

The Ore Bin



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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES**

The Ore Bin

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Credit given the State of Oregon Department of Geology and Mineral Industries
for compiling this information will be appreciated.

OREGON'S MINERAL AND METALLURGICAL INDUSTRY IN 1974

Ralph S. Mason, Deputy State Geologist
Oregon Department of Geology and Mineral Industries

The value of raw minerals produced in the State during 1974 increased 11.3 percent, eclipsing a gain of nearly 9 percent for the previous year. Preliminary compilations by the U.S. Bureau of Mines show mineral production of \$90,703,000 in 1974. Of this amount, stone and sand and gravel accounted for 76 percent. In its annual canvass, the U.S. Bureau of Mines does not include the value, estimated to be in excess of \$700 million annually, of primary metals produced in the State, such as iron and steel, aluminum, ferronickel, and the various exotics.

In a year marked by rapid increases in the value of gold and silver, mining companies showed renewed interest in Oregon mines. At the recreational level, the interest in gold was intense; if the economy worsens, an even greater number of "recreational" prospectors can be expected.

Industrial Minerals

Economic stresses and environmental constraints during 1974 resulted in a slight lowering in volume of aggregate production and a somewhat higher cost. Reduction in the amount of road and highway construction and maintenance, engineering works, and commercial and domestic construction accounted for a decline of 2.14 million tons of aggregate produced. An increase in value of \$3.54 million came as a result of substantial raises in costs of all forms of energy, the price of money, and the ever-longer hauls from pit to market.

The industrial minerals industry in the State generally had a fairly quiet year. 1974 was a time of belt-tightening, increasing regulation, decreasing availability of resources, and a rising level of resistance from land and home owners located near aggregate production. Lack of adequate

SOME OF OREGON'S MINERALS AT A GLANCE

<u>Mineral</u>	<u>1973</u>	<u>1974*</u>
Clays	\$ 291,000	\$ 196,000
Gemstones	700,000	650,000
Lime	2,552,000	2,400,000
Nickel	W	W
Pumice, volcanic cinder	1,902,000	2,090,000
Sand and gravel	32,751,000	37,042,000
Silver	3,000	W
Stone	21,843,000	22,091,000
Value of items that cannot be disclosed: cement, gold, copper, diatomite, talc, tungsten, and values indicated by symbol "W"	<u>21,424,000</u>	<u>26,234,000</u>
Total	\$81,466,000	\$90,703,000

W = Withheld

* Preliminary

BY COMPARISON - - -

<u>State</u>	<u>1972 Value</u>	<u>Value per capita</u>	<u>Rank per capita</u>
California	\$1,851,365,000	\$ 93	25
Wyoming	746,743,000	2,249	1
Nevada	181,702,000	372	11
Washington	109,806,000	32	38
Idaho	106,206,000	149	17
Oregon	76,516,000	37	36
U.S. TOTAL	\$32,217,000,000	159	

land-use planning plus an under-funded mined-land reclamation act were responsible for some of the industry's problems.

Other industrial minerals produced in the State included: expansible and brick-and-tile clays, bentonite, volcanic cinders and pumice, talc, limestone, cement, and silica. Oregon maintained its prominent position in the production of semi-precious gems, with the largest portion of the stones mined by amateurs or semi-professionals. Although no accurate canvass of the semi-precious gem industry is possible, it is estimated at about \$750,000 annually.

The Metals

Although gold commanded world-wide attention during 1974 with its great rise in price, the impact in the State was moderate, at least at the professional level. Several mines in the Baker area of northeastern Oregon were reopened, and sampling and re-evaluation programs were underway. Great interest was displayed by the recreationist and part-time gold miner. Late in the year, a mini-gold-rush developed and hundreds of claims were staked in Baker County.

Most of the gold produced in the past in the State has come from two widely separated areas, one in northeastern and the other in southwestern Oregon. Starting in 1850 with a discovery of placer gold in Josephine Creek at its confluence with the Illinois River in Josephine County, the search widened rapidly over the next 15 years, during which time most of the known placers were discovered. Following the decline of the easily won placer gold, the development of lode deposits proceeded briskly, with most of the important mines being discovered as early as the 1880's.

The high point in gold production occurred in 1940 with a total of slightly over 105,000 fine troy ounces. The forced closure of all gold mines in 1941 by Executive Order L-208 abruptly blunted this rapid rise. For the past 3 years, gold has not even appeared in the U.S. Bureau of Mine's statistics on the State's mineral production. Undoubtedly some gold is being recovered by the small army of non-professionals, but those who find it are not talking.

