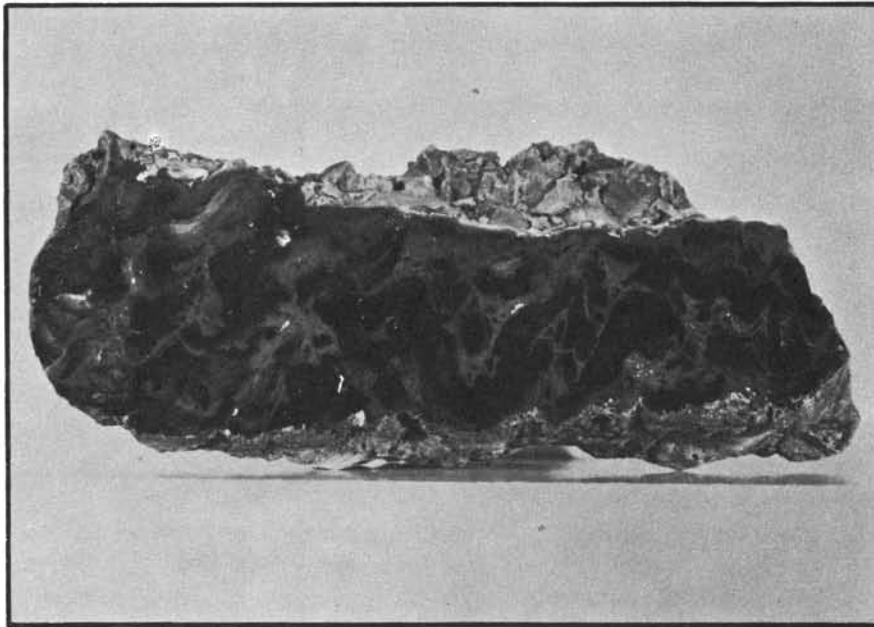


Figure 3. Petrified bark cut and polished to show pattern of structure.

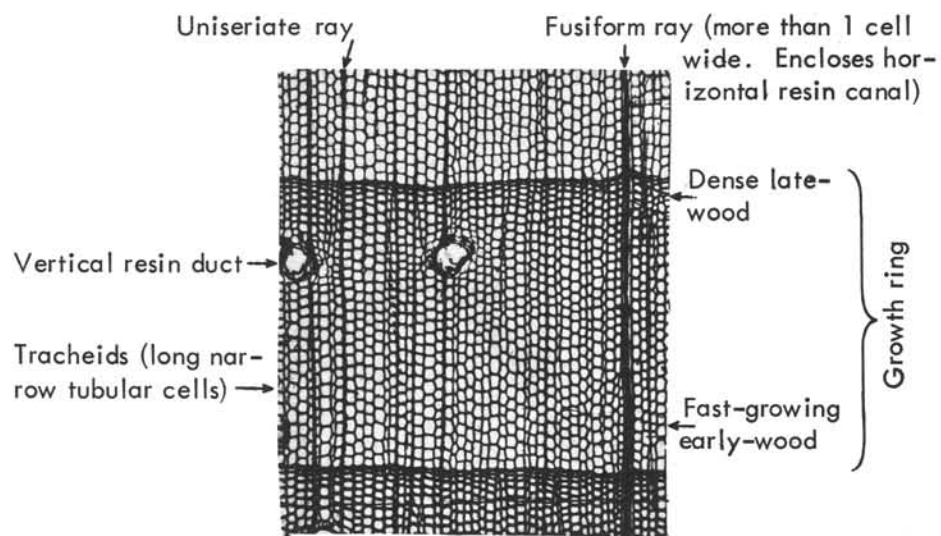


Figure 4. Anatomical features of Pinus monticola, a typical softwood; transverse view. Approx. 50X.

Systematic Description

Class	GYMNOSPERMAE
Order	CONIFERALES
Family	PINACEAE
Genus	PINUS Linnaeus

Pinus monticola Dougl.

(Figure 5A, B, C)

Anatomical description

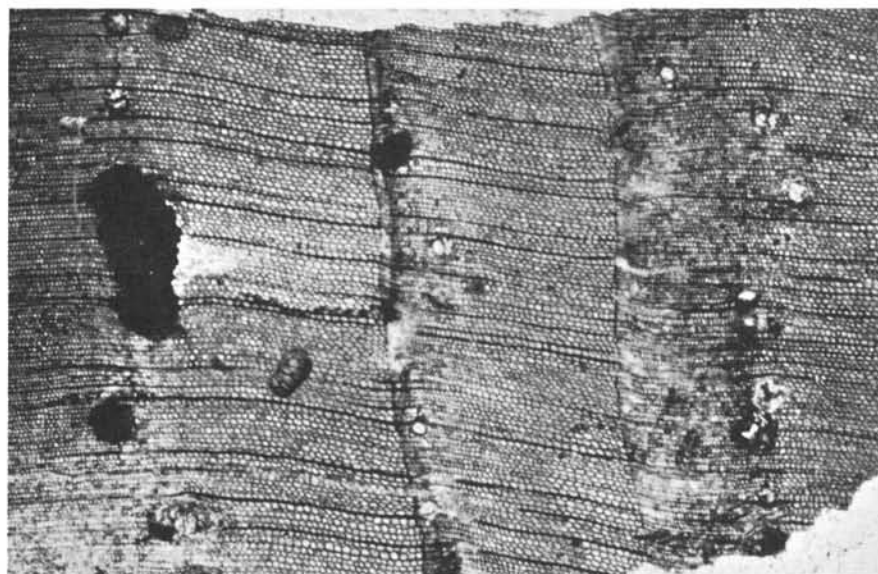
Growth rings: Distinct. Marked by a narrow band of denser (slow-growing) late-wood at outer margin. Fast-growing (larger celled) early-wood takes up most of the ring. Transition from early-wood to late-wood is very gradual.

Tracheids: Arranged in definite radial rows. Up to 50, but average 35 to 45 microns in diameter; bordered pits in one row (sometimes 2) on radial walls. Pits to ray parenchyma windowlike and large; 1-2 (usually 1) per cross-field.

Longitudinal parenchyma: Not visible.

Rays: Very fine. Not visible to naked eye except those few larger that enclose a transverse resin canal. Of two types but mostly uniseriate, 1-10 cells high as seen on tangential. Also scattered fusiform rays enclosing horizontal resin canal; 2-3-seriate in thickened area, tapering to uniseriate above and below; up to 12 cells high. Ray tracheids present in both types of rays, non-dentate.

Resin Canals: Vertical: easily visible with lens. Numerous. Scattered through central and outer part of ring. Solitary. Rarely two or three side by side. Appear as vertical streaks or lines on tangential. Epithelium thin-walled. Often occluded with tylosoids. Average diam. 135-160 microns. Horizontal: inconspicuous. Rather sparse. On transverse appear as more prominent wood rays irregularly spaced. Scarcely visible with lens on tangential. Avg. diam. less than 60 microns.



A



B



C

Figure 5. Photomicrographs of thin sections cut from fossil *Pinus monticola* from the locality in the Blue Mountains, Oregon.
 A. Transverse view; B. Tangential view; C. Radial view.
 (Photography by Thomas J. Bones, Vancouver, Washington.)

Discussion

Wood of the genus Pinus is easily distinguishable from other conifers because of its characteristic vertical resin ducts that can be plainly seen on the cross section with a hand lens; they appear as small rounded holes scattered about among definite, neatly arranged rows of cells (tracheids) of uniform size and approximate rectangular shape. Resin ducts are found also in other conifers such as spruce, larch and Douglas fir, but in these genera they are far less numerous and arranged in characteristic group patterns rather than scattered about as in pines. Vertical resin ducts are actually tubular intercellular spaces that carry resin in the sapwood; they are lined with a sheath of resin-secreting cells (epithelium). When using a high-power microscope, the thin walls of the epithelial cells of the resin ducts are the feature that serves to separate members of the genus Pinus from all other conifers. Horizontal resin ducts, inconspicuous and enclosed in rays, are also sparsely present in pines and may be seen under a microscope on the tangential surface.

All fossil pine wood has structures hardly distinguishable from similar pines living today; apparently pines adapted so successfully to climates of the time that only minute evolutionary changes have come about during the intervening ages. Consequently names of living pines can be applied to the fossil forms. That this also is true of the needles and seeds of pine is borne out by Wolfe (1964), who describes P. monticola parts from the Tertiary as being indistinguishable from similar specimens of extant P. monticola.

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* * * * *

CHROME MINER DIES

William Stanley Robertson, 79, prominent mining man in southern Oregon for more than a half-century, who died last December 9, had a strong role in the region's mining history. He was born May 31, 1893, in Portland.

In the same year that he was born his father moved the family to Sunny Valley, where the father went to work for L. A. Lewis as foreman at the Columbia Placer mine on Tom East Creek. Four years later, the family moved to Galice where his father was foreman of the Old Channel mine for many years.

Growing up in an era when mining was a key industry in Josephine County, it became a natural for him to enter the mining fields as an adult, fortified with knowledge gained from association with many persons active in mining. He and his brothers owned the Bunker Hill mine on Bear Camp Road above Galice and made their first big strike there in the early 1920's. They reportedly took out some of the richest gold ore mined in Josephine County and worked the mine until gold mining was shut down at the start of World War II and chrome mining became the big thing.

Undaunted by the change of events, Robertson became active in chrome mining both in California and southern Oregon. He headed a delegation to Washington, D.C. and was instrumental in getting the chrome program underway, a boon to Josephine County. He was one of the largest chrome producers in the United States, with operations at the Oregon Chrome mine on the Illinois River and at the Cyclone Gap mine in California.

He was highly respected by the industry for his keen knowledge of mines and mining, and frequently was consulted. His advice and help were freely given to many.

(Grants Pass Courier)

* * * * *

GROUND WATER GEOLOGY OF MEDFORD AREA PUBLISHED

"Availability and quality of ground water in the Medford area, Jackson County, Oregon," by J. H. Robison has been published by the U.S. Geological Survey as Hydrologic Investigations Atlas HA-392.

The Atlas consists of two sheets 26x36 inches, folded in an envelope. One sheet is a geologic map showing the rock units, thickness of the alluvium aquifer in Bear Creek Valley, and location of water wells. The other sheet presents a ground water availability map, chemical analyses of water from 76 wells, and information on chemical character of water from the various geologic formations.

Atlas HA-392 is for sale by the U. S. Geological Survey, Denver Center, Denver, Colorado, for \$1.25.

* * * * *

MARTYRING THE OTHER FELLOW

Although Arizona already has passed some of the most stringent air pollution laws in the nation, the majority of respondents to a recent research poll said that if business and industry do not meet the state's anti-pollution standards within one to two years, they should be shut down until they fulfill the requirements. But a more meaningful question, it seems to us, is how many Arizonans would themselves be willing to be unemployed to stop pollution.

It is painless to demonstrate one's environmental concern by threats to business and industry. We strongly oppose environmental irresponsibility by those who plunder resources with no thought of long-range detriment to the land and its people. But we also question the wisdom of "close it down" advocates.

However you look at it, compliance with the state's air quality requirements is going to be expensive, sometimes mighty expensive, for such Arizona businesses as the copper smelters, which have already spent \$700 million in this line in the last six years.

If businesses were forcibly shut, the economic dislocation they'd suffer could be so severe that they would declare bankruptcy rather than finance anti-pollution measures.

And, even if the companies were not closed for good, their temporarily unemployed workers would be thrown wholesale onto the rolls for unemployment compensation.

When companies are already beginning to clean up the environment, we see no sense in raising the specter of putting them out of business and throwing employees out of work. To do so would be to fly from a lessening evil into the arms of a greater one. (From The Arizona Republic)

* * * * *

OREGON ACADEMY OF SCIENCE PUBLISHES PROCEEDINGS

"Proceedings of the Oregon Academy of Sciences," volume 7, 1971, has been published by the Academy at Corvallis. The 99-page booklet includes symposium papers on "Approaches to the Population Problem," selected articles presented at the 29th meeting, and abstracts of papers given at the section meetings. The Geology Section is represented by abstracts of five papers. The Proceedings include memorial tributes and citations for outstanding achievement.

Copies of the 1971 Proceedings may be obtained from the OAS secretary, Dr. Courtland L. Smith, Dept. of Anthropology, Oregon State University, Corvallis, Oregon 97331, for \$1.25.

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GEOLOGY AND ORIGIN OF THE METOLIUS SPRINGS JEFFERSON COUNTY, OREGON

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

Introduction

"It flows from the north base of Black Butte, full bodied, and icy cold, and after winding northward through beautiful pine forests, swings around the north end of Green Ridge through a canyon of great depth and majestic grandeur, joining the Deschutes just north of the mouth of Crooked River." This description from Oregon Geographic Names by McArthur (1944) can only fit the Metolius River and its springs.

A visitor standing for the first time at the viewpoint overlooking the source of the Metolius cannot help but be astonished at this "instant river" and ask himself: "Where does all this water come from?" The purpose of this article is to explain the origin of the springs and their relation to the surrounding terrain.

Location and Geographic Setting

The Metolius Springs are situated in timbered country in the southwest corner of Jefferson County about 30 miles northwest of Bend and Redmond (Figure 1). The locality is easily reached by several roads that leave U.S. Highway 20 between Santiam Pass and Sisters. The shortest route is a paved road from a well-marked junction about 10 miles east of Santiam Pass or 9 miles west of Sisters, which trends northeast for about 4 miles to the springs and continues northward to a loop road that parallels the Metolius River and provides access to the famous fishing resorts and popular recreation area.

A few years ago Mr. and Mrs. Sam Johnson, owners of the Metolius Springs, placed the property in the hands of the U.S. Forest Service for protection and maintenance. The Forest Service has built a parking lot, rustic trail, and viewpoint structure from which visitors can see the river begin.

In the vicinity of the springs the Metolius Valley is about 3 miles wide and nearly flat. Its elevation is approximately 3000 feet above sea

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

** Private Geologist, Portland, Oregon

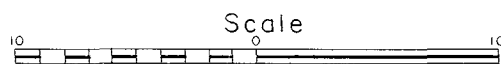
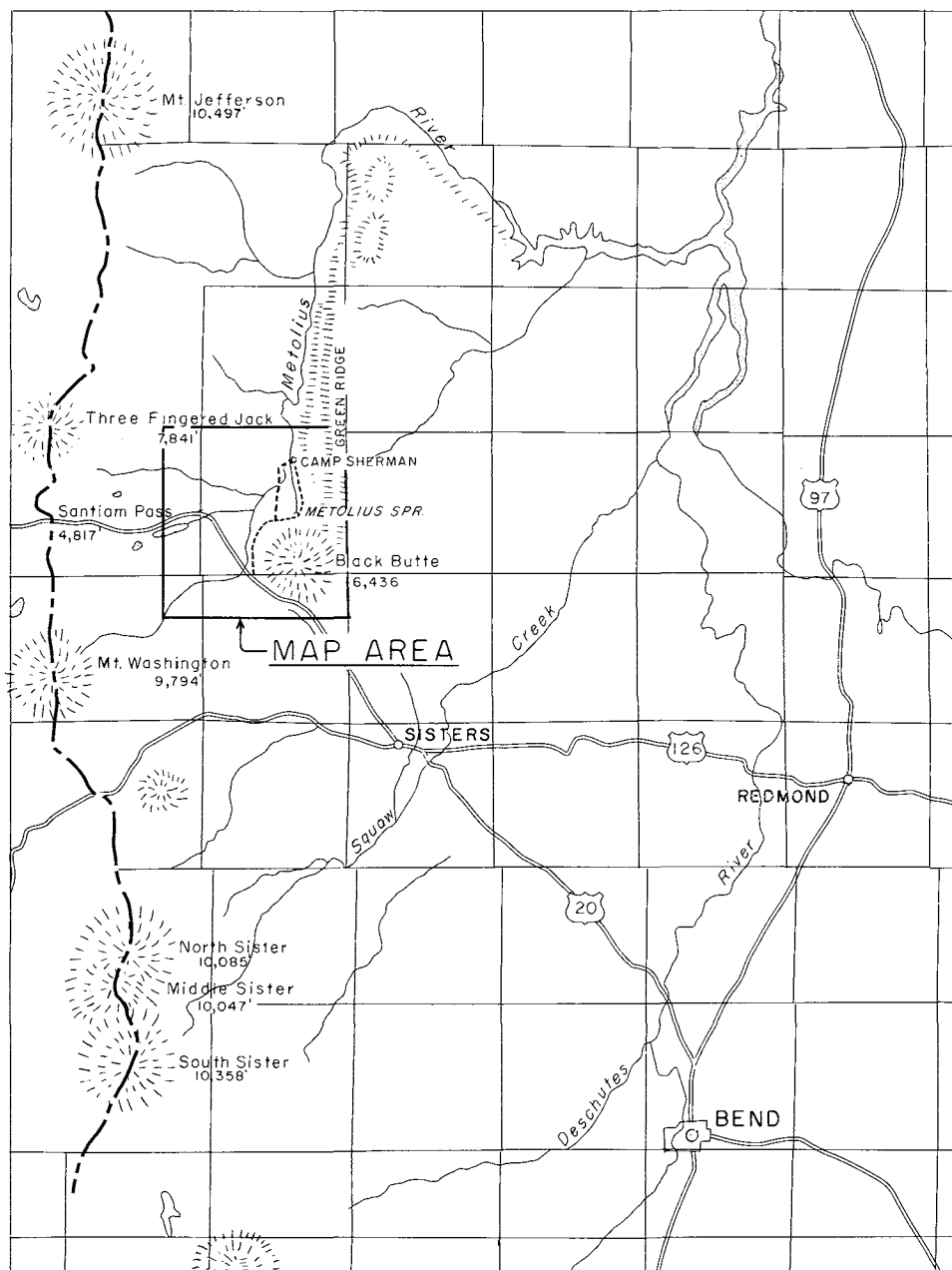


Figure 1. Index map showing location of Metolius Springs and area of geologic map shown on pages 48-50.

level. Immediately to the south is Black Butte, a symmetrical volcanic cone towering more than 3000 feet above the valley floor to a total elevation of 6346 feet. On the east is Green Ridge, a north-trending fault scarp which rises 2000 feet above the valley. On the west 10 miles distant are the snow covered volcanic peaks of Mt. Jefferson, Three Fingered Jack, and Mt. Washington.

The Metolius Springs rise from two groups of orifices about 200 yards apart at the northern base of Black Butte. The water bubbles out of bouldery valley fill at a chilly temperature of 48°F., and the two flows join within a short distance to make up the headwaters of the Metolius River (Figure 2). Total flow from the springs consistently measures from 45,000 to 50,000 gallons per minute the year around. In its 35-mile course northward and eastward to the Deschutes River, the Metolius gains an additional 600,000 gallons of water per minute from springs and tributary streams that drain the east flank of the Cascades.

Geologic History

The Metolius Springs are in the transition zone between the High Cascades geomorphic province on the west and the High Lava Plains on the east.

The oldest rocks in the vicinity are exposed in the steep escarpment of Green Ridge. They consist of alternating layers of basaltic-andesite and breccia and agglomerate typical of shield volcano eruptive centers. These eruptive rocks overlie tuffaceous sandstones, ashy diatomite, and pumice that resemble rocks of the High Lava Plains to the east. The Green Ridge rocks are considered to be of Pliocene age. (See geologic map, p. 48-50.)

The younger rocks of the Metolius Springs area are part of the High Cascades province. They include a variety of volcanic and glacio-fluvial materials. Taylor (1968) reports evidence that the High Cascades platform of coalescing shield volcanoes of andesite and basalt and the majestic peaks that rise from it were formed during the last $1\frac{1}{2}$ million years, (i.e., in Pleistocene and Holocene time rather than beginning far back in the Pliocene as had been commonly supposed). If Taylor's interpretation holds true for the Metolius area, then the numerous and varied geologic events post-dating the rocks of Green Ridge also occurred during this geologically short span of time.

The important geologic events associated with the Metolius Springs began with block faulting on a grand scale. Tensional forces in the earth's crust activated movement along north-trending normal faults gradually dropping a western block down to form the graben valley of the Metolius, causing Green Ridge, the eastern block, to stand as a horst. Once Green Ridge became an obstruction to drainage from west to east, surface water was diverted and an ancestral Metolius River began to flow northward.

The onset of volcanism in the High Cascades may have been coincident with this block faulting. The vast outpourings of basalt and andesite that



Figure 2. Head of Metolius River at Metolius Springs near northern base of Black Butte. Approximately 50,000 gallons of water per minute bubble out of ground (near willows, center of picture) and form an instant river.

built the chain of shield-shaped volcanoes in the High Cascades also obscured the western margin of the Metolius valley graben. After the lava from these shield volcanoes and their satellite vents had coalesced to form the broad, elevated platform of the High Cascades, some of the crowning peaks began to build by more violent volcanic eruptions.

In the High Cascades huge snow fields accumulated and glaciers advanced and retreated. Their powerful erosive forces spawned extensive debris for the streams to carry eastward and spread on the floor of the Metolius River valley.

By the time fault movement ceased and the Green Ridge escarpment reached its maximum height, volcanism was again triggered, this time in the Metolius Spring area along a fault within the graben. How long the eruptions continued we do not know but at their close Black Butte had attained its majestic stature (Figure 3). The rocks that make up Black Butte are typical of the High Cascades. They are light to dark gray, fine to medium grained, somewhat inflated, and of basaltic andesite composition. Outcrops of this blocky lava on the flanks are mixed with breccia zones and show that the cone was built from sluggish flows erupted from a central vent.



Figure 3. Black Butte volcano viewed from Indian Ford Creek area about 7 miles to the southeast. This symmetrical, craterless lava cone rises 3000 feet above the broad alluviated valley.

Taylor (personal communication) reports an age of 500,000 years for the Black Butte lava cone from K-Ar dating of its rocks. It hardly seems this old; no effects of glaciation can be seen and very little erosion; only shallow ravines scar its relatively smooth slopes.

Black Butte, by straddling the Metolius Valley and lapping onto the southern shoulder of Green Ridge, dammed the drainages and divided the valley into a northern part in which the Metolius River is now flowing and a southern park which contains Black Butte Swamp, Glaze Meadow, and the meandering Indian Ford Creek, which flows east, then south toward Sisters (see map). The Black Butte Swamp and Glaze Meadow area were probably once shallow lakes and they still act as sumps for the streams and subterranean drainages from the Cascade flanks southwest of Black Butte. U. S. Highway 20 affords a view of these beautiful upland meadow areas as it skirts the southwest flank of Black Butte.

After Black Butte was built, the High Cascade volcanoes continued to grow to their imposing heights. There were also sporadic eruptions from many small vents and cinder cones. Some of the more fluid lavas from these smaller eruptions reached the valley floor and one flow, now covered with

debris, laps on the western flank of Black Butte. Eruptions such as these have continued until very recent geologic time. One flow of stark black lava in the McKenzie Pass area not far to the west is only 1500 years old.

The last extensive glaciers of the High Cascades (late Wisconsin) were active until about 10,000 years ago. Long lateral moraines show the paths of the massive tongues of flowing ice which nosed toward the valley from the west. Hummocky piles of debris show where they stopped. On the map three of their glacial troughs are shown by the moraines they left. Suttle Lake occupies one of these. Glacial meltwaters continued to contribute large volumes of sands and gravels to the valley floor. This material, together with ash and cinders from the most recent explosive volcanic vents, provides the final cover which smooths the valley floor, laps onto the flanks of Black Butte, and covers all but the most recent lava flows in the McKenzie Pass area (Figure 4).

We come then to the present day--Black Butte astride a structural valley filled with tens of feet of glacial outwash, thin lobes of lava, and stream sediment.



Figure 4. Blanket of glacial outwash, cinders, and scoria between Black Butte and the High Cascades acts as sponge for snow and rain waters which percolate eastward into the Metolius River basin. Outcrop is about 3 miles west of Black Butte.

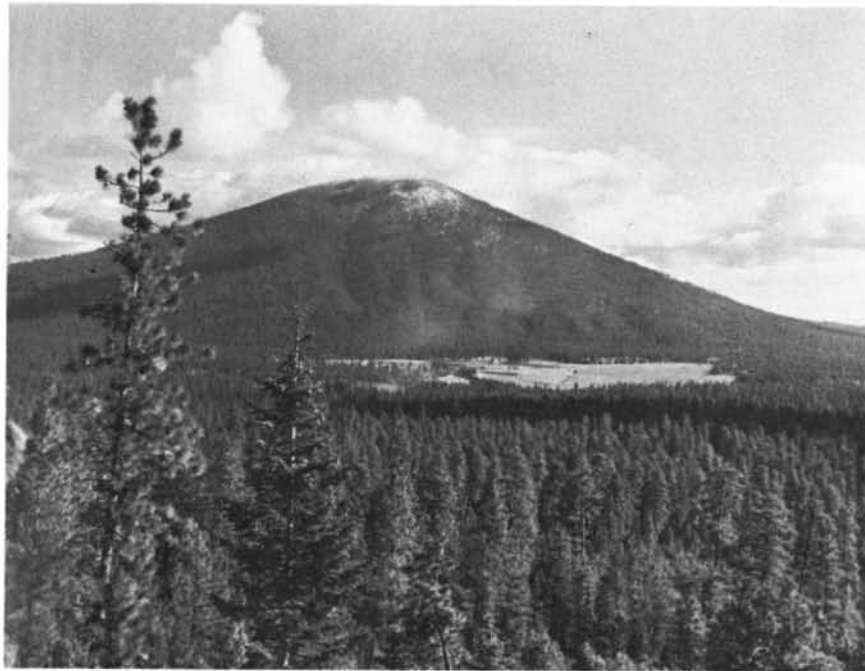


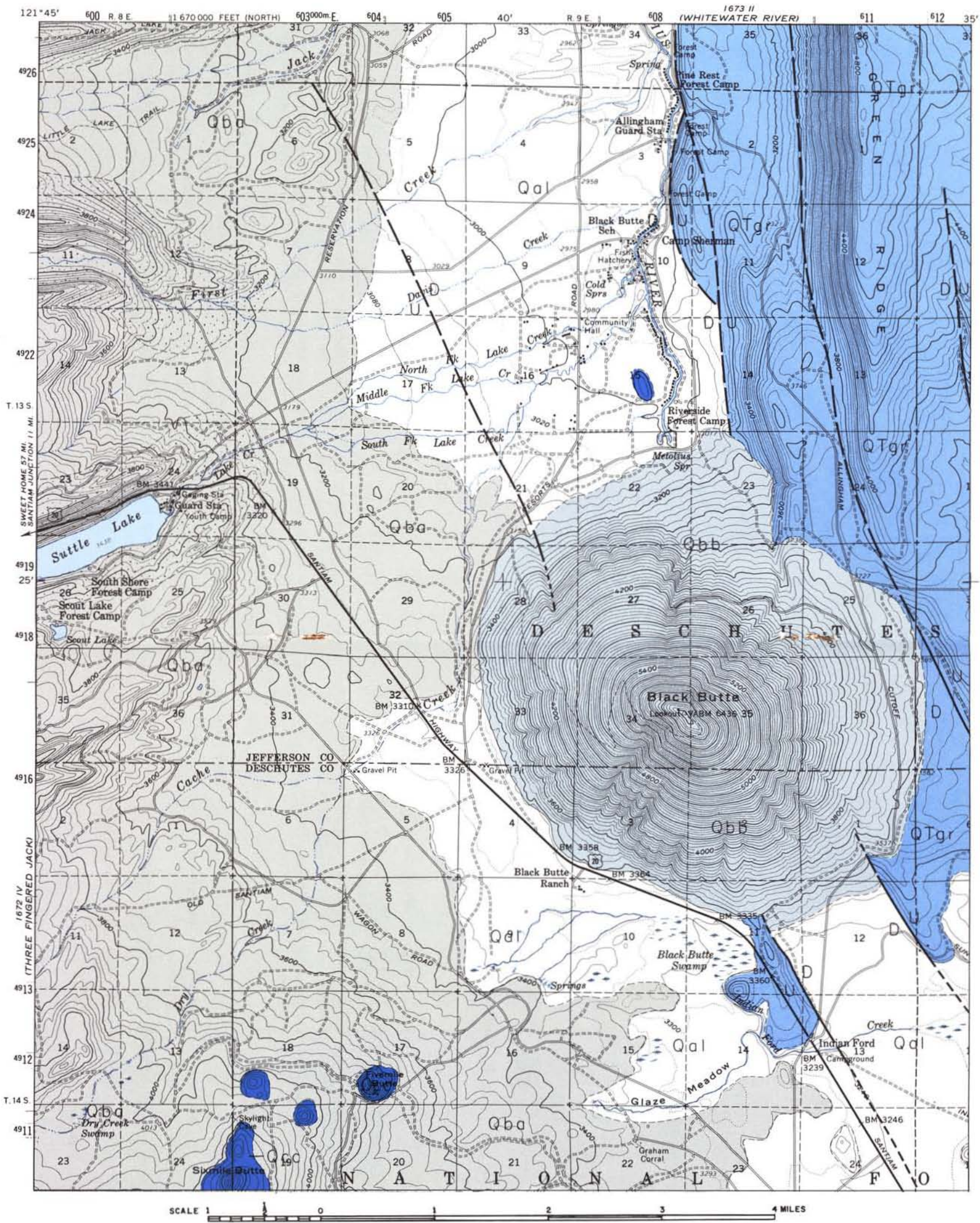
Figure 5. Black Butte viewed from the southwest at a distance of about 4 miles. The meadow area at the base, called Black Butte Swamp, is a sump for drainage northeastward from the High Cascades.

Origin of Metolius Springs

The origin of Metolius Springs may best be understood by looking at the geologic map (p. 48-50) and pretending momentarily that Black Butte is not there. Visualize the remaining geologic and topographic features. This gives a fairly accurate picture of the way the area looked prior to the formation of Black Butte.

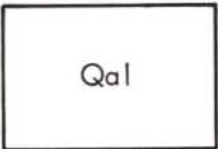
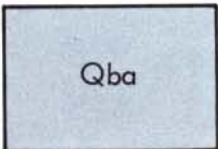

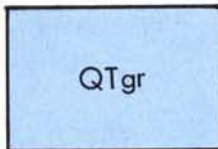


With Black Butte gone, the Metolius Springs do not exist. Instead the headwaters of the Metolius River extend to Black Butte Swamp or even farther south and west. Here, water from rain and melting snow in the High Cascades enters the valley in the form of small streams and as subterranean seepage through glacial outwash and porous zones of lava. Since drainage eastward is prevented by the southern extension of the Green Ridge escarpment, the upper Metolius River waters are channeled northward along the base of Green Ridge.

Now restore Black Butte to the present scene and it is apparent that Black Butte covers the ancestral course of the Metolius River. The water



GEOLOGIC MAP OF METOLIUS SPRINGS AND VICINITY, OREGON

MAP EXPLANATION

Holocene		Alluvium, includes glacial outwash, air-fall ash and cinders, and fluvial sediment.
		Rocks of Black Butte - gray, coarse to medium grained, olivine basaltic andesite flows and breccias.
Pleistocene		High Cascades basalt and andesite flows, breccia, and cinders; mostly covered with a veneer of glacial drift. Dotted pattern marks distinctive lateral and terminal moraines of last extensive glaciation. Qcc - cinder cones and vents
		Rocks of Green Ridge - thin to thick flows of basaltic andesite and breccia layers typical of shield volcano eruptive centers. Also minor tuffaceous sandstone, ashy diatomite, and air-fall pumice; probably correlates with the Dalles (Deschutes) Formation.
		
Contact, dashed where approximately located.		
		
Fault - dashed where inferred. U - up; D - down		

that once flowed on the surface as a river now percolates downward through the permeable sands and gravels of the ancient channel beneath the volcano and surfaces again at the lowest point just north of Black Butte, i.e., at Metolius Springs.

Black Butte Swamp plays an important role. The valley fill of which it is composed laps against the southern base of Black Butte and acts as a sump or container for the water migrating from the extensive drainage area to the southwest (Figure 5). An important feature is its elevation about 300 feet higher than the Metolius Springs. The collection basin that it forms acts as a standpipe and tends to keep a constant hydraulic head on the water from the springs, thus insuring their constant flow. More water enters Black Butte Swamp than surfaces at the springs. This excess is removed by Indian Ford Creek, which follows a circuitous route east then south past Sisters.

A geologist always welcomes an assignment when the landforms and the rocks give enough clues so he can be reasonably sure of the geologic history. In telling the story of the Metolius Springs we have not included all the geological details, many of which are found outside the map area. We are reasonably sure of the general sequence of events: the structural adjustments on the faults to form the valley and Green Ridge, the disruption and rerouting of the early drainages, the building of Black Butte, and the volcanism, glaciation, and natural erosion that have formed the present landscape.

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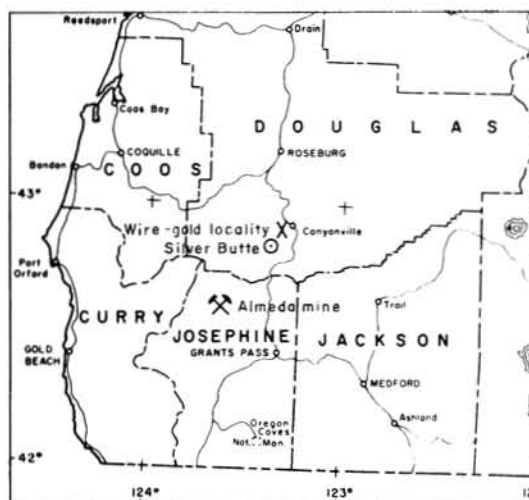
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AN UNUSUAL GOLD OCCURRENCE FROM DOUGLAS COUNTY

Ronald C. Bartley
Consulting Geologist, Ashland, Oregon

Sometime during the 1930's, a small amount of gold was recovered from an unusual geologic habitat near the town of Canyonville in Douglas County, Oregon.

This gold is in the form of wire-like nuggets which range from about 0.3 to 1.0 inch in length and average about 0.1 inch in thickness.* It is slightly lighter in color than most gold, probably because of alloyed silver. Its shape and commonly striated surfaces suggest it formed in association with a fibrous mineral, probably amphibole asbestos.



Index map of Canyonville area showing location of gold occurrence

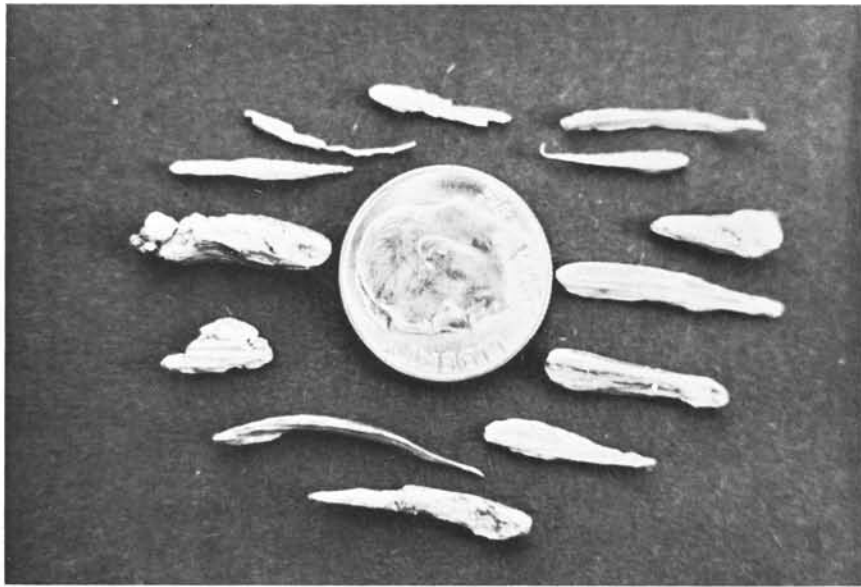
The gold was discovered in a near-surface "pocket" at the Gold Ridge mine, which is located in the SW $\frac{1}{4}$ Sec. 5, T31S, R5W. On a recent visit to the property the specific location could not be determined, since there are several small open pits and trenches.

The mine excavations are in a narrow belt of sheared serpentinite which apparently has intruded along a major fault zone separating the Jurassic Galice and Dothan Formations. Several narrow veinlets of amphibole asbestos were noted, and also some talc and minor amounts of chalcopyrite. Vein

quartz, which is so commonly associated with gold deposits was notably lacking.

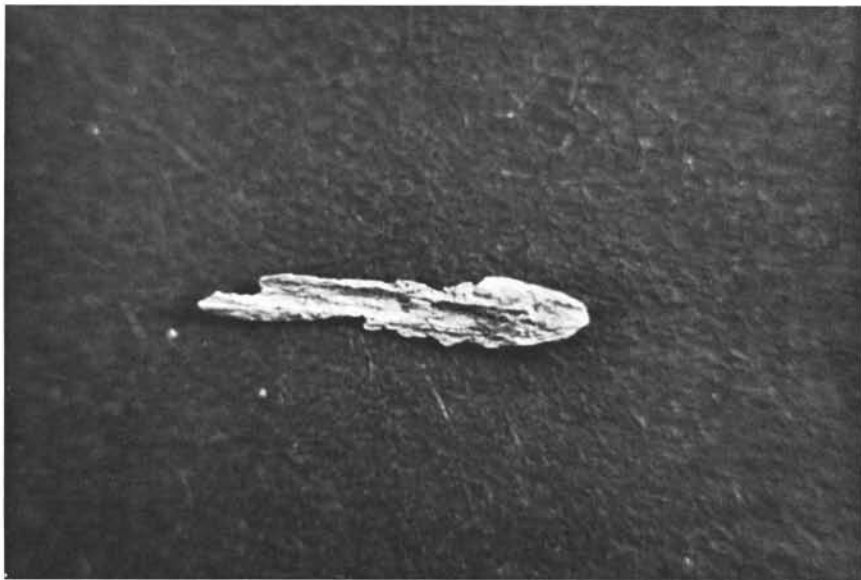
It is interesting to note that this old gold mine is one of at least 11 which are located along a very narrow structurally controlled zone extending southwest from Canyonville to Silver Butte. This zone is a northeast extension of the Almeda-Silver Peak trend, but exhibits a somewhat different type of mineralization. Although there are no other known occurrences of wire-like gold along the zone northeast of Silver Butte, a similar deposit has been reported a few miles southwest of Silver Butte and another on Tuller Creek west of Glendale.

* Specimens examined were made available to the writer by Elton Bollenbaugh.



Above: Wire-like gold nuggets from the Gold Ridge mine.
Enlarged; dime for comparison.

Below: Typical gold specimen. Note rough grooved surface.
Enlarged 3X.



(Photographs by W. B. Purdom, Southern Oregon College)

NATION TOO RELIANT ON METAL IMPORTS

An American Smelting and Refining Company official said in Caldwell, Idaho recently the United States is running the risk of losing its independence in foreign affairs by becoming increasingly reliant on imports of mineral raw materials.

S. Norman Kesten of Wallace, chief geologist for Asarco's Northwestern Mining Department, told the Caldwell Rotary Club that much legislation now being proposed would have the effect of further reducing domestic mining activity, thus forcing added dependence on foreign mineral sources.

Kesten said this nation exports only five major minerals--coal, phosphate, molybdenum, tungsten and magnesium--whereas it imports some or all of the dozens of its other essential mineral commodities. He noted, for example, that between 80 and 100 percent of America's chromium, nickel, asbestos, fluorite and aluminum are now imported.

"We are relying more and more on the good will and stability of other nations for many essential products," Kesten said. "However, other countries are not always stable, nor do they always feel good will toward us."

Kesten said it is plain that more ore deposits must be found and mined in the United States but there is a very strong tendency, among small but vocal groups, to try to prevent the discovery of new deposits. He said at least two major companies are prepared to invest large sums of money for mineral exploration and development in Idaho but are reluctant to do so because of possible harassment.

Kesten said 427 pieces of legislation which would adversely affect mining have been introduced at the Federal level. Some of the proposals are aimed at eliminating millions of acres from multiple use management and others at regulating mining to the point of destroying incentive for exploration and mineral development, he said.

(from The Wallace Miner, Wallace, Idaho)

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GEOLOGY OF OREGON NOW ON POSTCARDS

Now you can buy a geologic map of Oregon on a 4x6" postcard. Twelve different geologic units based on age and type of rocks are shown in multi-color. Also indicated on the map are the major volcanoes, calderas, and faults.

The cards are for sale by the Oregon Department of Geology and Mineral Industries at its Portland, Baker, and Grants Pass offices. The price over the counter is \$.10 each or 3 for \$.25 (7 for \$.50; 12 for \$1.00). They may also be ordered by mail, but at a minimum of 12 for \$1.00. In large quantity the price is \$7.50 per 100 over the counter and \$8.00 per 100 by mail.

* * * * *

SAMUEL H. WILLISTON

Samuel Hathaway Williston, retired Sun Oil Company executive and president of the American Quicksilver Institute, is dead at the age of 72. Mr. Williston was well known in mining circles throughout the west for his activities in quicksilver. Williston was instrumental in expanding Sun Oil Company's interest in mining by establishing Cordero Mining Company, which eventually became the second largest mercury producer in the United States. The famed Horse Heaven mine in Jefferson County operated by Cordero produced a total of 17,000 flasks of quicksilver before the mine was shut down in 1958. Just south of the Oregon line in Nevada, the Cordero mine was the principal quicksilver producer in that state for many years.

Williston, as a geophysicist employed by Sun Oil, perfected a well-surveying device employing gyroscopic principles which is still the most-used well surveying instrument of its kind and was the basis for founding the Sperry-Sun Well Surveying Company. In later years Williston developed many other products, including an automatic elevation computing device which could be towed behind a car or truck and which gave instant readings. Another invention made it possible to detect remanent magnetism in drill cores. This discovery was a spin-off from an earlier device which had been developed to determine the orientation of drill cores by means of north-south magnetism induced in the rock at the time it was cored. A few years ago Williston perfected a mercury "sniffer" which contained an ultra-sensitive mercury detection device. The "sniffer," when transported across the countryside, could easily pick up slight changes in the mercury content of the surrounding air; these anomalies can be useful in the delineation of ore bodies with which mercury is often associated.

Sam Williston lived in Oregon during World War II. In addition to numerous other commitments, such as membership on national mineral advisory boards, he found time to serve on the Governing Board of the Department of Geology and Mineral Industries from 1943 to 1947.

Upon his retirement Williston devoted his efforts to research involving mercury in industrial applications and its impact upon the environment.

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ASSAY AND SPECTROGRAPH PRICE SCHEDULE REVISED

The Department's assay and spectrograph prices, established as of July 1, 1971, have been changed to the benefit of those submitting samples. Up-to-date equipment recently installed in the Department's Portland laboratory makes it possible to process a number of the ores at a lower cost. The revised list of prices is available from the Department by writing to 1069 State Office Building, Portland, Oregon 97201. The list will also be published in a forthcoming issue of The ORE BIN.

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DR. PAUL HOWELL

Dr. Paul W. Howell, 62, retired geologist for the U.S. Army, Corps of Engineers and adjunct professor at Portland State University, died February 28, 1972. Dr. Howell attended the University of Oregon and the University of Washington and obtained a doctoral degree at the University of Arizona. He was engineering and supervising geologist for the U.S. Army, Corps of Engineers for 20 years and worked on the sites for the Look-out Point, Dorena, Cougar, Fall Creek, and Green Peter Dams. After retiring from the Corps of Engineers in November 1969, he taught geology at Portland State University. He was a member of the Association of Engineering Geologists, the Oregon Academy of Science, and the Geological Society of the Oregon Country. At the request of the GSOC, the Earth Science Department at Portland State University has set up the Howell Memorial Fund, proceeds to go to students at Portland State doing research on the Troutdale and Molalla Formations. Contributions to this fund should be made to: "Portland State University Development Fund--Paul Howell."