Hanna mining Co. continued to produce ferronickel at its Riddle smelter at Nickel Mountain in Douglas County. Improved plant efficiency and an increase in the price of nickel made it economic to mine nickel silicate ore of slightly lower grade than was mined in previous years. The Department of Geology and Mineral Industries, in cooperation with the U.S. Bureau of Mines, conducted a nickel study in southwestern Oregon during the year. The study is designed to identify all known and potential areas of nickel-bearing laterites in the State. Numerous samples were collected and are being analyzed in the Department's laboratories.

* * * * *

OIL AND GAS EXPLORATION IN 1974

V. C. Newton, Jr.

Petroleum Engineer, Oregon Dept. Geology and Mineral Industries

No new permits were issued for oil and gas drilling by the Department in 1974; however, increased interest in petroleum prospects of the State was reflected by renewed leasing activity and a steady stream of inquiries for geological data from the Department. Activity has been at a low ebb for the past 7 years, following termination of continental shelf exploration. Oregon is still one of the thirteen non-producing states.

Status of Federal Lands

Secretary of Interior Rogers Morton placed a moratorium on oil and gas leasing of Federal lands in Oregon in 1971 following objections by environmental groups to Texaco's drilling of a wildcat well in eastern Oregon. The intervenors wanted the Bureau of Land Management to initiate full impact procedure before issuing oil and gas leases. The BLM held the view that the full hearings process was not necessary in every case but should be applied when major conflicts arose. Officials of the BLM reported in December 1974 that the moratorium covering onshore leases has been lifted by Secretary Morton. The BLM will make regional environmental analyses in Oregon to determine what effect exploration and development will have on the environment. Specific studies will then be made for each area applied for to determine if protective stipulations are needed in the lease contract. This is the procedure now being used in other states. The four-year delay in issuing Federal leases has cost Oregon counties an estimated \$300,000 in lease rentals.

The major portion of Federal lands off the Oregon Coast is not scheduled for leasing by the U.S. Department of the Interior until after 1980. Should oil be found on these outer continental shelf lands, it will not reach refineries before 1985 at the earliest. Environmental concern is currently the main factor in delaying the work, but availability of capital to fund expensive offshore development probably would slow the pace of exploration even if the environmental delays were not present. A discovery of oil and gas on Oregon submerged lands, however, would force earlier lease sales on adjacent Federal lands. In the meantime, offshore drilling and production technologies are being perfected in the North Sea operations.

Onshore Prospects

Much of the state is underlain by marine rocks ranging in age from Devonian to late Tertiary, and detailed geological and geophysical studies

in these areas should reveal many prospective drill sites. The Tertiary marine basin in western Oregon covers an estimated 25,000 square miles. Pre-Tertiary marine rocks, although fairly extensive, have a covering of younger rocks in all but the uplifted regions, and very few deep test holes have been put down thus far to allow reasonable subsurface correlation. Geology of Oregon, like that of other states along the western margin of North America, is typically complex owing to tectonism and volcanism. Volcanic rocks overlies and are interbedded with most of the marine sediments in Oregon. Three-quarters of the State is covered by Cenozoic volcanic rock which obscures structural features as well as the physical character of the older rocks.

In the search for oil and gas, 22 deep holes have been put down in western Oregon and 12 in eastern Oregon. Many of these holes encountered shows of hydrocarbons (see Figure 1). Oil was recovered in formation tests from only one hole, but cores and cuttings from 7 other deep tests showed oil was present in at least trace amounts.

Leasing Areas

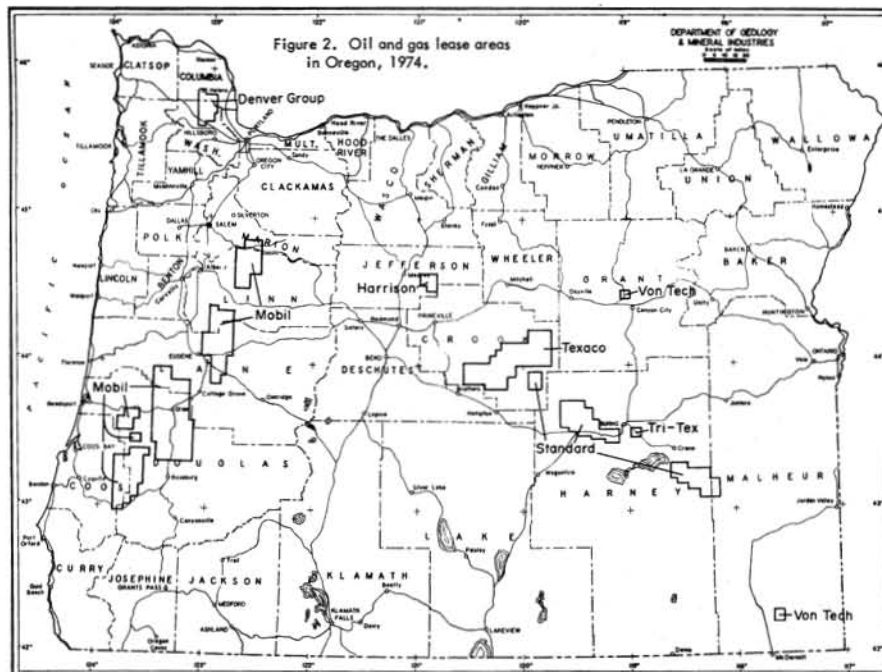
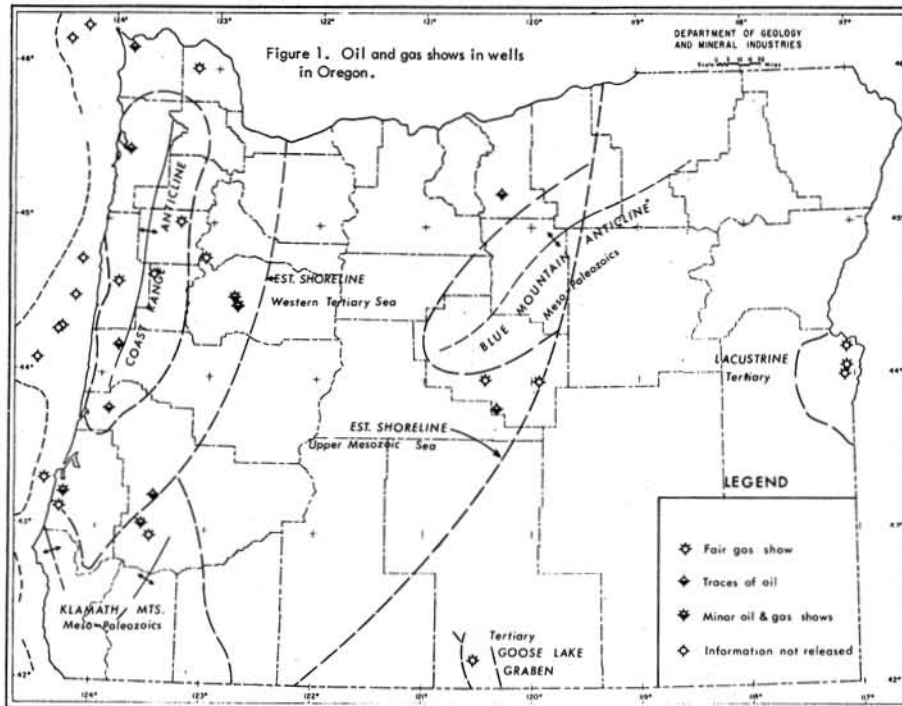
Petroleum exploration onshore is divided between the western Tertiary basin and the Mesozoic-Paleozoic prospects in eastern Oregon. Mobil Oil Company is building a major lease position in the western part of the State, having filed on more than 200,000 acres. Additional leases in western Oregon, totaling approximately 15,000 acres (see Figure 2), were acquired by independents.

East of the Cascades, Texaco, Inc. and Standard are the largest leaseholders with nearly 180,000 acres each. Independents have rights on another 15,000 acres in eastern Oregon.

Shell Oil Company and Texaco began leasing in three counties of south-central Washington last summer. The leases are located within the Columbia Plateau where Pliocene-Miocene flood basalts cover older rocks. Standard Oil Company of California and others drilled a 10,655-foot test hole in 1958 in the Rattlesnake Hills of that area and bottomed in Oligocene-Eocene volcanics. Interest in the Columbia Basin may later extend to the Oregon portion of the basin if drilling results are encouraging. Gas was produced between 1929 and 1942 from the Rattlesnake Hills structure in the vicinity of Standard's well and supplied four or five small towns in the area. The gas was found in fractured zones of the Plio-Miocene lavas (Glover, 1936).