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GEOHERMAL RESOURCES COUNCIL PUBLICATIONS AVAILABLE

Copies of the papers presented at the Geothermal Resources Council First National Conference held in El Centro, California on February 16-18, 1972 are available for sale at the Portland office of the Department of Geology and Mineral Industries, and from the California Division of Oil and Gas, 1416 - 9th Street, Sacramento, California 95814.

The Proceedings of the Conference will be assembled into two publications. Presently available is the Overview of Geothermal Exploration and Development in the Western States, which is a compendium of all papers presented on the second day of the meeting, consisting of reports on each western state, except Alaska; 220 pages, price is \$6.00 postpaid. A compendium of the first day's papers is now being assembled and will sell for \$4.00 postpaid. A list of attendees is also available for \$2.00 postpaid.

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NEW GEOHERMAL JOURNAL ANNOUNCED

A new publication devoted to geothermal resource research and development entitled GEOHERMICS will be published quarterly by the International Institute for Geothermal Research, Pisa, Italy. Information on subscription rates is available from: Maxwell Scientific International, Inc., Fairview Park, Elmsford, New York 10523.

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for compiling this information will be appreciated.

THRUSTING OF THE ROGUE FORMATION NEAR MARIAL ON THE LOWER ROGUE RIVER, OREGON

Ewart M. Baldwin and John O. Rud
University of Oregon

Introduction

Geologic exploration in the Klamath Mountains of Oregon and California has revealed the presence of large thrust sheets, a feature which adds to the complexity of the regional geology. One of the first to recognize the pattern of thrusting was Irwin (1960, 1964). He showed a thrust fault that placed the Rogue Formation upon the Dothan Formation along a contact that trends northeasterly through the Kerby and Galice quadrangles. The fault crosses the Rogue River a short distance west of the village of Galice. Baldwin (1969) also mapped this fault, and Hotz (1969) described the metamorphic effects on the rock adjacent to the fault. The presence of the thrust is now generally accepted, and a recent fossil discovery in the Dothan Formation (Ramp, 1969) supports Irwin's conclusion that the underlying Dothan is younger than the Galice and Rogue Formations.

Confusion has prevailed in separating the volcanic rock of the Rogue Formation from the bodies of volcanic rock mapped within the Dothan Formation. On the Geologic Map of Western Oregon, which represents an earlier interpretation of the study of the Klamath Mountains, Wells and Peck (1961) assign to the Dothan Formation a northeast trending belt of volcanic rock 20 miles west of Galice. The belt reaches from Gold Mountain on the north across Mule Creek and the Rogue River to Shasta Costa Creek to the south. It is the purpose of this paper to show that this volcanic belt is made up of Rogue volcanic rock, and that it was thrust westward over younger formations as part of the Rogue Thrust Sheet recognized elsewhere to the east. Subsequent downfaulting and erosion in the mapped area has isolated the body from the rest of the Rogue Formation, thus obscuring its relationships with that unit.

Baldwin (1968, 1969) mapped this western volcanic belt as Rogue Formation, but in the area he mapped the critical thrust relationships were covered by younger formations. It was during additional reconnaissance and more specific mapping in the southwestern quarter of the Bone Mountain quadrangle by Rud (1971) that the thrust relationship became more evident.

Mapping is continuing in the Mt. Bolivar-Gold Mountain area by Richard Kent (Portland State University) and in the area just north of Gold Mountain by Nils Johannesen (University of Oregon). The writers are indebted to both for additional information.

Stratigraphy

Introduction

A brief resume of the formations involved is informative. Beds assigned to the Galice Formation lie west of the Powers-Agness fault west of Bald Knob but are not mapped on Figure 1. They also extend farther to the northwest into the Langlois quadrangle (Lent, 1969), Powers quadrangle (Baldwin and Hess, 1971), and Port Orford quadrangle (Koch, 1966).

Colebrook Schist

The Colebrook Schist is of uncertain age but is tentatively assigned to the Jurassic pending more adequate proof of age. Coleman and Lanphere (1971) discuss the age and mode of emplacement. They assign a metamorphic age of approximately 130 million years to the lower-grade blueschist minerals of the Colebrook and a metamorphic age of 150 million years to the higher-grade blueschist minerals and amphibolites in scattered small bodies. The place of formation of the higher-grade metamorphic minerals is uncertain and the time and place of accumulation of the original sediments are unknown. Coleman and Lanphere (1971) suggest, however, that the Colebrook Schist occupies a thrust sheet that was shoved eastward upon beds as young as the Myrtle Group.

Serpentinite and diorite intrusions

Serpentinite and some less obviously altered bodies of peridotite are present in places along the edges of the Rogue Thrust Sheet. Coleman (1971) discusses the tectonic emplacement of such ultramafic bodies. He suggests that most of the serpentinite in this area had its origin in the upper mantle and was emplaced along geosutures created by collisions of the oceanic and continental plates. Emplacement prior to or during the Late Jurassic Nevadan orogeny is suggested by the intrusion of dioritic bodies of that age. Subsequently the serpentinite may have acted as a "tectonic carpet" upon which the Colebrook Schist was thrust, possibly during Cretaceous time (Coleman, 1969).

Dioritic bodies which intruded the pre-Nevadan formations and the serpentinite during the Nevadan orogeny have been discussed by Koch (1966), Lund and Baldwin (1969), and Dott (1971). Adding to the difficulties in interpreting the position of the serpentinite is the fact that it may have been remobilized one or more times during the Tertiary, thus possibly obscuring its original contact relationships.

Rogue Formation

The volcanic rock which extends southward from Gold Mountain through Mt. Bolivar and Mule Creek drainage and which crosses the Rogue River at Marial to continue southward into Illinois River drainage was called the Dothan volcanics by Wells and Peck (1961). Baldwin (1969), however, examined these rocks and noted that they were intruded and altered more like the pre-Nevadan Rogue Formation than the post-Nevadan flows and tuffs. He assigned them to the Rogue Formation.

The Rogue Formation, named by Wells and Walker (1953), includes approximately 15,000 feet of volcanic rocks that are exposed west of Galice (east of the mapped area, Figure 1). This volcanic section is separated from that lying west of Marial by a 12-mile wide belt of sedimentary rock along the Rogue River assigned to Dothan Formation. In its type area, the Rogue Formation consists mostly of submarine flows, breccias, and tuffs which have been altered to greenstone and intruded by peridotite and quartz diorite.

The Rogue Formation west of Marial (Figure 1) appears to be at least 10,000 feet thick. Unmapped intrusive bodies within the formation are exposed in the West Fork of Mule Creek, along the Rogue River trail downstream from Marial near the mouth of Stair Creek, and near the mouth of Indigo Creek, a tributary of the Illinois River. Although the composition of the intrusive rock was not determined petrographically, much of it appears to be gabbro in hand specimen. Contacts with the greenstone are gradational and it is possible that the rock is a metagabbro. Most of the primary structures of the volcanic rock have been obscured by alteration to greenstone. Epidotization is common along some of the shear zones.

The Rogue Formation in its type area is interfingered in places with the pre-Nevadan Galice Formation (middle Late Jurassic) and shows evidence of deformation prior to deposition of the later Dothan strata (late Late Jurassic). It apparently was thrust westward relative to the underlying Dothan Formation and then was dropped by normal faulting against the Dothan along a fault that crosses the Rogue River at the mouth of Mule Creek.

Dothan Formation

The Dothan Formation is made up of a thick section of graded thick-bedded graywacke with minor amounts of conglomerate, chert, and volcanic rock. The graywacke in many places is made up of rhythmically bedded indurated sandstone which generally dips eastward. Volcanic rock is present in places and it frequently shows the original pillow or fragmental structures. Although the Rogue and Dothan volcanics have been confused in the past, it is the observation of the writers that the Dothan volcanic masses are seldom as large or as altered as those of the Rogue Formation. The Dothan Formation is now generally assigned a Tithonian (Late Jurassic)

age (Irwin, 1964, and Ramp, 1969). It is not known to be intruded by dioritic rocks, a point which supports a post-Nevadan age.

Myrtle Group

Because the lithology of the Cretaceous beds in the area mapped is more like the Myrtle Group described by Imlay and others (1959) than the Humbug Mountain Conglomerate and Rocky Point Formations (Koch, 1966) of similar age along the coast, the term Myrtle Group is adopted here.

As described by Imlay and others (1959), the Myrtle Group includes the Riddle and Days Creek Formations. Although the two formations were not differentiated on the map, they can be distinguished in the field. The Riddle contains chert pebble conglomerate and some dark graywackes, and lies on the eastern edge of the outcrop belt. The Days Creek Formation is made up mostly of graded bedded graywacke with minor amounts of conglomerate. The Myrtle Group is mostly Early Cretaceous in age, although the base of the unit may extend into the Late Jurassic (Jones, 1969). The group can be traced southwestward to the lower Illinois River Valley along the front of the Rogue volcanic thrust sheet (Figure 1). Between the larger areas of outcrop, small exposures are present along the Rogue River near Clay Hill, midway between Illahe and Marial, and in a faulted block along Shasta Costa Creek.

Umpqua Formation

In the map area the Umpqua Formation occupies a north-trending syncline. Although the Umpqua Formation has been split into three map-pable members pending formal naming as formations by Baldwin (1965), the unit remains undifferentiated in Figure 1. All three members contain some conglomerate near the base and are composed primarily of rhythmically bedded, graded graywacke and siltstone. Distinction between the three members is sometimes difficult in the field and is based largely on stratigraphic position.

The age of the Umpqua Formation ranges from Paleocene and early Eocene in the lower member to middle Eocene in the middle and upper members. Unconformities separate the three members and also separate the Umpqua Formation as a whole from the overlying Tyee Formation. The Umpqua Formation unconformably overlies the Myrtle Group along an undetermined contact (dotted line on map) between Agness and Illahee on the Rogue River. Along the Illinois River-Horse Sign Creek divide near Horse Sign Butte basal black sands assigned to the middle Umpqua by Baldwin (1968) rest on pre-Tertiary rock.

On the accompanying map, the Umpqua Formation is shown to overlie both the Rogue Formation and the Dothan Formation in continuous outcrops, a feature which suggests at first that the proposed thrusting of the Rogue was

pre-Umpqua in age. More refined mapping indicates, however, that the involved exposures consist of middle or upper Umpqua only. Hence, the conclusion advanced by Baldwin and Lent (1972) that part of the thrusting may have occurred after the lower Umpqua was deposited is consistent with the distribution of the Umpqua Formation.

Tyee Formation

The Tyee Formation occupies the center of the syncline which in turn occupies a graben. The Tyee is unconformable on all underlying formations and oversteps the Umpqua onto the Rogue Formation at Hanging Rock, a short distance northwest of Marial. At the south end of the basin the Tyee becomes more massive, contains more conglomerate, and loses the graded bedding that is characteristic farther north in the Coast Range. Cross-bedding and the presence of intercalated coal beds indicate a shallow-water nearshore environment of deposition. Bald Knob is the southernmost exposure of Tyee in Oregon.

Structural Geology

Introduction

The stages of tectonism in the area mapped start with deformation of the Rogue and Galice Formations during the Nevadan orogeny. This episode is largely masked by later thrusting, but presumably the ultrabasic rock and dioritic intrusions were initially emplaced at this time. Subsequent basining, volcanism, and deposition formed the very thick sections of graywacke assigned to the Dothan Formation and the associated sedimentary and volcanic rocks of the Otter Point Formation to the west (Koch, 1966). The two units may represent deposition in part of a Late Jurassic island arc system (Coleman to Beaulieu, written communication, 1971).

Contemporaneous or later deformation has converted the Otter Point Formation to a melange as described by Hsu (1968). Thrusting is known to have followed deposition of the Myrtle Group (Blake, Irwin and Coleman, 1967).

Rogue Thrust Sheet

On the geologic map of the Kerby quadrangle (Wells and others, 1949) and the Geologic Map of Western Oregon (Wells and Peck, 1961) the elongate body of volcanic rocks which is situated along the western edge of the large intrusive belt southwest of Galice is assigned to the Dothan Formation. Hotz (1969) has examined the thrust as far south as Hobson Horn in the southern part of the Galice quadrangle, where dioritic intrusives are interpreted to rest with thrust contact upon the Dothan Formation. The

senior writer, however, in reconnaissance along the Silver Peak trail in the northern part of the Kerby quadrangle, found sheared volcanic rocks between the diorite and the thrust. Apparently the volcanics in the area are not separated from the intrusions of diorite, gabbro, and serpentinite but actually contain them. It is concluded that the volcanic rocks along the Silver Peak Trail are pre-Nevadan and part of the Rogue Thrust Sheet, and that they are not part of the Dothan Formation as concluded by Wells and others (1949) and Wells and Peck (1961).

The thrust apparently follows the western edge of the Mule Creek volcanic belt southward across Silver Creek, the Illinois River, and Tincup Creek. Near Tincup Creek exposures of the Rogue Formation (as recognized above) lie within eight miles of the exposures of volcanic rock (Rogue Formation of this report) along the Illinois River at the mouth of Collier Creek in the mapped area. The distance of eight miles is considerably less than the separation between the two units along the Rogue River nearer the mapped area, a situation which supports the interpretation that the two units may be genetically related.

It is concluded that the volcanic rocks in the mapped area, which are also intruded (see Rogue Formation), are part of the Rogue Formation, and that, together with the exposures near Galice, constitute part of the extensive Rogue Thrust Sheet.

Evidence suggests that the relative movement of the Rogue Thrust Sheet over the Dothan east of Galice was to the west. Drag folds in the underlying Dothan are displaced westerly, and the Rogue plate climbs in the section so that it overlies the Dothan Formation nearer the source and the Myrtle Group farther west. The Rogue plate is apparently eroded in the intervening area exposing the Dothan between Galice and Marial along the Rogue River.

It might be reasoned that if the Colebrooke Schist plate came from the west, the Rogue plate could have also, but there is little evidence to support such a theory. It is possible to show that relative westward movement of the Rogue may have been achieved by underthrusting of the lower plate during collision of the oceanic and continental plates. If so, then subduction of the oceanic plate may have directed the Dothan and underlying rocks beneath the Rogue Thrust Sheet at the same time that obduction (over-thrusting) caused the Colebrooke Schist to ride eastward over all pre-Myrtle formations and possibly over the lead edge of the Rogue plate as well.

Coleman (1969) describes the role of "tectonic carpets" of serpentinite in thrusting. A considerable quantity of serpentinite is present along the Illinois River, Figure 1, upon which the plates may have slid.

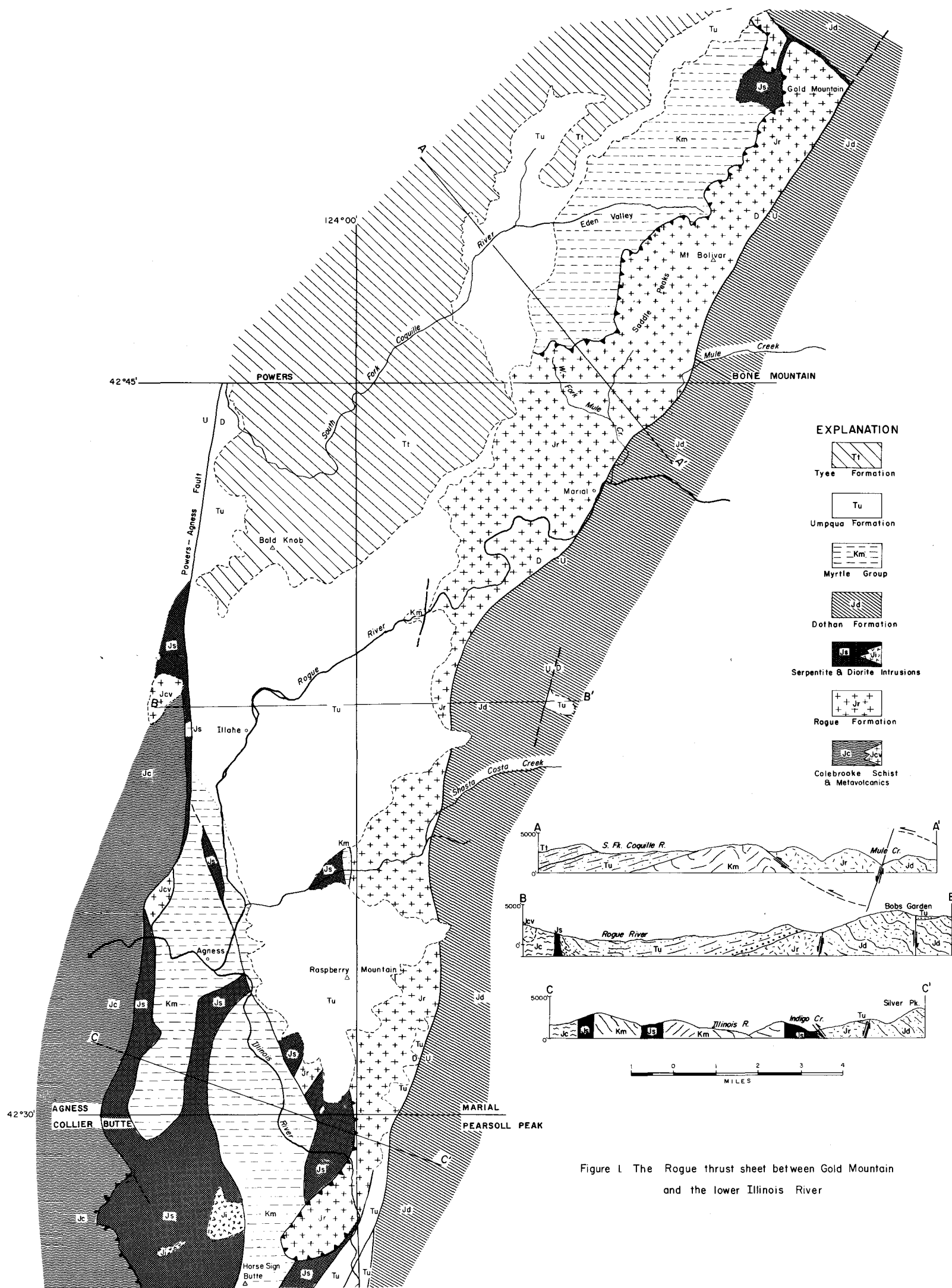
Serpentinite is absent in many places along the thrust in the Bone Mountain quadrangle and also in the Galice and Kerby quadrangles. Serpentinite, diorite and gabbro bodies split the Rogue belt in the Galice and Kerby quadrangles, but only in a few places does the serpentinite furnish a "tectonic carpet" along the thrust margin.

The relationship between the Dothan Formation and the Myrtle Group is obscured by the presence of the Rogue Thrust Sheet as it is recognized in this report. Because the exposures of Rogue represent parts of a regional thrust sheet, it is possible that the immediately underlying Dothan Formation may in places be in thrust contact with the Myrtle Group.

Erosion of edges of the thrust sheets and overlap by later sedimentary formations obscure the thrust fault in the area mapped, but further work in this complex but interesting area should cast further light on geologic events.

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MINED LAND RECLAMATION ACT COPIES AVAILABLE

The Department has prepared copies of HB 3013, popularly referred to as the "Mined Land Reclamation Act," which goes into effect July 1, 1972. The Act is of interest to all operations which extract more than 10,000 cubic yards of minerals or disturb more than two acres per year. The Act requires operators to secure an operating permit, a performance bond and provide an excavation plan and a reclamation plan. Rules and regulations are currently being prepared. The Department of Geology and Mineral Industries will administer the Act. Operators may obtain copies of the Act at the Department's offices in Portland, Grants Pass, and Baker.

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SHELDON APPOINTED U.S.G.S. CHIEF GEOLOGIST

Dr. Richard P. Sheldon has been named Chief Geologist of the U.S. Geological Survey to succeed Dr. V. E. McKelvey, who was appointed Survey Director in December 1971 (see December 1971 ORE BIN). Dr. Sheldon has been with the U.S.G.S. since 1947, most recently holding the position of Assistant Chief Geologist for Mineral Resources.

* * * * *

GEOHERMAL GRADIENT STUDIES IN OREGON

Richard G. Bowen*

Heat flows from the interior of the earth at an average rate of 1.5 micro-calories per square centimeter per second. This is equivalent to about 150 Btu's per square mile per second; over the whole earth over a year's time this heat energy is equivalent to that contained in 170 billion barrels of oil. In most of the world this heat is too diffuse to be used, but in some regions, such as the circum-Pacific volcanic belt, heat flow is several times normal. Under some geologic conditions this heat energy is transferred to circulating underground waters, forming a geothermal reservoir. In that way the earth's heat is trapped and stored and can be tapped by drilling, making the heat available for use as either hot water or steam, depending upon the characteristics of the particular reservoir.

Surface manifestations, such as hot springs and geysers, indicate the presence of geothermal reservoirs, but in some regions where these hot waters do not come to the surface they can be detected by the measurement of geothermal gradients or heat flow.

The geothermal gradient is the rate of temperature increase with depth. Normally this is about 1 degree Celcius per 100 feet or more, frequently written as $30^{\circ}\text{C}/\text{Km}$. In geothermal areas the gradient is often several times the "normal;" for example, at The Geysers geothermal field in California steam at temperatures of about 240°C is reached at 3000 to 4000 feet. This is a geothermal gradient of 200 to $250^{\circ}\text{C}/\text{Km}$ or six times the world "normal."

Geothermal gradients are relatively simple to measure as they are merely a plot temperature and depth, but certain factors must be taken into consideration in order that the geothermal gradient figure be meaningful. For example, the annual change in near-surface temperatures due to variations in solar heating makes it necessary to take the temperature measurements at a depth not influenced by solar heat, generally at least 150 feet. Temperature gradients measured in open holes or in areas of permeable rocks can be affected by upward or downward movement of ground water. If these factors are taken into consideration, geothermal gradients can be a useful tool for outlining prospective geothermal areas.

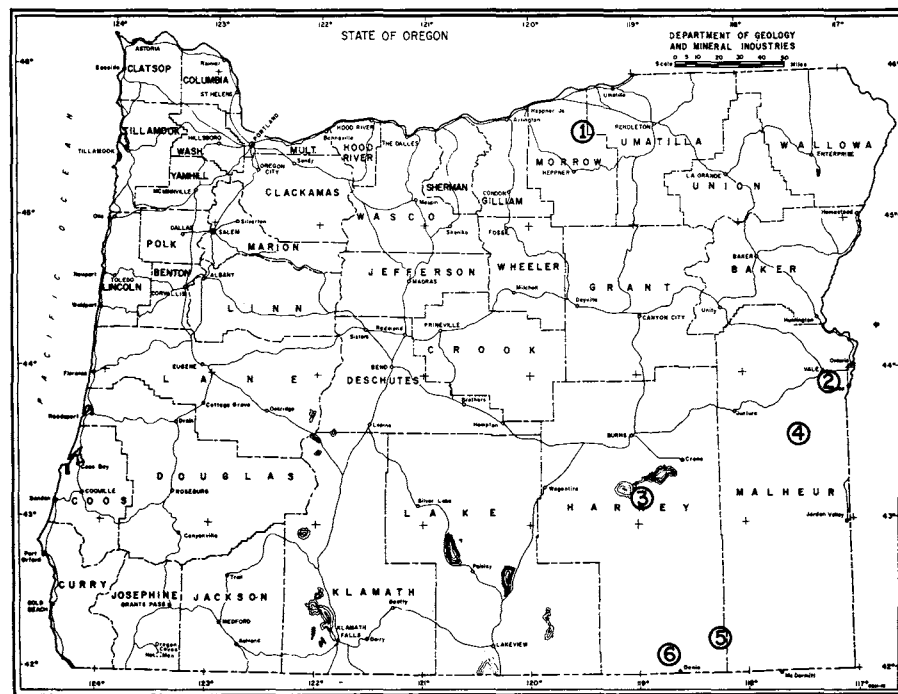
For thermal gradient measurements to be most useful, however, the thermal conductivity of the rocks should also be determined, as they vary widely in their ability to conduct heat. A rock that is a good insulator, such as loosely compacted tuff, will, for the same amount of heat flow, show a high geothermal gradient; a rock with poor insulating ability, like

* Economic Geologist, Oregon Dept. of Geology and Mineral Industries

a granite, will show a low geothermal gradient. By combining thermal gradient measurements and thermal conductivity data, a heat-flow determination can be made that will give a more accurate picture of subsurface conditions than would temperature gradient alone.

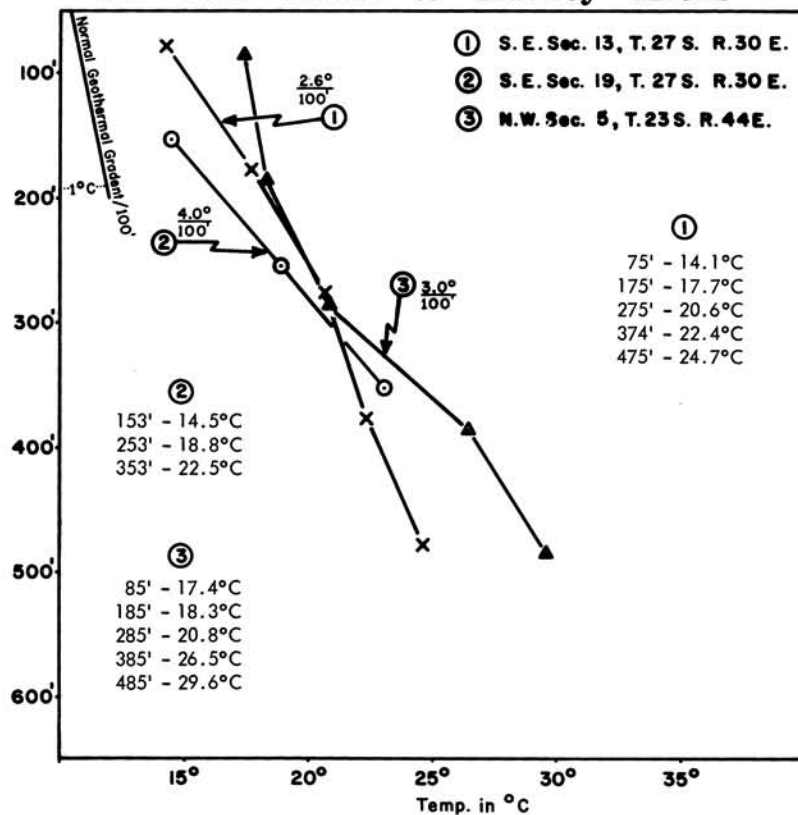
Heat-flow measurements are very sparse and as yet there are none in Oregon because of the complexity of the conductivity measurements and because of a former lack of economic incentive to make them. The Department of Geology and Mineral Industries has been taking geothermal gradient measurements over the last few years whenever drill holes, made for other purposes, have become available (see map for locations). Although geothermal gradients do not present as accurate a picture as do heat-flow measurements, with some knowledge of the underlying rocks a reasonable estimate of conductivity, and therefore heat flow, can be made.

The accompanying graphs show geothermal gradients taken at scattered points in eastern Oregon. They are presented as a progress report. Others will be published from time to time as more data become available.

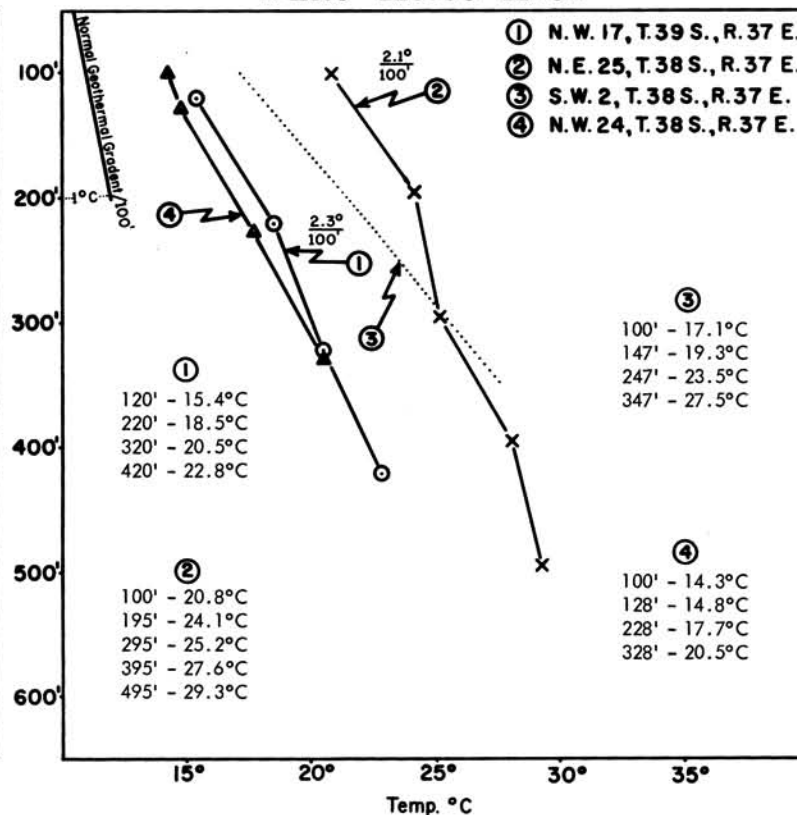


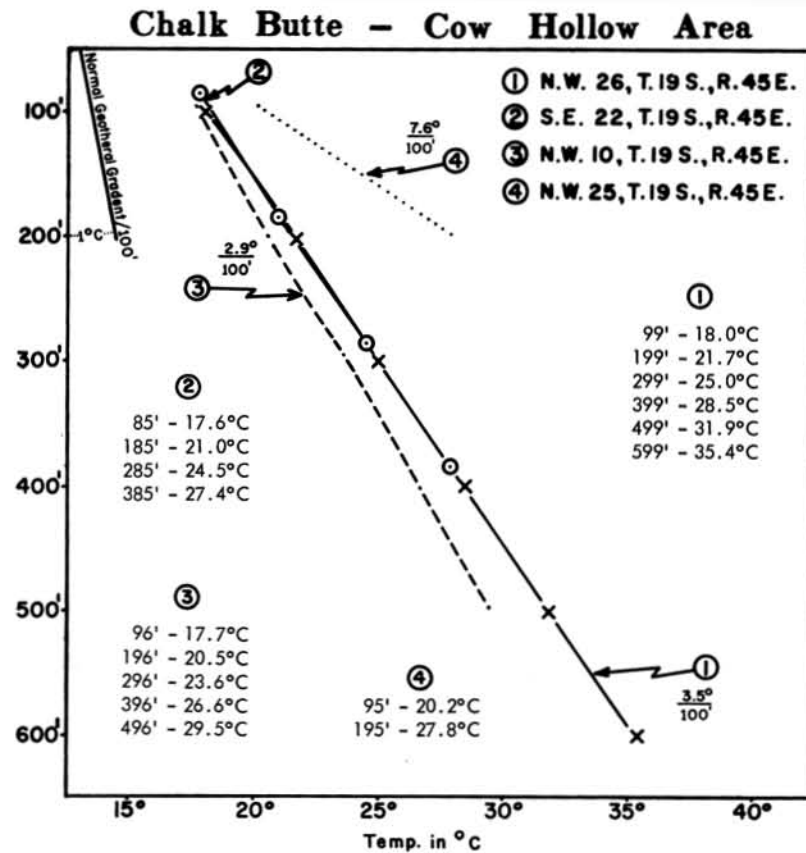
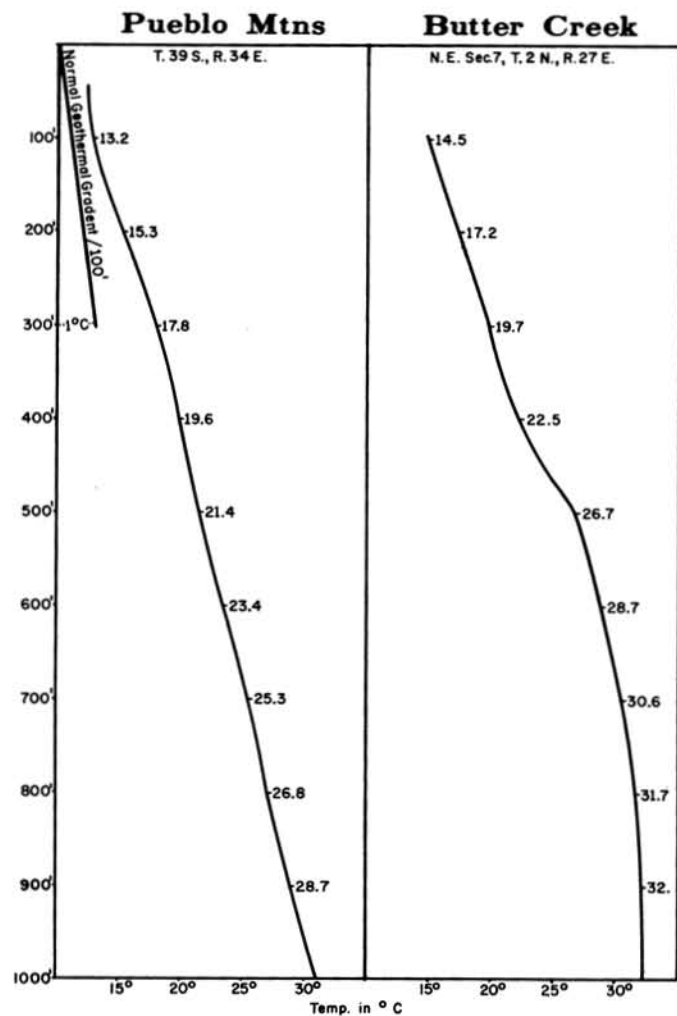
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|-----------------------------|---------------------|
| 1. Butter Creek | 4. Ox Bow Basin |
| 2. Chalk Butte - Cow Hollow | 5. White Horse |
| 3. Harney | 6. Pueblo Mountains |

Ox Bow Basin & Harney Areas



White Horse Area





TRANS-ALASKA PIPELINE IMPACT STATEMENT RELEASED

The Department of Interior has released its Final Environmental Impact Statement on the application for right-of-way to construct the oil pipeline from Prudhoe Bay near the Arctic Ocean to the ice-free Pacific port of Valdez. The report is contained in 6 volumes, plus a 3-volume analysis of the economic and security aspects of the proposal, and is the result of three years of study by the Department. Advice and guidance came from a number of other Federal departments, as well as the State of Alaska. Three task forces were set up to study and compile the material concerned with the environmental impact along the proposed land route, the proposed marine tanker route from Valdez to West Coast ports, and possible alternative pipeline routes through Canada.

Copies of the nine volumes may be purchased from the National Technical Information Service, Springfield, Virginia, or are available for inspection at a number of offices, including the following in the Pacific Northwest: Bureau of Land Management, 710 N.E. Holladay St., Portland; Interior Department Field Representative, Pacific Northwest Region, 1002 N.E. Holladay St., Portland; and Bureau of Outdoor Recreation Regional Director, 1000 Second Avenue, Seattle.

* * * * *

GROUND-WATER RESOURCES IN UPPER JOHN DAY RIVER STUDIED

"Potential ground-water resources of the upper John Day River valley, Grant County, Oregon," by T. P. Thayer, has been released by the U.S. Geological Survey as an unpublished Open File Report. The 8-page preliminary study is concerned with the availability of ground-water for irrigating bench lands in the Prairie City basin area. Included in the report are a geologic map and cross sections. A copy of the report may be consulted at the Department's office in Portland.

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COASTAL LANDFORMS BETWEEN YACHATS AND NEWPORT, OREGON

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Department of Geology, University of Oregon, Eugene, Oregon

The Oregon Coast between Yachats and Newport is a narrow, slightly elevated coastal plain. With the exceptions of basalt rock at Yachats and Seal Rock, the bedrock along this segment of the coast is sedimentary (see map, page 74). Several Pleistocene marine terrace levels are discernible at places along the plain, and sand dunes, both active and stabilized, impart a rolling topography to most of it. Numerous streams have incised small valleys and ravines into its surface; at Waldport the plain is interrupted by the estuary of the Alsea River and at Ona Beach State Park by the alluvial plain of Beaver Creek. Except in the two localities where basalt is exposed, the shore is marked by long stretches of sandy beaches bounded by low sea cliffs. Where the basalt is exposed, the shore has the rugged features that are characteristic of Oregon shores bounded by this type of rock.

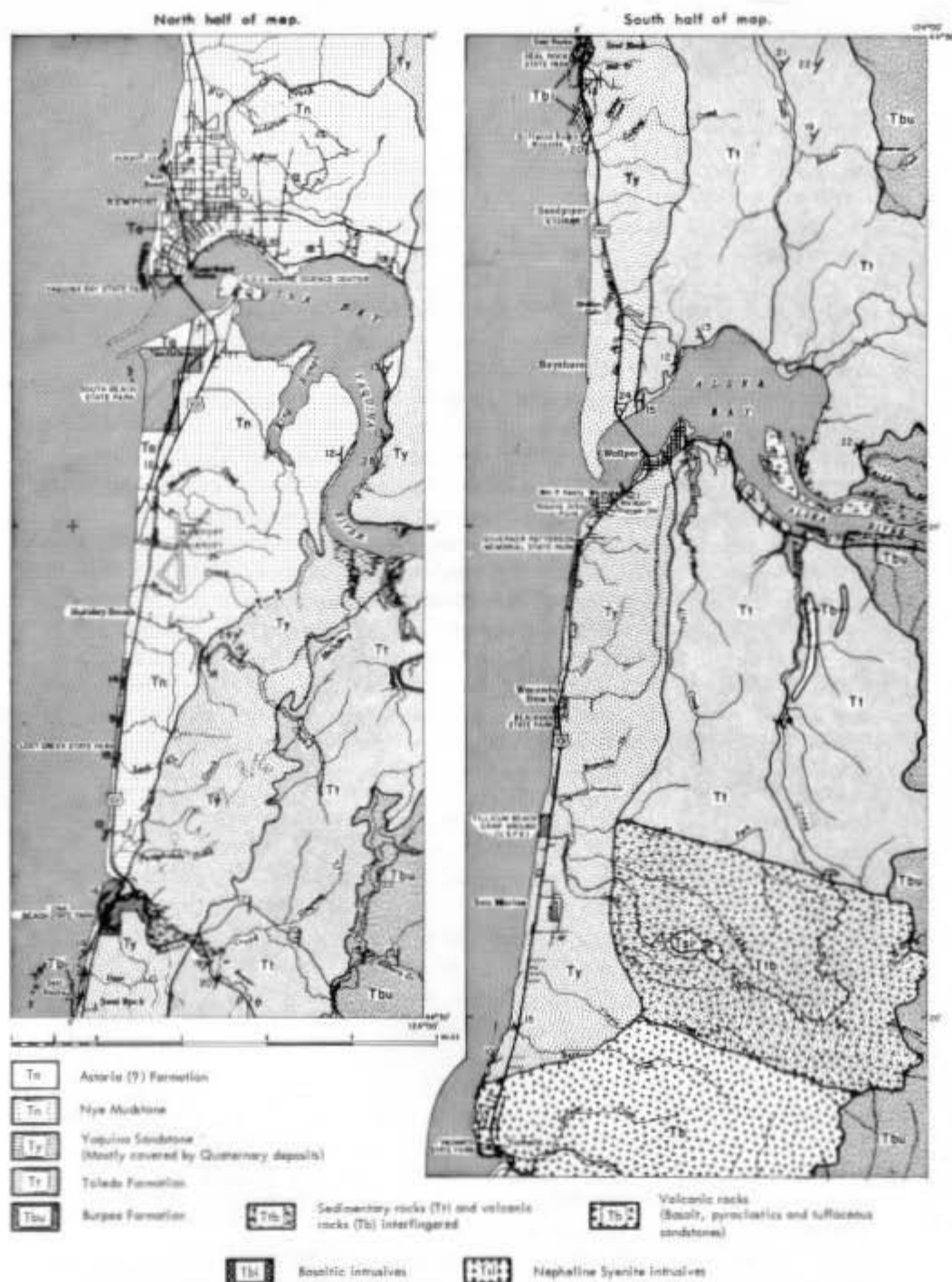
Tertiary Bedrock

Basalt

Two basalt formations are present in this segment of the coast: lava flows at Yachats and a sill at Seal Rock. (See Glossary, page 87.)

The basalt at Yachats is at the northern edge of a complex mass of lava flows and pyroclastic material that extends southward a short distance beyond Sea Lion Point. These rocks represent the remains of a huge center of volcanic activity in late Eocene time. At Yachats the basalt is mostly coarse flow-breccia. Its fragmentation is due in part to the breaking up of a solid crust of lava rafted along on the surface of a flow and in part to sudden chilling of the lava as it poured into the Eocene sea. Dense basalt is interlayered and otherwise intermixed with the breccia, and in places small dikes cut through the rock.

The basalt at Seal Rock is in the form of a sill intruded between beds of the Yaquina Formation. It is probably of late Miocene or younger age (Vokes, et al., 1949) and contemporary with the Columbia River Basalt. Its lower contact with the sedimentary strata is well displayed at the base of the large basalt rock mass known as Elephant Rock in Seal Rock State



INDEX AND GEOLOGIC MAP OF OREGON COAST, YACHATS TO NEWPORT
(modified from Vokes, Norbistrath, and Snively, 1949)
See road log (page 91) for mileage between points of interest



Figure 1. Elephant Rock, an elongate knob of columnar jointed basalt at Seal Rock State Park, is a remnant of a sill emplaced between layers of the Yaquina Formation.



Figure 2. Conglomerate consisting of large basalt boulders overlies basalt along the shore about 100 yards north of the Adobe Motel at Yachats. These boulders were eroded from the basalt and rounded into their present shape by wave action.



Figure 3. Excellent examples of spheroidal weathering are present in the upper part of a very coarse, local sand unit of the Yaquina Formation. Layers of the partly weathered rock separate from the non-weathered central core in a series of concentric shells.



Figure 4. Dark beds of the Yaquina Formation, exposed in sea cliff at Alsea Bay, have a gentle seaward inclination and are overlain by lighter colored, horizontal layers of terrace and dune sandstones.

Park (Figure 1). Sedimentary beds that once overlay it have long since been removed by erosion. The rock of this sill is fine grained and dense and has well-developed columnar jointing. It extends for a distance of about a mile and a half along the coast, and its position offshore is marked by numerous reefs and small sea stacks.

Sedimentary rocks

Yaquina Formation: About 100 yards north of the Adobe Motel at Yachats, the Eocene basalt is overlain by a conglomerate consisting of basalt particles that range in size from pebbles to boulders several feet across (Figure 2). The conglomerate extends northward along the shore for about 140 yards and gives way abruptly to a very coarse, pebbly sandstone made of basalt fragments. The age of the conglomerate is not definitely known, but it is considered a local aspect of the late Oligocene Yaquina Formation, which is younger than the basalt (Vokes, et al., 1949).

The coarse-grained sandstone is exposed along the shore in a bench that extends northward to the foot of Salmon Street, a distance of less than half a mile. Here it ends abruptly and gives way to a sand beach. At the northern end of the bench the sandstone is weathered, and the separation of concentric layers through spheroidal weathering is remarkably well displayed (Figure 3).

In a low cliff at the northern end of the bench one can see coarse sandstone overlying layers of finer textured sandstone, siltstone, and shale. The finer beds are exposed for a very short distance along the beach and disappear beneath Pleistocene terrace sediments. The coarse sandstone is assumed to be another local aspect of the Yaquina Formation, whereas the underlying siltstone, shale, and sandstone are more representative of the Yaquina Formation in the area covered by this study.

The Yaquina Formation borders the shore from its contact with the basalt at Yachats to a point about a mile north of Seal Rock, but it is exposed in only a few places over this distance. North of its exposure near Yachats it is next seen in a sea cliff on the south side of Alsea Bay just west of the city limits of Waldport (Figure 4), and from there it continues along the cliff that extends into the town. The formation is exposed along the shore at Seal Rock, where its beds are tilted seaward beneath the basalt sill at Elephant Rock. It forms low reefs that are exposed at low tide along the beach south of Elephant Rock (Figure 5). To the north it is exposed in places along the beach and at the base of the low sea cliff.

Nye Mudstone: The Nye Mudstone, which overlies the Yaquina Formation with a gradational contact, is exposed at numerous places on the beach and at the base of the sea cliff from a point about a mile north of Seal Rock almost to South Beach State Park south of Newport.



Figure 5. Beach at Seal Rock State Park. Outer reef is basalt; reef exposed on beach is a resistant layer of the Yaquina Formation dipping seaward beneath the basalt.

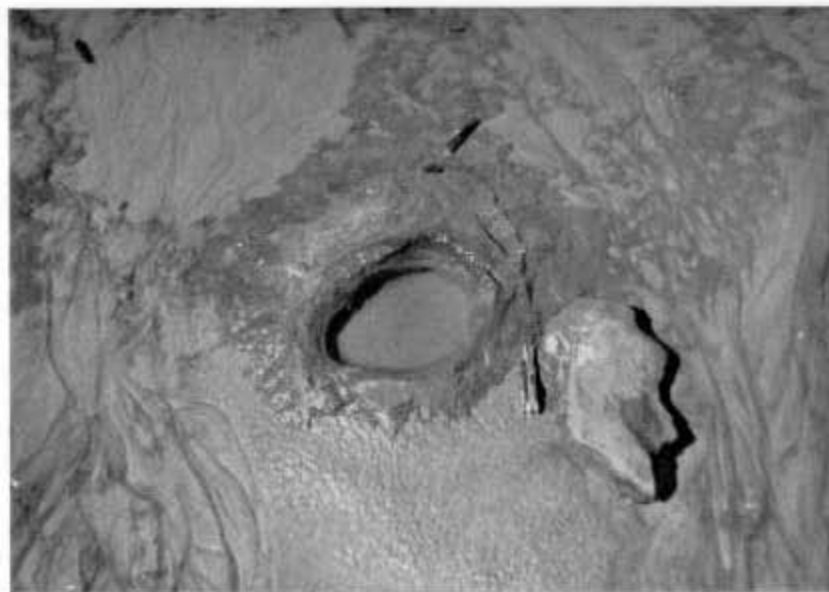


Figure 6. Hollow ironstone concretion, the upper part of which has been removed by erosion. These concretions are in the Nye Mudstone; some are exposed on the beach near the sea cliff about 200 yards south of Ona Beach State Park.

The formation is described as "... predominantly medium to dark olive-gray, massive, organic-rich mudstone and siltstone. Freshly broken samples have a strongly petroliferous odor. Calcareous and dolomite concretions as much as 4 feet across and lenticular beds 2 inches to more than 1 foot occur locally" (Snively, et al., 1969, p. 38). Some of the smaller concretions have been replaced by iron oxide and are hollow (Figure 6). These can be seen on the beach near the base of the sea cliff a short distance south of Ona Beach State Park. Molluscan fossils are reported to be sparse in the lower part of the formation but abundant in the upper part.

Quaternary Sediments

Marine terrace deposits

Beds of Pleistocene conglomerate and sandstone overlie the wave-cut surfaces that were formed on the several bedrock formations when sea level was higher during an interglacial stage (Figure 7). The base of the terrace deposits is usually a pebble conglomerate of varying thickness, and above this is sandstone, which makes up the greater part of the terrace sediments. The thickness of the terrace deposits ranges from a few feet to 20 feet or more. Sandstone up to 20 feet thick is exposed in the sea cliff at Yachats. In a few places the terrace sandstone overlies an older sediment that is finer textured and has logs and smaller pieces of wood in it. The older sediment is probably ancient stream channel filling.

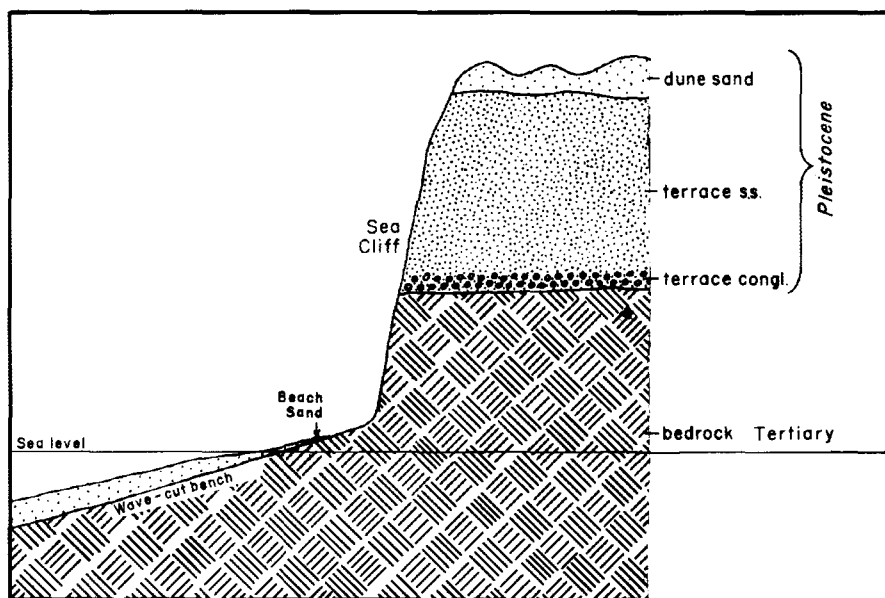


Figure 7. Generalized shore profile.



Figure 8. Beach and foredune at Ona Beach State Park. Dune is formed from sand swept off the dry beach and moved landward. It forms a barrier to Beaver Creek, which winds through an alluvial plain behind the dune before entering the ocean.



Figure 9. Present-day wave-eroded surface on the Nye Mudstone south of Ona Beach State Park. The bedrock extends seaward under a thin veneer of sand and continues landward in the sea cliff.

Dune deposits

Dune deposits can be divided into two groups according to age: old, stabilized wind-blown deposits that overlie the terrace sediments and the younger dunes that occupy the low areas around Yaquina and Alsea bays and at the mouth of Beaver Creek (Figure 8).

Landforms

Marine terrace

The marine terrace is the dominant landform between Yachats and Newport. It was formed at a time during the Pleistocene Ice Age when the sea level stood higher than it does at present and the waves cut a bench on the bedrock over which they moved. The present-day counterpart can be seen during low tide at many places along the shore where at high tide the waves are moving back and forth over bedrock. Where waves of Pleistocene seas were moving over sedimentary rock, the rate of erosion was greater than where they were working on basalt. Consequently the rate at which the sea encroached upon the land was greater in those areas underlain by sedimentary rock, and the coastal plain is much wider where the bedrock is sedimentary types than where it is basalt.

At Yachats and for a distance of about a mile north of the Yachats River, the terrace was formed on brecciated flow basalt, and at Seal Rock it is on a basalt sill for a short distance. With the exception of these two places, the terrace is on sedimentary formations of middle- to late-Tertiary age.

On the seaward side, the terrace ends abruptly at a sea cliff, the height of which ranges from a few feet to several tens of feet. Where the cliff is composed of bedrock, it is generally vertical or nearly so; terrace sediments and the older dune sands are also sufficiently cemented to maintain steep or vertical slopes (Figure 4). Younger dune sands, however, are not capable of supporting cliffs very long, and seaward-sloping surfaces develop on them along the terrace edge.

Wave-cut bench and beach

At the foot of the cliff is the wave-cut bench which forms the floor of the present-day beach. Most of the year, particularly during the summer, this bedrock surface is covered by sand, but during the winter months when the energy level of the storm waves is high, the sand may be swept off, exposing bedrock (Figure 9).

In the Nye Mudstone, layers high in calcium carbonate are harder than others, and because the formation has a gentle westerly tilt to it, these



Figure 10. Low spine of rock protruding through the sand south of Ona Beach State Park is a layer of calcareous sandstone in the less resistant Nye Mudstone.



Figure 11. Looking west across wide sand spit at Alsea Bay. A low dune ridge borders the ocean (left side of photo) and a grassy plain slopes gently toward the bay (right of photo). See Figure 18 for aerial view.

beds stand out in low reefs or broken ridges that are nearly parallel to or at a small angle to the shoreline. This type of rock forms small ridges on the wave-cut bench between Ona Beach and Seal Rock State Parks (Figure 10).

Sand dunes

Most of the terrace has areas of wind-blown sand, though dune forms are not prominent between Yachats and Waldport. Between Waldport and Newport, by contrast, the surface configuration is essentially one of dune forms. Low elongate ridges, low smoothly rounded hills, and small depressions occupied by lakes or marshy ground attest to the role of wind in shaping the surface. Dunes on the terrace are sufficiently old that a soil layer has developed on them, and they have been stabilized by a forest cover. Dune-type cross-bedding observed in many of the roadcuts gives further evidence of the wind's influence in shaping the surface on the terrace.

Young dunes north of Alsea Bay, at the mouth of Beaver Creek at Ona Beach State Park, and south of Yaquina Bay can be distinguished from the older ones by their lower position, scarcity of soil, and susceptibility to wind erosion, and are stabilized only in places by grass, bushes or scrubby trees.

The recent dunes north of Alsea Bay begin on the sandspit on the north side of the bay entrance and continue in a narrow strip northward a short distance past Driftwood Beach Wayside. On the sandspit a dune ridge lies near the beach, and this slopes off into a low sandy plain that borders Alsea Bay (Figure 11).

At Ona Beach State Park a small dune area that begins at the sea cliff on the south side of the park has formed a barrier to Beaver Creek that causes the creek to flow northward in a roundabout way before it enters the ocean. North of the creek a dune ridge lies between the highway and the beach for a distance of about half a mile (Figure 8).

Modern dunes cover an irregularly shaped area of several square miles south of Yaquina Bay. These dunes occupy, for the most part, an area that was once part of a more extensive bay at the mouth of the Yaquina River. Infilling of this part of the bay with sand and a lowering in sea level exposed a low surface to the wind, which was very effective in shaping a dune topography.

Bedrock bench at Yachats

The bedrock bench at Yachats is part of the Pleistocene marine terrace that extends from Yachats to Newport. For a distance of about a mile along the shore at Yachats the bedrock in the bench is basalt; northward for a distance of about half a mile it is composed of resistant conglomerate and coarse sandstone.

Wave erosion has stripped the terrace sediments off the surface of the bench and is chewing away at the hard bedrock. Where wave action has



Figure 12. Remnants of a Pleistocene wave-cut bench on basalt at Yachats State Park. This "exhumed" bench is slowly being removed by present wave action. Erosion is cutting trenches along fractures.



Figure 13. Short sandy beach at Yachats State Park where erosion along a fracture has removed the basalt. The people in the surf are netting smelt that come to spawn at these small beaches. (Oregon Highway Dept. photo)

not removed too much of this bedrock, the original terrace shape is still apparent (Figure 12). Differences in hardness of the rock and presence of fractures influence the rate of erosion and allow it to proceed faster in some places than in others, resulting in an interesting variety of landforms.

Where wave erosion is guided by fractures, narrow trenches (Figure 12) develop. In places where the trenches have been considerably widened and lengthened, the gaps in the bench are occupied by short, steeply sloping beaches of coarse sand (Figure 13).

Some small caves have been eroded along fracture zones, and where the cave roof has a hole in it, water is forced out during storms and high tides. These are the spouting horns which are so numerous along the Oregon Coast, especially where it is bounded by basalt. The widening of a cave may take place where a less resistant layer is overlain by a more resistant one, or it may go on simply by the abrasion caused by sand washing back and forth along the base of the cave wall. Undercutting at the base of a vertical surface by wave attack is evident in many places, especially around the small beaches (Figure 14).

Small arches (rock bridges) are seen in places where either a tunnel passes through a rock point (Figure 15) or a cave roof has collapsed (Figure 16). Adding to the ruggedness of this locality are the rough surfaces on the bench remnants and the numerous irregular rock masses of varying sizes and shapes that have been isolated from the bench.

Reefs and sea stacks at Seal Rock

One of the most spectacular parts of the coast between Yachats and Newport is at Seal Rock, where erosion of a basalt sill has formed sea stacks, reefs, and numerous rock knobs of varying sizes and shapes (Figures 5 and 17). The most prominent feature here is Elephant Rock, which looms up at the north end of the beach at Seal Rock State Park (Figure 1). This rock mass, now part of the mainland, was a sea stack at times of higher sea level during the Pleistocene Ice Age.

The basalt sill and the sedimentary rock layers between which it was emplaced have a seaward tilt of a few degrees at this locality. This tilt is apparent where the base of Elephant Rock is in contact with the underlying sedimentary rocks.

The sill was once continuous over the entire area where basalt is exposed along the shore and offshore, but wave erosion has removed a large part of it. The alignment of the remnant reefs and stacks nearly parallel to the shore here (best seen north of Elephant Rock) is related to the tilt in the rock layers. Sedimentary layers overlying the sill on its seaward side and sedimentary rock under it and on its landward side were removed by wave erosion, and the more resistant basalt projects above the general level of the sea floor in its variety of forms. This inclination of beds is also reflected in the small reef developed on a hard layer of sedimentary rock



Figure 14. The basalt bench has been eroded to these remnant knobs at Yachats State Park. Scouring by wave-carried sand cuts notches at base of knobs; overhanging rock collapses and is ground to smaller particles. A lower bench is being formed.



Figure 15. Small arch where erosion has penetrated through a point of basalt at Yachats State Park.

landward from the more prominent basalt reef at Seal Rock State Park (Figure 5).

Estuaries

The Alsea and Yaquina Rivers, and to a lesser extent the smaller Yachats River, are affected by tides for some distance upstream. The lower parts of these rivers, the bays, are said to be "drowned" and are referred to as estuaries (Figure 18). The development of these estuaries is closely tied to the sea level fluctuations during the Pleistocene Ice Age.

Four times during the Ice Age large amounts of the world's water were frozen in ice sheets that covered much of North America and northern Europe and Asia, as well as Antarctica and Greenland; sea level during those periods was several hundred feet lower than it is now. The mouths of the coastal streams of Oregon were then some considerable distance west of their present position. During the interglacial stages when most of the ice had melted and returned to the oceans, the sea stood at least 150 feet above its present level, and during these time of high sea levels the sea projected far inland along the larger river valleys. Wave erosion along the shore in the outer parts of these embayments enlarged them. With a lowering of sea level below its present position, the bays again came under the influence of the rivers.

In recent times the main effect of the rivers has been an infilling of sand and other sediment; the sizes and shapes of the bays vary according to the currents that are generated by the flow of the river together with the tidal rise and fall of sea level.

Sand spit

At the mouth of the Alsea River, ocean currents have constructed a southward-projecting sand spit that has blocked off most of the bay mouth and restricted the passage through which the Alsea River flows into the ocean. The size and configuration of the sand spit is in delicate balance with the forces that created it. That it has changed in its configuration since the Alsea Bay area was settled is shown in logs with sawed ends that were once covered by sand and that are now being uncovered by wind and wave erosion (Figure 19).

Glossary

Alluvial: Refers to sediment deposited by streams.

Basalt: Dark-colored, fine-grained rock of volcanic origin.

Bedrock: Solid rock beneath soil or sediment layer. May be exposed.

Breccia: Rock made up of large, angular fragments.



Figure 16. Two arches (bridges) where roof of small cave has collapsed.



Figure 17. Beach at Seal Rock State Park. Aligned small knobs in upper center of photograph are along a hard layer of the Yaquina Formation. The larger knobs are remnants of the basalt sill of Elephant Rock. (Oregon Highway Dept. photo)

Concretion: Structure (may be spherical or irregular in shape) in sedimentary rock; formed where mineral matter deposited around nucleus.

Conglomerate: Rock containing numerous rounded pebbles or large particles.

Dike: Tabular-shaped igneous rock body that cuts through another rock.

Estuary: Lower part of river affected by tides and mingling of salt water from ocean with fresh water from river.

Formation: 1. Land form. 2. Body of rock, the parts of which are related in space, time, and/or origin.

Gradational contact: Contact between two rock units that is transitional rather than abrupt.

Mudstone: Sedimentary rock composed essentially of solidified mud.

Pyroclastic: Volcanic rock made up of fragments erupted from a volcano.

Quaternary: The latest Period of geologic time; began about 2 million years ago. Includes Pleistocene (Ice Age) and Holocene (recent) Epochs.

Reef: Ridge in the sea floor partly or entirely covered by water.

Sandstone: Sedimentary rock made of sand that has been cemented together.

Sea stack: Small prominent island of bedrock near the shore.

Shale: Laminated sedimentary rock made of solidified mud.

Sill: Tabular-shaped body of igneous rock intruded into and lying parallel to sedimentary rock layers.

Siltstone: Sedimentary rock of particles finer than sand, coarser than clay.

Terrace: Bench-like landform cut into bedrock or built up by sedimentary deposition. Oregon shore terraces have aspects of both.

Tertiary: Period of geologic time between 65 million and 2 million years ago. Includes Eocene, Oligocene, Miocene, and Pliocene Epochs.

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Figure 18. Aerial view east across Alsea Bay, estuary of the Alsea River. U.S. 101 crosses the estuary at Waldport. Wide sand spit, bottom of photo, shelters bay from ocean and constricts river mouth to right of photo. (Oregon Highway Dept. photo)



Figure 19. Logs being uncovered by wave and wind erosion on the outer edge of sand spit at mouth of Alsea Bay. Sawed end on log in center indicates burial after Alsea Bay area was settled.

ROAD LOG BETWEEN YACHATS AND NEWPORT

<u>S-N</u> <u>Mileage</u>	<u>Mileage</u> <u>Increment</u>	<u>N-S</u> <u>Mileage</u>	
0.0		22.7	Yachats Post Office
0.5	0.5	22.2	Adobe Motel entrance
0.8	0.3	21.9	Yachats city limits
1.2	0.4	21.5	Salmon Street
2.5	1.3	20.2	Small interdune pond west of highway
3.6	1.1	19.1	Blodgett Road
3.8	0.2	18.9	Tillicum Beach Forest Camp
4.1	0.3	18.6	Big Creek; highway on low terrace
4.9	0.8	17.8	Beachside State Park
6.4	1.5	16.3	Viewpoint
7.1	0.7	15.6	Governor I. L. Patterson State Park
7.5	0.4	15.2	Waldport Ranger Station
7.6	0.1	15.1	Viewpoint at mouth of Alsea River
7.8	0.2	14.9	William P. Kealy Wayside
8.3	0.5	14.4	South end of Alsea bridge
8.9	0.6	13.8	North end of Alsea bridge and turnout
9.4	0.5	13.3	Bayshore Drive; small interdune lake west of highway
9.9	0.5	12.8	Entrance to Sandpiper Village
10.1	0.2	12.6	Small lake west of highway (one of several along highway here)
11.0	0.9	11.7	Driftwood Beach Wayside
12.7	1.7	10.0	Viewpoint; quarry in basalt east of highway
13.2	0.5	9.5	Seal Rock State Park
13.5	0.3	9.2	Seal Rock Post Office
14.0	0.5	8.7	Turnout; beach viewpoint and access
15.1	1.1	7.6	Ona Beach State Park and Beaver Creek
15.5	0.4	7.2	Dune ridge west of highway
16.8	1.3	5.9	Lost Creek State Park
19.2	2.4	3.5	Entrance to Pacific Shores community
19.7	0.5	3.0	Airport junction; entrance to Surfland community
20.7	1.0	2.0	South Beach State Park
21.6	0.9	1.1	South Beach community
22.0	0.4	0.7	South end of Yaquina bridge; access to O.S.U. Marine Science Center
22.7	0.7	0.0	North end of Yaquina bridge; Yaquina Bay State Park

NORTH

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GEOLOGY OF MITCHELL QUADRANGLE PUBLISHED

Just off the press from the Oregon Department of Geology and Mineral Industries is Bulletin 72, "Bedrock Geology of the Mitchell Quadrangle, Wheeler County, Oregon." Authors are Dr. Keith F. Oles and Dr. Harold E. Enlows, Department of Geology, Oregon State University. The 62-page bulletin has a multicolored geologic map and is illustrated by numerous photographs with interpretive line drawings beneath them.

Bedrocks described range in age from Permian through Tertiary. They include Permian metasediments, Cretaceous marine beds (Hudspeth and Gable Creek Formations), lavas and tuffs of the Clarno and John Day Formations, Columbia River Basalt, Rattlesnake ignimbrite, and a variety of small intrusive bodies. A number of the rocks are analyzed petrographically and chemically. Special emphasis is given to the Clarno Formation, which the authors raised to group status on finding an upper and a lower phase separated by a marked unconformity. Keyes Mountain is shown to be the roots of a huge volcano that provided most of the material for the upper part of the Clarno rocks.

Bulletin 72 is for sale by the Department's Portland, Baker, and Grants Pass offices. The price is \$3.00.

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HOMESTAKE TO BUILD NEW GOLD PROCESSING PLANT

A year ago Homestake Mining Co. was having problems. Minute traces of mercury were getting into the Cheyenne River from its Lead, South Dakota gold mine. Homestake, the nation's largest producer of gold, mines the ores in workings as much as 6,000 feet underground, making mining and recovery costly endeavors.

Mercury played a vital role in the recovery of the gold. It was used as an amalgam to take the metal out of the ore during the milling process prior to cyanidation. But because of environmental concern, Homestake suspended the mercury circuit from its flow sheet, badly hampering production. Then while its own metallurgists sought new answers, the company asked the U.S. Bureau of Mines for help.

At the time of Homestake's request, the Bureau's Salt Lake Metallurgy Research Center was engaged in a study of ways to improve gold production in the United States. In a matter of six months Bureau researchers had devised a carbon-in-pulp method to capture the gold, completely eliminating the use of mercury from the process.

A pilot plant was built at Lead, and in March success of the research was confirmed. Homestake Mining Co. has announced it will build a full-scale plant with a capacity of 2500 tons a day. The new carbon-in-pulp plant will be completed in 15 months at a cost of \$850,000.

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GEOLOGIC ANALYSIS OF THE PORTLAND HILLS- CLACKAMAS RIVER ALIGNMENT, OREGON

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Introduction

The striking linear east face of the Portland Hills (Tualatin Mountains) passes southeastward into co-linear segments of the Clackamas River. An analysis of the fault-like lower Clackamas portion of this alignment was completed in 1971 as part of a master's thesis (Schmela, 1971).

Because the nature of the linearity in the lower Clackamas River area is obscured by overlying lava flows, alluvium, and vegetation, indirect morphologic and geophysical methods were required to study it. As discussed below, the analysis of morphologic and structural alignments, geological relationships, and gravity magnetic data strongly suggest the presence of a northwest-trending fault in this area.

Previous Work

The origin of the linear eastern front of the Portland Hills has long been a subject of debate. Diller (1915) and Treasher (1942) both noted the Portland Hills linearity and believed it to be a possible fault. Trimble (1963) studied the Portland area and concluded that there was no evidence of a major fault fronting the Portland Hills or along the Clackamas River. Schlicker and Deacon (1967), however, show a segment of a major regional fault fronting the Portland Hills.

Balsillie and Benson (1971) support the concept of a fault along the northeast face of the Portland Hills on the basis of a structural interpretation of the columnar jointing in the Columbia River Basalt. Briefly, they infer the orientation of the flow surfaces from the orientation of the columnar jointing. The flow surfaces, in turn, indicate vertical offsets along the eastern front of the ridge, a relationship which Balsillie and Benson attribute to faulting.

First-motion studies of Portland earthquakes have been conducted by Dehlinger and Berg (1962), Westphal (1962), Dehlinger and others (1963),

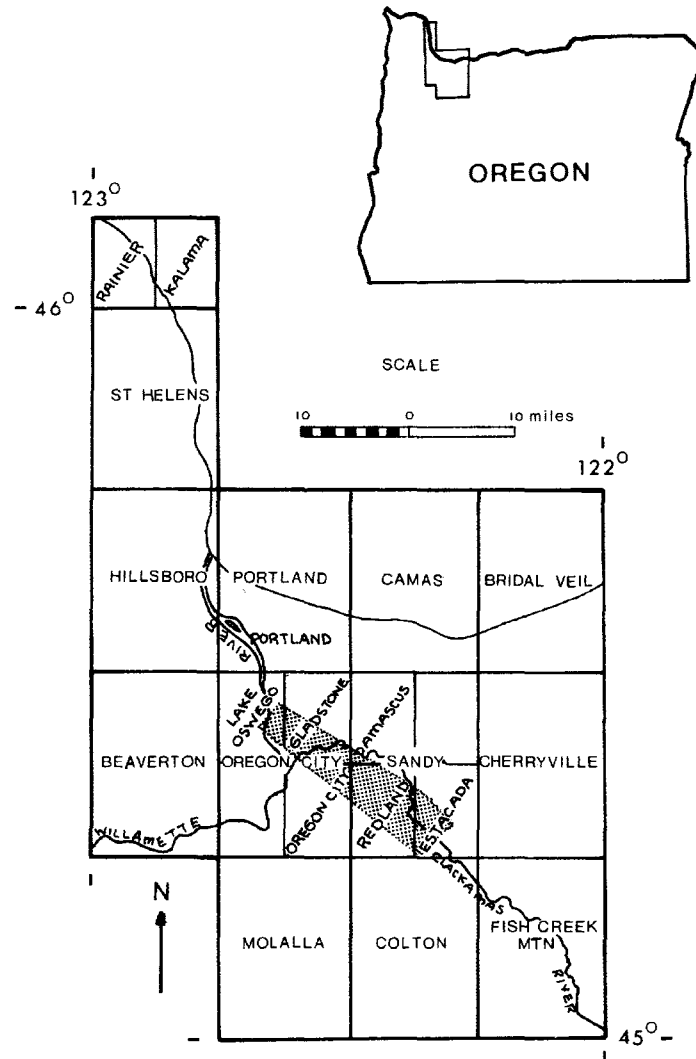


Figure 1. Location map showing quadrangles included in morphologic alignment study. Area of geophysical investigation indicated by shading.

Schlicker and others (1964), and Heinrichs and Pietrafesa (1968). These studies present evidence in support of one or more northwesterly trending faults in the Portland area.

Morphologic and Structural Alignments

Method

Analysis of linear landforms was performed to evaluate morphological alignments for structural significance. Twelve 15-minute and two 7½-minute quadrangle maps (Figure 1) were analyzed for quantitative distribution of length and orientation of alignments. Geologic maps were similarly evaluated for orientation of faults and fold axes. Structural alignments were compared to the morphological orientations.

Faults, joints, and bedding commonly form morphological alignments by the process of differential erosion. Linear landforms including straight stream segments, ridge crests, and linear breaks in slope angle, are easily recognized and are not subject to significant interpreter bias.

Following standard procedures rose diagrams were assembled for the purpose of interpreting the linear geomorphic features. As shown in Figure 2 linear landforms exceeding a preselected length were plotted for each of the quadrangles in the study area. The length and orientation of the lineations were then tabulated and graphically assembled on rose diagrams (Figure 3). Figure 4 is a composite of the rose diagrams for each of the quadrangles, and emphasizes the prominent northwesterly trend of the linear geomorphic features in the study area.

Analysis

Anomalies from a random distribution are believed to reflect underlying structural alignments. In the region studied, the morphologic rose diagrams, Figures 3 and 4, show that 50 percent of all the alignments trend northwest; nearly 25 percent trend N. 20° W. and N. 40° W.; 21 percent form other secondary trends oriented N-S, E-W, and N. 50-60° E. The prominent northwesterly trend is present even in the quadrangles nearest the west flank of Mt. Hood, where a dominant east-west trend from consequent drainage would be expected to mask regional trends. A strong structural framework underlying the Portland area is indicated by the consistency and prominence of the northwesterly morphologic trend in all quadrangles.

The northwest trend is further supported by the orientation of known faults (Figure 5) and fold axes in the area and by seismic first-motion studies. Approximately 60 percent of the known mapped faults and fold axes concur with the dominant northwest morphologic trend of N. 40° W.; 22 percent trend N. 40-50° E.; and 17 percent trend in the N-S orientation. The structural alignments coincide very closely to the morphological

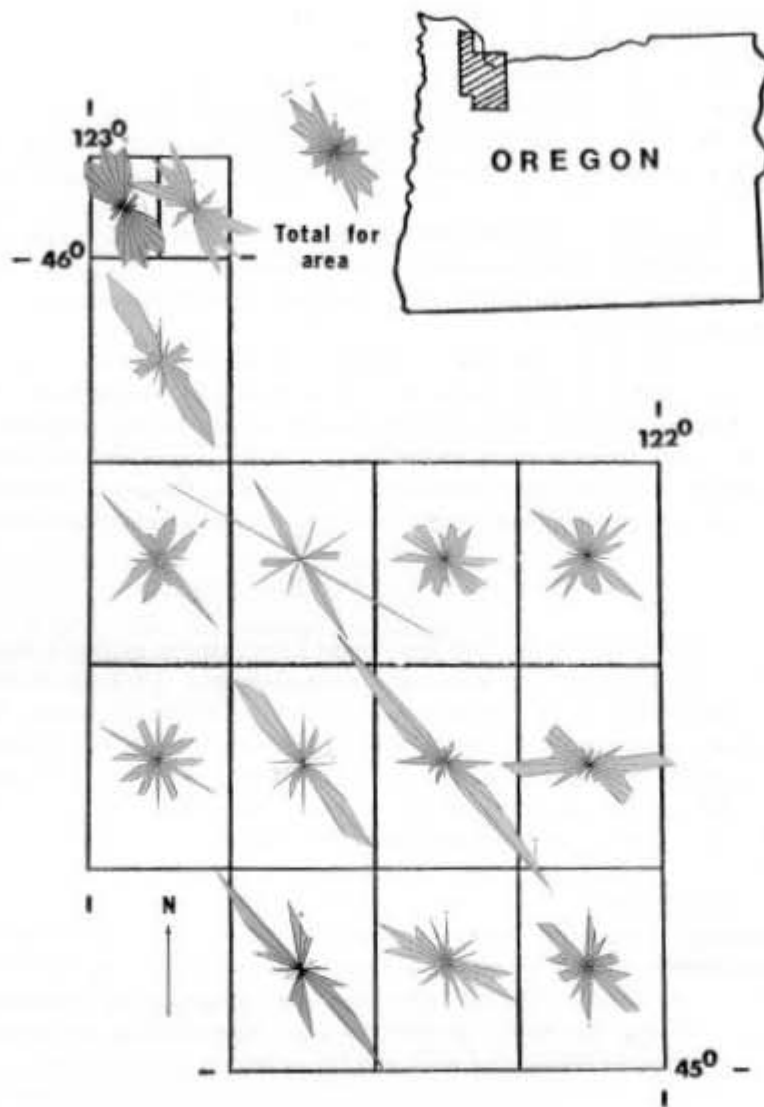


Figure 3. Orientation-length distribution of morphologic alignments measured in individual quadrangle sheets. Quadrangle names are listed on the location map, Figure 1.

alignments. Seismic first-motion analyses of the November 5, 1962 Portland earthquake suggest a motion source of a northwest-trending, right-lateral strike-slip fault. The motion data, however, also fit a northeast-trending, left-lateral strike-slip fault (Dehlinger and others, 1963). Westphal (1962) suggested that the seismic activity was related to the Portland Hills fault. Gallagher (1969) indicates that the motion occurred along a normal fault striking N. 54°E. or along a right-lateral strike-slip fault striking N. 12°W. Gallagher believed the data were most consistent with the N. 54° E. trending fault.

In summary, the dominant morphologic and geologic trends are consistent, sympathetic and parallel as determined by morphology, structure, and seismicity. The Portland Hills-Clackamas River alignment parallels the most prominent trend.

The preferred northwest orientation of the morphologic alignments is not in itself conclusive evidence for interpretation of the geologic structure. This statistical analysis method is intended as a preliminary indicator of probable structural features to guide geologic studies. However, the consistency and parallelism of geologic and seismic alignments strengthen the interpretation that it represents a geologic structural trend of major significance.

Geologic Investigations

Geologic cross sections developed from existing geologic maps and from all available well log data were made (Schmela, 1971) in an attempt to test the possibility of offsets along the Portland Hills-Clackamas River alignment. Cross sections show 120 to 195 feet of possible east-side-down faulting or folding of units across the Portland Hills-Clackamas River alignment. Generally, the map and well data are not sufficient in themselves to determine conclusively the nature of the subsurface structure along the alignment.

Entrenchment of the Clackamas River into Quaternary terrace deposits provides evidence for recent rejuvenation of the Clackamas River. The entrenchment is probably caused by tectonic uplift which may still be in progress. The downcutting may also have been caused or accentuated by a change in stream regimen by non-tectonic processes such as an increase in stream competency associated with glacial retreat.

Structure

Broad northwest-trending synclines and anticlines typify the Portland-lower Clackamas River area. Surface evidence for offset of geologic units to verify faulting is obscured by more recent volcanic units and alluvium and by the presence of a thick soil cover.

A broad synclinal downwarp in the Columbia River Basalt underlies the lower Clackamas River area. The basalt is downfolded to a depth of

Figure 4. Summary of all orientation-length distribution of morphologic alignments. Area within circle represents the area of random alignment orientation. Scale: 1"=4%

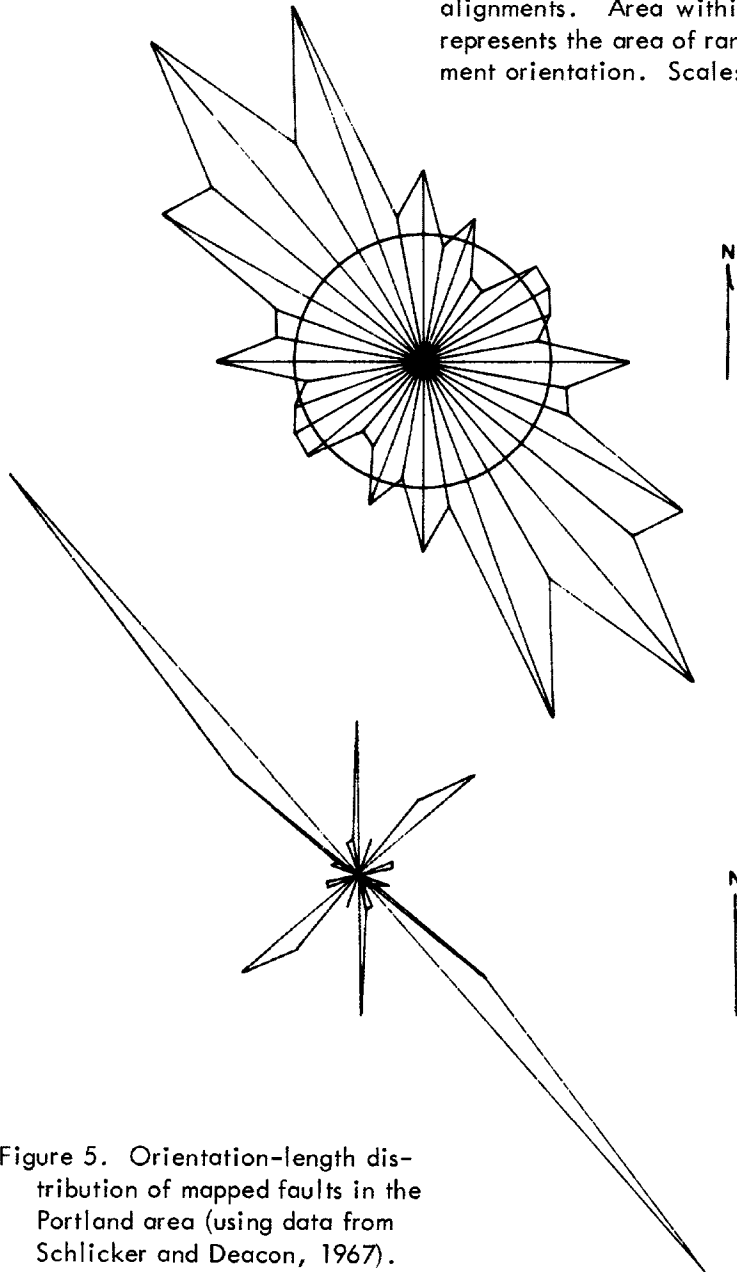


Figure 5. Orientation-length distribution of mapped faults in the Portland area (using data from Schlicker and Deacon, 1967).

about 60 feet below sea level in the area a few miles east of Oregon City (Wells and Peck, 1961). Farther north in the Portland area, the Ladd well (39th and Glisan Streets) encountered basalt downfolded to a depth of at least 1070 feet below sea level. The inferred top of the Columbia River Basalt horizon is upwarped to elevations of 1000 to 1200 feet along the Portland Hills anticline.

Schlicker and Deacon (1964) indicate that a major normal fault separates the eastern side of the Portland Hills from the syncline under Portland. Balsillie and Benson (1971) present evidence for more than 700 feet of offset north of downtown Portland.

Geophysical Evidence

Gravity data

Gravimetric information was obtained from six gravity traverses, averaging three miles in length, with a total of 166 gravity stations. It was believed that an anomaly might exist in this locality due to either a fault or a steep fold in the Columbia River Basalt.

Gravitational anomalies result from lateral variations in the gravitational pull of the earth caused by contrasting near-surface densities. The negative Bouguer anomalies in all traverses show the regional influence of low density Cascade Range volcanic rocks in causing a 2.5 milligal/mile decrease in gravity to the southeast (Berg and Thiruvathukal, 1967). The Bouguer values obtained in this study are in close agreement with the Oregon gravity map and show the steadily westward decreasing negative anomaly that suggests a westward rising of the Columbia River Basalt. Well log data support this conclusion.

In addition, the detailed gravity traverses of this study show an average 2.18 milligals/0.2 mile gravity downdrop to the east, coincident with the morphologic alignment. The gravity change is consistent in direction and amplitude and defines a zone of possible faulting or steep folding aligned with the southeasterly extension of the Portland Hills fault.

Magnetic data

Magnetic data were obtained from three traverses, averaging two miles in length, with a total of 50 magnetic stations. The magnetic traverses revealed a consistent abrupt change in the magnetic gradient across the morphologic alignment suggesting a structural feature, possibly a fault.

The methods used in conducting the geophysical traverses along with the data from the gravity, magnetic, and well logs are described by Schmela (1971, p. 69-113). The gravity and magnetic stations are plotted as cross profiles, correlated to surface geology, and are contained in the map pocket of that thesis.

State-wide alignment

Alignments on a state-wide scale support local interpretation. Preliminary trends recognized from studies in progress (by the authors) on morphological alignments of the state of Oregon and by studies conducted by Dr. John E. Allen on alignments of volcanic eruption centers in the Portland area (Allen, personal communication, 1971) are compatible with the dominant trends recognized in this study.

A series of co-aligned linear morphologic features trending N. 40-50° W. extends over 300 miles southeasterly across the state of Oregon. The regional features line up with the Portland Hills-Clackamas River trend and include segments of the Metolius River, Crooked River, and the southern edge of Hampton Buttes. The alignment is readily seen on the state 1:250,000 plastic relief map series.

The geologic map of Oregon (Walker and King, 1969) shows numerous faults with a general trend of N. 40-50° W. occurring along the above mentioned trend. The Brothers fault zone is one segment of the co-linear features (Higgins and Waters, 1967) and is believed to be a reflection of a deeply buried fault with lateral displacement (Walker, 1969). Furthermore, several volcanic vents are concentrated along this segment of the state-wide alignment (Walker and King, 1969).

We believe these features indicate that a major fault system which includes the Portland Hills-Clackamas River structural alignment extends for considerable distances across much of Oregon.

Origin of alignments

The mechanism and time of origin of the structural alignments is not well known. A major northwest-southeast structural alignment in the state of Washington has been shown by Mackin and Cary (1965) to be a result of the folding of the Eocene Weaver Plain. They indicate that these recent alignments are trends controlled by the ancestral Calkins Range, a range dominant during Oligocene time in the Pacific Northwest.

It is possible that the trends we see today in the Portland-Clackamas River area were first developed in older underlying rock units and that they have been regenerated in the overlying younger rock units by more recent sympathetic deformation.

Conclusions

It is concluded that the Portland Hills-Clackamas River alignment is part of a major structural fault system which extends across the state of Oregon to the southeast as far as Steens Mountain. A series of regionally co-aligned morphologic and structural features striking N. 40-50° W. are aligned with the Portland Hills-Clackamas River alignment. Surface and

subsurface geology and gravity and magnetic data in the Portland region all support this interpretation.

The morphologic and structural alignments in the Portland region are significant indicators of underlying geologic structure. The consistency of the dominant northwesterly morphologic trends, N. 20° W. and N. 40° W., is considered to be a reliable structural indicator because the known faults and fold axes present a matching dominant northwest orientation when statistically plotted. The dominant local northwest trends are suggestive of underlying geologic control, possibly remnants of the Oligocene Calkins Range. The alignments, including the secondary northeast trends, may reflect continued or renewed deformation along these pre-established structures.

In the Portland area, the geologic information derived from map and well data generally lack any definitive evidence concerning the specific nature of subsurface structural feature which controls the morphologic alignment. The gravity traverses present a consistent Bouguer anomaly across the alignment which suggests possible fault or fold displacements in the Columbia River Basalt. Magnetic anomalies coincident with the Portland Hills-Clackamas River alignment further support the presence of an underlying geologic structure.

Acknowledgments

Dr. Richard Blank aided greatly in the interpretation of the geophysical data. Appreciation is expressed to Robert J. Deacon, Dr. John E. Allen, and members of the Oregon Department of Geology and Mineral Industries for their criticism of this manuscript.

Geophysical instruments used in this study were loaned by Dr. Richard Couch, Oregon State University, and by Dr. Richard Blank, University of Oregon.

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GEOCHRONOLOGY OF THE CLARNO IGNEOUS ACTIVITY IN THE MITCHELL QUADRANGLE, WHEELER COUNTY, OREGON

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Introduction

Detailed mapping of the geology of the Mitchell quadrangle by Oles and Enlows (1971) led to the discovery that those rocks lying above the Cretaceous and below the John Day Formation which Merriam (1901) had referred to his Clarno Formation might best be termed a "group." Two sequences of rock, each ascribed to the Clarno in the Mitchell quadrangle, are separated by an angular unconformity. The authors, therefore, referred to the two sequences informally as Lower Clarno and Upper Clarno.

The Lower Clarno consists of about 4000 feet of andesite flows and intrusions, basaltic intrusions, volcanic breccia and tuffaceous sediments. The Upper Clarno consists of 2000 feet of similar andesite flows, mudflows, tuffaceous sediments, and dikes of both basaltic and andesitic composition chiefly associated with Keyes Mountain, an exhumed Oligocene volcano.

Although separated by an angular unconformity, the lithology, petrography and chemistry of all Clarno flows are so similar that they are considered comagmatic.

Procedure and Analytical Techniques

In order to determine the time span of Clarno volcanic activity in the Mitchell quadrangle, a sequence of samples was collected, including specimens from the oldest and the youngest flows, dike rocks, and two of the older plug intrusions. To these can be added two Clarno samples collected by R. L. Hay and reported in Evernden, et al. (1964).

Sample KA 818 collected by Hay near the center of the SW $\frac{1}{4}$ sec. 8, T. 11 S., R. 21 E. is described as, "Pyroxene andesite from 100 foot lava flow about 100 feet above base of a 400 foot series of flows forming the uppermost part of the Clarno Formation (approximately 5000 feet of Clarno here)." Although collected near the top of the Clarno sequence in this location, it is actually near the top of the lower Clarno as defined by Oles and Enlows (1971). Sample KA 824A was collected by Hay from a bentonite claystone 20 feet thick which underlies KA 818.