Offshore Exploration

Exploration along the Oregon and Washington coasts has been minimal since the last hole was drilled offshore in 1967. Sporadic non-explosive seismic surveys have been conducted in the past 7 years. Digicon, Inc., Houston, Texas, made air-gun studies along the Coast in April 1974. Gulf



Oil Company, U.S., applied in October 1974 to conduct geophysical surveys along the Oregon Coast. Standard and Texaco maintained exploration permits for offshore geophysical work but did not make investigations in 1974.

References

- Deacon, R. J., and Benson, G. T., 1971, Oil and gas potential of Oregon, Washington, and Idaho: Am. Assoc. Petrol. Geologists Mem. 15.
 Glover, S. L., 1936, Preliminary report on petroleum and natural gas in Washington: Wash. Div. of Geology R.I. no. 4, 12 p.
 Kirkham, V. R. D., 1935, Natural gas in Washington, Idaho, eastern Oregon, and northern Utah, in Geology of natural gas: Am. Assoc. Petrol. Geologists, p. 221-244 (June).

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GEOHERMAL LEASE AREAS IN OREGON

The accompanying map outlines general areas of applications for Federal lands and existing leases on private lands. Geothermal leasing activity covers more than 2 million acres of land in the Cascade Range and volcanic terrain of eastern Oregon. Applicants and lessees by area are:

Mount Hood	Summer Lake
Republic Geothermal	LVO Corporation
Breitenbush Hot Springs	Chevron
Hydro Energy	Earth Power
Sun Oil	Thermal Resources
Hook, et al.	Glass Butte
Belknap Hot Springs	California Geothermal
Sun Oil	Sun Oil
Energy Partners	Klamath Falls
Chevron	Dowdle Oil
Hydro Energy	Gulf Oil
Pacific Energy	Hunt Family
McCredie Hot Springs	Earth Power
Oil Resources	Creslenn Oil
Hydro Energy	Natomas
Newberry Crater	Geothermal Resources Int'l
California Geothermal	Lakeview-Warner Valley
Chevron	Gulf Oil
Sun Oil	Chevron
Phillips Steam	Mobil
Union Oil	Phillips Steam
	Union

Lakeview-Warner Valley, cont'd

Energy Partners
Hunt Family

La Grande

Gulf Oil
Magma Power
AMAX Exploration

Burns

LVO Corporation
Earth Power
Pacific Energy
Gulf Oil
Geothermal Resources Int'l
Thermal Resources
Sun Oil

Cow Lakes

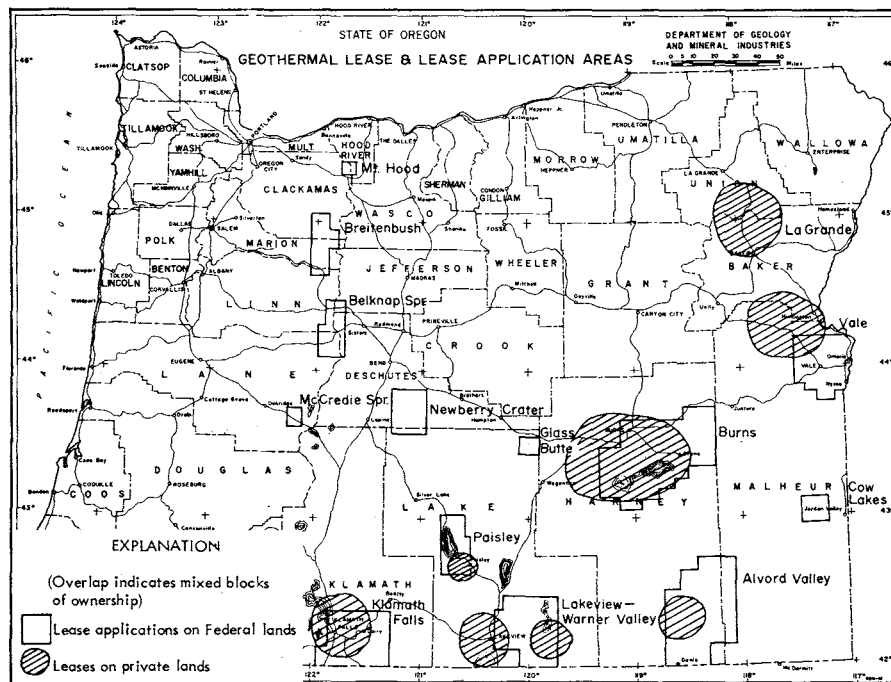
MacColl
Douglas, et al.