Three samples of the John Day Formation collected in the Mitchell area by Hay and reported by Evernden et al. (1964) have been used in an attempt to define the top of the Clarno.

K-Ar dates for all the rock specimens mentioned above, both Clarno and John Day, are listed in Tables 1 and 2.

Clarno specimens were processed at the Kline Geology Laboratory of Yale University of Donald Parker. Mineral separates were recovered from the 40- to 100-mesh sieve fraction of crushed rock using a vibrating shape sorter, magnetic separators, and heavy liquids. Whole rock samples were prepared by crushing the rock and recovering the 5-mesh material for the Ar analysis. The material was then further ground for the K analysis.

The K analyses were done with a model 303 Perkin-Elmer atomic absorption spectrophotometer using a Na-Li alkali buffer. The Ar analysis was done by typical isotope dilution analysis procedures in the static mode on a modified Nier type 60° sector mass spectrometer (Armstrong, 1970). The total analytical error is given with the dates in Table 2.

Table 1 illustrates the time span of Clarno igneous activity in the Mitchell quadrangle. Lowermost Clarno rests on Cretaceous strata of Cenomanian age. Clarno igneous activity lasted for about 16 million years, from about 46 million years before present to 30 million years before present. Apparently deposition of the John Day Formation began very soon after extrusion of the last Upper Clarno flow. In the northwestern part of the Mitchell quadrangle the John Day Formation rests with angular discordance on a regolith-mantled terrane of Lower Clarno flows. Unfortunately in the southeastern part of the quadrangle where John Day rests upon Upper Clarno the contact is poorly exposed and the relationships of the units are obscure. Both formations are gently inclined. John Day, however, does rest upon an irregular Upper Clarno topography, and occasional inliers of Upper Clarno interrupt the John Day cover.

Summary

In the Mitchell quadrangle for a period of 16 million years, from approximately 46 to 30 million years before present, a series of hornblende and/or hypersthene andesite flows of markedly similar texture and composition with associated dikes and volcanic-derived sediments built up a rock mass some 6000 feet thick. A basal sequence, informally termed Lower Clarno, is apparently of upper Eocene (Uintan and Duchesnean) age. Sometime in the period between 37.5 and 32.7 million years ago in lowermost Oligocene (Chadronian) time, these rocks were subjected to orogenic activity and major folds were produced. Following or during the period of orogeny, weathering and dissection formed a topography of considerable relief upon which was deposited a younger sequence of similar flows and volcanic-derived sediments (informally termed Upper Clarno) approximately 2000 feet thick. This second period of volcanic and sedimentary activity lasted until about 30 million years before present and was immediately succeeded by the deposition of the extensive volcanoclastic sediments of the John Day Formation.

Table 1. Geochronology of the Clarno Rocks of the Mitchell Quadrangle

Epoch	Time in millions of years before present	Clarno rocks	John Day rocks near Mitchell	Age	North American land mammal stages
MIOCENE (lower)	-20-				
	-25-		Upper tuff Mid. ignimbrite	24.9my* 25.3my*	Arikareean -- 25.6 --
OLIGOCENE	-30-	Nelson Creek dikes		29.4my	Whitneyan -- 29 ? --
	-35-	Keyes Mtn. flows Airport dikes	Lower John Day tuff	31.1my* 32.7my 33.3my	Orellan -- 31.6 --
		Lower Clarno bentonite**		36.5my*	Chadronian -- ? --
		Uppermost Lower Clarno flow		37.5my*	
	-40-	White Butte (whole rock)		40.5my	Duchesnean -- 40 --
EOCENE	-45-	Lowermost Lower Clarno flow Marshall Butte		43.3my 44.8my	Uintan -- 45.4 --
	-50-	White Butte (hornblende)		46.1my	
	-55-				

Time scale after Harland, W. B., et al., 1964

* From Evernden, et al., 1964

** Stratigraphically below uppermost Lower Clarno flow

*** Orogeny occurred sometime between 37.5 and 32.7 million years ago

=== Precise boundaries between Epochs unknown

Acknowledgments

The authors thank Richard L. Armstrong of Yale University for the use of his equipment and for his technical assistance.

Table 2. K-Ar dates on Clarno and John Day rocks
of the Mitchell quadrangle

EMT-11

Material: Diabase dike, whole rock analysis
 Locality: Nelson Creek, sec. 2, T. 12 S., R. 21 E.
 Stratigraphy: Cuts Cretaceous sedimentary rocks and upper Clarno flows
 Data first analysis:
 K = 0.8810, 0.8750, 0.8660 Avg. = 0.8740%
 Ar 40/38 = 0.52722
 Age = 29.3317 ± 0.5866 m.y.
 Data second analysis:
 K = 0.8810, 0.8750, 0.8660 Avg. = 0.8740%
 Ar 40/38 = 0.60354
 Age = 29.4461 ± 0.5889 m.y.

M-859

Material: Diabase dike, whole rock analysis
 Locality: West of landing strip, sec. 26, T. 11 S., R. 21 E.
 Stratigraphy: Cuts Cretaceous sedimentary rocks
 Data first analysis:
 K = 0.8360, 0.8280, 0.8250 Avg. = 0.8297%
 Ar 40/38 = 1.5636
 Age = 33.4757 ± 1.2738 m.y.
 Data second analysis:
 K = 0.8360, 0.8280, 0.8250 Avg. = 0.8297%
 Ar 40/38 = 1.48080
 Age = 33.2966 ± 1.2327 m.y.

KFO-901

Material: Andesite flow, whole rock
 Locality: Keyes Creek, SW $\frac{1}{4}$ sec. 32, T. 11 S., R. 22 E.
 Stratigraphy: Upper Clarno flow off Keyes Mountain
 Data first analysis:
 K = 0.1290, 0.1310 Avg. = 0.1300%
 Ar 40/38 = 0.17265
 Age = 35.5886 ± 3.4077 m.y.
 Data second analysis:
 K = 0.1290, 0.1310 Avg. = 0.1300%
 Ar 40/38 = 0.22100
 Age = 30.0923 ± 4.7059 m.y.

Table 2. Continued

W-3-58

Locality: White Butte SE $\frac{1}{4}$ sec. 17, N $\frac{1}{2}$ sec. 20, T. 12 S., R. 21 E.

Stratigraphy: Intrudes Cretaceous sedimentary rocks and Lower Clarno volcanic breccia

- A. Material Hornblende from hornblende andesite
 Data K = 0.4710, 0.4880 Avg. = 0.4795%
 Ar 40/38 = 0.21901
 Age = 46.1110 \pm 3.9601 m.y.
- B. Material Hornblende andesite, whole rock
 Data K = 1.5100, 1.4900 Avg. = 1.5000%
 Ar 40/38 = 1.96280
 Age = 40.5524 \pm 0.9020 m.y.

KFO - 1112

Material: Andesite, whole rock

Locality: Bridge Creek, sec. 21, T. 11 S., R. 21 E.

Stratigraphy: Lower Clarno flow, initial Clarno deposition in this region

Data first analysis:

K = 0.9250, 0.9500 Avg. = 0.9375%
 Ar 40/38 = 0.89660
 Age = 42.3114 \pm 0.8462 m.y.

Data second analysis:

K = 0.9250, 0.9500 Avg. = 0.9375%
 Ar 40/38 = 0.99160
 Age = 43.3548 \pm 0.8671 m.y.

KFO - 1702B

Material: Melabasalt, whole rock

Locality: Marshall Butte, sec. 29, T. 11 S., R. 22 E.

Stratigraphy: Intrudes Cretaceous sedimentary rocks, is overlain by Upper Clarno mudflows

Data first analysis:

K = 1.2000, 1.2000, 1.1900 Avg. = 1.967%
 Ar 40/38 = 1.07110
 Age = 45.0299 \pm 0.9006 m.y.

Data second analysis

K = 1.2000, 1.2000, 1.1900 Avg. = 1.967%
 Ar 40/38 = 1.10430
 Age = 44.8056 \pm 0.8961 m.y.

Table 2. Continued

*KA 818

Material: Pyroxene andesite, whole rock
Locality: Near center SW $\frac{1}{4}$ sec. 8, T. 11 S., R. 21 E.
Stratigraphy: Pyroxene andesite from 100-foot lava flow about 100 feet above base of 400-foot series of flows forming the uppermost part of the Clarno Formation

Data:

$$K = 0.972\%$$

$$A_{40}^{at} = 54\%$$

$$\text{Age} = 37.5 \text{ m.y.}$$

*KA 824A

Material: Sanidine
Locality: Near SE corner sec. 2, T. 11 S., R. 20 E.
Stratigraphy: Sanidine from a crystal-rich bentonite claystone 20-foot thick bed which underlies the pyroxene andesite of KA 818

Data:

$$K = (4.59 \pm 0.15)\%$$

$$A_{40}^{at} = 14\%$$

$$\text{Age} = 36.5 \pm 0.9 \text{ m.y.}$$

*KA 489

Material: Sanidine
Locality: NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 1, T. 11 S., R. 20 E.
Stratigraphy: From 8-foot sequence of tuffs interbedded 165 feet above base of John Day Formation, which is at least 2000 feet thick in this area. Bridge Creek flora well developed in beds both above and below tuff.

Data:

$$K = 5.71\%$$

$$A_{40}^{at} = 54\%$$

$$\text{Age} = 31.1 \text{ m.y.}$$

* Taken from Evernden, J. F., et al., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: Amer. Jour. Sci., v. 262, p. 145-198.

Table 2. Continued

*KA 648

Material: Obsidian
 Locality: SW $\frac{1}{4}$ sec. 31, T. 10S., R. 21 E.
 Stratigraphy: 1100 to 1135 feet above base of John Day Formation 1-inch lapilli (only interior fragments used for run) from widespread ignimbrite unit which has been commonly used to separate middle and upper members of John Day Formation, Early Arikarean fossils abundant below, Late Arikarean fossils above.

Data:
 K = 4.51%
 A_{40}^{at} = 58%
 Age = 25.3 m.y.

*KA 649A

Material: K-albite
 Locality: SW corner sec. 29, T. 10 S., R. 21 E.
 Stratigraphy: Approximately 1550 feet above base of John Day Formation

Data:
 K = 1.43%
 A_{40}^{at} = 70%
 Age = 24.9 m.y.

* Taken from Evernden, J. F., et al., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: Amer. Jour. Sci., v. 262, p. 145-198.

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* * * * *

"ENGINEER OF THE YEAR" HONORED

Harry Czyzewski, President of Metallurgical Engineers, Inc., has been selected as the 1972 "Engineer of the Year" by the Professional Engineers of Oregon. He was honored at the annual PEO meeting and awards banquet held at the Sheraton Hotel on May 12, 1972. The topic of the PEO meeting was "Involvement," which fits Harry Czyzewski to an "I."

Czyzewski organized MEI as a Metallurgical Consulting Engineer in 1946. He joined PEO in 1949. He served as president and is now chairman of the PEO Goals for Engineering Education Committee.

He is also active in the Consulting Engineers Council of Oregon and CEC-USA, American Foundrymen's Society, American Institute of Mining, Metallurgical & Petroleum Engineers, and American Society for Metals. He is a member and past president of the State Board of Engineering Examiners of Oregon, and a Fellow in the American Institute of Chemists.

* * * * *

THREE GROUND WATER STUDIES IN OREGON PUBLISHED

Harney Valley

"Ground-water Resources in Harney Valley, Harney County, Oregon," by A. R. Leonard, has been published as Ground Water Report No. 16 by the Oregon State Engineer, in cooperation with the U.S. Geological Survey and Harney County Court. The 85-page bulletin discusses the geology, ground-water availability, quality of the water, uses, and other pertinent data including information on hot-water wells and springs. Accompanying the report are a generalized geologic map, an aquifer map, and a map showing variations in chemical quality of ground water. A limited number of copies of the report are available from the Oregon State Engineer in Salem.

Molalla-Salem slope area

"Geology and Ground Water of the Molalla-Salem Slope Area, Northern Willamette Valley, Oregon," by E. R. Hampton has been published by the U.S. Geological Survey as Water Supply Paper 1997. The 83-page report includes a summary of the geologic history of the area, descriptions of the geologic units, discussions of the distribution, quality, and quantity of ground water in the area, and basic well data. A geologic map and a map showing the thickness of the principal water-yielding units accompany the report. Water Supply Paper 1997 is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price is \$5.25.

Ashland area

"Availability and Quality of Ground Water in the Ashland Quadrangle, Jackson County, Oregon," by J. H. Robison, has been issued by the U.S. Geological Survey, in cooperation with the State Engineer and Jackson County, as Hydrologic Investigations Atlas HA-421. The Atlas is on one sheet 30 by 40 inches and includes a geohydrologic map, information on distribution of ground water in the various geologic units, data on chemical character of the water, and its chief uses. Atlas HA-421 is for sale by the U.S. Geological Survey for \$1.00.

* * * * *

GEOLOGIC MAP OF BURNS AREA PRINTED

A preliminary, uncolored geologic map of the Burns and West Myrtle Butte 15-minute quadrangles, by R. C. Green, has been printed by the U. S. Geological Survey as Miscellaneous Field Studies Map MF-320. The map is to be incorporated into the AMS Burns sheet, which will be published in color at a later date. The area mapped lies mainly north and west of Burns in Harney County, and is occupied by Traissic(?), Jurassic, Tertiary, and Quaternary rocks. A copy of the map may be consulted at the Portland office of the Oregon Department of Geology and Mineral Industries.

* * * * *

MINED LAND RECLAMATION LAW

On July 1, 1972 the Mined Land Reclamation Law goes into effect. All surface operations which remove more than 10,000 cubic yards of material or disturb more than two acres of land annually come under the law. The Department of Geology and Mineral Industries will administer the law in cooperation with various other state agencies and local governments. All operators subject to the law must obtain a permit. Forms will be available from the Department shortly before the first of July. Requests for permit application blanks or information concerning the law should be addressed to the Department at 1069 State Office Building, Portland 97201.

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THE TRACE FOSSIL TISOA IN WASHINGTON AND OREGON

Robert W. Frey* and John G. Cowles**

Introduction

Recently we described and interpreted some specimens of the trace fossil Tisoa from the Tertiary of Washington (Frey and Cowles, 1969), the first reported occurrence of this fossil burrow in North America. Specimens were collected near Megler, Washington, along a bluff facing the Columbia River (Figure 1); the fossils weathered out of the Lincoln Creek Formation. Distinct variations in trace fossil morphology were observed, representing differences in behavior of the animals responsible for the burrows.



Figure 1. The Megler locality, Pacific County, Washington.
(On Columbia River, approximately 400 feet east of boundary
between sections 8 and 9, T. 9 N., R. 9 W.)

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Tisoo has since been identified at various other places in Washington, but until very recently all of our attempts to locate specimens in Oregon opposite the Megler locality had failed. The fossil is now known from the Astoria Formation (early Miocene).

Considering the potential environmental, paleoecological, and paleontological significance of trace fossils generally (Frey, 1970, 1971), further searches should be undertaken in Oregon and Washington, aimed at documenting variations in, and the stratigraphic and facies distributions of, this fossil burrow.

Characteristics of Tisoo

Megler specimens of Tisoo typically consist of two parallel tubes contained within elongate calcareous concretions (Figure 2A, B), which are thus very similar to specimens reported from other countries (Häntzschel, 1962, Figure 137.4; 1965). The concretions collected by us are of assorted sizes but are invariably less than 15 cm in length and 7 cm in diameter. The enclosed tubes are generally 1 to 1.4 cm in diameter, and they run the full length of the host concretion; distances between adjacent tubes range from 2.5 to 7 mm (Frey and Cowles, 1969, Figure 1). Individual tubes are commonly lined with diagenetic pyrite, and the pairs of tubes may also be encircled by a thin layer of pyrite (Figure 3C, D). These tubes, evidently remaining open for a time during deposition of Lincoln Creek sediments, were eventually filled with a variety of detrital and diagenetic minerals.

Actually, rare specimens from Megler show that the "normal" twin tubes are in reality fragments of the upper part of a single U-shaped tube (Figure 3A), conceivably as much as a meter in original length (Häntzschel, 1962, p. W218). U-shaped fragments are less common now than "normal" specimens because (1) the break-up of the original structure produced more fragments of the upper part than of the basal part (Figure 4C), and (2) the basal part may have been less well constructed by the burrowing animal originally (Frey and Cowles, 1969, p. 19).

Rare Megler specimens also show that the tubes are not invariably straight (Figure 4A) and that the twin tubes may branch into additional pairs of tubes (Figure 4B). Furthermore, single-tube varieties of Tisoo are fairly common at this locality (Figure 2C); although these are identical to "normal" specimens in all other respects, no evidence for an original second tube has been observed.

Peculiarly, many of the tisoans observed at various places in Washington, other than Megler, consist predominantly of the single-tube variety, and at some localities the "normal" twin tubes are apparently very rare. Weldon W. Rau (1968, personal communication) wrote us that:

"Although we frequently find concretions with a single tube of some sort in the middle, I do not recall ever seeing any like your specimens with the double tube. Those I have

enclosed (by mail) are not particularly good specimens but are a sample from outcrops where I saw hundreds and possibly thousands. They were all oriented with the long axis normal to bedding. They range from a few inches up to possibly 8 inches in length. They all seem to have evidence of a crude tube through the middle."

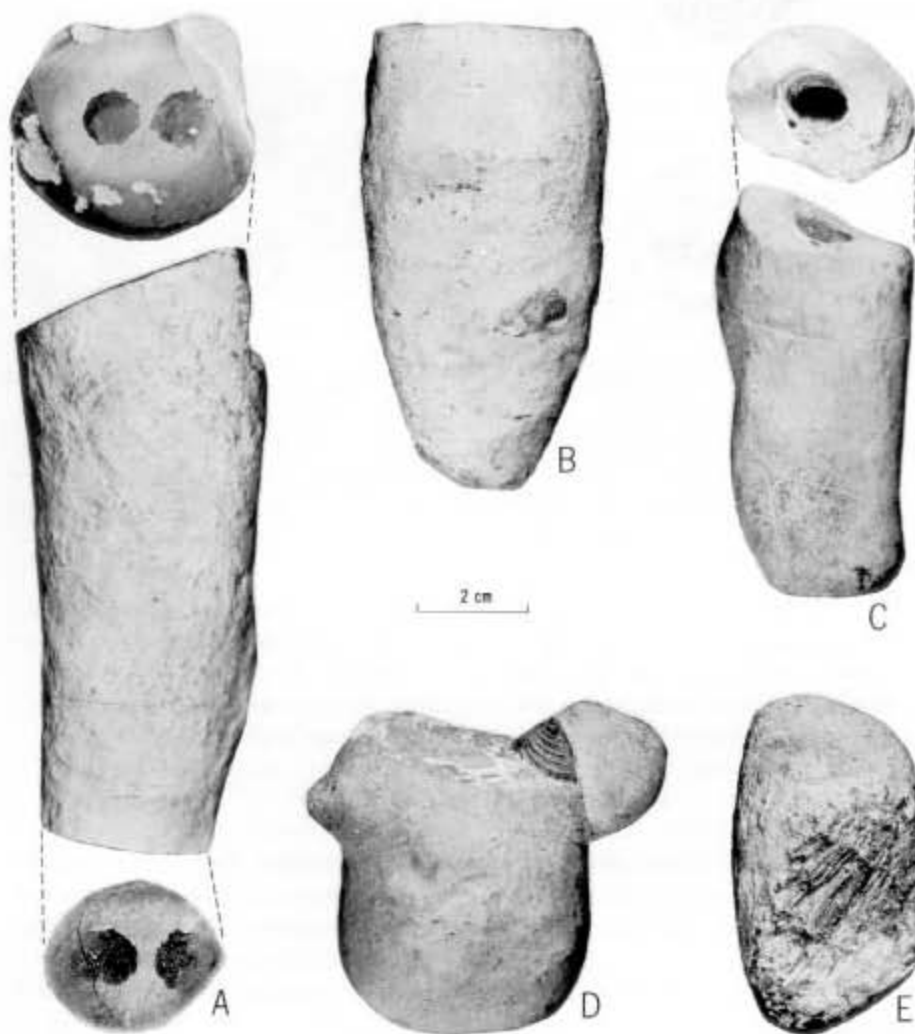


Figure 2. Tisoans from Megler. A, B. Typical double-tube specimens. C. Typical single-tube specimen. D. Bivalve *Lucinoma* cf. *L. acutilineata* (Conrad) embedded in tisoan concretion. E. Fish fin on side of tisoan concretion.

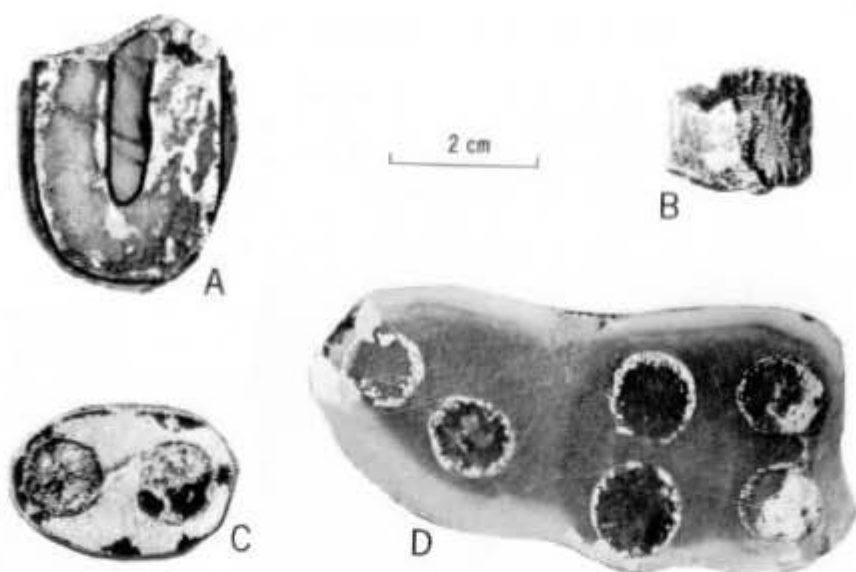


Figure 3. Tisoans from Megler. A. Longitudinal section through U-shaped tube (outlined in ink). B. Longitudinal view of tube fragment, mostly weathered out of its concretion, showing scratch marks. C. Transverse view of tisoan having pyrite concentrations around tubes and circumference of concretion. D. Transverse section through concretion containing three pairs of tubes, each lined with pyrite (cf. Figure 4B).

The morphological variations and interrelationships among local and regional assemblages of *Tisoo* thus clearly need additional study. Such work may eventually show that the genus is too broadly conceived and that it could realistically be split into two genera, although we would certainly discourage taxonomic splitting if possible (see Frey, 1971, p. 103-104).

Interpretation of *Tisoo*

The wall linings seen in many tisoan tubes suggest that the burrowing animal reinforced its domicile with organic secretions, which later reacted biogeochemically and thus helped concentrate secondary minerals such as pyrite (see Frey, 1971, p. 101-102). These alterations and the formation of enveloping concretions took place early in diagenesis, as suggested by a nearly intact fish fin and a closely articulated clam found embedded in tisoan concretions (Figure 2D, E); otherwise, bioturbation and other sedimentary and diagenetic processes probably would have disarticulated and scattered these fossil remains.

On the basis of morphology, requisite behavior, and the presence of small scratch marks on certain burrow walls (Figure 3B), we interpret *Tisoo*

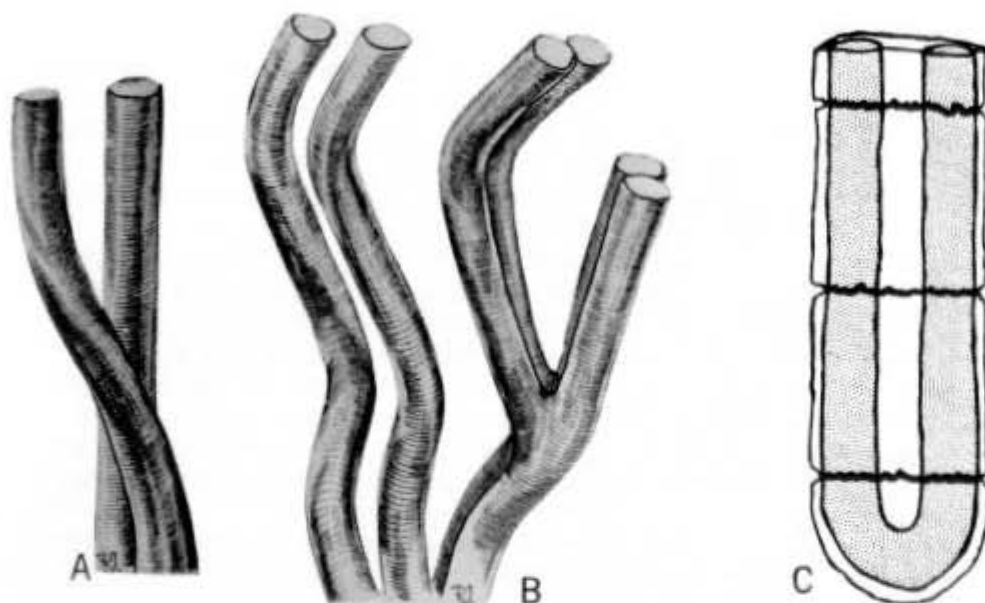


Figure 4. Reconstructions of Megler tisoans. A. Spiraled tubes. B. Branched tubes (cf. Figure 3D). C. Hypothetical specimen illustrating how several short, double-tube tisoans may be derived from a single long, U-shaped tube.

as the dwelling burrow of a shrimp- or amphipod-like arthropod (Frey and Cowles, 1969, p. 20). None of our burrow specimens contain arthropod remains, and virtually none of the fossil arthropods reported by Weaver (1942) are likely candidates; yet arthropod remains are rarely found even in well-documented Holocene and fossil arthropod burrows (Bramley, 1967, p. 170-172).

A possible exception among invertebrates reported by Weaver are such decapods as *Callianassa knapptonensis* (Rathbun, 1926, p. 112-113, Pl. 38, Figure 4), collected from the Oligocene near Megler. By analogy with the Holocene shrimp *C. californiensis* (Warne, 1967), *C. knapptonensis* conceivably could have constructed tisoan burrows having smooth exteriors, rather than the more popularly known knobby exteriors of Holocene *C. major* burrows and *Ophiomorpha* (Weimer and Hoyt, 1964). *Callianassa californiensis* does not, of course, make U-shaped burrows having closely appressed limbs, but certain other features of the burrow are somewhat comparable.

Overall, the burrowing habits reflected by Megler tisoans are more like that of the Holocene amphipod *Corophium volutator* (see Häntzschel, 1939), although the tisoan organism must have been substantially larger in size.

Distribution of Tisoa

Tisoa was previously known only from foreign localities, including the Oligocene of Tunisia, Cretaceous of Russia, and Jurassic of France and Madagascar (Häntzschel, 1962, p. W218). Hartmut U. Wiedemann (1970, personal communication) informed us that he has also observed the trace fossil in Jurassic marls near Aalen, Württemberg, Germany. Specimens from all of these localities consist predominantly of the twin-tube variety.

We have collected additional specimens southeast of Megler, especially on the western slope of K M Mountain, half a mile or more below the summit, along U.S. Highway 101. Weldon W. Rau (1968, 1971, personal communications) notes having seen Tisoa-like concretions in several other places, including the structures mentioned in his report on the Quinault Formation (Rau, 1970, p. 10). We examined a few of his specimens and found them extremely similar to those from Megler. Specimens from all of these localities consist mostly (or perhaps wholly) of the single-tube variety however.

In contrast, we have not personally located any unequivocal tisoans in Oregon. On the Oregon side of the Columbia we collected certain of the fossils and other concretions associated with Tisoa at Megler but no unmistakable evidence of Tisoa itself. Recently, however, Sam Boggs of the University of Oregon informed us (1971, personal communication) that he has collected a few specimens from an area along Youngs River near Astoria; we examined some of these specimens (from the Astoria Formation) and indeed found them to be single- and double-tube varieties of Tisoa, the latter being rare.

We strongly suspect that continued searching will eventually yield many additional specimens from Oregon, which will help establish further the morphological variation and overall distribution of this trace fossil in the Pacific Northwest.

Conclusions

Additional observations on the morphology and distribution of Tisoa are needed. Primary consideration should be given to the documentation of behavioral, biostratigraphic, and facies relationships of the different varieties of this trace fossil in Oregon and Washington. Only with this kind of information at hand can the full paleontological and environmental significance of Tisoa be evaluated.

Acknowledgments

We are grateful to Weldon W. Rau, Washington Department of Natural Resources, Ewart M. Baldwin, University of Oregon, and Richard E.

Thoms, Portland State University, for their comments and suggestions concerning this manuscript, and to Sam Boggs, University of Oregon, for sending us specimens of Tisoo collected by him in Oregon.

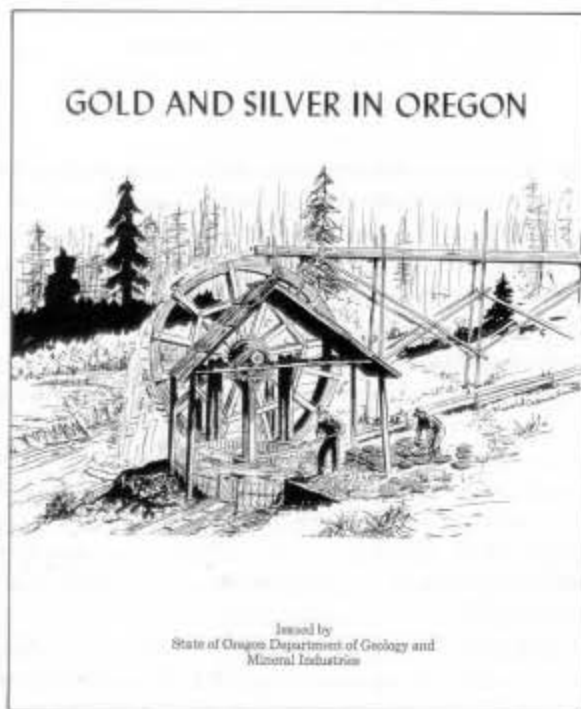
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ORE BIN SUBSCRIBERS: Moving? Send Change of Address, Please!

POPULAR GOLD BULLETIN REISSUED



The Department's Bulletin 61, "Gold and Silver in Oregon," by Howard C. Brooks and Len Ramp, has been reprinted and is again available from the Department's offices in Portland, Baker, and Grants Pass. The price is the same: \$5.00.

The bulletin was originally published in 1968 and went out of print in a very few months. Because of the great demand, it has been reprinted in its entirety. It contains a wealth of information about gold and silver in the state that was previously scattered through a great number of published and unpublished records.

The gold bulletin is organized in three parts: Part I contains a general discussion of the economics of gold and silver and a review of the production, history, and geologic occurrences of these metals in Oregon; Part II describes the principal gold-mining areas in eastern Oregon, particularly those in the "Gold Belt of the Blue Mountains;" and Part III describes the principal gold-mining areas in the Klamath Mountains and Western Cascades in western Oregon. In all, some 500 lode and placer mines and prospects are discussed.

The 337-page publication contains mine maps, index maps of mining areas, production statistics, historical information and photographs. The volume serves as a guide to future exploration and development.

* * * * *

A NEW LOOK AT MODERN MINING

Ralph S. Mason*

Mining in Oregon began with the discovery of gold at Jacksonville in 1851. That same year gold was also discovered at Griffin Gulch, not far from Baker. The next quarter of a century saw a full-fledged gold rush in Oregon. Placer gold, found in the streams and later in the adjacent banks, formed the basis for this tremendous activity, which brought thousands of people to the state, provided a wilderness society with an abundance of wealth, and established the first semblance of a legal structure. It is significant that Oregon became a state long before much of the territory lying to the east, mainly because of the search for gold.

The abuses perpetrated by the early-day miners are common knowledge. However, miners were not alone. The farmer, the stockman, the logger -- all moved to Oregon because of the land. Many brought injurious practices with them and left wreckage behind. The prospect of limitless land and an abundance of natural resources made conservation of any kind uneconomic and unheard of.

Once the easily obtainable stream placers were exhausted, miners turned first to the gold-bearing stream banks and later to the rich veins cropping out on the hillsides. To work the banks required capital and in many instances water for the hydraulic giants. Ditches to supply the water were dug by hand, often in record time, in mountainous unsurveyed areas. The Auburn Canal, the Rye Valley Ditch, the Sparta Ditch, and the Eldorado Ditch were completed in the 1860's and '70's. The Eldorado Ditch, incidentally, was 100 miles long, an engineering feat which would be of major proportions even today with earth-moving machinery. To mine underground required even more financing and for the first time the large mining companies appeared. The completion of the transcontinental railroads in the 1880's signalled the beginning of a period of intensive mining and milling, which was to continue, with some fluctuations, until World War II and the ill-advised government order L-208, which permanently closed nearly all of the state's metal mines. Gold dredging in Oregon began in earnest about 35 years ago. In 1938 there were 12 dredges active in eastern Oregon; in 1939 the state had 15 floating dredges and 13 nonfloating washing plants. Gold dredging came to an abrupt halt with World War II, and only a few attempts have been made to revive it since.

Of all the mining activity in the state during the past 121 years, none has been subjected to more criticism than gold dredging. Admittedly there

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

were abuses, but the outcry has been largely based on an emotional rather than a factual basis. In 1939, a total of .0015 percent of the state's crop land was dredged. Translated, this amounts to only 70 acres. It has been estimated that if all of the potential dredgeable ground should be dredged it would amount to .04 percent of the state's crop land.

Land abuse and stream pollution are always related. The relationship is sometimes obvious, as in some dredging where water is muddied and silt introduced into the stream. In other instances, the tie between land abuse and stream pollution is not so readily apparent. An over-cropped farm or a hillside stripped of trees will eventually pollute the streams with topsoil and silt. The big difference is that pollution from dredging occurs at the time of the operation, but pollution from poor farming or logging takes place during periods of heavy rain when the muddy water is assumed to be due to "natural" causes.

Today the mining industry presents a far different picture from that of 50 years ago. Mining companies have largely replaced the individual operator who was primarily interested in immediate return rather than a long-term investment. The high cost of setting up any type of industry today requires a long period for amortization - and the assurance that it will be permitted to stay in business. The mining industry is particularly vulnerable to this situation, with amortization periods of 20 years or more required for most large-scale operations.

Mining has recognized that it must accept its share of community responsibility, just as manufacturers and logging companies have done. Any well-established business realizes that good public relations are a "must." Mining companies also have learned that it is good business to police their own ranks rather than to have punitive and restrictive legislation forced upon them. A few examples of present-day mining company reclamation practices illustrate this point. In the southeastern United States, areas which have been mined for bauxite by ALCOA have been reseeded to trees which are tended as carefully as our own tree farms in the Northwest.

Here in Oregon, Reynolds Metals Co. is also in the tree farm business -- before they have started to mine bauxite. In Washington and Columbia Counties, where this company owns a considerable acreage of land underlain by ferruginous bauxite, a two-fold program of restoration and timber cutting is underway. Much of this land had been cut over, was brush covered, and was nonproductive when purchased by the company. Incidentally, much of this area was made unproductive by bad cutting practices of early loggers.

Some of the Reynolds' land has reseeded naturally, and trees are being harvested on an individual basis with care exercised to prevent damage to surrounding trees. In other areas, the land has been reforested and some of the trees are approaching marketable size. Several planted areas are designed for Christmas tree production. No clear cutting is permitted and the entire region of approximately 5000 acres is being managed on a sustained yield

basis. Several test pits opened to a depth of 10 feet or more 20 years ago are now obscured by trees. As a direct result of this program, soil erosion and stream pollution have been reduced and the land is esthetically enhanced.

Sand and gravel operators have found that unsightly gravel pits can be landscaped and made into attractive home sites featuring a lake with swimming and boating facilities. Currently in the Salem area, Walling Sand and Gravel Co. is converting mined-out gravel pits into public-use areas. In addition to picnic facilities, the company has arranged with the Oregon Game Commission to have the ponds occupying the former pits stocked with legal-size fish. The response from the public has been enthusiastic. As a side venture the company obtained plans for duck-nest platforms, which were erected in a secluded location within the pit, and several pairs of migratory birds have nested there.

The reclamation work of Porter Brothers in Bear Valley, Idaho, is well known. In northern California, as long as 30 years ago Harmes and Larson dredged and then leveled and resoiled 100 acres along Horse Creek. In this instance it is interesting to note that the cost of doing the reclamation work was exactly double the original value of the land.

Most surface-stripped land can be reclaimed and water pollution held to a minimum. The mining industry is willing and eager to do it, but the sad fact remains that all too often the land owner is more interested in immediate gain from rents and royalties on his mineral deposit than in a long-term investment. Clearly something must be done.

The problems are these:

1. The failure by large segments of the people to recognize that mining is an essential industry, indispensable to our way of life and to our very existence. What sets modern man apart from his ancestors is his use of metals and minerals.
2. Although mining operations on state and federal lands are controlled by existing legislation and present mining practices, there has been a real problem where the operation was on privately-owned land. The landowner has needed to be educated in the value of his land after mining, not just for himself but for the economy of the community. Hopefully the new reclamation law will help correct this.
3. Mining is not the only industry that has environmental problems, and the matter should be viewed in its entirety. Basically, stream pollution and land abuse are the by-products of civilization, and the record dates back 7000 years.
4. There is a need for realization that any regulatory measures to control mining activity must be drawn with care lest the industry be destroyed. Over the past 30 years most of the legislation related to mining has been of a restrictive nature, in sharp contrast to a great number of laws passed to help nearly every other phase of our economy.

The Mined Land Reclamation Act for the state of Oregon, which went into effect July 1, 1972, is designed to rectify many of the problems related to the increasing demand for minerals, particularly aggregate. In some areas there is a diminishing supply of these non-renewable resources, plus steadily shrinking areas where mineral resources may be obtained, and a growing awareness by the public generally that far better use must be made of all our land. Briefly the new law requires aggregate producers and miners who mine more than 10,000 cubic yards or disturb more than two acres of land annually to provide a performance bond, a mining plan, a reclamation plan, and evidence that the operation and the proposed use following cessation of mining meet with the approval of the appropriate local government. Visual screening, where necessary, will be required; water pollution will be controlled; and when the mining operation is completed the site must be left in a suitable condition for a planned subsequent use.

This new law closely parallels one now in force in the State of Washington. It is hoped that the experience reported from Washington will be repeated here in Oregon. Our sister state has been getting excellent cooperation from aggregate operators, state and federal agencies, and local governments. Some Washington operators, too small to come under the law, have voluntarily agreed to abide by the regulations, no doubt considering that it is good public relations to do so.

Gold miners of the early days had it easy. They could dig gravel, remove the gold, and leave the pits and piles of tailings behind, because in those days gold mining was the major source of income in the remote regions where gold was found, and no one really cared about the appearance of the environment. Nowadays, gravel deposits are being mined for another purpose - aggregate. Billions of tons of sand and gravel, plus large amounts of limestone, gypsum, and clay, go into the concrete for freeways, bridges, office buildings, shopping centers, apartment houses, condominiums, forecourt fountains, and a hundred other concrete uses that have come with the rise in our standard of living and increase in population. As a result, pits and piles of gravel can be seen across the land. Strictures are being placed on industry to curtail the environmental effects created by these and all other mining operations. This reclamation will cost large amounts of money and the added expense must be passed on ultimately to the consumer, who willingly or grudgingly will pay more for commodities in order to maintain or improve his life style. Thus, in the final analysis, the consumer is as much a contributor to the environmental consequences of mining as is the miner himself.

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ORE BIN SUBSCRIBERS ----- PLEASE NOTE

Ore Bin Subscription price for 1973 ----- \$2.00

WEISSENBORN HONORED FOR SPOKANE SERVICE

Albert E. Weissenborn, head of the U.S.G.S. office in Spokane for many years, has been awarded the Interior Department's 1972 Distinguished Service Award. Interior Secretary Rogers C. B. Morton made the presentation at a Washington, D.C. ceremony in June.

"Since joining the Geological Survey in 1943," the citation reads, "Mr. Weissenborn has rendered exceptional service in mineral resource programs of the Department of the Interior.

"As regional geologist for the Pacific Northwest, he established and maintained liaison with state and federal agencies, representatives of the mineral industry, professional organizations and other groups in the field of mineral resources.

"As executive officer for the Defense Minerals Exploration Administration Pacific Northwest field team, he skillfully directed a large mineral exploration program in Montana, Idaho, Oregon, Washington and Alaska.

"Mr. Weissenborn is internationally acclaimed as an expert technical advisor on mineral development programs and has served with distinction in this capacity in Liberia, Dahomey, Guyana, Saudi Arabia, and Turkey."

"Mineral and Water Resources in Oregon," a 462-page booklet originally issued for the Congressional Committee on Interior and Insular Affairs and subsequently published as Oregon Department of Geology and Mineral Industries Bulletin 64, was under the direction of Mr. Weissenborn.

* * * * *

GEOHERMAL REPORT FOR WASHINGTON ON OPEN FILE

The Washington Department of Natural Resources' Division of Mines and Geology has "open-filed" a Report on Geothermal Ground Noise Measurements in Washington State. Copies are available for examination at:

Dept. of Natural Resources, Div. of Mines and Geology
335 General Admin. Bldg., Olympia, Wash. 98504
Dept. of Geology and Mineral Industries
1069 State Office Bldg., Portland, Ore. 97201
California Division of Oil and Gas
1416 9th St., Rm. 1316-35, Sacramento, Calif. 95814

Data were gathered at 83 stations, all in the vicinity of either thermal springs or Pliocene-to-Recent volcanism. The report includes 14 pages of text plus references, tables, maps, with plots of power spectra for the Klamath Falls, Oregon, and Klickitat and Tum Tum Mountain, Washington areas.

* * * * *

GEOTHERMAL STUDY CONTRACT AWARDED DEPARTMENT

The U.S. Bureau of Mines is funding a continuation of the geothermal study being conducted by the Oregon Department of Geology and Mineral Industries. The contract calls for the Department to continue the geologic studies, begun several years ago, by N. V. Peterson and E. A. Groh to determine areas of greatest geothermal potential. In addition to the geologic studies, geothermal gradients and heat flow measurements will be made.

This study is a part of the plan outlined by R. W. deWeese, member of the Department's Governing Board, at the hearing on geothermal drilling regulations held in Klamath Falls on February 29, 1972. The plan evolved because Oregon and the rest of the Pacific Northwest lack identified resources with potential to supply some of the increasing demand for energy. Since materials to supply fossil fuel and nuclear power plants would have to be imported into the area at high cost and potential environmental hazard, geothermal resources, with their proven low cost and minimal environmental impact, appear to be the most attractive energy source for this region. Eastern Oregon abounds in indications of large geothermal reservoirs, and this is the region that will be given first attention in the study that will begin the joint state-federal development proposed by deWeese. The Bureau of Mines contract, amounting to \$76,000, will provide sufficient funds for the Department to continue the structural geologic studies related to geothermal areas and carry out a program of geothermal temperature measurements.

The basic physical property sought in exploring for geothermal fluids is available heat. Because water is only the carrier of this heat energy, measurements of heat flow from the earth provide a direct exploration tool for the location of usable geothermal energy. Information on geothermal gradient and heat flow will add a new dimension to the knowledge of the presently known thermal manifestations, such as hot springs.

Three distinct types of gradient and heat-flow measurements will be made to locate areas of high heat flow and to develop exploration techniques that might be applied to large areas at a minimal cost. The program will start with the locating of previously drilled holes or the drilling of new holes to a depth of 20 meters, at which depth the bottom of the hole will be unaffected by annual temperature variations resulting from the flow of solar heat. These wells will be instrumented with temperature-recording devices at several levels to monitor changes in temperature over a year, a full cycle of solar heating. The holes will be located in various geographic and climatic zones in the state in order to determine what portion of the heat flow from the ground surface to the atmosphere is dependent upon variations of the solar heating cycle and what part is dependent upon heat radiated from the interior of the earth. Data from the monitor wells can then be applied to shallow wells to obtain heat-flow determinations rather than drilling the 150- to 200-meter holes normally used for heat-flow measurements.

During the period that the monitor wells are being located, a series of shallow (3-meter) holes will be drilled and geothermal gradients will be measured over an interval of 1 meter to locate anomalously high gradients. The amount of temperature variation sought in these holes will be very minute but well within the capabilities of available instrumentation. Normal temperature gradient amounts to 30°C/km or 0.03°C per meter; within geothermal areas gradients run as high as 200° to 250°C/km or 0.2 to 0.25°C per meter. The low thermal conductivity of the tuffaceous sediments and lake beds of eastern Oregon, where the shallow-hole survey will be conducted, will make it easy to determine an apparent increase in the temperature wherever areas of high heat flow are found.

At the end of the shallow-drilling program, four or five of the anomalies will be drilled to a depth of 150 to 200 meters to determine the heat flow by conventional methods in order to confirm results obtained from the shallow holes. All of the holes will be drilled under conditions specified by the Department's geothermal drilling regulations and will be abandoned by backfilling and plugging. Prior to taking measurements the holes will be cased with plastic pipe and capped as a safety measure for grazing animals that might otherwise step into the holes and be injured.

The study this summer will begin with the drilling of shallow-gradient and monitor holes in the Vale-Owyhee upland region of Malheur County. The contract with the Bureau of Mines covers the studies for 15 months, after which time a report will be prepared and made available. Supervision of the project will be by Richard Bowen, Department economic geologist. Two geology graduates, Alan Preissler and Richard Kent, have been hired by the Department to perform the drilling. Consultant on the heat-flow studies is Dr. David Blackwell of the Geology Department of Southern Methodist University, Dallas, Texas. Dr. Blackwell has been working on heat-flow determinations in the Northwest for several years and has outlined the general method of operation for this study.

* * * * *

WILLIAM T. PECORA

Our Department has just received word of the untimely passing of Undersecretary of the Interior William T. Pecora. Dr. Pecora spent many years as a geologist for the U.S. Geological Survey, and in 1965 was promoted to Director. His most notable work in Oregon was the investigation of nickeliferous laterite deposits near Riddle. These deposits were subsequently developed by the M. A. Hanna Company into the nation's only nickel mine. President Nixon nominated Pecora as Undersecretary on April 20, 1971, and the Senate confirmed the post the following month. Secretary of the Interior Rogers C. B. Morton stated that "Few men possessed the leadership qualities which Dr. Pecora showed in the quest for balance and harmony in resource development and conservation."

* * * * *

CHANGES IN DEPARTMENT PERSONNEL

The most recent addition to the staff of the Department of Geology and Mineral Industries is Robert C. Sauve of Vancouver, Washington. His position is that of Spectroscopist-Assayer. Bob Sauve attended Clark College and Portland State University, majoring in chemistry. He was employed by Reynolds Aluminum Co. for 19 years before joining the Department in February 1972. He replaces Thomas C. Matthews, Spectroscopist, and Wm. Kahn, Chemist.

Thomas C. Matthews, now retired from the Department, is associated with the Dayton Travel Agency, which has headquarters in Seattle. Tom joined the Department in October 1966 and during his nearly 26 years as Spectroscopist performed thousands of analyses of rocks, ores, trace elements, rare earths, metallurgical materials, and substances from crime laboratories. William Kahn joined the staff in September 1967 and was employed as Chemist-Assayer for 4½ years. He is now sales representative with Penrose Realty in Tigard.

Other changes in staff in recent years that we have failed to note in The ORE BIN include Rudolph P. Zobl, who was accountant from November 1953 until his retirement in December 1970. His position has been filled by Clifford Speaker, who joined the staff in December 1970.

Miriam Roberts (Mrs. Ted) was Editor-Librarian for the Department between August 1960 and January 1971, when she moved to Eugene, Oregon. Previously her position had been held for 17 years by Mrs. Lilliam Owen, who produced the early issues of The ORE BIN on an ancient multilith machine which she held together by sheer will power. After Miriam's retirement, Sally Lillis was Editor-Librarian for 6 months, and the position is now filled by Carol Brookhyser (Mrs. Robert), who joined the staff in June 1971. Previously, Carol was a publications editor for National Institutes of Health.

Employed on a part-time basis as a secretary is Barbara Jacob (Mrs. Laurance), who has been with the Department in its Portland office since January 1971. In the Grants Pass office, Ruth Pavlat (Mrs. Howard) has been secretary since the retirement of Arline Jacques in October 1970.

* * * * *

GEOLOGIC FORMATIONS OF EASTERN OREGON PUBLISHED

"Geologic Formations of Eastern Oregon (east of longitude 121°30')" by John D. Beaulieu, has just been released by the Department as Bulletin 73. This is a companion to Bulletin 70, "Geologic Formations of Western Oregon" also by Beaulieu, providing a complete compendium for the state. Information about each geologic formation includes original description, distribution, lithology, contacts at base and top of unit, age, and references. Included are index maps, correlation charts, and an extensive bibliography. Bulletin 73 is available at Portland, Baker, and Grants Pass offices for \$2.00.

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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

8.	Feasibility of steel plant in lower Columbia River area, rev. 1940: Miller	0.40
26.	Salt: 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 Valseu 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
39.	Geology and mineralization of Morning mine region, Grant County, Oregon 1948: R. M. Allen & T. P. Thayer	1.00
46.	Ferruginous bauxite deposits, Salem Hills, Marion County, Oregon, 1956: Carcason 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
57.	Lunar Geological Field Conference guide book, 1965: Peterson and Groh, editors	3.50
58.	Geology of the Supplee-Izee area, Oregon, 1965: Dickinson and Vigross	5.00
60.	Engineering geology of the Tualatin Valley region, Oregon, 1967: Schlicker and Deacon	5.00
62.	Andesite Conference Guidebook, 1968: Dole	3.50
63.	Sixteenth Biennial Report of the State Geologist, 1966-68	Free
64.	Geology, mineral, and water resources of Oregon, 1969	1.50
66.	Reconnaissance geology and mineral resources, eastern Klamath County & western Lake County, Oregon, 1970: Peterson & McIntyre	3.75
67.	Bibliography (4th supplement) geology & mineral industries, 1970: Roberts	2.00
68.	The Seventeenth Biennial Report of the State Geologist, 1968-1970	Free
69.	Geology of the Southwestern Oregon Coast W. of 124th Meridian, 1971: R. H. Dart, Jr.	3.75
70.	Geologic formations of Western Oregon, 1971: Beaulieu	2.00
71.	Geology of selected lava tubes in the Bend area, 1971: Greeley	2.50

GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1971: (over the counter)	2.15
Geologic map of Oregon (12" x 9"), 1969: Walker and King	2.00
Geologic map of Albany quadrangle, Oregon, 1953: Allison (also in Bull. 37)	0.25
Geologic map of Galice quadrangle, Oregon, 1953: Wells and Walker	0.50
Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts	1.00
Geologic map of Bend quadrangle, and reconnaissance geologic map of central portion, High Cascade Mountains, Oregon, 1957: Williams	0.75
GMS-1: Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka	1.00
GMS-2: Geologic map, Mitchell Butte quad., Oregon, 1962: Carcason et. al.	1.50
GMS-3: Preliminary geologic map, Durkee quad., Oregon, 1967: Prostka	1.50
GMS-4: Gravity map of Oregon, onshore & offshore, 1967: [Sold only in set] flat, \$2.00; folded in envelope, \$2.25; rolled in map tube	2.50
GMS-5: Geology of the Powers quadrangle, 1971: Baldwin and Hess	1.50

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| 21. Lightweight aggregate industry in Oregon, 1951: Mason | 0.25 |
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MISCELLANEOUS PAPERS

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| 2. Key to Oregon mineral deposits map, 1951: Mason | 0.15 |
| Oregon mineral deposits map (22" x 34"), rev. 1958 (see M. P. 2 for key) | 0.30 |
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| 7. (Supplement) Bibliography of theses, 1959 to Dec. 31, 1965: Roberts | 0.50 |
| 8. Available well records of oil & gas exploration in Oregon, rev. 1963:
Newton | 0.50 |
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| 12. Index to published geologic mapping in Oregon, 1968: Carcoran | Free |
| 13. Index to The ORE BIN, 1950-1969, 1970: M. Lewis | 0.30 |
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1969: Newton | 2.50 |

PLATE TECTONICS IN OREGON

John D. Beaulieu

Stratigrapher, Oregon Department of Geology and Mineral Industries

While studying Paleozoic strata in the Appalachians of New York, James Hall, in the middle of the 19th century, formulated a theory which for more than 100 years explained to most people's satisfaction the regional relationships of the sedimentary rocks of the Appalachian Mountains. In fact, his theory was thought to explain the origin of the sedimentary rocks occurring in most of the mountain ranges of the world. He hypothesized the development of long linear troughs bordering the continents in the geologic past into which sediments derived from the continents were deposited. The troughs sank in harmony with deposition so that great prisms of rock commonly approaching 8 miles in thickness were produced. Later, according to his theory, the prisms were differentially folded, faulted, intruded, and metamorphosed to give the highly complex suites of rocks characteristic of so many of the mountain belts of the world today.

Although Hall failed to propose a name for his concept, it is generally referred to as the geosynclinal theory. In subsequent years, the theory has undergone a number of revisions and modifications. Among the more significant refinements is the concept that the geosyncline consists of two more or less distinct parts: the miogeosyncline, situated immediately adjacent to the continent, in which relatively well-sorted sediments and limestones accumulated; and the more distant eugeosyncline, into which poorly sorted graywackes and volcanic rocks were dumped from the scattered island arcs growing in the outer parts of the geosyncline. Throughout its evolution the concept of the geosyncline has embodied the concept of deposition in an actual trough (Figure 1).

In recent years the new concepts of sea-floor spreading, or plate tectonics, have superseded many of the tenets of the geosynclinal theory. The plate tectonic model maintains that the earth's crust is divided into slabs or plates which are continually shifting position relative to one another (Figure 3). Continents are rooted in the plates like logs frozen in shifting ice; they are best viewed as incidental by-products of the overall tectonic process. In regions of plate collision, the slabs are believed to override one another, producing regional stresses and tectonic processes which eventually

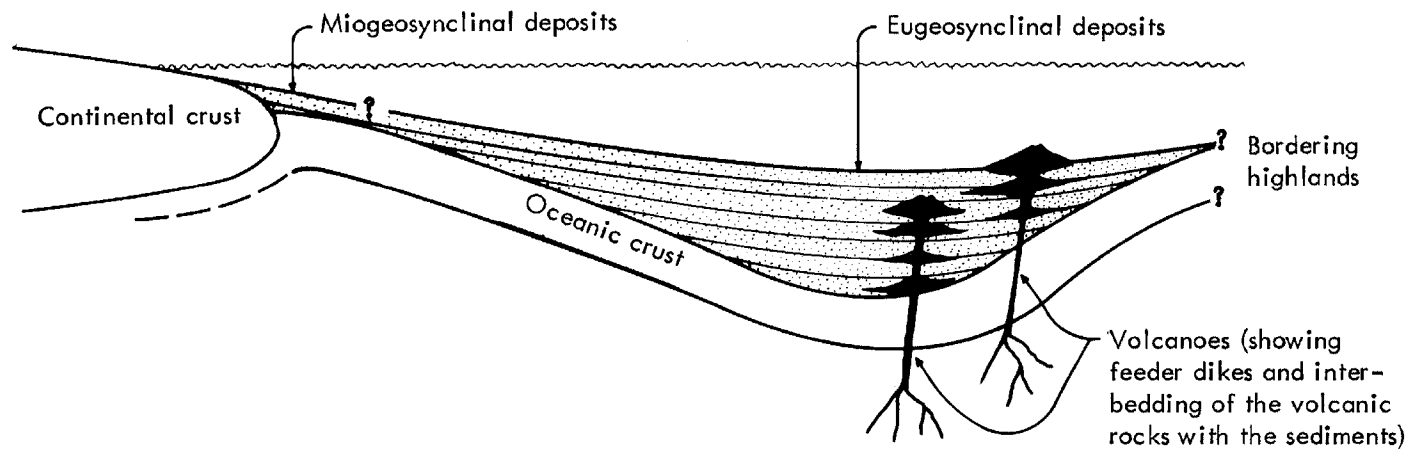


Figure 1. The concept of geosynclines maintained that the marine sedimentary rocks we now see in our mountain belts were deposited in large linear troughs, a cross section of which is shown above. The well-sorted miogeosynclinal sediments were deposited adjacent to the continental interior, whereas the eugeosynclinal deposits were laid down in the outer part of the trough in areas of volcanism.

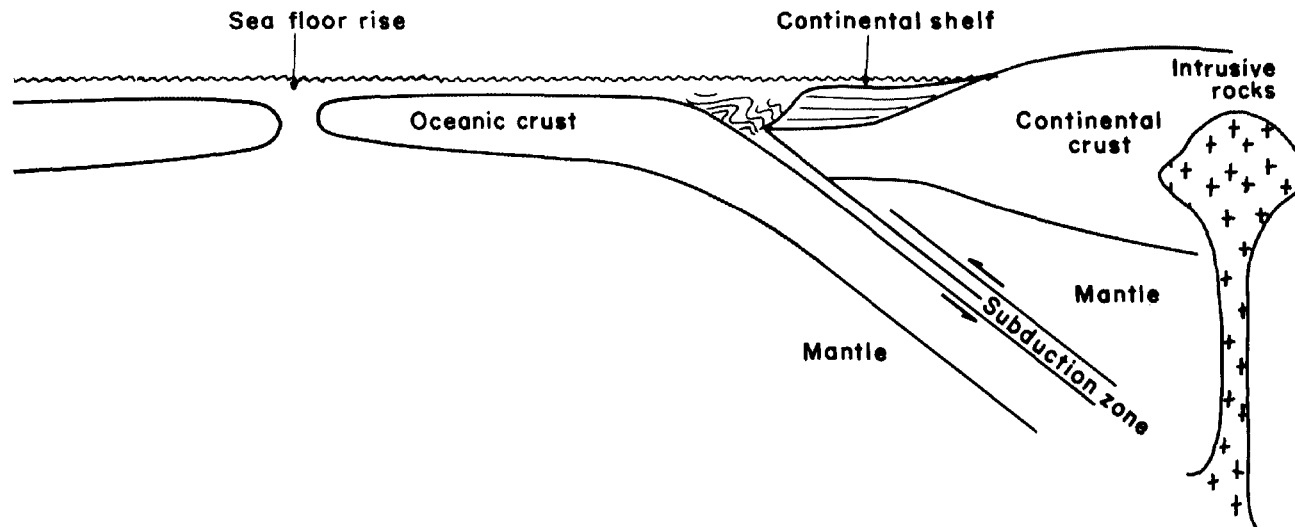


Figure 2. In the plate tectonic model sediments of the continental shelf represent the so-called miogeosyncline. The eugeosyncline is made up largely of the highly deformed rocks of the oceanic crust (mainly basalts and deep-sea sediments).

produce mountain ranges. In regions of divergence, hot material wells up from the mantle to fill the void and new crust is formed.

Regions of plate convergence often have associated with them at depth a dipping plane of seismic activity where one plate scrapes over the other (Figure 2). In currently active areas these are termed Benioff or subduction zones. In the rock record, they are more commonly referred to as subduction zones. Areas of plate divergence are characterized by rifting and are commonly represented by sea-floor rises. A classic example is the mid-Atlantic Ridge, along the axis of which new sea floor is being produced at the present time. In many areas plates glide past one another along lateral faults termed transform faults. Displacement along some of these faults (e.g. San Andreas Fault) is measured in terms of hundreds of miles.

Actually, the plate tectonic model in no real way alters the basic geometry of the rock distributions as described by Hall. Well-sorted sediments are restricted to the edge of the continent, and eugeosynclinal deposits are laid down in more distant areas. However, the original pattern of distribution or deposition is greatly modified. Most notably, deposition is not thought to occur in a trough (Figure 2).

Briefly, the miogeosynclinal rocks represent wedges of sediment laid down on the continental shelf; they thicken away from the continent and terminate abruptly at the continental slope (Dietz and Holden, 1966). The eugeosynclinal rocks are thought to represent deep ocean-floor crustal material that has been rafted against the continent into juxtaposition with the wedge deposits of the continental shelf (Dietz, 1972).

Because no trough as such is proposed by the plate tectonic model one of the major difficulties of the geosynclinal model is avoided. That is, nowhere in the world are eugeosynclinal and miogeosynclinal deposits seen being deposited side by side in the manner required by the geosynclinal theory. Failure to find such a depositional pattern is easily explained in terms of the plate tectonic model.

No longer, then, are continents viewed as quiescent fixtures rooted since antiquity in immobile crust and mantle. Continents are now seen as dynamic and complex structures imbedded in shifting lithosphere plates. In areas of plate collision the continents grow in size as more sea-floor material is rafted into them and also through volcanism and plutonism. Elsewhere, as in the Red Sea area today, continents are literally torn apart as the lithosphere plates beneath them diverge in response to deeper seated activity in the earth's mantle.

Paleozoic Tectonics

Paleozoic rocks in Oregon are limited to a few small exposures in the southwestern and northeastern corners of the state. In the southern Klamath Mountains quartz-mica schists, termed the Abrams Schist, and hornblende-epidote-albite schists, termed the Salmon Hornblende Schist, are thought

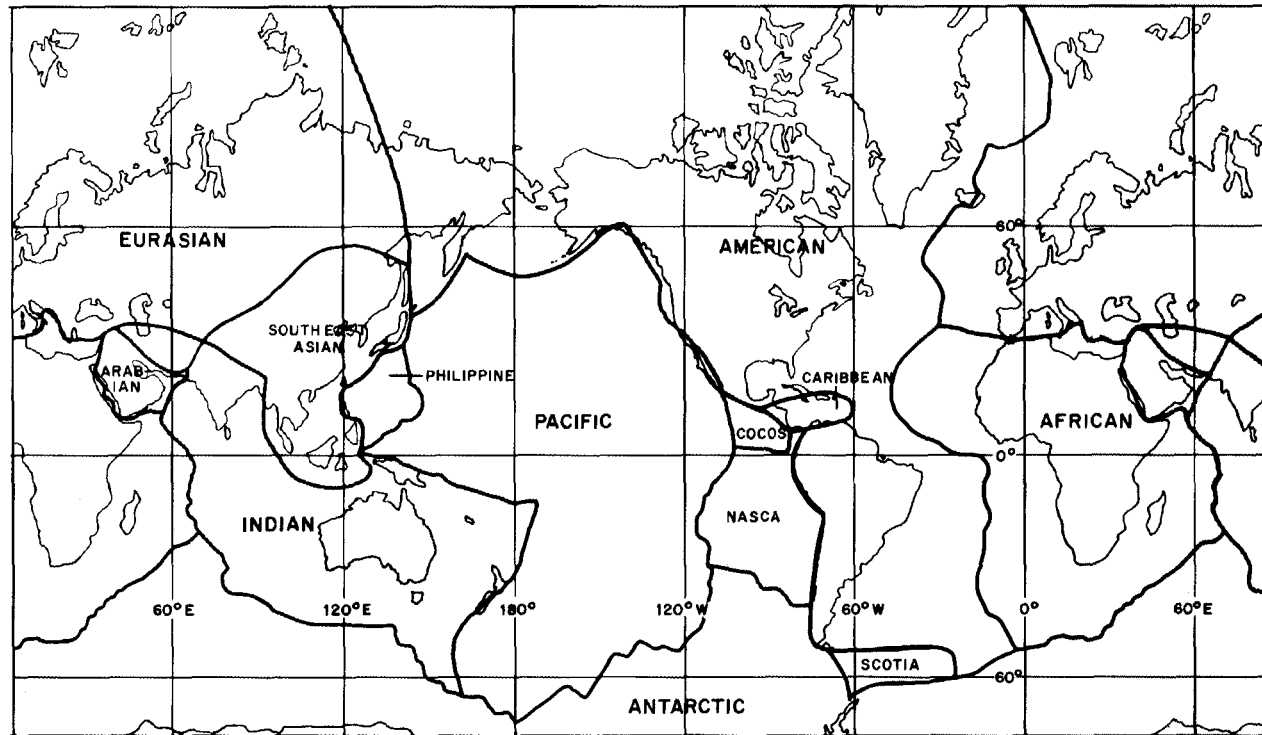


Figure 3. Projection of the lithospheric plates. According to the plate tectonic model, the outer 50 to 200 kilometers of the earth (the lithosphere) is divided into numerous plates which are in motion relative to each other. Zones of divergence are termed rises or ridges; zones of convergence are typified by trenches. In places, long transform faults separate the plates.

to represent metamorphosed mafic volcanic rocks and associated sedimentary rocks. On the basis of strontium isotopic data Lanphere and others (1968) conclude that a Devonian age of metamorphism is most likely for the strata. According to the plate tectonic model, the gross composition of the schists suggests that they may represent early Paleozoic sea floor that was metamorphosed in a subduction zone as one plate overrode another in Devonian times. Although not specifically stated in the literature, such interpretation is alluded to in a diagram by Burchfield and Davis (1972), who show a Devonian subduction zone in the vicinity of the Klamath Mountains.

Adding to the complexity of the area are the reported Asian and east European affinities of the early Paleozoic brachiopods and trilobites recovered in parts of the Siskiyou Mountains to the south. It is possible that the early Paleozoic rocks were originally part of Asia, that they were rafted eastward away from Asia, and that they subsequently collided with the North American continent (Sedden, oral communication, 1970). More recently Beck and Noson (1971) have postulated a similar idea that various Cretaceous granitic bodies in northern Washington originally were not a part of the North American continent and that they were rafted against the continent later in Tertiary times.

In northeastern Oregon, more extensive Paleozoic units consist of Permian exposures of greenstone, argillite, chert and limestone pods assigned to the Clover Creek Greenstone, the Burnt River Schist, and the Elkhorn Ridge Argillite. Unfortunately, structural and metamorphic patterns are complex and fossils are scarce. Gross lithology, however, is consistent with the concept that the units represent ancient sea floor; possibly the various units represent slabs of oceanic crust that were rafted against the continent and metamorphosed in a late Paleozoic subduction zone.

Triassic-Jurassic Subduction

On the basis of a wide variety of evidence accumulated from around the world it is widely agreed that at the beginning of Mesozoic times all the continents of the world were closely clustered to form one super-continent (Figure 4). In the literature this continent is referred to as Pangaea. Although the exact paleogeography and specific position of the super-continent is debated, the super-continent concept is fairly well accepted. Beginning in Triassic times, rifting of the lithosphere beneath Pangaea initiated the progressive splitting of the super-continent into a series of fragments. By the close of Mesozoic times, the separate continents of North and South America, Europe, Asia, Africa, Antarctica, Australia, and the subcontinent of India were fairly well established.

Synchronous with Mesozoic rifting in the eastern United States, a variety of collision features were produced in the west as the North American Plate was rafted westward to impinge upon the ancestral oceanic East Pacific Plate. The andesitic breccias of the Late Triassic Applegate

Formation and Late Jurassic Rogue Formation in the Klamath Mountains and the meta-andesites of the Late Triassic Clover Creek Greenstone in the Blue Mountains conform favorably on a lithologic basis to the types of rocks that are produced over active subduction zones in oceanic areas. Moreover, the siltstones and thin turbidite sandstone of the Late Jurassic Galice Formation overlying the Rogue Formation may represent the distal edges of an abyssal fan spreading westward from the former continental slope.

The Nevadan (Late Jurassic) intrusive and metamorphic features of the Klamath Mountains may record deformation and fusion arising from active subduction. In this connection also, the older high-grade blueschist slabs of the Colbrooke Schist, supposedly derived from the Galice Formation (Coleman, in press), acquire added significance. Blueschist pods are indicative of high-pressure low-temperature conditions and are generally interpreted to be signposts of previous zones of plate subduction.

Postdating the Nevadan orogeny are the massive sandstones of the Dothan Formation and the more westerly, more tectonically deformed, and highly sheared sandstone, greenstone, blueschist, serpentine, chert, and limestone exposures of the Otter Point Formation. Possibly the Dothan represents the near-shore facies of an abyssal fan and the Otter Point represents the distal edges of the fan as it spread westerly to mingle with other deep-sea-floor deposits. The sheared disordered appearance of the Otter Point Formation and the presence of tectonic blocks within it suggest tectonic deformation immediately following deposition. Possibly the unit was partially engulfed in a subduction zone prior to lithification as the North American Plate continued to ride westward over the ancestral oceanic East-Pacific Plate. A similar process is hypothesized for the contemporaneous Franciscan Formation of California (Hamilton, 1969) with which the Dothan and Otter Point Formations are commonly equated.

Masses of peridotite and other ultramafic rock occur as large sheets (Medaris and Dott, 1970) throughout much of the Mesozoic terrain of the Klamath Mountains Province and closely resemble ultramafics recovered from ocean ridges today. Lacking in chrysotile, a relatively high-pressure mineral of the serpentine group (Medaris, 1972), they are quite different mineralogically from the peridotites formed in subduction zone tectonic settings. It is postulated that the ultramafic bodies represent slabs of upper-mantle material which were brought up from depth along ancestral sea-floor rises in the Pacific Ocean (Medaris and Dott, 1970). They were subsequently rafted eastward against the continent. According to Coleman (1971), the mobile serpentine derived from hydration of the peridotites may have functioned as lubricating layers that permitted great blocks to slide over one another during periods of late Mesozoic thrust faulting.

Cretaceous Folding and Thrusting

The Cretaceous strata of the Klamath Mountains Province consist of well-washed sandstones, chert-pebble conglomerates, and siltstones.

Evidence of contemporaneous volcanic activity is completely lacking; overall, the Cretaceous section differs markedly from the eugeosynclinal piles of earlier Mesozoic times. The strata represent deposition on the continental shelf rather than on the continental slope and the deep-sea floor and are most appropriately referred to as miogeosynclinal. In a plate-tectonic sense they record deposition during the later stages of development of the basement rocks of the Klamath Mountains area.

The Cretaceous was not a time of tectonic inactivity, however. Compression continued, and regional folds, faults, and large-scale thrusts developed. According to Coleman (1972) the Colebrooke Schist is involved in imbricate thrust pattern with the Myrtle Group, indicating post Early Cretaceous thrusting. Thrust faults in the lower member of the Umpqua Formation and isoclinal folding (Baldwin, 1964) indicate that compressional deformation may have continued intermittently well into the Eocene (Baldwin and Lent, 1972).

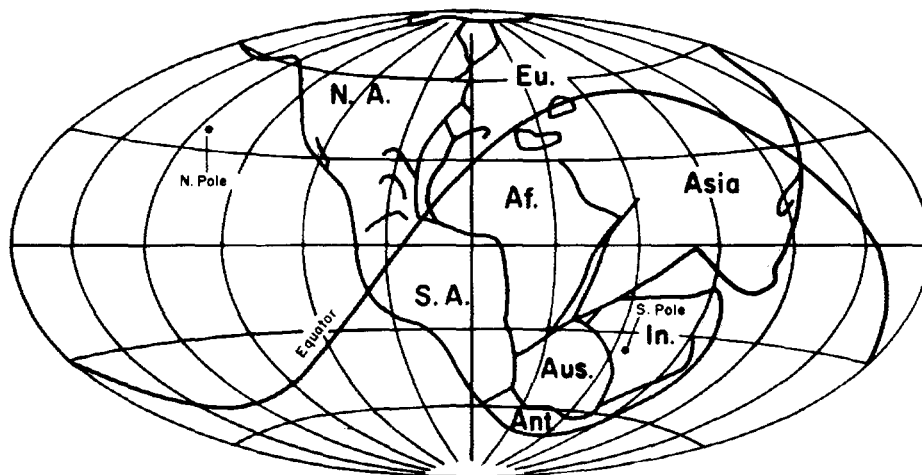


Figure 4. A generalized representation of the Permian supercontinent of Pangaea. By the end of Mesozoic times crustal rifting had fragmented the protocontinent to give the seven more or less autonomous continents we recognize today (adapted from Clark, 1971).

Eocene Rifting

The Eocene epoch is represented by the Clarno Formation in north-central Oregon, the Colestin Formation in southwestern Oregon, and a variety of subaerial and submarine volcanic and marine sedimentary rocks in northwestern and west-central Oregon including the Umpqua Formation, Siletz River Volcanics, Tyee Formation, Nestucca Formation, Elkton Siltstone, Yamhill Formation, Goble Volcanics, and others. The extent of Eocene strata in the subsurface of southeastern Oregon is unknown. The andesitic composition of the Clarno and Colestin Formations may suggest possible subduction in Eocene times.

Attention has been focused recently on the more mafic volcanic units that make up much of the Coast Range. According to McWilliams (1972), the pattern of distribution of the various volcanic and sedimentary rock units is such that progressively older Eocene strata form the basement northward in Washington and southward in Oregon. Paleocene ages have been assigned to parts of the lower Umpqua in southwestern Oregon (Baldwin, 1964), whereas rocks no older than late and possibly middle Eocene (Nestucca Formation, Goble Volcanics, Keasey Formation, and the Tillamook Volcanics) are known in northwestern Oregon. McWilliams (1972) infers an easterly trending zone of rifting in northwestern Oregon throughout Eocene times and postulates that the volcanic rocks were generated along a sea-floor rise. It is noteworthy that Atwater (1970) independently postulates an east-trending sea-floor rise in the vicinity of Oregon in Eocene times on the basis of paleomagnetic data.

Previously, Snively and others (1968) noted the close petrographic similarity between the Siletz River Volcanics and the floor of the present-day Pacific Ocean. Also, Thiruvathukal and others (1970) and Johnson and Couch (1970) demonstrate rather conclusively on the basis of geophysical evidence that no appreciable root underlies the Coast Range.

If the Eocene volcanic rocks of the Oregon Coast Range do indeed represent volcanic activity closely related to the rifting floor of the Eocene Pacific Ocean as suggested by the above data, it follows that the concept of an Eocene trough as proposed by the geosynclinal model is no longer valid (McWilliams, 1972). We may have to begin thinking in terms of Eocene sea floor generated along a rift zone which progressively displaced the older rocks to the north and the south. There may be no rocks older than late Eocene in the subsurface of parts of northwestern Oregon.

According to the rift model, the Eocene volcanics and associated sediments of present-day western Oregon became incorporated into the North American continent in early Tertiary times through progressive deformation, overriding, and uplift brought about by the continuing westward migration of the North American Plate. Reconstructing the Eocene paleogeography, the various turbidite units including the Umpqua Formation and Tyee Formation may represent abyssal fans spreading over the crumpling sea floor. The

numerous scattered unconformities throughout the Eocene may record periods of especially intense collision. It is noteworthy that the lower member of the Umpqua Formation is characterized by thrusting and isoclinal folding, features which are strongly suggestive of plate collision.

Oligocene Subduction

Explosive volcanism of andesitic composition characterized much of Oregon in Oligocene times and is recorded in a variety of marine and non-marine units throughout the state. The John Day Formation consists of several thousands of feet of ash blown from scattered vents and deposited throughout north-central Oregon. Although Oligocene beds in southern Oregon are poorly exposed, the Pike Creek beds on the southeast flank of Steens Mountain and the "Cedarville Series" of south-central Oregon suggest that volcanism analogous to that of the John Day was extensive throughout eastern Oregon in middle Tertiary times.

To the west the andesitic breccias, flows, and ash-flows of the Little Butte Volcanic Series (Peck and others, 1964) constitute the bulk of the Western Cascades. Farther to the west in the Coast Range, scattered intrusive rocks of Oligocene age indicate additional tectonic activity in that area. Moreover, virtually all the marine deposits of Oligocene age in western Oregon (including the Tunnel Point Formation, siltstone at Alsea, the Eugene Formation and other Oligocene marine units) are notably tuffaceous in composition.

On the basis of widespread explosive andesitic volcanism similar to that associated with active Benioff zones of today, active subduction beneath what is now the state of Oregon is inferred for Oligocene times. Recently Lipman and others (1971) defined two east-dipping subduction zones underlying western North America on the basis of plotted variations of K_2O/SiO_2 ratios in carefully collected igneous rocks. Conceivably one of these subduction zones was active in the Oligocene. Also, heat-flow patterns plotted by Blackwell (1971) are consistent with the concept of plunging lithosphere plate beneath Oregon in the geologic past. More recently, MacKenzie and Julian (1971) have defined on the basis of seismic evidence a subducted plate plunging eastward beneath the state of Washington.

Miocene Rifting

Oligocene explosive andesitic volcanism was succeeded in middle to late Miocene times by a tremendous outpouring of flood basalts over much of the northwestern United States on a scale that has been equalled only rarely in all of geologic time. The flows contrast markedly with the earlier eruptions and consist primarily of tholeiitic (little or no olivine) and high alumina basalt. They are assigned to the Columbia River Group in

southern Washington and northern Oregon, to the Owyhee Basalt in eastern Oregon, to the Steens Basalt and the unnamed igneous complex (Kittelman and others, 1965) in southeastern Oregon, and to a variety of unnamed Miocene volcanic rock units in south-central Oregon. In Idaho the slightly younger Snake River Basalts are analogous to the Miocene outpourings in many respects.

The great volume and markedly different composition of the Miocene basalts signal a profound and fundamental change in tectonic style in the northwestern part of the United States in middle Miocene times. The rocks are not the kind commonly associated with subduction zones and regions of plate collision. Rather they are characteristic of rifting and plate divergence. Swarms of dikes which fed the flows have been identified in parts of eastern Oregon and central Washington and are suggested in the subsurface in the Pasco Basin by geophysical evidence (Hill, 1972). The dikes and regional patterns of late Miocene and Pliocene block faulting are suggestive of tensional processes. Clearly, the whole tectonic character of the northwestern United States shifted abruptly from one of compression to one of rifting in middle Miocene times.

Regional geophysical evidence also favors the concept of rifting in middle and late Miocene times. As in present-day areas of rifting, the parts of Oregon underlain by flood basalts are characterized by high heat flow (Blackwell, 1971), shallow crust (Hill, 1972; Hamilton and Myers, 1966), and anomalous mantle (Gilluly, 1970). Hamilton and Myers (1966) and Gilluly (1970) have rigorously analyzed the geometry of the block faulting of the Basin and Range Province and conclude that significant crustal extension in an east-west direction has occurred since the Miocene. Finally, the uplifted structural pattern of the entire Basin and Range Province is similar to that observed in areas overlying inferred crustal rifting elsewhere in the world.

From a variety of regional plate tectonic and topical studies involving the western part of North America, the Pacific Basin, and the San Andreas Fault a picture is emerging in which the North American continent is seen to override the deep-sea floor of the ancestral east Pacific Ocean in early Tertiary times and to meet the actual sea-floor rise system of the Pacific Ocean in the mid-Tertiary (Atwater, 1970). At this time the compressional processes resulting from subduction were superseded by tensional processes the nature of which is not clearly understood.

Until recently it was postulated that the East Pacific Rise was overridden by the North American Plate and that tensional phenomena in late Tertiary times were an indirect result of continued rifting deep within the mantle. According to Atwater (1970), however, present concepts relating to plate mechanics and the precise nature of the boundaries between plates no longer permit such an interpretation; lithospheric slabs cannot override sea-floor rises.

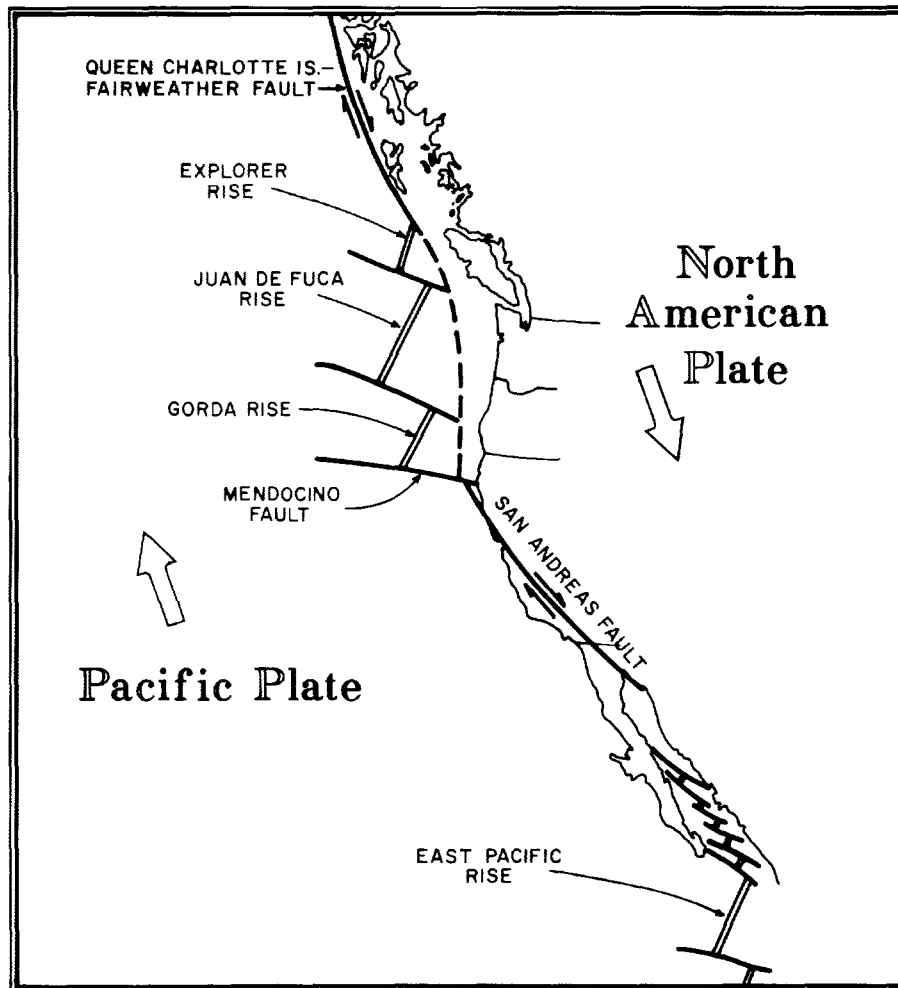


Figure 5. Index map of western North America showing the various faults and rift systems which make up the boundary between the North American Plate and the East Pacific Plate. At present the East Pacific Plate is moving northwest relative to the North American Plate. In the opinion of Atwater (1970) much of the late Tertiary deformation of the Western United States can be explained in terms of a broad zone of shearing between the more rigid central portions of the two plates.

Atwater (1970) postulates, rather, that a wide zone of deformation separates the North American Plate and the Pacific Plate (Figure 5). The geometry of relative movement allows for considerable tension as the two plates grind past one another. Although this may be the mechanism by which late Tertiary block faulting and tholeiitic volcanism has developed in Oregon, many advocates of sea-floor spreading do not find it very appealing. If plate movement and plate interaction is to explain tectonism, we cannot relegate tens of thousands of square miles of anomalous terrain to poorly defined "mush zones" between plates. Clearly, much remains to be done in the field of plate tectonics.

Conclusions

The plate tectonic history of Oregon is but one piece of a worldwide jigsaw puzzle encompassing much of geologic time. With the splitting of Pangaea in Mesozoic times, Oregon has occupied the leading edge of the North American Plate as it has impinged upon the ancestral oceanic East Pacific Plate. In the process Oregon has undergone profound subduction type tectonism. In addition, it may have acquired much lithospheric material from other plates, possibly some of the Paleozoic rocks of the Klamaths from Asia, ultramafic rocks and volcanic rocks from the Triassic oceanic crust, and the Siletz River Volcanics from the Eocene deep-sea floor.

In middle Tertiary times, Oregon, along with the rest of western North America, actually caught up with the East Pacific Rise, an event which profoundly altered the pattern of tectonic behavior within the state. Flood basalts and block faulting replaced andesitic volcanism and thrust faulting as the dominant mode of tectonism. The pattern of deformation in late Tertiary times is extremely complex and a plate tectonic model consistent with all the data has yet to be formulated.

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ORE BIN SUBSCRIPTION FOR 1973

\$2.00

January 1 through December 31

FORMER COUNTY COMMISSIONER ON GOVERNING BOARD

Governor Tom McCall has announced the appointment of Donald G. McGregor of Grants Pass to the Governing Board of the Department of Geology and Mineral Industries. McGregor succeeds Fayette I. Bristol of Rogue River, who served two terms.

McGregor, who will serve on the Board until March 15, 1976, was a Grants Pass retailer for 25 years, served six years on the Josephine County Board of Commissioners, and was Josephine County "Man of the Year" in 1945. He has served as State Parks Advisory Board representative to the Governor's Livable Oregon Committee and is a member of the Citizens Advisory Council to Southern Oregon College.

McGregor was born in Lincoln, Nebraska, graduating from the University of Nebraska School of Business Administration in 1924. He and his wife, Lucille, live at 924 N.E. Savage Street in Grants Pass. They have two sons and two daughters.

* * * * *

GEOLOGICAL HIGHWAY MAP SERIES IN PROGRESS

A series of full-color, regional geological highway maps are being issued by the American Association of Petroleum Geologists (in cooperation with the U.S. Geological Survey) for the benefit of tourists, amateur geologists, and the general public. The colored maps show the age and distribution of the various rock types and explain the origin of the land forms. Up-to-date state and federal highway maps are used as the base. Maps published so far cover the following regions:

- Map 1. Mid-Continent (Kan., Mo., Okla., Ark.)
- Map 2. Southern Rockies (Ariz., Colo., New Mex., Utah)
- Map 3. Pacific Southwest (Calif., Nev.)
- Map 4. Mid-Atlantic (Ky., W.Va., Va., Md., Del., Tenn., N. Car., S. Car.)
- Map 5. Northern Rockies (Ida., Mont., Wyo.)

A regional map that will include Oregon and Washington will be available within the next year, it is reported.

Each map is 28 by 36 inches at a scale of 1 inch = 30 miles. The maps may be ordered from AAPG, P.O. Box 979, Tulsa, Oklahoma 74101. The price per map is \$1.50 folded, or \$1.75 rolled, plus 50 cents for handling charges.

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THE GEOLOGY OF SOME ZEOLITE DEPOSITS IN THE SOUTHERN WILLAMETTE VALLEY, OREGON*

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Pullman, Washington

Introduction

Little work has been done and few descriptions have been published concerning the zeolites of the southern Willamette Valley. Mitchell (1915, p. 50), Zodac (1940), and Roberts (1945) note that some zeolites are found in the stream gravels of the area; Staples (1946, p. 578-579) discusses some of the zeolites from Coburg Butte; Lewis (1950, p. 31) notes zeolites in the vesicles of some of the lavas of the Coburg Hills; Wilson (1954, p. 486) describes some of the zeolites from Springfield Butte.

The general geology of the area, which is discussed by Lewis (1950), Vokes, Snavely and Myers (1951), Schlicker and Dole (1957), and Peck and others (1964) may be briefly described as follows. A series of sandstone, siltstone, and tuffaceous beds of Oligocene age lie under recent alluvium and crop out in the hills along the edge of the southeastern Willamette Valley. Basic dikes and sills intrude, and lava flows cap the sedimentary rocks. The igneous rocks are Oligocene to Miocene in age and typically are basalts, andesites, or dacites. The Willamette River and McKenzie River have broad flood plains over which a considerable amount of recent alluvium has been deposited. Small amounts of zeolites are found in many of the lava flows and plutons.

In this area the zeolites occur in veins and in cavities of various origins. The cavities are seldom completely filled. The zeolites commonly occur as well-formed crystals, and many of the minerals may be recognized by their morphology. Six zeolite deposits were studied in detail by the writer and approximately 15 more were studied in less detail (Kleck, 1960). Four of the six deposits studied in detail were chosen for description in this report (Figure 1).

*The descriptions of the deposits presented in this report are taken from the author's master's thesis completed at the University of Oregon in 1960. Since deposits have not been checked recently, it is probable that the appearance of some has been modified by quarrying or by weathering.

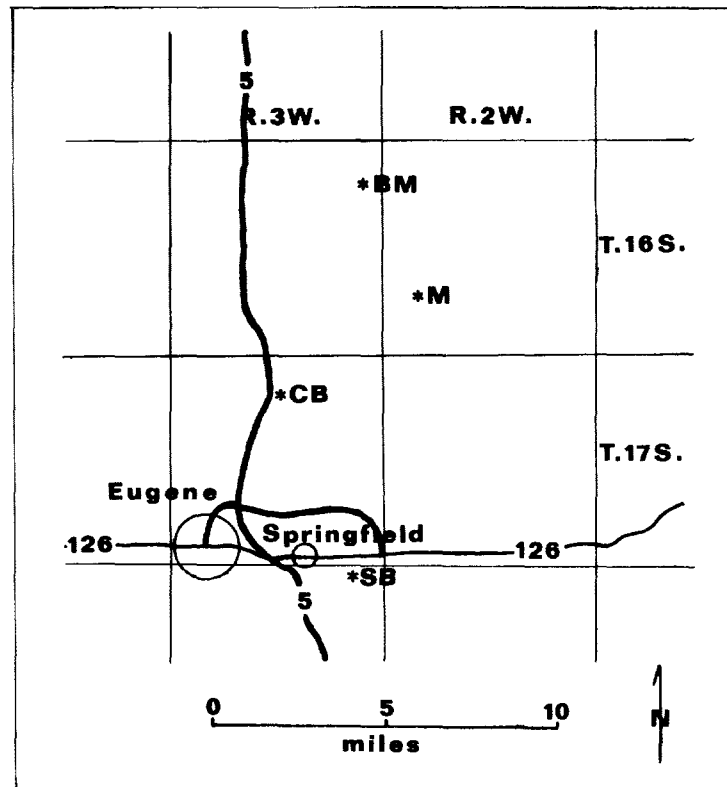


Figure 1. Locality map. BM=Buck Mountain deposit; M=M-120 deposit; CB=Coburg Butte deposit; SB=Springfield Butte deposit.

Description of the Deposits

Buck Mountain deposit

This deposit is in a small quarry located in the SW $\frac{1}{4}$ sec. 12, T. 16 S., R. 3 W. of the Eugene quadrangle. The zeolites occur in a basalt flow approximately 15 m thick. The flow consists of about 75 percent labradorite, 20 percent clinopyroxene and small amounts of magnetite, nontronite, and altered olivine. The lower part of the flow is dark-grey, dense, and contains scattered large vugs (figure 2); the upper part is composed of partly to highly altered, vesicular basalt. The estimated zeolite content of the flow ranges from about 1 percent in the lower, dense part to about 30 percent in the upper, altered part. In the lower part of the flow the zeolites are confined to fractures and vugs; in the upper part zeolites replace some of the minerals in the rock as well as fill fractures and vesicles (Figure 3). The zeolites and associated minerals in order of abundance are thomsonite,

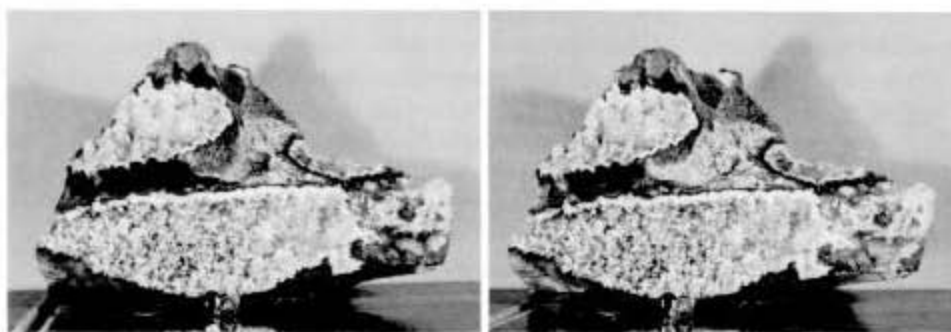


Figure 2. Stereo-pair of gas-formed vugs in the dense part of the flow at Buck Mountain. The specimen contains nontronite, stilbite, and calcite.



Figure 3. Fractures and vesicles filled with zeolites in red, altered basalt. Mesolite comprises approximately 30 percent of this rock.

mesolite, calcite, chabazite, stilbite, heulandite (note: heulandite is not distinguished from clinoptilolite in this paper), nontronite. Analcime is uncommon. Thomsonite and mesolite predominate in the upper part of the flow; chabazite, stilbite, and heulandite predominate in the base of the flow. These two assemblages grade into one another in the center of the flow.

M-120 deposit

This deposit is located in a road cut in the NE $\frac{1}{4}$ sec. 32, T. 16 S., R. 2 W. of the Eugene quadrangle. The zeolites occur in a basalt flow which at minimum is 8 m thick. The basalt consists of about 75 percent labradorite, 20 percent clinopyroxene, 5 percent magnetite, and small amounts of nontronite and altered olivine. The upper 3 m of the flow is vesicular, altered, and purplish-grey; this is gradational with about 2 m of grey, dense basalt. Zeolites compose about 10 percent of the flow and occur in vesicles, vugs, and fractures. Cavities which are not intersected by fractures are not mineralized. The secondary minerals in order of abundance are thomsonite, mesolite, analcime, chabazite, calcite, nontronite. Heulandite, stilbite, and copper are uncommon. Thomsonite and mesolite are by far the most common zeolites in the upper part of the flow; chabazite and analcime predominate in the lower part.

Coburg Butte deposit

This occurrence of zeolites is located in a road cut on U.S. Highway 99E about 100 m north of the McKenzie River Bridge. The zeolites occur in a basalt porphyry which intrudes the Eugene Formation. The basalt has large phenocrysts of plagioclase and contains about 70 percent bytownite, 20 percent clinopyroxene, 5 percent nontronite, and 2 percent magnetite. Thomsonite was observed to replace some of the plagioclase near the edges of fractures (Figure 4). The zeolites occur within the pluton in a faulted and brecciated zone (Figure 5) about 8 m wide. They compose about 2 percent of this zone. The zeolites and associated minerals in order of abundance are analcime, nontronite, thomsonite, calcite. Natrolite, stilbite, laumontite, and pyrite are uncommon.

Springfield Butte deposit

This deposit is located in a quarry in the NE $\frac{1}{4}$ sec. 1, T. 18 S., R. 3 W. of the Marcola quadrangle. The zeolites occur within a fine-grained basalt pluton which intrudes gently dipping lava flows. The basalt contains about 75 percent labradorite, 20 percent clinopyroxene, and small amounts of magnetite and nontronite. The zeolites occur in a "U"-shaped area of altered and brecciated rock. They have been deposited in fractures and large fracture-formed cavities (Figure 6). Zeolites compose about 20 percent of

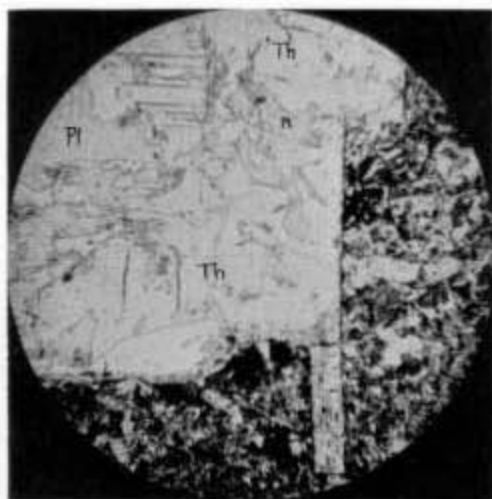


Figure 4. Photomicrograph of thompsonite (Th) replacing plagioclase (pl). Approximately 30 percent of the plagioclase remains. Plain light, X34.



Figure 5. A cut section of rock from the brecciated zone at Coburg Butte showing cementation by thompsonite and analcime. X0.7

the rock. In places, up to 50 percent of the primary minerals in the rock may be replaced by zeolites, nontronite, or other secondary minerals. The secondary minerals in order of abundance are natrolite, chabazite, heulandite, nontronite, analcime, calcite, mordenite. Gmelinite, copper, thomsonite, and phillipsite are uncommon. The deposit is zoned, grading from an area dominated by natrolite to one in which chabazite is the dominant zeolite.

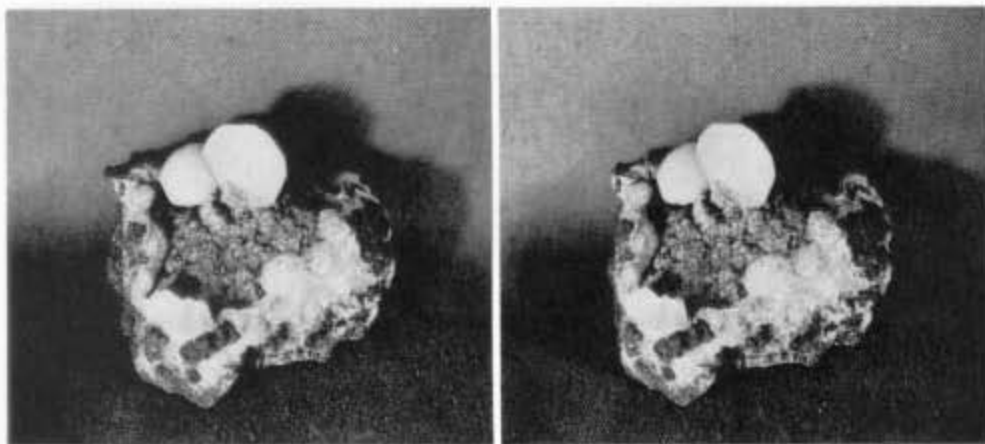


Figure 6. Stereo-pair of chabazite (phacolite habit) on heulandite from a fracture-formed vug. $\times 0.7$

Genesis of the Zeolites

Hydrothermal fluids may have supplied some of the elements and some of the water necessary for the formation of the zeolites. However, the largest amount of the elements were probably derived from the host rock. This is suggested by two observations: (1) the host rock has been altered where the zeolites are deposited; (2) a definite correlation exists between the amount of alteration of the host rock and the amount of zeolites deposited, i.e., the greater the amount of alteration, the greater the amount of zeolites.

The deposits of zeolites in the intrusive rocks (Coburg Butte and Springfield Butte deposits) appear to have followed this sequence of events: (1) emplacement and solidification of the pluton; (2) faulting and/or brecciation; (3) entry of hot fluids (magmatic or magmatic and meteoric water); (4) alteration of the host rock and deposition of the zeolites.

The sequence and place of deposition of the zeolites within the two lava flows (Buck Mountain and M-120 deposits) indicate a different origin than has been yet suggested. The zeolites (except analcime) deposited at

higher temperatures should contain less water than those deposited at low temperature (Coombs and others, 1959). The paragenetic sequence in the lava flows indicates that the zeolites were deposited with falling temperature. The predominance of higher temperature zeolites (low water content) in the upper part and lower temperature zeolites in the base of the flows is characteristic. These observations strongly indicate that the overlying lava flow is the source of heat.

The sequence of formation of this type of zeolite deposit might be: (1) solidification of a lava flow, (2) fracturing and jointing during cooling, (3) weathering[?], (4) heat (and magmatic fluids[?]) plus meteoric water to alter the older flow and result in the deposition of the zeolites.

Acknowledgments

The writer wishes to thank Dr. Lloyd W. Staples, University of Oregon, for his assistance during the course of this study.

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ZEOLITES IN SEDIMENTARY ROCKS*

During the last two decades, the scientific world has witnessed major research and development efforts on the occurrence and use of natural zeolite minerals and their synthetic molecular-sieve counterparts. Since their discovery in saline-lake deposits of Tertiary age in the western United States and in bedded volcanic tuffs in central and northern Japan in the 1950s, more than a thousand occurrences of zeolites have been discovered in sedimentary deposits throughout the world.

Previously known only as well-formed crystals in vugs and cavities of basalts and other traprock formations, zeolites are now recognized as major constituents in numerous bedded pyroclastics, and are accepted today as some of the most widespread and abundant authigenic silicate minerals in sedimentary rocks. Zeolites have found important applications in many phases of technology and are of particular value in the fields of drying, ion-exchange, gas separation, and catalysis, as well as other applications that take advantage of their low mining cost, such as for fillers in the paper industry, as soil conditioners, in animal husbandry, in pozzolanic cements, and as acid-resistant adsorbents in gas drying.

To foster closer cooperation between scientists of the two leading countries in the field of sedimentary zeolites, a seminar on the "Occurrence and Mineralogy of Sedimentary Zeolites in the Circum-Pacific Region" was held last July 19-24 in Nikko and Kaminoyama, Japan. The seminar was attended by 8 geological scientists from the United States, 16 from Japan, and 1 representative from the Soviet Union, and was sponsored by the U.S.-Japan Cooperative Science Program with the cooperation of the National Science Foundation and the Japan Society for the Promotion of Science. The seminar successfully combined formal papers on the occurrence, mineralogy, crystal chemistry, areal distribution, and industrial use of zeolites with informal field trips to important zeolite deposits, and permitted on-the-site examinations in the presence of a geologist or mineralogist who had studied the deposit in detail.

The history of research and early interest in sedimentary zeolites in Japan and in the United States was discussed at the opening of the seminar by M. Koizumi (University of Osaka) and one of the authors of this report

*Excerpts from: "Zeolites," by Frederick A. Mumpton, State Univ. College, Brockport, N.Y., and Richard A. Sheppard, U.S. Geol. Survey, Denver, Colo. Reprinted by permission of *Geotimes*, v. 17, no. 3, p. 16-17, 1972.

(Mumpton), the seminar coordinators. They emphasized that although a few scattered occurrences of zeolites in sedimentary rocks were known as early as the 1920s, it was not until a commercial interest in these materials had developed in the 1950s that the full significance of these discoveries became apparent. At present, zeolite occurrences have been recognized in all ages of sedimentary rocks of pyroclastic origin from late Paleozoic to recent, and active research programs are now underway on these materials not only in Japan, the United States and the Soviet Union, but also in Bulgaria, Italy, Yugoslavia, Argentina, New Zealand, Australia, Hungary, France and Great Britain.

The widespread occurrence of the six most common zeolites in altered tuffs of the United States--clinoptilolite, mordenite, erionite, chabazite, phillipsite, and analcime--was outlined by the junior author of this report (Sheppard), who suggested that most of these occurrences are the result of vitric volcanic materials reacting with either meteoric or connate waters of saline, alkaline lakes. In general, the zeolites seem to have formed from volcanic ash by solution-precipitation mechanisms; however, analcime in these deposits occurs only as an alteration product of pre-existing zeolites. In many areas, potassium feldspar is the end product of the alteration process.

The extensive use of natural zeolites in industrial and agricultural applications was outlined by H. Minato, who said that about 5,000-6,000 tons of clinoptilolite and mordenite are mined each month from eight open-pit deposits in Japan. The deposit at Itaya is the largest of these and produces more than 4,000 tons of zeolite per month. In Japan, refined zeolite products are used as inexpensive dessicants, as deodorizing agents in agricultural operations, as soft white filters in paper, as soil conditioners where their large ion-exchange capacities are used, as dietary supplements for chickens and swine, and in the production of oxygen- and nitrogen-gas products from air. This latter use was discussed in detail by T. Tamura (University of Tokyo), who has developed an oxygen-purification process based on the preferential adsorption of nitrogen from air by dehydrated mordenite. The process is used commercially to produce >90 percent oxygen for use in pig-iron smelting operations. A paper was read for R. Sersale (University of Naples, Italy) in which was described the use of phillipsite- and chabazite-rich tuffs from Italian volcanic areas in pozzolanic cements. Sersale has also been able to transform typical vitric tuffs into zeolitic products by treatment in 1 percent KOH solutions at 235°C and 30 kg/cm² pressure.

The current and potential uses of zeolites from sedimentary deposits in the United States were discussed by Leonard B. Sand (Worcester Polytechnic Institute). He reported that in addition to small amounts of mordenite and chabazite-erionite used as drying agents for acid gases, and clinoptilolite for radioactive-waste disposal, mordenite may be suitable for the removal of SO₂ in several pollution-abatement applications.

* * * * *

NEEDLE ROCK

Len Ramp



A. Needle Rock seen from Crater Lake Highway.



B. Close-up view of the 30-inch "eye."

Needle Rock is a prominent landmark rising 400 feet above Crater Lake Highway (Oregon 62) about 7 miles west of Prospect in Jackson County. The feature is named for a tiny window near the top of the rock. From a distance this hole, which is 30 inches across, looks as small as the eye of a needle. It is visible to highway travelers approaching the rock from either direction.

The top of Needle Rock is a remnant of the rubbly portion of a Miocene lava flow composed of angular basalt fragments ranging from pea size to a foot in diameter. Natural processes of weathering and erosion (wind, rain, freezing, thawing, and gravity) have reduced the top of the outcrop to a narrow ridge only 2 to 15 feet wide. The "eye" is in the thinnest part, about 6 feet below the ridge top, where loosened rubble has gradually fallen out. Another hole, as yet only about 6 inches across, is developing a few feet away. It will probably enlarge, just as did the bigger one, when more basalt fragments weather loose and drop out. These holes represent erosional caprices of nature and will eventually disappear as the top of Needle Rock is slowly worn away.

* * * * *

MARKETS AND RECYCLING - CONFLICTS IN PUBLIC POLICY*

Fred Berman, President
Institute of Scrap Iron and Steel

Although the concept of recycling is not new, I believe we would all agree that the popularity of this concept has now firmly entrenched itself in the United States. It is probably fair to say that popularity, as far as the general public is concerned, is beginning to give way to the realization that reclamation of our discards is an absolute must.

Those concerned with the quality of our environment, from a decision-making point of view, readily acknowledge the validity of reclamation as the objective in reducing land pollution.

Yet, at this point in time, there exist basic conflicts in public policy which place an unworkable burden on those engaged in the day-to-day business of converting discards into a form which can be used as a raw material for making new products.

The iron and steel scrap processing industry dates back to the 1800's in the United States. It was in 1928 that the Institute of Scrap Iron and Steel was formed. The 1300 member firms which make up the Institute today are actively involved in taking iron and steel discards - the effluents of our affluence - and processing them into grades of scrap for remelting into new products by steel mills and foundries.

With scrap processing plants located throughout the country, representing tremendous investments in equipment and expertise in the processing of metals, you may wonder why General Motors estimates there are 800,000 automobiles abandoned annually despoiling the countryside. This is in addition to those stockpiled in auto wreckers' yards and auto graveyards. Not to be overlooked are the untold numbers of abandoned refrigerators, stoves, washing machines, farm machinery and the like. It is estimated that the obsolete automobiles alone represent more than \$1 billion worth of reusable metal which is not being recycled.

And what about the steel cans and other small forms of metallics which find their way into each home's trash can - the can that generates a total of nearly one ton of household waste per person per year? Our ability to generate waste is rapidly increasing. A recent survey by the Department of Health, Education and Welfare indicates that by the end of the century the one ton figure will almost double. These somewhat frightening statistics emphasize the validity of the recycling objective. Why then, in the case of iron and steel, do we find accumulations of metallic solid waste?

*Reprinted by permission from Phoenix Quarterly, public service magazine of the Institute of Scrap Iron and Steel, Inc., v. 4, no. 1, 1972.

Collection is not Recycling

The basic answer to that question comes in the form of one word - markets. Without markets for the processed commodity, there is no recycling. The act of waste being collected in one or a group of locations cannot be construed as recycling. The act of converting metallic solid waste into a grade of scrap which remains in the scrap processor's plant cannot be construed as recycling. Nothing is recycled until it is used as a raw material to make a new product which is then sold in final form in the marketplace. The scrap recycled would conserve a limited natural resource, namely iron ore.

For the concept of recycling to function properly, a closed cycle is required. The reason we are faced with continuing accumulations of metallic solid waste is that there exists a rather large gap in the cycle - the link between the scrap processor and the steel mill and foundry is not as strong as it should be. Running the cycle in reverse order, if steel mills and foundries choose not to use the available iron and steel scrap as a raw material, the scrap processor will obviously reduce his production capabilities. This means the scrap processor will reduce the amount of unprepared iron and steel that he buys; which means that if this material does not move to the scrap processor, it will go to landfills, dumps or accumulate in the cities and countryside.

This was the problem facing the iron and steel scrap processor throughout 1971 and the prognosis for 1972 appears none too bright at this time. To be sure, scrap is moving, but not in the tonnages which it can and should be moving.

The price for the material is also depressed. With deflated tonnages and prices, the obsolescent grades of scrap - those grades which originate from metallic solid waste - are the hardest hit. They are the discards which, in the absence of strong markets for processed scrap, accumulate and deface the landscape.

There are two factors which hinder the marketability of iron and steel scrap - two conflicts in public policy which I cited previously.

Freight Rate Discrimination

The first is freight rates to haul scrap which are about $2\frac{1}{2}$ times higher than the rates for virgin iron ore, an irreplaceable natural resource. The Interstate Commerce Commission, a regulatory agency established by the Federal government, refuses to acknowledge the fact that scrap and iron ore compete as raw material inputs in steelmaking. We find this incredible and defying all logic. World renowned metallurgists have testified before the Commission that scrap and ore do compete and no one has ever refuted this testimony.

A recent study conducted for the Institute documents that this discrimination in freight rates presently results in a \$4.21 higher cost than necessary to produce a ton of steel using purchased-scrap as the raw material. The freight rate alone pushes the recycled material to a tremendous disadvantage.

The second factor is the 15 percent ore depletion allowance - an incentive which the Institute does not oppose. There seems to be good reason for this tax advantage. However, the concept begs the statement - some form of tax incentive should also be provided to the secondary product in order for it to compete with the virgin material. Denying the tax incentive to the secondary material is to provide a major advantage to the virgin product and to hinder the use of otherwise desirable scrap materials.

Let there be no misunderstanding - the scrap industry is not seeking a subsidy from any level of government. If there is to be an incentive to consume, and we believe there should be, the logical recipient would be the consumers, such as steel mills, or if necessary, the railroads. There is no need to subsidize the scrap industry to produce, but there is need to stimulate other industries to consume.

Competing Resources

The point is, scrap should certainly be allowed to compete fairly and equitably with virgin iron ore. If we desire to reclaim our wastes, conserve our natural resources and beautify the landscape, we must stimulate the melting of scrap.

The importance of these market factors, unfortunately, is not generally appreciated. Because local governments throughout the country are faced with mounting problems of solid waste, they are investigating and looking to the concept of recycling as the solution to their community problem. Most of their attention is directed to the establishment of recycling centers as a total systems solution.

As you may be aware, this technique involves the handling of refuse or solid waste which has been collected under local government control and brought to a central point for either disposal or transfer to its final disposal area. Resources are to be recovered from the wastes, so that the volume of wastes which have no value can be reduced, and income would be derived from the sale of the recycled materials.

However, this is a supply based concept. The recycling center, as it is referred to, does not recycle. It merely increases the supply of waste that is available for recycling. The concept is based on pulling materials from refuse that would normally go to the dump or landfill site for final disposal.

But, is the problem we are confronted with a need for more materials for potential recycling - more supply? It has been suggested that the sale of the reclaimed materials from such recycling centers would not only cover the cost of the facility, but could also result in a profit for the program operation. We have yet to be shown just one facility at any location in the entire country able to meet this test or even come close to it.

If the recycling center is only a generator of supply, is the concept economically sound? Are there markets for the reclaimed materials within the area which the recycling center complex will serve? Of what value is an increased supply, if markets do not now exist for the materials already being processed by the scrap processing industry? To make an increased supply a viable solution there must be an increased demand.

Economic Incentives

The expansion of recycling within this country must be parallel to and in conjunction with the development of markets which can absorb the recovered materials. Although the technology exists, the economic incentives do not at this point in time.

In a recent interview Mr. Samuel Hale, Jr., Deputy Assistant Administrator of the Environmental Protection Agency's Office of Solid Waste Management Programs, responded this way to a question concerning public funds versus private enterprise in the area of recycling. He said that private industry would be allowed "to do those things which it can do best, particularly those things where the profit motive is going to lead them in the right direction." He added, "I don't see us getting into the business of establishing a public secondary materials industry. That simply is not an area in which public energy should be channeled."

Concerning markets for recycled commodities he said, "the answer is not primarily in trying to find ways to get more materials recovered, but building up the markets for recovered materials."

Yet many people are clamoring for such centers, funded with public taxes despite the lack of economic rationale. What will be the feedback and reaction to public officials who urged the establishment of these publicly funded centers when the cost far exceeds the rosy projection?

Depressed Markets

Another point of consideration is what would happen to existing markets if there was suddenly a significant increase in supply? The scrap processor is without sufficient markets now and with depressed prices in the markets that exist - a marked increase in the tonnage available on the market would drive prices for processed scrap down even further. The impact would be most dramatic in the case of the obsolescent grades which are in less demand when the market is depressed. The outcome could well be a more thorough depressing of the entire recycling industry, with stockpiles of increased accumulation of metallics throughout the country.

Ecology and citizen groups who have established collection centers have found that the problem of markets can be most frustrating. In some instances they find no outlet whatsoever; in others their products become mere substitutes in that for one recyclable material to move, another

recyclable material that was already moving is now unable to be sold. In many cases the collection centers find that there is a total absence of markets for the collected material; it can't even be given away. Or they may find that the cost to haul the material to the user is greater than the dollar return for the material.

Again, it is a matter of limited demand and the continuing creation of additional supply, in the name of recycling.

I am sure that the individuals who devote time and energy to setting up such a center, in promoting the concept of people bringing materials to them, in getting trucks, containers, a site and all of the other details involved, encounter a great deal of disappointment when they find there is no market for the materials which they have collected to improve the quality of the environment and conserve natural resources.

The scrap processor understands this source of frustration. He is often faced with the same problem. There is a difference, however, which cannot be overlooked. He has invested hundreds of thousands, and in many cases millions, of dollars in equipment to perform the reclamation of metallic wastes. Why then should government consider it necessary to invest again in the same type of equipment? The capacity to process all of the metallic solid waste generated in this country is on line; it is the absence of sufficient markets which causes the problem to grow. The scrap processing industry can make all available metallic waste a recyclable commodity; but the recycling can only occur if markets are available.

If our objective is to insure that recyclable materials are reclaimed, and the scrap cycle is closed so that materials move in an orderly manner from manufacturer, to user, to discard, to reclamation, to manufacturer again, there simply must be markets. To direct our energies and concern at creating more supply, when the need is clearly more demand for what is now available, is an exercise in futility.

Policy makers must reconcile themselves to the fact that recyclable materials - our manmade resources - must be allowed to compete with natural resources. For the system to function, it must be based on sound economic principles. Such is not the case today.

Certainly our objective is recycling, but our attention must be directed first to the need for more demand, not more supply. When the demand for recyclable materials is stimulated, the supply will be forced to follow, and it will follow in the natural course of events. But there is no need for that supply as long as markets cannot absorb what is already available. When that demand is present, I assure you the scrap processing industry will be able to handle the supply. The key to the lock on recycling is demand, and that is what must come first.

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For a copy of the folder, "Scrap Is Not Junk," write the Institute of Scrap Iron and Steel, 1729 H Street, N.W., Washington, D.C. 20006.

ABANDONED MINING CLAIMS NOW SUBJECT TO CANCELLATION

Failure of a mining claimant to comply substantially with annual assessment requirements is grounds for cancellation of his claim under an amendment to the Code of Federal Regulations appearing in the Federal Register of Sept. 1. The new regulation is based on a 1970 decision of the Supreme Court and applies to all mining claims.

The right of the government to cancel claims for failure to comply with assessment requirements had never been established until the Court's decision in *Hickel v. Oil Shale Corporation*.

The new regulation was published in the Federal Register as "Proposed Rule Making" on July 15, 1971.

American Mining Congress Memorandum, Sept. 6, 1972

* * * * *

BURNS QUADRANGLE GEOLOGY PUBLISHED

"Geologic Map of the Burns Quadrangle, Oregon," by R. C. Greene, G. W. Walker, and R. E. Corcoran, has been published by the U.S. Geological Survey as Misc. Geologic Investigation Map I-680. It can be purchased for \$1.00 from the Survey's Distribution Section, Federal Center, Denver, Colorado, 80225.

The Burns quadrangle is one of the AMS series at a scale of 1:250,000. It is bounded by lat. 43° and 44° and by long. 118° and 120°. The map is in multicolor and shows the distribution of nearly 60 geologic units ranging in age from Devonian to Holocene. Included are cross sections, a small tectonic map, and descriptions of units. The map area covers the northern half of Harney County and edges of adjacent counties; Harney Basin lies in the center. The region is largely covered by Tertiary and Quaternary volcanic rocks and sediments; a small part of the Suplee Paleozoic-Mesozoic region extends into the northwest corner.

* * * * *

BLUE MOUNTAIN DRILLING PERMIT ISSUED

The Department of Geology and Mineral Industries issued State Permit No. 64 to Standard Oil Co. of California on September 7, 1972, for a 9000-foot exploratory test drilling in southeastern Oregon. The hole is to be drilled on the 100,000 acre Blue Mountain Federal Unit located near Blue Mountain Pass, SW $\frac{1}{4}$ sec. 34, T. 37 S., R. 41 E., Malheur County, approximately 16 miles north of McDermitt. The U.S. Geological Survey, on August 10, 1972, gave Standard permission to drill.

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FOSSIL SHARKS IN OREGON

Bruce J. Welton*

Approximately 21 species of sharks, skates, and rays are either indigenous to or occasionally visit the Oregon coast. The Blue Shark Prionace glauca, Soup-fin Shark Galeorhinus zyopterus, and the Dog-fish Shark Squalus acanthias commonly inhabit our coastal waters. These 21 species are represented by 16 genera, of which 10 genera are known from the fossil record in Oregon. The most common genus encountered is the Dog-fish Shark Squalus.

The sharks, skates, and rays, (all members of the Elasmobranchii) have a fossil record extending back into the Devonian period, but many major groups became extinct before or during the Mesozoic. A rapid expansion in the number of new forms before the close of the Mesozoic gave rise to practically all the Holocene families living today. Paleozoic shark remains are not known from Oregon, but teeth of the Cretaceous genus Scapanorhynchus have been collected from the Hudspeth Formation near Mitchell, Oregon.

Recent work has shown that elasmobranch teeth occur in abundance west of the Cascades in marine Tertiary strata ranging in age from late Eocene to middle Miocene (Figures 1 and 2).

All members of the Elasmobranchii possess a cartilaginous endoskeleton which deteriorates rapidly upon death and is only rarely preserved in the fossil record. Only under exceptional conditions of preservation, usually in a highly reducing environment, will cranial or postcranial elements be fossilized. The hard outer enamel of all sharks teeth enables them to resist weathering and transportation prior to deposition. Considering this fact and also the fact that tooth progression and replacement in the elasmobranchs is a perpetual process which continually contributes teeth to nearby sediments, it is no wonder that teeth constitute almost 100 percent of all the shark material found in Oregon.

* Student, Department of Earth Sciences, Portland State University

Previous Work

Although elasmobranch faunas from the Tertiary of Oregon have never received extensive taxonomic treatment, their existence has, however, been noted by early workers, dating as far back as the mid-1800's. In 1849, J. D. Dana explored the Astoria Formation in search of vertebrates and was one of the first to recognize shark remains from Oregon.

Packard (1940), in describing a leatherback turtle, Psephophorus(?) oregonensis, commented on the occurrence of sharks teeth in the Astoria Formation at the mouth of Spencer Creek. Packard (1947) again noted the presence of sharks teeth in the Astoria Formation, but unfortunately this material was never described.

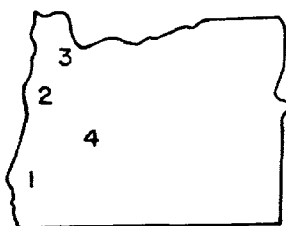
Steere, in a series of papers describing fossil collecting localities from the Tertiary marine sediments of western Oregon, mentions the occurrence of sharks teeth from the Cowlitz Formation (1957) and again in a later publication (1958, p. 58) states that "a few shark teeth have been collected from Oligocene marine sandstones of the Eugene Formation."

Sands of the Spencer Formation west of Monmouth, Oregon, have yielded an unusually high concentration of shark and ray teeth of late Eocene age. Schlicker (1962, p. 174) noted this concentration, stating that "Sharks teeth are abundant in a roadcut near the Luckiamute River just north of Helmick Park on U.S. Highway 99-W."

The first shark remains from Oregon to receive taxonomic treatment were collected from Scoggins Creek by members of the Oregon Department of Geology and Mineral Industries in 1967. Twenty-two vertebrae, one anterior tooth, and a few patches of calcified cartilage were collected from a well-bedded, fine-grained dark mudstone in the Yamhill Formation of Eocene Age. All of the specimens were forwarded for identification to Shelton P. Applegate, Associate Curator of Vertebrate Paleontology at the Los Angeles County Museum of Natural History. Shortly thereafter, an article appeared in The ORE BIN (Applegate, 1968) describing the dentition and skeletal elements as belonging to an Eocene Sand Shark Odontaspis macrota.

Hickman (1969, p. 104) described the occurrence of two sharks teeth in the Eugene Formation, south of Salem, Oregon. In her discussion she states, "Sharks teeth are occasionally found in the Eugene Formation. The teeth represent two major groups of sharks. The single cusps are typical of the modern galeoid type of shark (Hickman, 1969, pl. 14, fig. 12) and the saw-like teeth typical of the primitive hexanchoid genus Hexanchus (Notidanus) (Hickman, 1969, pl. 14, fig. 13). Both of these groups are abundantly represented by teeth in Tertiary marine deposits, although they are not well known from the Pacific Coast."

Specimens of the hexanchid sharks, Notorhynchus and Hexanchus, are relatively abundant in beds of lower Tertiary age in Oregon. Sharks of the genus Notorhynchus are known from sediments of Eocene and Oligocene



Locality map for stratigraphic sections

Epoch	Southern Coast Range (1)	Central Coast Range (2)	Northern Coast Range (3)	Southern Willamette Valley (4)
PLIOCENE	Port Orford			
	Empire Fm.			
MIOCENE		Astoria Fm.		
	Miocene Beds			
OLIGOCENE		Nye	Scappoose Fm.	
		Yaquina		
	Tunnel Point Fm.	Upper Toledo Fm.	Pittsburg Bluff Fm.	Eugene Fm.
	Bastendorff		Keasey Fm.	
EOCENE	Coaledo	Nestucca	Cowlitz Yamhill	Spencer

Figure 1. Correlation chart for geologic formations of western Oregon. Adapted from J. D. Beaulieu, 1971, p. 63.

age in northwestern Oregon, and early and middle Miocene beds of the central Oregon Coast Range have yielded teeth of the Six-gilled Shark Hexanchus. The first North American occurrence of the genus Heptranchias is represented by a single tooth collected from the Keasey Formation at Mist, Oregon.

Occurrence

Fine-grained black Cretaceous mudstones of the Hudspeth Formation crop out along numerous small exposures north of Mitchell in east-central Oregon. These sediments have yielded three teeth, the only Mesozoic shark teeth known at this time from Oregon. One of the teeth may be tentatively assigned to the common Cretaceous genus Scapanorhynchus. A more thorough search of these rocks will undoubtedly reveal an abundance of material.

Five upper Eocene formations in western Oregon have yielded elasmobranch remains, representing over 75 percent of all the Tertiary shark material known from Oregon.

The Yamhill Formation, cropping out along stream beds in Scoggins Valley, west of Forest Grove, Oregon, has yielded a disarticulated skeleton of the Eocene Sand Shark, Odontaspis macrota (Pl. 1, 3a, b) (Applegate, 1968). In association with this skeleton are five teeth of a yet undescribed species of echinorhinid or Spiney Shark (personal communication from Shelton P. Applegate). Apparently these teeth represent normal tooth loss during post-mortem scavenging by the Spiney Shark.

Coarse sandstones and fine-grained mudstones of the Coaledo Formation, exposed from Yokam Point south to Shore Acres State Park below Charleston, yield many teeth, usually included in biostromes of clastic shell material. Over 700 shark and ray teeth have been recovered from sediments at Shore Acres State Park. This assemblage is characterized by Odontaspis macrota, Squalus, and the Eagle Ray Myliobatis (Pl. 1, 8a, b, c). The abundance of myliobatid teeth at this locality far exceeds any other area in Oregon.

Sands of the Spencer Formation at Helmick Hill, 9 miles west of Monmouth, Oregon contain a single discontinuous lens of weathered limonite-stained pebbles and sharks teeth, not exceeding a foot in thickness. Disaggregation and screening of these sediments has yielded over 2,000 teeth, of which 95 percent belong to the Sand Shark Odontaspis macrota. Teeth of Squalus, Myliobatis, Isurus, the Angel Shark Squatina, and the Horn Shark Heterodontus (Pl. 1, 4c) are encountered.

Transport prior to deposition at the Helmick Hill locality has destroyed the roots and severely abraded most of the teeth. Weathering and leaching by groundwater have also contributed to tooth destruction. Lateral edges and crown points on most teeth are smooth and rounded, and lateral denticles have been broken off most of the odontaspids. Only by the sheer abundance of teeth is it possible to find a few specimens which still exhibit morphologic

Sharks	Yamhill Fm.	Coaledo Fm.	Cowlitz Fm.	Spencer Fm.	Nestucca Fm.	Keasey Fm.	Pittsburg Bluff Fm.	Scappoose Fm.	Nye Mudstone	Astoria Fm.	Miocene Beds at Cape Blanco
Carcharodon				X		X				X	
Centrophorus						X					
Centroscyrnus							X				
Echinorhinus	X										
Galeocerdo				X	X					X	
Galeorhinus		X									
Hepranchias						X					
Heterodontus		X		X							
Hexanchus									X	X	
Isurus		X	X	X	X	X			X	X	
Lamna		X	X	X	X	X			X	?	
Notorhynchus						X	X				
Odontaspis	X	X	X	X	X	X	X		X		
Pristiophorus			X			X	X		X		
Scyliorhinus		X									
Sphyrna				X							
Squalus		X	X	X	X		X		X		X
Squatina		X	X	X		X	X	X	X		
Rays											
Myliobatis		X	X	X					X	X	
Raja					X		X		X		
Rhinoptera		X									

Figure 2. Checklist of Tertiary Elasmobranchii from Oregon.

features suitable for description and identification. Unfortunately, less frequently occurring forms are usually quite abraded and classification beyond the generic level may be impossible for many. The probability also exists that these teeth were reworked from older underlying sediments.

Explanation of Plate 1

1. Notorhynchus sp. Agassiz (Seven-gilled Shark), Pittsburg Bluff Formation, Oligocene, lower left lateral tooth. X 2, PSU 13-17.
2. Hexanchus sp. Rafinesque (Six-gilled Shark), Nye Mudstone, lower lateral tooth. X 1.8, Taylor collection, Portland, Oregon.
3. Odontaspis macrota Agassiz (Sand Shark), Yamhill Formation, second lower right anterior tooth; a. lingual view, b. lateral view. X 1.5, PSU 13-24.
4. Heterodontus sp. Blainv. (Horn Shark), lateral pavement teeth, a. lateral view, b. dorsal view, both collected from the Quimper Sandstone, Washington; c. dorsal view of tooth collected from Spencer Formation, Oregon. X 2.5, PSU 13-18 and PSU 13-19.
5. Squatina sp. Valmont (Angel Shark), Nye Mudstone, a. Lateral view, b. labial view. X 1.7, PSU 13-23.
6. Pristiophorus sp. Muller and Henle (Saw Shark), Pittsburg Bluff Formation, rostral spine. X 1.7, PSU 13-22.
7. Squalus sp. Linne (Dog-fish Shark), Pittsburg Bluff Formation. X 4.2, PSU 13-21.
8. Myliobatis sp. Cuvier (Eagle Ray), Coaledo Formation, pavement tooth, medial row, a. ventral view showing roots, b. lateral view, c. dorsal view. X 2.2, PSU 13-20.

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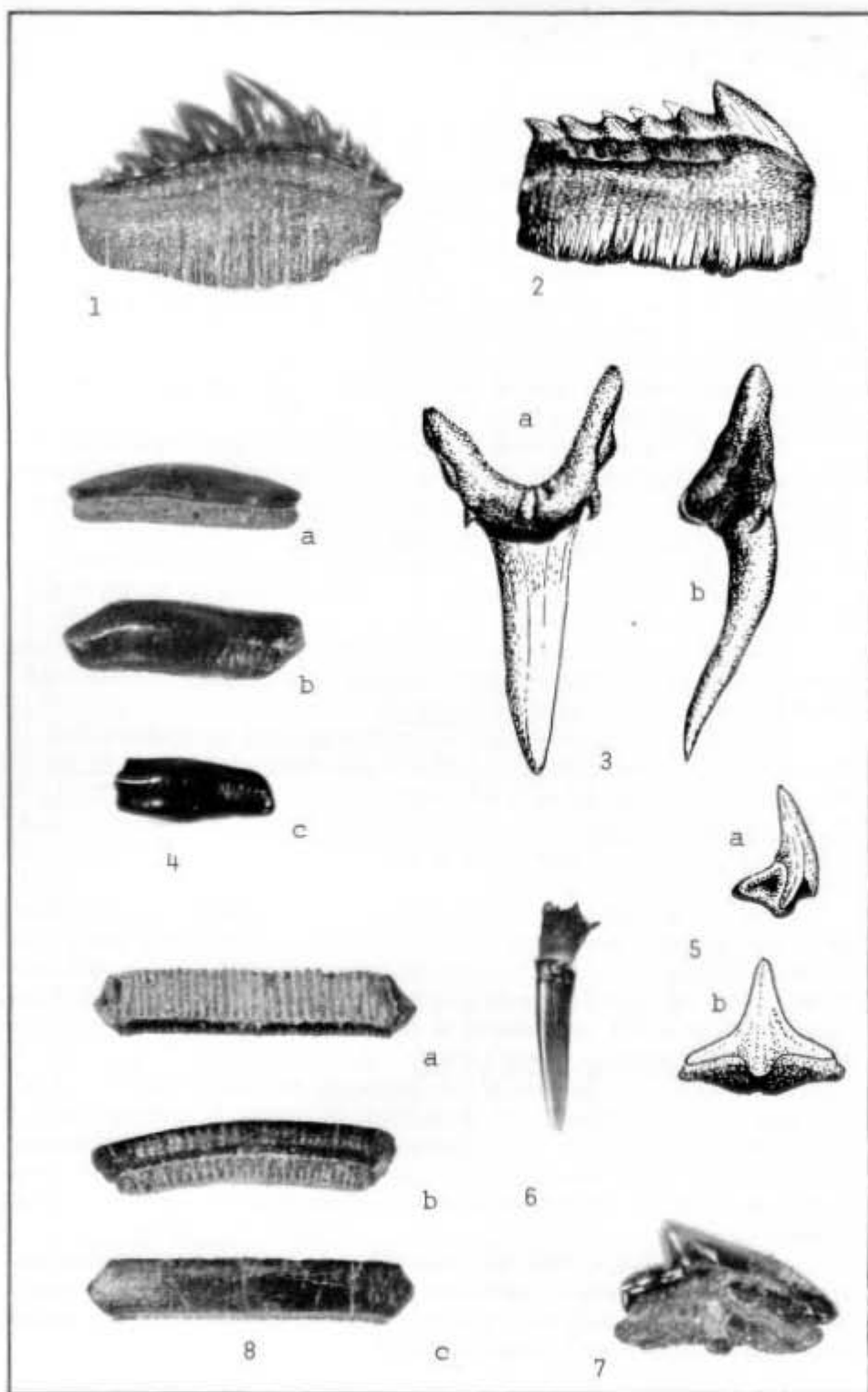
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Glaucinitic green sands of the Nestucca Formation at Toledo yield fair to poorly preserved teeth of the Mako Shark Isurus, the Tiger Shark Galeocerdo, and what appears to be small teeth of the skate Raja. Mammalian bone fragments and teleost remains have also been found.

A well-known Tertiary crinoid locality at Mist, Oregon has contributed a number of smaller sharks from sediments of the Keasey Formation of late Eocene to early Oligocene age. Aside from such forms as Squatina, Odontaspis, the Seven-gilled Shark Notorhynchus, and Centrophorus, a new species of Seven-gilled Shark Heptranchias is being described from this locality by the author. Elsewhere the Keasey sediments have yielded a large and well-preserved tooth of the White Shark Carcharodon, Saw Shark Pristiophorus, and the Mako Shark Isurus.

Coquina-like concretionary biostromes of clastic shell material which crop out along roadcuts in the lower sections of the Pittsburg Bluff Formation yield numerous teeth of a small squalid shark Centroscyrnus and not uncommonly teeth of Raja, Squatina, Odontaspis, Squalus, Pristiophorus (Pl. 1, 6), and Notorhynchus (Pl. 1, 1). These genera, plus several additional forms, collectively constitute the most diverse assemblage yet known from the middle Oligocene of Oregon.

Younger Oligo-Miocene sands of the Scappoose Formation, which conformably overlies the Pittsburg Bluff Formation, have produced teleost teeth and a fragmentary tooth crown of Squatina.

Underlying the Astoria Formation at Newport and south toward Seal Rock are found sediments of early Miocene age which are assigned to the Nye Mudstone. A Six-gilled Shark Hexanchus (Pl. 1, 2), Squalus (Pl. 1, 7), Pristiophorus, Squatina (Pl. 1, 5a, b), Odontaspis, and Isurus are found. This constitutes the only assemblage of early Miocene sharks yet known from Oregon.

The Miocene Astoria Formation has extensive exposure along the Oregon coast north of Newport, yet it has yielded only a few sharks teeth. This is quite surprising in light of the great abundance of teeth found in sediments of equivalent age from California and the Atlantic Coast of the United States. The assemblage at this time consists of the following: Carcharodon megalodon, Hexanchus, Myliobatis, Isurus planus?, and Galeocerdo cf. aduncas. In addition, Dr. E. M. Baldwin of the University of Oregon Department of Geology has in his possession a large tooth belonging to a Mako Shark, Isurus hastalis. This tooth was collected from sediments which were dredged up in Coos Bay and presumably are Miocene in age. Two Squalus teeth have also been collected from late Miocene sandstones immediately south of Cape Blanco, Oregon.

To my knowledge, teeth of sharks or rays have not yet been collected from Pliocene or Pleistocene sediments in Oregon. This is not to say that they do not exist but only that very little attention has been directed towards searching for shark teeth in these sediments.

Discussion

It is difficult to identify unassociated fossil sharks teeth; to do so requires a thorough understanding of the variability of tooth morphology among species of modern sharks and rays. Teeth may be individually examined for the presence or absence of the following general features: crown and root shape; position of nutrient canals; serrations on the crown and denticles; number of lateral denticles; tooth size; and flexures in the crown. Any number of these characteristics may require critical examination in order to segregate teeth of different species.

Variations in tooth morphology may be observed within the jaws of almost any modern shark or ray. Teeth of a single species may differ in the upper and lower jaw or laterally in a single tooth row. Tooth variation also occurs as a result of age and sexual dimorphism. In order to establish valid taxa when working with unassociated fossil teeth, it is necessary to construct entire tooth sets which define the total range of variation within the species. This technique has proven to be useful for the interpretation of large faunas in California and is presently being applied to Oregon sharks and rays.

The paucity of some of the faunas previously described is for the most part apparent rather than real. It is due to the nature and conditions of deposition of the sediments and does not accurately represent the characteristics of the actual biotic community. The physical conditions of sedimentation and biologically limiting factors in the environment directly influence the resultant fossil assemblage. Where active transport or agitation of sediments occurs during deposition, organic remains may be subjected to severe abrasion, often resulting in the accumulation of clastic shell debris and total destruction of all softer parts. Sorting of teeth may occur as a result of strong current action, and post-depositional leaching by ground water can destroy tooth dentine. The latter best describes the conditions which must have existed during the formation of the Helmick Hill shark tooth bed. Only rarely do Oregon localities yield nontransported shark material. However, excellent undisturbed faunas have been obtained from a few outcrops of the Coaledo, Nestucca, and Keasey Formations.

Summary

The purpose of this paper is to give some account of the fossil shark faunas of Oregon. This has been, at best, only introductory to the more than 5,000 specimens now being studied by the author. Many of the genera are listed in Figure 2, but species determinations have not yet been completed. In most instances, more than one species exists for each genus listed. Newly developed localities are continuing to yield more material, and it is hoped that each of the faunas mentioned herein will be treated in full at a later date.

Acknowledgments

Special thanks are expressed to Dr. Shelton P. Applegate, Los Angeles County Museum of Natural History, for the opportunity to study specimens of sharks at the Museum and for his assistance in the verification of the Oregon material.

I am also grateful to David Taylor of Portland, Oregon, the Oregon Museum of Science and Industry, and the State Department of Geology and Mineral Industries for making their collections of Tertiary sharks teeth available for this study.

Thanks are given to Dr. R. E. Thoms, Brian Gannon, Dr. Ronald Wolff, Margaret Steere, and Frank Kistner, who kindly read and criticized the manuscript. Photographic equipment was loaned by Larry Chitwood, and the manuscript was typed by Chris Lewis.

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* * * * *

GEOLOGY, KEY SCIENCE IN RESOURCE AND ENVIRONMENTAL PROBLEMS

Geological sciences are the key to understanding many of the problems related to resource development, land use, and the preservation of environmental quality, according to Dr. V. E. McKelvey, Director, U.S. Geological Survey, Department of the Interior.

In an address at Syracuse University, Syracuse, N.Y., McKelvey emphasized the urgency of advancing our knowledge about the earth and its resources. "In a physical sense," he said, "our life is dependent on the use we make of the earth and its resources."

"Between now and the end of the century," he said, "we will need to build a Second America in the sense that we have to duplicate the entire U.S. plant -- factories, homes, highways, and hard goods."

"We will need at least as much in the way of mineral and fuel resources in the next 28 years as we have used in all our previous history," the Survey Director warned, noting also that "if we do not conduct our activities in an environmentally safe manner, we could do as much harm to the environment as we have done previously. In some areas of environmental stress, this might well mean that we would destroy the suitability of our environment for human habitation."

"With our dependence on minerals and fuels," McKelvey said, "the consequences of failure to anticipate mineral shortages in time to make appropriate adjustments could well be catastrophic. And if, as some fear, potential resources are not adequate to support continued economic growth, considerable time would be required to bring about the economic and social changes necessary for our society to function at a far lower level of resource consumption without suffering economic collapse and perhaps social chaos."

Noting that many doubt that we can long continue our accelerating use of resources, McKelvey cited a study (conducted at M.I.T. under the sponsorship of the Club of Rome) concluding that world resources would be exhausted in less than 100 years if we continue our exponentially increasing consumption, and that consequent growth in pollution and environmental damage would be equally disastrous.

"While I find much to commend in this study," McKelvey said, "I do not share fully in the conclusions, partly because they substituted assumptions about the magnitude of resources for knowledge of the potential, and partly because they did not allow for the effects of exponentially accelerating knowledge and ingenuity in creating resources and controlling the effects of their production and use. Nevertheless, the study shows clearly that we will have to scramble to meet future needs, and to preserve the viability of our environment."

"In appraising these problems we need to substitute knowledge for the optimism or pessimism that is now the principal basis for speculation about man's future," McKelvey said.

* * * * *

COAST ENVIRONMENTAL GEOLOGY PUBLISHED

Engineering geologists, stratigraphers, and ground-water specialists have collaborated in preparing the Department's latest publication, Bulletin 74, "Environmental Geology of the Coastal Region of Tillamook and Clatsop Counties, Oregon." The authors are H. G. Schlicker, R. J. Deacon, J. D. Beaulieu, and G. W. Olcott.

The bulletin and accompanying maps are designed primarily for county officials, planners, engineers, and private citizens concerned with future construction and development appropriate to the geologic character of the region. In this part of Oregon, unstable bedrock, heavy rainfall, topographic extremes, and proximity to the ocean are inherent features that combine to produce geologic hazards such as landsliding, flooding, soft ground, wave erosion, and dune movement.

The 164-page publication is abundantly illustrated by photographs and charts. Eighteen full-color maps in a separate envelope illustrate engineering geology, geologic hazards, and degree of slope for each of six quadrangles. The report itself describes the geologic units, engineering characteristics of each unit, economic mineral resources, and geologic hazards. A summary and recommendations and a glossary of technical terms are also included. Quarry sites, water-well logs, and other pertinent data are given in the appendix.

Bulletin 74 and maps are for sale as a unit by the Oregon Dept. of Geology and Mineral Industries at its Portland office. The price is \$7.50.

* * * * *

DOLE OUTLINES GROWING RELIANCE ON MINERAL IMPORTS

Hollis M. Dole, Assistant Secretary of the Interior for Mineral Resources, recently outlined the degree to which the United States is becoming dependent on foreign supply sources for its mineral requirements. Speaking Oct. 3 at an AIME meeting, Dole said, "The gap between our supply and our demand (for minerals) has risen from \$2 billion in 1950 to \$8 billion in 1970 and is projected to increase to \$31 billion in 1985 and \$64 billion in the year 2000." He based these figures on Interior's first annual report under the Mining and Minerals Policy Act of 1970.

Among the problems that prevent the full potential of the nation's resources from being realized, Dole stated, are environmental constraints that have forced the closing of almost half the nation's zinc refining capacity; the loss of markets by coal which is unable to meet sulfur content limitations; the denial of access or withdrawal from development of mineralized lands; and competition from other nations for access to foreign supplies.

(American Mining Congress News Bull., Oct. 13, 1972)

* * * * *

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COASTAL LANDFORMS BETWEEN TILLAMOOK BAY AND THE COLUMBIA RIVER, OREGON

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The 50-mile stretch of the Oregon coast between Tillamook Bay and the Columbia River can be divided into three nearly equal segments according to the kinds of landforms along them. The southern segment extends from Tillamook Bay to Neahkahnie Mountain (map 1), the middle from Neahkahnie Mountain to Tillamook Head inclusive (map 2), and the northern from Tillamook Head to the Columbia River (map 3). The discussion of the landforms is presented in the order of these divisions.

In preparing this article, an attempt was made to use as few technical terms as possible in view of the fact that many of The ORE BIN readers may not have had formal education in the earth sciences. It is not possible, however, to avoid all technical terms in a presentation such as this; therefore, a glossary of words most likely to be troublesome is available at the end of the article.

Tertiary Bedrock and its Role in Landform Development

Bedrock along this part of the Oregon coast consists of marine sedimentary strata of Oligocene to mid-Miocene age and Miocene basalt of intrusive and extrusive varieties. The sedimentary rocks have been subdivided by Schlicker and others (1972) into two parts: unnamed strata of Oligocene to mid-Miocene age and the middle Miocene Astoria Formation as redefined. Miocene sedimentary rocks and basalt are in part contemporaneous, and in places the two are interbedded (Snively and Wagner, 1963). Their distribution is the main factor in the development of the shore's configuration and of the landforms along it.

Marine sedimentary rocks

Many of the coastal exposures consist of sedimentary strata assigned to the Astoria Formation. The deposits were probably laid down in shallow marine embayments along the western margin of Oregon during middle Miocene time after the Coast Range uplift had begun. Beds vary from place to place in rock type but consist mainly of olive-gray sandstone and dark-gray siltstone and shale. There are also beds of yellowish-gray, water-laid volcanic ash that range from a few inches to 18 feet in thickness, and because the ash is similar in composition to ash of the same age in the western Cascades, it is believed to have come from eruptions in an ancestral Cascade Range (Snively, Rau, and Wagner, 1964). In comparison to the basalt, the sedimentary rock is weak in its ability to withstand erosion, and it is in this rock that the coves, bays, and other re-entrants along this part of the coast are formed.

Basalt

At the time lava was pouring out of the earth to form the Columbia River Basalt in the Columbia River Gorge and the basalt layers of the Columbia Plateau, basalt lava was erupting from vents near the present shoreline. Some of the basalt erupted under the sea, or poured into it, where it became complexly intermixed with the sediment on the sea floor. The rock of these flows is usually fragmental in contrast to the more homogeneous, dense rock that poured out on land. Associated with the flows are intrusions, mainly dikes and sills, that solidified at shallow depth beneath the earth's surface. The rock of the smaller intrusions is fine grained and dense, but in the larger ones the grain size is coarse enough that individual mineral grains are readily discernable. Some is sufficiently coarse to be classed as gabbro, the coarse-grained equivalent of basalt.

Basalt was once continuous over a large area along the northern part of the Oregon coast and inland from it and probably was continuous with basalt of the Columbia River Gorge and the Columbia Plateau. Only remnants, mainly at or near centers of eruption, are left, and where they are located along the shore, they form the prominent headlands and points and the reefs, stacks, and arches just offshore from them.

Differences in hardness of the basalt from place to place and fractures and shear zones cutting through it have contributed to different rates of erosion, and differential erosion accounts for the variety of forms developed on basalt along the shore and offshore. Masses of hard rock surrounded by less resistant rock get isolated from the mainland by wave erosion to form the stacks and arches. The aligned rock reefs are remnants of what was once mainland. Trenches are cut into the basalt where it has been fractured, and caves penetrate the sea cliff along fractures or where a weak layer is exposed within reach of the waves. The irregularity of a given rock mass is a function of the rate at which its parts get removed by erosion, the attack of the waves being guided by the weak places.

Quaternary Deposits

Terrace deposits

Terraces are not as prevalent along this part of the Oregon coast as they are along the central and southern parts. However, in a number of places terrace sand and gravel are preserved over a wave-cut bench of Pleistocene age. The terrace was eroded into the marine sedimentary rocks at a time when sea level stood higher relative to the land than it does now. In places the terrace deposits are covered by sand dunes, and the bench form of the terrace is obscured.

Dune sand

Dunes are extensive in the southern and northern segments, where they occupy the lowland areas underlain by marine sedimentary bedrock. Sea cliffs along the shore of the middle segment have prevented dune development there, except at the mouth of Elk (Ecola) Creek. The complicated cross bedding seen in some road cuts through dunes is the diagnostic feature that distinguishes dune sand from the horizontally bedded terrace sand.



Figure 1. Twin Rocks are offshore remnants of basalt. The one at the left is an arch and the other a stack.



Figure 2. Alluvial plain of Nehalem River formed during the Pleistocene at a time of higher sea level.

Alluvium

Deep alluvial deposits are extensive along the major streams and around the bays. Sand, silt, and mud are presently being deposited by streams, especially at their lower ends where their flow is checked by tidal currents. Much of the sediment, however, was laid down at times during the Quaternary when the condition of flooding was promoted by higher sea levels.

Landforms

Southern segment (map 1)

The shore from Tillamook Bay to the base of Neahkahnie Mountain is bordered by a sand beach that is continuous except where it is interrupted by the Nehalem River. Aside from some very small areas of basalt that lie back from the beach and Twin Rocks that lie just offshore opposite the Twin Rocks community, the area is underlain by marine sedimentary strata.

At the southern end is Tillamook Bay, a large bay lying behind a sand peninsula that projects northward from Cape Meares. The water body is shallow over most of its extent, and it covers only about a fourth of the area once occupied by water in a Pleistocene embayment. The other three-fourths has been filled by bay sediment and river alluvium laid down by the Tillamook, Trask, Wilson, Kilchis, and Miami Rivers and smaller streams that flow into the bay.

Small sea stacks and an arch just inside the bay about three-quarters of a mile east of Barview were formed when waves of the open ocean washed this part of the bay shore. These stacks are unusual in that they are composed of sedimentary rock.

Between Tillamook Bay and the mouth of Nehalem Bay is a narrow strip of coastal plain that is on a low bench cut on marine sedimentary rock. The western edge of the strip is occupied by dunes that begin in a dune complex just north of the outlet of Tillamook Bay and continue in a dune ridge that extends northward just behind the shore. A low, relatively level terrace surface lies between the dune ridge and the upland. Small lakes, the largest of which are Smith Lake, Crescent Lake, and Lake Lytle, are impounded by the dunes.

Two basalt remnants, Twin Rocks (Figure 1), lie a few hundred feet off the Beach at the Community of Twin Rocks south of Rockaway. One of them is a sea stack and the other is an arch.

At its north end, the narrow coastal plain strip is terminated by Nehalem Bay, the estuary of Nehalem River. As with Tillamook Bay, Nehalem Bay occupies only a fraction of the area of an earlier Pleistocene embayment. Bay filling and deposition of alluvium by the Nehalem River have formed an alluvial plain that extends inland along the river for nearly 10 miles (Figure 2). The fertile alluvial plains around several bays, including Tillamook and Nehalem, and along the many coastal streams support the Tillamook County dairy industry, which produces world-famous Tillamook cheese.

Projecting southward in front of Nehalem Bay is a long sand peninsula, a sand-spit, that deflects the flow of the Nehalem River southward $2\frac{1}{2}$ miles from the main body of the bay (Figure 3). Sandspits such as this have formed at the mouths of bays all along the Oregon coast. Some project northward and others southward, the direction being determined mainly by whether they are influenced more by the northward



MAP 1
Tillamook Bay to Neahkahnie
Mountain

EXPLANATION

- Qal** Alluvium and dune sand
- Qmt** Marine terraces

UNCONFORMITY

- Tms** (dotted pattern) Miocene volcanic rocks
 Localized accumulations of massive basalt breccia, basalt flows, poikiloblastic breccia and pillow lavas
- Tms** (cross-hatched pattern) Intrusive rocks
 Middle to late Miocene basaltic intrusive rocks which include thick sills

UNCONFORMITY

- Tms** (horizontal line pattern) Oligocene to Miocene sedimentary rocks
 Over 5,000 feet of thin-bedded to massive, medium-gray to dark-gray, silty, claystone and claystone with subordinate amounts of sandstone and shale locally

UNCONFORMITY

- Tms** (dotted pattern) Undifferentiated Eocene volcanic rocks
 Several thousand feet of interbedded basalt flows and basalt breccias of submarine and subaerial origin

- F** Faults
 Dashed where approximately located or indefinite, dotted where concealed
 U, upthrown side; D, downthrown side

- C** Contacts
 Dashed where approximately located

- S** Approximate strike and dip of beds or flow

- L** Active landslide





Figure 3. View south from Neahkahnie Mountain. The community of Neahkahnie, at far left, is partly on a terrace segment, and the forested area is on stabilized sand dunes. A sandspit projects southward and deflects the Nehalem River to the south. (Oregon State Highway Div. photo)



Figure 4. Foredune on the Nehalem sandspit. The dune is stabilized by marram grass, bushes, and young trees. Neahkahnie Mountain is in the distance.

longshore drifting of winter or the southward longshore drifting of summer.

Waves generated by wind move shoreward, where, on encountering the shallow water near the beach, they break and the water moves back and forth over the beach in the swash zone. Where waves strike the beach obliquely instead of head on, the water in the swash moves onto the beach obliquely and off again in the backwash. The repetition of this cycle imparts a zig-zag motion to the water particles as they are moved on and off the beach by successive waves. Sand particles moved by water in the swash zone follow a similar zig-zag path and are transported along the beach according to the direction at which the waves strike the shore. This movement of sand is referred to as beach drifting.

Just off the beach, water affected by the waves approaching the shore obliquely is caused to flow along the shore in what is termed a longshore current. Sand churned up by the turbulent water in the surf zone is moved by the longshore current in the same direction as sand is moved by beach drifting, and the combined movement is referred to as longshore drifting.

Where there is a marked change in the direction of the shore, as at the mouths of bays, some of the sand moved by longshore drifting is deposited in a sandspit, which is attached to land at one end and terminates in water at the other. The force of waves moves sand towards the bay, but the outflow of water from the bay presents an opposing force. The site of deposition of sand in the sandspit represents a position of compromise between these two forces. The southward-projecting spit in front of Nehalem Bay was built by the longshore drifting of sand in the summer months, when the winds along the coast come mainly from the north and northwest.

A foredune ridge extending along the Nehalem sandspit on its seaward side (Figure 4) is of recent origin and was formed by the accumulation of sand blown off the beach. The sand has accumulated in hillocks around logs and clumps of marram grass, a beach grass imported from Europe for the purpose of stabilizing dune areas along the west coast. As the hillocks increased in size, they coalesced to form a continuous, knobby ridge.

At its north end, the foredune merges into an older dune complex that is stabilized by a forest. Over most of their area the older dunes are superimposed on a segment of marine terrace. Along their edge closest to the mountain they rest on sedimentary bedrock, which forms the hilly land just south of the mountain. The town of Manzanita and part of Neahkahnie community are built in this area of older dunes.

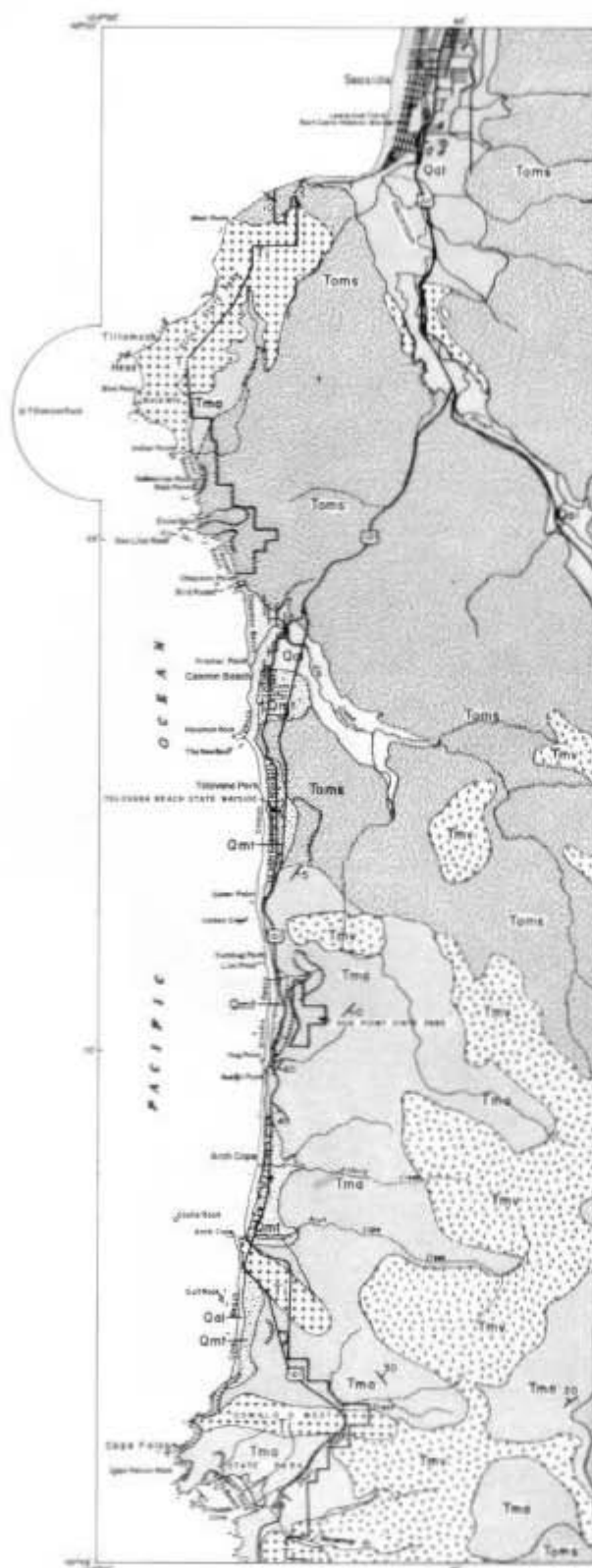
Middle segment (map 2)

Basalt promontories with their associated shore forms and the beaches that lie between them characterize the shore between Neahkahnie Mountain and Tillamook Head.

Neahkahnie Mountain, which rises steeply from a hilly terrain of Astoria Formation north of Nehalem Bay, is made of coarse-textured basaltic rock that solidified at shallow depth in some form of igneous intrusion. The texture of the rock is distinctly coarser than that of basalt in other headlands, and the rock is properly referred to as gabbro. Somewhat elongate in an east-west direction, the mountain terminates in a high, steep sea cliff (Figure 5). The slope angle of the cliff is determined by joints that are steeply inclined seaward. As the base of the cliff is undermined by the waves, large slabs of rock break off along the joint surfaces and slide into the ocean. At the outermost point of the mountain, erosion has worked along joints in such a way that rock was removed from behind the cliff face to form a tunnel.



Figure 5. Cliff face on Neahkahnie Mountain. Cape Falcon is in the distance, and Smuggler Cove lies between these promontories. (Oregon State Highway Div. photo)



MAP 2
Neahkahnie Mountain to Till-
amook Head

EXPLANATION



Alluvium and dune sand



Marine terraces

UNCONFORMITY



Miocene volcanic rocks
 Localized accumulations of massive basalt breccia,
 basalt flows, pelagonitic breccias and pillow
 basalts



Intrusive rocks
 Middle to late Miocene basaltic intrusive rocks
 which include thick sills



Astoria Formation
 Approximately 2,000 feet of consolidated to semi-
 consolidated, thick-bedded to thin-bedded,
 medium-grained, buff, micaceous, arkose sand-
 stone and interbedded siltstone of early Miocene
 age

UNCONFORMITY



Oligocene to Miocene sedimentary rocks
 Over 5,000 feet of thin-bedded to massive,
 medium-gray to dark-gray, buffaceous siltstone
 and claystone with subordinate amounts of sand-
 stone and shale locally



Faults
 Dashed where approximately located or
 indefinite, dotted where concealed
 U, upthrown side; D, downthrown side



Contacts
 Dashed where approximately located



Approximate strike and dip of beds or flow



Active landslide

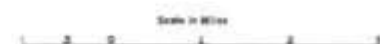




Figure 6. Short Sand Beach and Smuggler Cove. The rock behind the beach and flanking Neahkahnie Mountain on the north is sedimentary.



Figure 7. Small cove between two points of land on Cape Falcon. The rock in the sea cliff is intrusive basalt overlain by sedimentary beds.

Lying between Neahkahnie Mountain and Cape Falcon to the north is Smuggler Cove with Short Sand Beach (Figure 6) at its head. The cove is in the Astoria Formation, which forms sea cliffs on both the north and south sides and behind Short Sand Beach. Several small streams flow into the cove. Where Short Sand Creek and Necarney Creek enter it at the south end of the beach, there is a small area of low terrace on which camping and picnic facilities have been built. The water in the cove is sufficiently deep to be used by small craft when the open ocean gets rough. The configuration of the cove gives protection against the strong northwest winds of summer.

Cape Falcon is a headland comprising two points separated by a very small cove. Like the other headlands along this part of the coast, Cape Falcon is composed principally of basalt, but the southernmost point, the one bordering Smuggler Cove, is mainly sedimentary rock. This appears to be an anomalous condition but is explained by the presence of basalt beneath the sedimentary rock. Basalt forms the northern point and is exposed beneath sedimentary rock in the sea cliff around the small cove between the two points (Figure 7). The basalt is a sill-like body which is inclined toward the south at such an angle that, although exposed in the cove, it is below the water's surface on the south side of the southern point. Here a very hard layer of sandstone, further hardened by the intrusion of the basalt beneath it, is at the water's edge and offers unusual resistance to erosion. The basalt, however, gives the main support to the point. Several shallow caves have been cut along fractures in the basalt on the south side of the small cove between the two points, and a tunnel, visible from the highway, passes through the tip of the point bordering Smuggler Cove.

Neahkahnie Mountain and Cape Falcon are parts of a headland complex that extends northward to Arch Cape and lies at the southern end of an extensive area of basalt that forms a mountainous terrain inland. Sedimentary rock is interspersed with basaltic rock, and coves with sand beaches at their heads are developed where belts of the sedimentary rock are sufficiently wide. Short Sand Beach and Cove Beach are examples of sandy coves cut into sedimentary rock in a dominantly igneous terrain.

From Arch Cape to the promontories of Tillamook Head, the bedrock is almost continuously sedimentary and the land is low. The lowland area is level where there is a terrace and irregular where ridges of the hills to the east project to the shore. Elk (Ecola) Creek has removed the terrace and formed an alluvial plain at the northern end of the lowland, and the business section of Cannon Beach is built on this plain. North of the city a prominent dune, Pompadour Ridge, lies between the beach and the alluvial plain.

The shore in front of the lowland is sand beach interrupted here and there by small points of land supported by basalt and in some places massive sandstone. One of the breaks in the continuity of the beach is at Hug Point, a cluster of small promontories and intervening short beaches (Figure 8). North of Silver Point, Cannon Beach extends without interruption as far as Chapman Point. The beach segment between Elk Creek and Chapman Point is sometimes referred to as Chapman Beach.

Besides the several small promontories of basalt along the shore, numerous basalt remnants in the form of rock knobs and sea stacks lie just off shore. The most notable of these is Haystack Rock (Figure 9). This stack is principally fragmental basalt cut by numerous dikes. Near its base and in the satellite stack attached to the south side there is sedimentary rock intermixed with the basalt, which suggests the rock is of submarine origin or of lava that poured into the sea. Haystack Rock can be reached at low tide by a strip of sand, a tombolo, that extends to it from the beach.



Figure 8. Beach and promontory at Hug Point State Park. The rock at this locality is mixed basalt and sediment and contains numerous sea caves, mostly in sedimentary rock. (Oregon State Highway Div. photo)



Figure 9. Haystack Rock is mainly of fragmented basalt. At its base and in the small "satellite" stack next to it, sedimentary rock is intermixed with the basalt.



Figure 10. Interlayered basalt and sedimentary rock at Crescent Beach. The light bands are the sediment.



Figure 11. Contorted folding in sedimentary strata at the north end of Crescent Beach. This complex folding is probably the result of slumping in the sediment brought on by volcanic activity. A sill-like body of basalt lies at the base of the folded beds.

North of Cannon Beach is Tillamook Head, a complex of bold headlands, points of land, and intervening coves and shallow indentations. The main rock of this area is basalt, but in places basalt is complexly intermixed with sedimentary rock. Most of the basalt was emplaced as flows of both dense and fragmental varieties, and sedimentary beds are interlayered with basalt flows (Figure 10). Numerous basalt dikes and sills intruded the sedimentary strata.

The igneous activity, both intrusions and submarine flows, disturbed the sedimentary strata (Figure 11), which was not yet consolidated into firm rock, and unstable zones were formed in the rock masses. Where unstable zones are exposed to wave erosion, they are sites of landslides. Slides have been particularly active south of Tillamook Head between Chapman Point and Indian Point and are described by Schlicker, Corcoran, and Bowen (1961) and North and Byrne (1965). Rock in slide areas is predominantly sedimentary.

Destructive though they may be, landslides have had their role in shaping the indentations that lie between the points of land and have thereby made their contribution to the magnificent scenery at this locality. The coves that lie between Chapman and Ecola Points (Figure 12) and Ecola and Indian Points (Figure 13, 14) are both sites of ancient as well as active landslides. Bald Point, just south of Indian Beach, is the toe of an old landslide behind which is an active landslide area. The parking and picnic area at Ecola Point is on a landslide area that moved in February 1961 (Schlicker, and others 1961). Fortunately landslides in this locality move slowly, no more than a few feet a day, and take place during the winter months.

The rocks that lie off Chapman and Ecola Points mark former positions of these promontories, and the points once extended seaward much farther than the outermost rocks. As erosion continues the existing points will be destroyed, and their remnants will become units of the reefs as part of the very gradual but continuous change in scene along the shore.

One of the most remarkable features of this part of the coast is Tillamook Rock (Figure 15), a 100-foot high basalt sea stack that lies a little more than a mile west of Tillamook Head. This stack, which was once part of the mainland, has survived the attack of the sea through the millenia that were required for the rock around it to be removed and the shore to be eroded landward to its present position. This stack is the site of Tillamook Lighthouse, which operated for more than 80 years until discontinued in 1962.

The main mass in the complex, Tillamook Head, consists of two major lobes separated by a broad, crescent-shaped indentation (Figure 16). The basalt along the front of the headland is dense and without layering and is some sort of intrusive body, probably a thick sill. Sedimentary rock underlies the lower slopes on the north side of the head. A high, steep cliff bounds Tillamook Head, and at numerous places, especially around the south side, indentations cut into bodies of sedimentary rocks impart an irregularity to the shore line. Narrow, rocky beaches that are not easily accessible lie at the base of the sea cliff.

Northern segment (map 3)

Stretching from Tillamook Head northward to the Columbia River is a strip of coastal lowland, the Clatsop Plains (Figure 16), which is covered mainly by dunes. At its southern end the strip is a little more than a mile wide, and in its northern part it is about 3 miles wide. The plain extends eastward along Young's Bay as river alluvium, and alluvial plains extend southward from it along Young's River and Lewis and Clark River.

MAP 3 **Tillamook Head to Columbia** **River**



EXPLANATION



Alluvium and dune sand

UNCONFORMITY



Intrusive rocks
 Middle to late Miocene basaltic intrusive rocks
 which include thick sills

UNCONFORMITY



Oligocene to Miocene sedimentary rocks
 Over 5,000 feet of thin-bedded to massive,
 medium-gray to dark-gray, buffaceous siltstone
 and claystone with subordinate amounts of sand-
 stone and shale locally



Faults
 Dashed where approximately located or
 indefinite, dotted where concealed
 U, upthrown side; D, downthrown side



Contacts
 Dotted where approximately located



Approximate strike and dip of beds or flow



Active landslides





Figure 12. Crescent Beach viewed from Ecola Point. Chapman Point, at its south end, appears to be a remnant of a basalt sill. Beyond are Cannon Beach and Haystack Rock. The mountains that form the skyline are of basalt. (Oregon State Highway Div. photo)



Figure 13. Indian Beach in the upper right of the photograph, is bounded on the north by Indian Point, composed of basalt, and on the south by Bald Point, the toe of a landslide. The sea caves at lower right are in basalt overlain by sedimentary rock. (Oregon State Highway Div. photo)



Figure 14. Indian Beach and Bald and Ecola Points. Sea Lion Rock, near the end of the reef off Ecola Point, is an arch. The rock in the reef is principally basalt, but some complexly folded sedimentary rock is intermixed with it. (Oregon State Highway Div. photo)



Figure 15. Tillamook Rock is a basalt sea stack lying about a mile west of Tillamook Head. Use of the lighthouse was discontinued in 1962 after 80 years of service. (Oregon State Highway Div. photo)



Figure 16. Tillamook Head, a basalt headland, is the central feature of this aerial photograph. The Clatsop Plains extend northward to the Columbia River in the distance. Indian Point is at center of photograph, and Ecola Point is at right of center. (Univ. Calif. Hydraulic Eng. Lab. photo)

The dunes of the Clatsop Plains are described and their origin is well explained in a book on the dunes of the Oregon and Washington coast by Cooper (1958), and the writer of this article draws heavily from Cooper's work. A map that shows the distribution of Tertiary bedrock, dunes, and alluvium accompanies an article on the hydrology of the Clatsop Plains by Frank (1970).

Dunes of the Clatsop Plains are impressive in the extent and uniformity of individual dune ridges and their parallel arrangement with each other and with the shoreline (Figure 17, 18). Ridges that vary only slightly in height and width and that curve gently to conform to the shoreline can be traced for long distances, in places for miles.

The Clatsop Plains is an area of fill where sand has been deposited parallel to a westward shifting shoreline along a coastal indentation which extends from Tillamook Head in Oregon to Cape Disappointment in Washington. Filling (prograding) began some time after sea level reached its maximum height following the most recent glaciation, and the origin of the dunes is closely tied to the prograding of the shore.

Prior to prograding, the shore was along the Tertiary upland, and the mouth of the Columbia River lay between Cape Disappointment on the north and the upland east of the Skipanon River on the south. Cooper (1958) believes that building of the plains was initiated by the deposition of a northward-projecting sandspit at the south side of the mouth of the Columbia River and that progradation along the shore began with construction of a sand bar in front of what is now Cullaby Lake. This was followed by the building of a succession of sand ridges along the shore as the beach shifted westward. Most of the ridges originated as foredunes. Sand transported mainly



Figure 17. Dune ridges and lakes on the Clatsop Plains. Sunset Lake is the long one extending from the lower left corner of the photograph. Though it doesn't conform strictly to a single interdune valley, its shape is determined by the ridge-valley pattern. The north end of West Lake, right of center in the lower part of the photograph, cuts diagonally across the ridge-valley pattern and probably was a channel that connected to the sea when the shore stood along the edge of the dune ridge immediately west of it. (Univ. of Calif. Hydraulic Eng. Lab. photo)



Figure 18. Green and fairway (hole 14) in an interdune valley on the Astoria Country Club golf course.



Figure 19. Coffenburg Lake in Ft. Stevens State Park is one of the largest interdune lakes on the Clatsop Plains. (Oregon State Highway Div. photo)

by the south-flowing summer currents washed up onto the beach, where it was picked up by wind and redeposited just behind the beach. Cooper believes that where a ridge has a wide strip of bog or a lake of considerable size behind it, origin as an offshore bar is indicated. Once a bar becomes exposed above sea level, it comes under the influence of the wind, and its size is increased by the addition of wind-blown sand.

Point Adams was the terminus of the sandspit that initiated progradation and was the end of land until the beginning of jetty construction in 1885. With the building of the south jetty, sand filled in over the shoal area off Point Adams to form Clatsop Spit. A wedge-shaped area of new land that is about half a mile wide at Fort Stevens was built up along the shore south of the spit. Sand was added to the beach as far south as Seaside, and parts of the beach that were formerly rocky are now covered with sand. A foredune ridge stabilized by marram grass lies behind the beach at Clatsop Spit and continues along the shore to the south, where it widens out into a terrain of grassy hillocks. South of Sunset Beach the hillocks give way to a narrow, grassy plain that lies between the beach and the first dune and extends to the mouth of the Necanicum River.

The numerous lakes on the Clatsop Plains owe their origin to the dunes. Most occupy depressions in the interdune valleys and are generally elongate in the direction of the ridges. Sunset (Figure 17), Coffenbury (Figure 19), and Smith Lakes are examples of this type. Cullaby Lake was impounded against the upland by dune sand, and the configuration of its eastern edge conforms to the erosional surface on the upland. Valleys in the topography became the finger projections of the lake and the dividing ridges the points of land between the fingers.

Many of the lakes have no surface outlets or appreciable inlets. The level of the lakes conforms to the level of the ground water table, and movement of water into and out of the lakes is by percolation through the sand. Sunset Lake has an outlet in Neacoxie Creek, which, although it is located within half a mile of the ocean at the point it leaves the lake, must flow southward about 4 miles to join Neawana Creek and the Necanicum River before it enters the ocean. The Necanicum River, which is deflected northward nearly 3 miles by a rock and sand barrier, is the only stream that crosses the beach between Tillamook Head and the Columbia River. North of it the wide, gently sloping beach extends without interruption for more than 15 miles.

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Glossary

Alluvium: Sediment deposited by streams.

Basalt: Dark-colored, fine-grained rock of volcanic origin.

Bedrock: Solid rock beneath soil or sediment layer. May be exposed.

Dike: Tabular-shaped intrusive igneous body that cuts through another rock.

Estuary: Lower part of river affected by tides and mingling of salt water from the ocean with fresh water of the river.

Foredune: Dune ridge that forms just behind and parallel to the beach.

Formation: 1. Land form. 2. Body of rock, the parts of which are related in space, time, and/or origin, such as Astoria Formation.

Igneous: Refers to rock formed from molten matter (magma) that originates deep below the earth's surface.

Intrusion: An igneous rock body that solidifies below the surface of the earth where magma invades older rock.

Joint: In geologic language, a fracture or parting which interrupts the physical continuity of a rock mass.

Quaternary: The latest Period of geologic time; began about 2 million years ago. Includes Pleistocene (Ice Age) and Holocene (recent) Epochs.

Sea stack: Small prominent island of bedrock near shore.

Shale: Laminated sedimentary rock made of solidified mud.

Shear zone: A zone in a rock body where the rock has been broken into fragments by fracturing and shearing.

Sill: A tabular-shaped intrusive igneous body that has been emplaced parallel to the bedding of the intruded rock.

Terrace: Bench-like landform cut into bedrock or built up by sedimentary deposition. Oregon shore terraces have aspects of both.

Tertiary: Period of geologic time between 65 million and 2 million years ago. Includes Paleocene, Eocene, Oligocene, Miocene, and Pliocene Epochs in order of decreasing age.

* * * * *

NEWPORT AREA MAPS ON OPEN FILE

The U.S. Geological Survey has released on open file three preliminary bedrock geologic maps of six quadrangles in the area of Newport, Oregon, by P. D. Snively, Jr., N. S. MacLeod, and H. C. Wagner. The maps are printed in black and white on three sheets as follows: Cape Foulweather and Euchre Mountain, Yaquina and Toledo, and Waldport and Tidewater quadrangles. They are available for inspection at the Oregon Department of Geology and Mineral Industries in Portland, and copies can be purchased at \$1.00 per sheet at a scale of 1:62,500, or \$1.50 per sheet at a scale of 1:48,000. If ordered by mail, add 10 cents per sheet for cost of mailing.

* * * * *

COLEBROOKE SCHIST DESCRIBED IN SURVEY BULLETIN

"The Colebrooke Schist of Southwestern Oregon and its Relation to the Tectonic Evolution of the Region," by R. G. Coleman, has been published as Bulletin 1339 by U.S. Geological Survey. The 61-page bulletin with one plate in pocket is for sale by the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. The price is \$1.00.

The Colebrook Schist occurs in the Klamath Mountains in western Curry and Coos Counties. It consists of sediments and lavas similar to the Galice Formation which were metamorphosed in Early Cretaceous time and in Late Cretaceous were thrust on top of shelf and trench sediments that range in age from Late Jurassic to Early Cretaceous.

* * * * *

ASSESSMENT WORK NECESSARY TO RETAIN MINING CLAIMS

A change in Federal government regulations which became effective September 9 says that persons claiming minerals under the Mining Claim Act of 1872 must do the \$100 annual assessment work or face loss of their claim. The change was announced by Archie D. Craft, State Director of Bureau of Land Management, the agency which administers the mining laws in Oregon.

The new regulations say that failure of a claimant to do the annual work in either labor or improvements will render the claim subject to cancellation. Failure will also subject the claim to relocation by another party unless the original locator or his successors in interest resume the annual work before someone else "jumps the claim."

Craft said, "We anticipate the new rules will help appreciably in clearing titles to public lands which are clouded by abandoned or dormant mining claims."

* * * * *

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SOME COMMERCIAL AND INDUSTRIAL USES OF SAND AND GRAVEL

Many people, if asked about minerals mined in Oregon, would not think of sand and gravel. Yet the mining of sand and gravel constitutes over a third the mineral production in Oregon -- \$26 million in 1970. Some of its many uses:

Concrete aggregate	Road and highway construction
Bitulithic aggregate	Landscaping (sand, cobbles, boulders)
Railroad ballast	Pebble mills (grinding media)
Riprap and jetty stone	Cobblestones and flagstones
Filter sand	Highway sand (icy pavements)
Sandblasting	Artificial beaches
Exposed aggregate	Grinding and polishing
Fill material	Roofing sand and gravel
Engine sand	Percolation tower fill (chemical process industry)
Sand traps (golf)	Percolation tank fill (sewage treatment)
Cigarette urns	Aggregate for French drains
Poultry grit	Aggregate for plunge-pool energy absorption
Floor sweep	Sand for vehicular emergency speed reduction traps
Leachate field fill	Sand for egg timers
Sand drains	Make-weight and ballast for hollow objets d'art
Moulding sand	Ballast for "squaw" fence posts
Mortar sand	Wire saw sand
Stucco sand	Plaster sand

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OREGON "SUNSTONES"

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Introduction

Within Oregon there is a small but unusual occurrence of semiprecious gems known as "sunstones." The locality is in the Rabbit Basin of southeastern Lake County, and the "sunstones" occur as phenocrysts (large crystals) of gem-quality feldspar in a basaltic lava flow.

Specific field information about the sunstone occurrence was gathered by the author during three days late in the summer of 1972. Bob Rogers and George Marshall of Portland, Oregon; Don Sellers of Lakeview, Oregon; Truman Mitchell of Milwaukie, Oregon; and Mrs. T. Mapes of Klamath Falls, Oregon, were very helpful in providing information about local geography and about sunstone mining and collecting in general. They also furnished specimens for study and photographing.

Definition of Sunstones

"Sunstone" is the name given to a certain variety of feldspar that exhibits a brilliant pink to reddish metallic glitter or shimmer. The metallic glitter results from the reflection of light from myriads of minute flat scales of hematite or other mineral impurities. The enclosed scales are so small and thin they appear transparent; however, their reddish color can be seen plainly by examining a thin piece of the feldspar with a magnifier. The mineral inclusions are usually arranged parallel to the direction of perfect cleavage in the feldspar crystal, so the glittering reflection is only seen when looking at the cleavage surface. The glitter or shimmer is called "aventurescence;" crystals of feldspars exhibiting aventurescence are called aventurine or more commonly sunstones.

Sunstones in general occur in both orthoclase and plagioclase feldspars. At the Oregon locality, however, the sunstones consist of crystals of calcic labradorite (one type of plagioclase feldspar); the colors range from red to green as well as the coppery aventurescence.

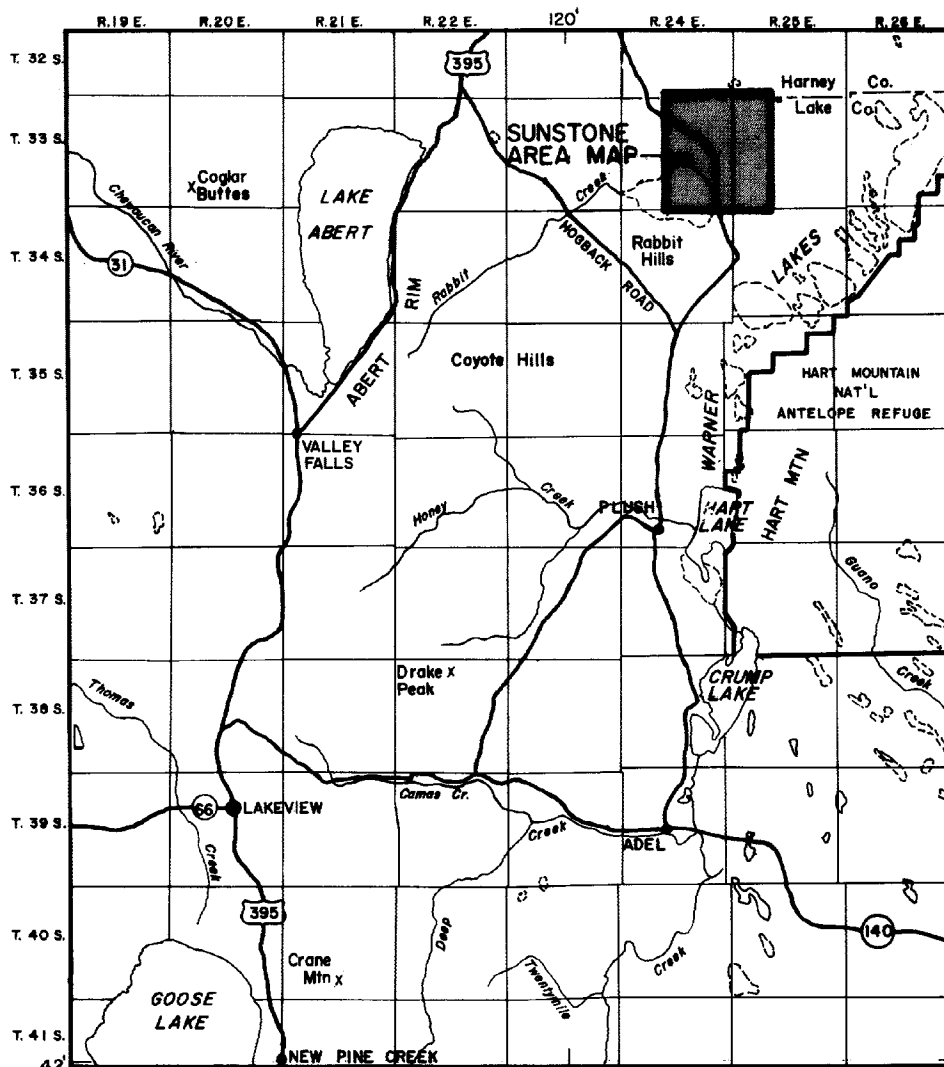


Figure 1. Index map of a part of Lake County, Oregon, showing routes to the sunstone locality and area of geologic map, Plate 1.

In most gemology references, sunstone is listed with the feldspar group as a semiprecious gemstone. In the early 1800's, sunstone was considered extremely rare and was very costly, but with subsequent discoveries in Siberia, Norway, and other parts of the world, it has become more available and less expensive. In the United States sunstone occurs at several locations, a partial list of which is given in Table 1.

Location and Geographic Setting

The Oregon locality is a small area of about 7 square miles in the northern part of the Rabbit Basin in Warner Valley, about 25 miles north of Plush (Figure 1). The area is in the northwestern part of the Rabbit Hills NE quadrangle, Oregon (7.5 minute series, U.S. Geol. Survey topographic map, 1966).

The area can be reached from Lakeview by following State Highway 140 north and east for 20 miles, then proceeding north on a paved county road to Plush. From Plush, gravel and dirt roads continue northward to the sunstone area; signs at road junctions give directions. An alternate route reaches the area via the Hogback Road, which leaves U.S. Highway 395 near the Hogback Summit about 50 miles north of Lakeview. About 14 miles east, at a marked junction, a dirt road leads eastward to the sunstone area. Roads beyond Plush are only periodically maintained, so travel to and from the area is only practical from late spring to early fall.

In this part of Lake County, extreme seasonal temperature changes and a very low rainfall limit the vegetation to low-growing sagebrush and clumps of desert grass. There is no drinking water available in Rabbit Basin, the closest available supply being at Plush.

Rabbit Basin, at an elevation of 4,600 feet is an area of low relief (Figure 2). Occasional arcuate beach ridges mark levels of an ancient pluvial lake that once occupied the basin. The highest shoreline encircles Rabbit Basin at an elevation of about 4,780 feet. In the northern part of the basin, a low, broad north-trending ridge known locally as Dudeck Ridge (Figure 3) is formed by the lava flows that contain the sunstones.

History of the Oregon Occurrence

It has long been known that sunstones, or aventurine feldspar of appreciable size and good quality occur in the Warner Valley in Lake County, Oregon (Figure 4). Locally the sunstones are referred to as "Plush Diamonds," and it is reported that the old maps of Lake County show the "Sunstone Mine."

The first collectors of Oregon sunstones may have been the Indians that inhabited or traveled through Warner Valley. A group of small stones (Figure 5), some of which show the aventurine glitter, are displayed with the Indian artifacts in the Jacksonville Museum. These sunstones, which



Figure 2. View south across Rabbit Basin from Dudeck Ridge showing the flat surface and sparse, arid-type vegetation. On Rabbit Hills in background, about a quarter of way up slope, can be seen the shoreline of an ancient pluvial lake.

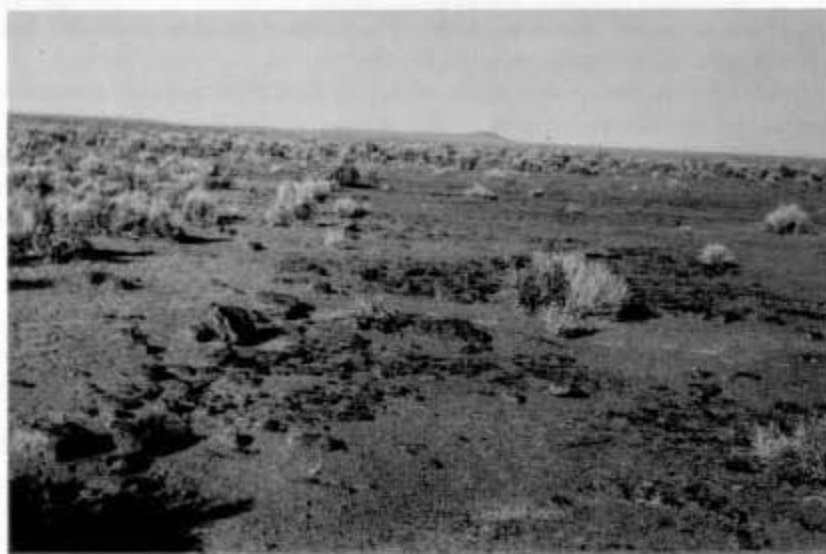


Figure 3. View of the surface of Dudeck Ridge showing the pellet-like residue that accumulates from the weathering of the basalt.

Table 1. Sunstone Localities in the United States

<u>Location</u>	<u>Type of feldspar</u>	<u>Color and quality</u>
Arizona Globe area	Andesine	Pale yellow with bright copper-colored reflections
California Modoc Co.	Labradorite	Clear, colorless, with bright coppery red reflections
New York Crown Point Chappaqua	Orthoclase	Small stones, almost colorless with a marked metallic sheen
North Carolina Medlock Mtn., Bakersville Co. Gold Hill, Rowan Co.	Oligoclase	Hematite inclusions extremely small
Oregon Rabbit Basin, Lake Co.	Calcic labradorite	Clear to amber stones with salmon sheen; clear red and green stones, some exhibit red and green in same stone
Pennsylvania Fairville, Pennsbury Twp.	Oligoclase	Very good sunstone, with fine reflections
Pennsbury, Chester Co.	Oligoclase	Grayish-white with copper reflection
Ashton Township	Oligoclase	Same description
Media, Delaware Co.	Orthoclase	Very fine green and red sunstone
Middletown Twp., Delaware Co.	Orthoclase	In small nodular lumps scattered through the soil
Glen Riddle, Delaware Co.	Orthoclase	A very rich salmon color, quite transparent and streaked with white
Kennett Twp., Chester Co.	Oligoclase	A beautiful variety found with hornblende
Mineral Hill, Delaware Co.	Orthoclase	Greenish orthoclase showing a very good sunstone effect
Virginia Hewlett, Hanover Co. Amelia Court House, Amelia Co.	Orthoclase	Associated with other varieties of feldspar



Figure 4. A large aventurine feldspar fragment (scale in inches) from the Oregon sunstone locality showing typical conchoidal fracture.

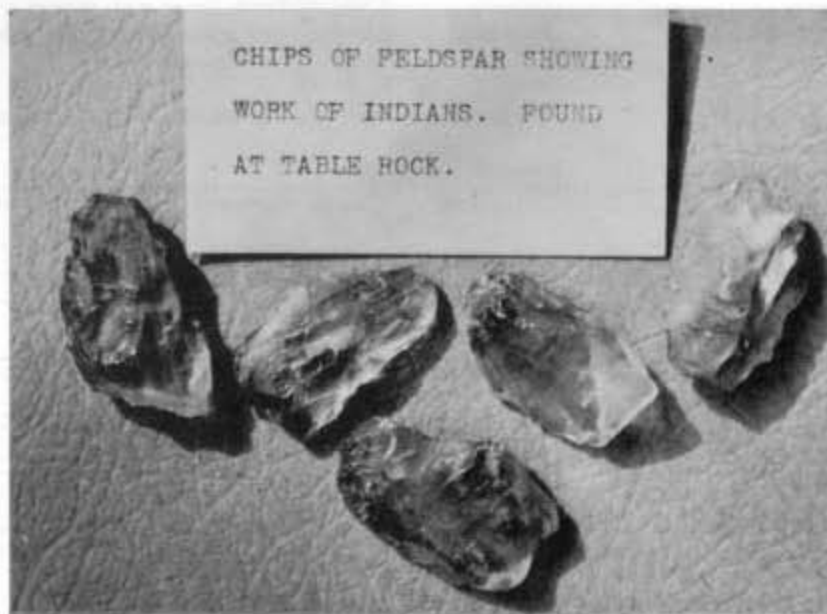


Figure 5. Collection of sunstones in the Jacksonville Museum believed to have been brought into the area by Indians.

are identical to the Warner Valley specimens, were found at Table Rock near Medford in Jackson County by an early resident. Some of the stones appear to have been flaked, and it is probable that the Indians from the Warner Valley traded them with the Rogue Valley tribes.

The reported occurrence of aventurine labradorite from Modoc County, California, listed in Table 1, was described by Olaf Andersen in 1917 and was based on a study of ". . . a number of pebbles and 6 cut stones in the collection of the U.S. National Museum." The properties of the feldspar he describes are almost identical to those of the Oregon labradorite. No recent references to a California occurrence in Modoc County can be found, so it is entirely possible that the material described could have come from Lake County, Oregon.

Aitkens (1931) in his discussion of the gem varieties of feldspar, states, "About 1908, a report of a discovery of a new deposit of labradorite in southern Oregon was made by Maynard Bixby of Salt Lake City, Utah, who stated that this mineral would yield handsome gem material. This labradorite ranges from colorless to a dark variety, showing fine red, salmon, and green tints."

Dake (1938), in describing the semiprecious gemstones of Oregon, indicates that "Good specimens of sunstone suitable for cutting are found in the detrital surface materials at localities in the central part of Lake County." He further reports:

"The rough gem is sold by the ounce and good material showing the proper amount of included extraneous material brings a price well worth collecting the gem."

Stewart, Walker, and others (1966) describe in detail the physical properties of the transparent calcic labradorite from Lake County. In their study they discuss the petrology and petrography of the feldspar-bearing lava flows, chemical composition, optical properties, unit cell parameters, and thermal expansion characteristics of the feldspar crystals. They do not, however, mention the red or green colors or the aventurescence to which some of the feldspars owe much of their appeal.

Numerous other short articles giving brief descriptions of the sunstone and information about the locality have appeared in the popular mineralogical journals, lapidary magazines, and rockhound club journals.

Many rockhounds and gemstone collectors have made annual pilgrimages to the sunstone area to search the surface of the ground for stones or to screen the soil cover for buried stones. In 1970 a group of avid collectors discovered that in some places the sunstone-bearing lavas were decomposed beneath the thin veneer of surface soil. They found that by disintegrating the parent material, larger, better-quality, and more colorful sunstones could be recovered. This led to the staking of several mining claims in the area. Subsequently, at the request of organized gem and



Figure 6. Exposure of weathered pahoehoe lava on Dudeck Ridge showing hummocky bulbous flow units of the sunstone-bearing basalt. Fine-grained weathering products are blown away and the coarser fragments accumulate in depressions.



Figure 7. Another view of a thin flow unit of pahoehoe lava on Dudeck Ridge. Extremes in temperature acting on coarse-grained, open-textured basalt produce granular disintegration.

mineral groups, the Bureau of Land Management withdrew 4 square miles from mineral entry so that anyone desiring to look for and collect sunstones could have access to a part of the area. The withdrawal boundary and the approximate location of the original group of mining claims is shown on the geologic map (Plate 1).

Local Geology

A detailed study of the geology of the whole Rabbit Basin and the surrounding hills was not attempted for this report. The approximate extent of the sunstone-bearing basalt and the general distribution of other geologic units are shown on the geologic map.

Most of the bedrock appears to be no older than Pliocene. Two major rock types are present in about equal amounts beneath the basin alluvium, which obscures the bedrock in most places. The older bedrock type is a vesicular to dense black basalt of unknown thickness. Overlying this unit is a gray to buff, pumice-rich ash-flow tuff of variable thickness that is moderately to highly welded. The ash-flow tuff was mapped as Danforth Formation by Larson (1965). In the northern part of Rabbit Basin, thin flows of medium-gray, vesicular pahoehoe lava overlie the older rocks and crop out in Dudeck Ridge (Figures 6 and 7). This is the unit that carries the sunstones.

The sunstone basalt is medium to coarse grained and highly porphyritic. It is mainly feldspathic with lesser amounts of pyroxene, olivine, and magnetite. The characteristic texture is diktytaxitic to intergranular. The flow units appear to have a local source, probably at the north end of the ridge, and to have spread generally southward and westward to form the low, rounded mass as shown on the geologic map. At the thickest place, the pile of basalt is probably no more than 100 feet thick, and it tapers quickly to the edges where the flow units are only a few feet thick.

In much of the area occupied by the sunstone-bearing basalt, the rock is fairly to moderately susceptible to weathering and breaks down into a residuum of pellet-like fragments (Figure 3). The liberated feldspar phenocrysts resist further weathering and tend to concentrate at the surface. The margins of the sunstone-bearing lava flows were determined by observing the concentration of feldspar fragments in the surface materials. Where the feldspar fragments can no longer be found, the presence of a different bedrock is inferred. In some places, feldspar phenocrysts constitute over 50 percent of the rock. Most phenocrysts are fractured and split into numerous fragments as they are liberated from the parent rock; seldom are phenocrysts recovered intact. The fracture is conchoidal to hackly (Figure 4).

Stewart, Walker, and others (1966) discuss the history of the crystallization of the feldspar and conclude that the labradorite phenocrysts formed by primary crystallization in a magma chamber at depth under relatively uniform conditions at a temperature greater than 1100°C. (The large size

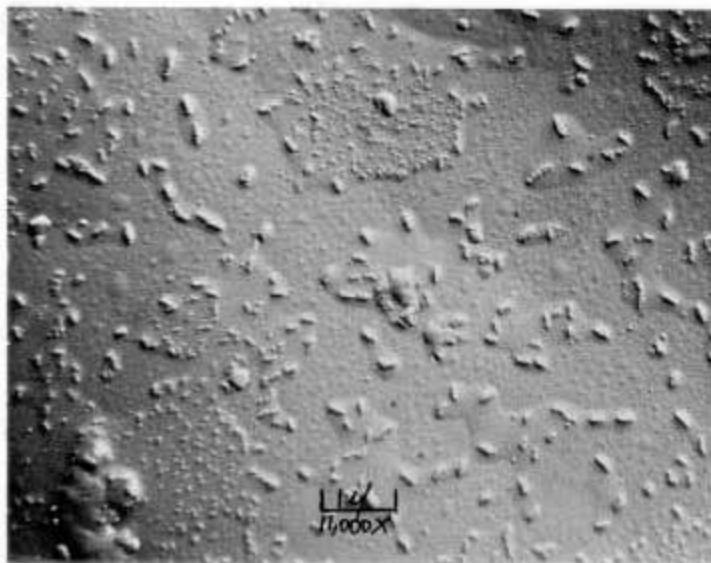


Figure 8. Electron micrograph of a colony of precipitates in straw-colored labradorite with schiller. U.S. Bureau of Mines, X11,000

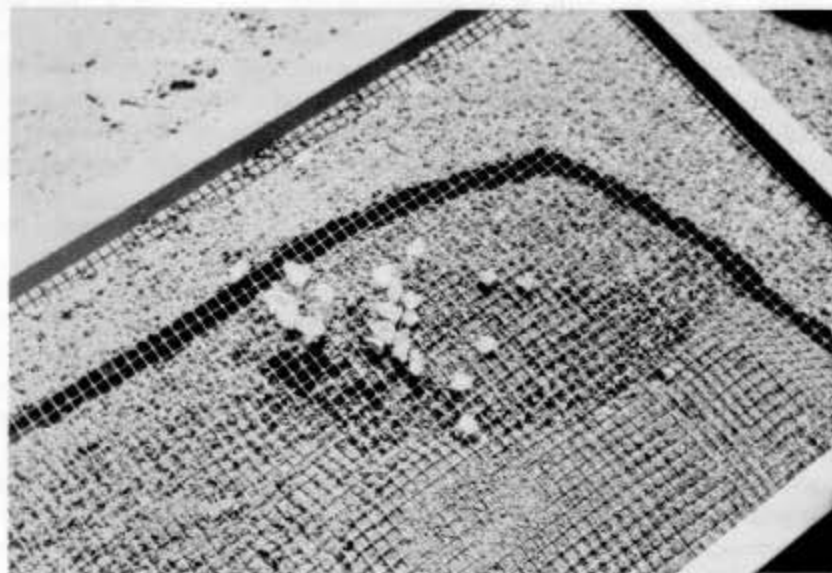


Figure 9. Sunstone fragments are easily separated from surface materials or from decomposed basalt by simple screening with a $\frac{1}{4}$ " screen.

of the equigranular phenocrysts and the inclusions on the growth planes suggest that the growth was relatively rapid.) The lava, with the phenocrysts, was quickly erupted and almost instantly cooled. The mechanical fracturing probably resulted from the rapid and violent flow movement during extrusion.

Source of Color

Most of the references with descriptions about aventurine feldspars attribute the scintillating reflections to inclusions of minute plates of hematite. No discussion of red or green colors in labradorite has been found so far in the literature. To determine why the colors of the labradorite range from colorless through aventurine to red and green or combinations thereof, specimens of each variety were sent to the U.S. Bureau of Mines at Albany, Oregon for a detailed petrographic examination. Their findings are essentially as follows:

"Pieces of the labradorite crystals showing different colors were mounted and polished and examined with the microprobe. Major element and trace impurity concentrations were found quite uniform on a micro scale and no differences between the clear, red, green, or straw-colored portions could be detected. Fe (iron) is present at a constant level of 0.3 percent and K (potassium) at 0.08 percent. Cu (copper) was not detected at 0.03 percent, Mg (magnesium) not detected at 0.2 percent, and Mn (manganese) not detected at 0.1 percent. Some of the straw-colored crystals have precipitates or inclusions in the size range of 5 to 15 microns (1 micron = .000001 meter). These inclusions are a mixture of which iron oxide and aluminum silicate are major constituents. Some Ti, S, and P were also detected. After microprobe analysis, the mounted crystals were etched with a hydrofluoric acid solution and replicas were made of the surfaces. Replicas were then examined with the transmission electron microscope. Numerous colonies of small precipitates were located in the crystal having schiller (similar to aventurescence). Many of the particles are in the size range of 500 to 1000 angstroms across and are separated 1000 to 2000 angstroms (Figure 8). These dimensions are ideally suited to cause color from optical interference."

The Bureau of Mines also performed emission spectroscopic analysis on these crystals. Trace quantities of copper, iron, manganese, and titanium were detected in addition to the major elements. Trace quantities of transition elements such as these are known to affect the color of a host crystal. A single element with various valence states in solid solution conceivably could result in a variety of colors as well. It is difficult, therefore, to



Figure 10. A typical sunstone mining operation. The thin overburden has been removed exposing decomposed basalt, which is easily disintegrated by hand picks and chisels and then screened to separate the sunstones.



Figure 11. This view of a sunstone mining operation shows the inverted cone-shaped area of decomposed basalt. Note piles of screened debris in background.

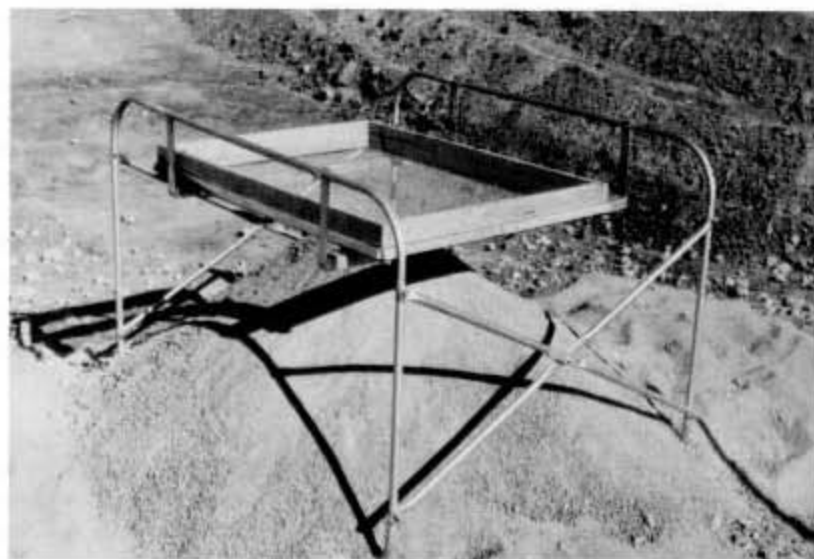


Figure 12. One of the types of screen used to separate disintegrated basalt dug out of the pits.

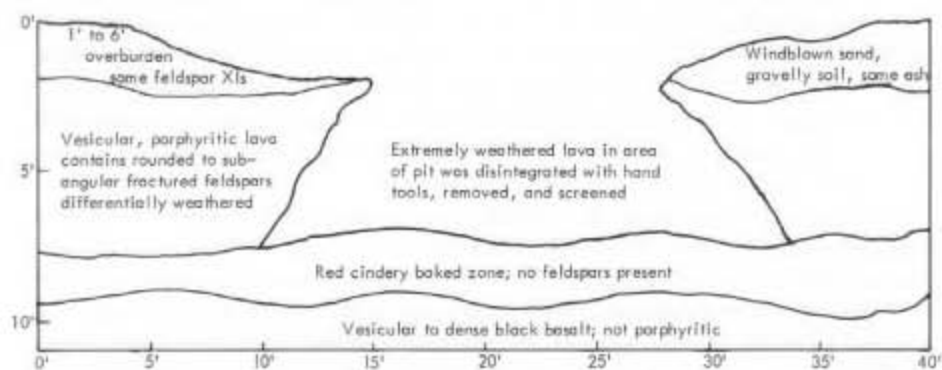


Figure 13. Generalized cross-section of a typical pit showing types of material encountered and the inverted cone shape of the decomposed basalt. The basalt flow varies in thickness from 5 to 9 feet and is always underlain by a red, ashy layer.

determine exact conditions for a particular color. Colors of individual stones are probably the result of several effects. Cyclical precipitation probably could cause the iridescence observed in some crystals and could add to the observed colors.

Although the above analyses are not conclusive, it appears probable that the aventurescence of the Oregon labradorite is produced by reflections from thin scales of mixed precipitates rather than by crystalline hematite as in other described sunstones. We cannot be as certain about the cause of the red or green coloration. However, the influence of transition elements such as iron and manganese is most likely an important factor.

Oregon Labradorite as a Gemstone

In addition to scanning the 7 square mile area and picking up stones that have been weathered from the lava and concentrated at the surface, simple screening of the surface soil is a popular way to collect sunstones (Figure 9). Although serious mining of the parent material has been conducted only since 1970, this method has probably produced more of the larger-sized, higher-quality, and deeper-colored stones than scanning. There are several one-man operations where roughly cone-shaped bodies of decomposed lava are further disintegrated by means of hand tools and the sunstones separated by screening (Figures 10, 11, and 12). Figure 13 shows a cross section of a typical pit and the materials encountered. It is not known why the lava weathers in cone-shaped masses.

The most common variety of crystal fragments are transparent and colorless to amber. Size varies greatly and the minimum collectible size will not pass through a one-quarter inch screen. Intact fragments as large as $3" \times 1\frac{1}{2}" \times 1"$ have been found, and it is reasonable to expect that the original phenocrysts were somewhat larger. Stewart, Walker, and others (1966) observed a giant lath 8.3 cm long, 2.6 cm wide, but only 0.8 cm thick ($3\frac{1}{2}" \times 1" \times .3"$).

The next most common variety of stones are those that exhibit the pink to coppery glitter of true sunstone or aventurine. Experienced collectors cite a rule of thumb that for every 100 colorless feldspar stones they will find one true sunstone. Then for every 10 of these pink shimmers they will turn up one transparent red. Clear green stones are even less common, and for approximately every ten reds there is one green. Occasionally a real rarity that exhibits both red and green in the same stone will show up on the sorting screen.

As commercial gemstones, the Oregon sunstone has many of the necessary or desirable properties. Even though the hardness is only 6 and a definite cleavage is present, it is a fairly tough stone which does not seem to damage easily. The clear and amber stones as well as the small pink shimmers and red and green colors in small size are suited for tumbling and are used in key chains, bracelets, pendants, necklaces, and gem sculptures.

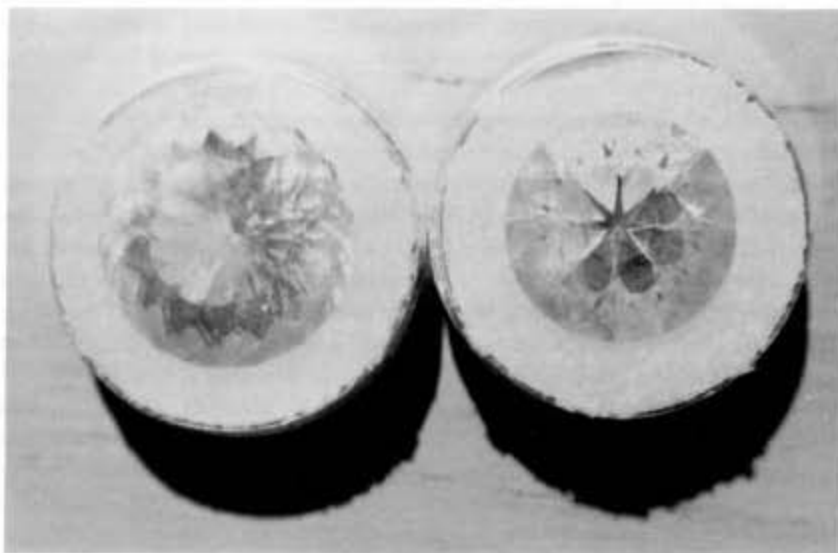


Figure 14. Clear-to-amber labradorite from the Oregon sunstone locality occurs in sizes and quality for faceting. 2X

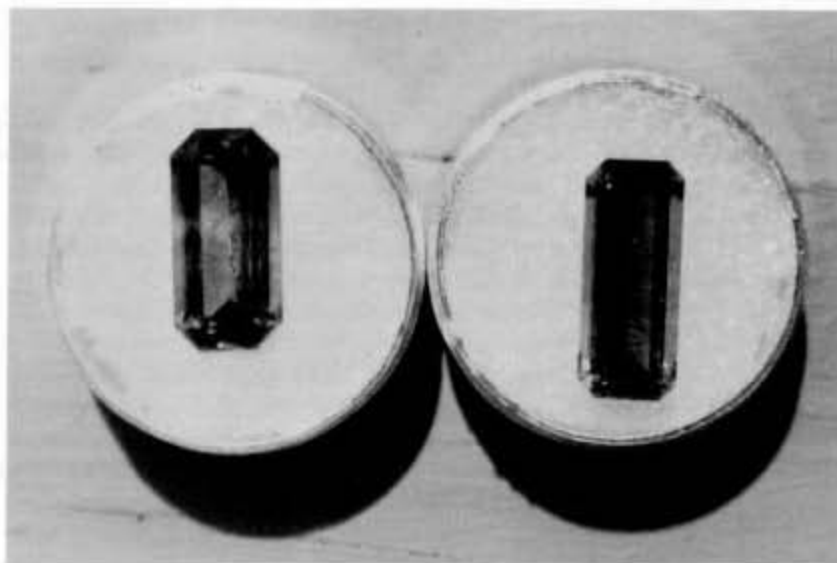


Figure 15. Another pair of faceted labradorites; one is green and the other red. 2X

The larger sunstones or aventurine feldspars are usually cut in cabachon shapes to accentuate the aventurescence. The red and green transparent stones are the most sought after and are almost always sold for faceting (Figures 14 and 15).

Most Oregon sunstones are marketed at rock and mineral shows or by mail order through advertising in lapidary magazines. Minor quantities are sold at the diggings. As is true for most gemstones, prices vary greatly. Each dealer usually has his own classification by size and color. One dealer lists field-run stones with some pink and rarely red or green at \$6.00 per pound. The red and green small size are sold by the gram and prices range from \$2.00 to \$4.00 a gram. Selected red and green stones from 1 to 3½ grams in size are quoted at \$4.00 to \$8.00 per gram. Larger stones of intense color and good transparency are sold individually at negotiated prices. Faceted stones are sold by the carat and, as with other gems, the size, quality, and fashionability determine the price. It may be of interest to note that color photographs of "an unusual red, 14-carat faceted labradorite" and a faceted "record-size 24-carat stone of amber labradorite from Oregon" are shown in The Gem Kingdom by Desautels.

It is difficult to predict what impact the Oregon sunstones will have as a commercial gem. If sufficient quantities of large-size, good-color, high-quality stones continue to be found, they might reach the jewelry-store market. If not, the main market will continue to be limited to individual mineral collectors. Recent trends indicate an increased interest in faceting stones.

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PENROSE OPHIOLITE FIELD CONFERENCE

Len Ramp

Geologist, Oregon Dept. of Geology and Mineral Industries

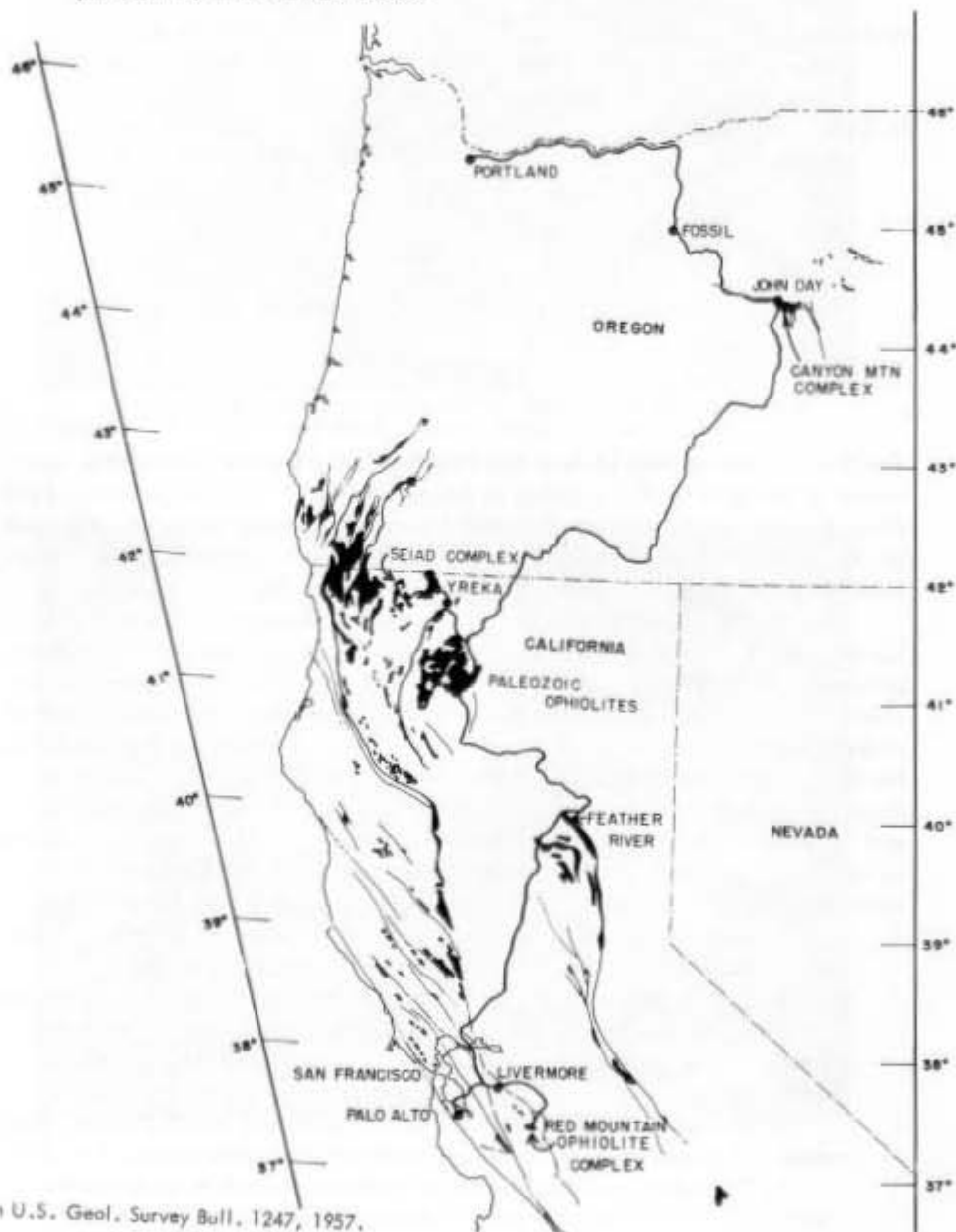
The Geological Society of America Penrose Conference on Ophiolites convened in Portland on the evening of September 14, 1972, and ended in Palo Alto, California, September 24. The 10-day field conference was attended by 55 geologists from 9 countries including Australia, Brazil, Canada, England, France, Italy, Netherlands, Venezuela, and the United States.

Dr. R. G. Coleman and Dr. T. P. Thayer of the U.S. Geological Survey, Dr. L. G. Medaris of University of Wisconsin, and Dr. E. Moores, University of California, Davis, arranged the conference for the purpose of viewing and discussing, both in the field and in seminar, the assemblages of rocks termed "ophiolites." The rapid development of plate tectonic theories has brought this term out of the older literature and into general usage by those working in areas of ultramafic rocks. It refers to assemblages of mafic and ultramafic rocks and their hydrated equivalents. Ophiolites are believed to represent ancient oceanic crust and subjacent mantle. The goals of the conference were to examine the following features of ophiolites:

1. Contacts between country rock and ophiolite complexes. Contacts examined are depositional, tectonic, and metamorphic.
2. The relationships between plutonic (peridotites and gabbros) and volcanic (pillow lavas, diabase, tuffs, etc.) rocks with particular attention to contrasting petrographic types with varied deformational histories.
3. The occurrence of diorites, albite granites, trondhjemites, and keratophyres as part of peridotite-gabbro-basalt complexes.
4. To determine the presence or absence of stratigraphic continuity and the implied relations to oceanic crust-mantle sequences.

Penrose Ophiolite Conference Map

Approximate route and location of principal areas visited. The black areas represent ultramafic rocks, and include gabbro, serpentinite, peridotite, and related rocks.



From U.S. Geol. Survey Bull. 1247, 1957.

5. The metamorphic nature of certain complexes (contact metamorphism vs. regional metamorphism).

6. The regional structural setting as it helps to explain how upper mantle rocks have been moved into their present positions in the crust.

Some of the more interesting ideas and theories this geologist obtained from the conference were related to the occurrence of nickel sulfides and chromites in the ultramafic rocks. For example, Dr. A. J. Naldrett, University of Toronto, observed that all known commercial deposits of nickel sulfides in the world are older than 1.7 billion years. It is presumed that the source of sulfur in the mantle of the earth must have become depleted by this period in its history.

Mechanisms of emplacement of ultramafic rocks containing very large bodies of high-grade, massive chromite were discussed, but it appears that much remains to be learned about these deposits and their origin in light of the global plate tectonics interpretations.

Another very interesting concept presented is that the coarse skeletal olivine crystals in ultramafic rocks of Canada and Australia are comparable to quench textures that can be produced in the laboratory. From this and other textural evidence, it is presumed that these rocks may actually be submarine ultramafic lava flows.

The itinerary followed is outlined below.

On September 15 the group traveled by bus to John Day via the Columbia River Gorge, Arlington, Condon, Fossil, and Picture Gorge (see accompanying map of route). This portion of the tour was guided by Dr. John E. Allen of Portland State University and Dr. T. P. Thayer of the U.S. Geological Survey, Washington, D. C.

On September 16 and 17, the group, guided by Dr. Thayer, visited the Canyon Mountain Complex. Each evening a seminar related to the problems seen in the field was conducted.

On September 18 the group traveled to Yreka, California with a few brief stops to view Oregon's volcanic terrain. Stops included Lava Butte, Newberry Caldera, and the Klamath graben in south-central Oregon.

The 19th was spent in the field, under the guidance of Dr. L. G. Medaris of the University of Wisconsin, observing rocks of the Seiad Complex. On the 20th Dr. Eldridge Moores of the University of California at Davis and Mrs. N. L. Griffin, student at Oregon State University, led the group in an examination of Callaghan Ophiolite.

On September 21 the geologists traveled from Yreka to Lake Almanor at the head of the Feather River. The route took them through Mt. Lassen National Park and included some interesting stops in the Sierra Nevada Foothill Belt. On the 22nd, the group traveled down the Feather River Canyon through the Foothill Belt and central valley of California to Livermore. This portion of the tour, guided by Dr. Eldridge Moores and Dr. R. G. Coleman, included a few stops in the metamorphic and ultramafic rocks.

On Saturday September 23, the group, guided by Dr. Coleman, spent its last day in the field at Red Mountain Ophiolite Complex south of Livermore, and then traveled to Palo Alto for the final seminars that evening and Sunday morning. At this time the committee in charge of defining the term "ophiolite" reported; revisions and additions were made by the entire group. The final result of their efforts is quoted as follows:

"Ophiolite", as used by those present at the G.S.A. Penrose Conference on Ophiolites, refers to a distinctive assemblage of mafic to ultramafic rocks. It should not be used as a rock name or as a lithologic unit in mapping. In a completely developed ophiolite, the rock types occur in the following sequence starting from the bottom and working up:

Ultramafic complex, consisting of variable proportions of hornblende, hornblende and dunite, usually with a metamorphic tectonite fabric (more or less serpentinized).

Gabbroic complex, ordinarily with cumulus textures commonly containing cumulus peridotites and pyroxenites and usually less deformed than the ultramafic complex.

Mafic sheeted dike complex.

Mafic volcanic complex, commonly pillowed.

Associated rock types include:

An overlying sedimentary section typically including ribbon cherts, thin shale interbeds, and minor limestones; podiform bodies of chromite generally associated with dunite; and sodic felsic intrusive and extrusive rocks.

Faulted contacts between mappable units are common. Whole sections may be missing. An ophiolite may be incomplete, dismembered, or metamorphosed, in which case it should be called partial, dismembered, or metamorphosed ophiolite. Although ophiolite generally is interpreted to be oceanic crust and upper mantle, the use of the term should be independent of its supposed origin.

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SOUTHEASTERN OREGON AEROMAGNETIC MAPS AVAILABLE

The U.S. Geological Survey has released on open file the two aeromagnetic maps listed below. Material from which copies can be made at private expense is on file with Oregon Dept. of Geology and Mineral Industries, Portland. Each map is one sheet, and both are at a scale of 1:250,000.

1. "Aeromagnetic map of the Adel and parts of the Burns, Boise, and Jordan Valley 1° by 2° quadrangles, Oregon," by U.S. Geological Survey.
2. "Aeromagnetic map of the Klamath Falls and part of the Crescent 1° by 2° quadrangles, Oregon," by U. S. Geological Survey.

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(Please include remittance with order; postage free. All sales are final - no returns. Upon request, a complete list of Department publications, including out-of-print, will be mailed)

BULLETINS

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26. Soil: Its origin, destruction, preservation, 1944: Twenhofel	0.45
33. Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
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