Vale

Union Oil
Magma Power
Republic Geothermal
LVO Corporation
Gulf Oil
Hydro Energy
Thermo Resources

Alvord Valley

Anadarko
California Geothermal
Chevron
Getty
Gulf Oil
Magma Power
Mobil
Thermex
Republic Geothermal
Union Oil
Pacific Energy



GEOTHERMAL ACTIVITY IN 1974

Richard G. Bowen
Consultant in Geothermal

The level of geothermal activity showed significant increases in some categories but decreases in others. Most importantly, the U.S. Department of the Interior started implementing the 1970 Geothermal Steam Act to lease Federal lands for exploration and development. The number of exploratory wells drilled throughout the West has increased, and several pilot studies in the Imperial Valley of California are underway to utilize the high-temperature brines found in that region. At The Geysers, new step-out wells have continued to enlarge the field. Direct use of geothermal energy for heating or process use is increasing worldwide. The realization that fossil fuels are finite and subject to political manipulation has triggered an increased interest in geothermal potential. On the national scene some companies associated with high-energy use, such as producers of aluminum and chemicals, have also entered the geothermal field to assure themselves of a reliable energy source.

Delays in the development of geothermal resources have been numerous and frustrating during the year. The complex leasing procedure set up by the Federal Geothermal Steam Act of 1970 requires much more time and expense than does the leasing of lands for other fuels, such as oil and gas or uranium. The imposition of environmental studies prior to each step - leasing, exploration work, drilling, development, plant construction - has caused many delays and added greatly to the over-all expenses. These delays are now being resolved, however, and a few competitive leases have been signed. The Interior Department expects that some non-competitive leases will be granted in 1975. At The Geysers field, the local requirements for extensive environmental studies have caused a two-year holdup on new plant construction within the field.

World-wide, the oil embargo has caused countries to re-evaluate their geothermal potential and accelerate development to reduce the drain of funds to pay for oil. In Italy, a new steam field was discovered at Alfino, 60 miles south of the Larderello field between Florence and Rome. In New Zealand, studies have been started to assess the geothermal potential in areas away from Wairakei, and efforts are also underway to increase heating and process use in several areas. In Japan, new discoveries have been made and a new field, Hachimantai, came into production this year. Exploration and development activities continue in Mexico, El Salvador, Chile, the Philippines, Indonesia, Greece, Turkey, The Azores, Iceland, Martinique, and Canada.

In Oregon and other western states, a flurry of leasing started in January 1974, with a steady follow-up during the rest of the year. By the time the year ended, applications and deposits for over 1.6 million acres in Oregon had been received by the BLM. Similar patterns developed in Washington, with approximately .6 million acres under application; California with 1.6 million; Idaho, 1.1 million; Utah, .8 million; and Nevada, 2.1 million acres. Most of these states have had some additional leasing activity on private and State lands. The accompanying map shows areas where geothermal lease applications have been filed. Applicants are listed below by geographic areas.

Although the level of interest is high, as shown by leases, drilling activity has not kept pace. During the year only one geothermal test was drilled, that by Magma Energy near La Grande. This well, planned as a 5,500-foot test, was abandoned at 2,800 feet after encountering difficult drilling conditions costing more than the funds budgeted for the job. A well drilled near Klamath Falls by the Presbyterian Intercommunity Hospital intersected a flow of 200°F water at 1,500 feet. The successful geothermal heating installation at nearby Oregon Institute of Technology, together with the rising price of natural gas, were the deciding factors in this enterprise. The system will be modified to run the water directly through the existing natural-gas-fired hot water heating system. Based on the 10 years experience at OIT, it appears this method should be successful and over the next few years give a good return on the drilling investment.

If impediments are removed, 1975 should see the beginning of serious geothermal exploration within the State.

* * * * *

BOWEN RESIGNS TO DO CONSULTING WORK

Richard G. Bowen, Economic Geologist with the Oregon Department of Geology and Mineral Industries for the past 15 years, resigned January 1, 1975 to enter private consulting in geothermal resource investigations and development. Bowen is a well-known expert in geothermal realms and for the past 4 years has been in considerable demand at national and international conferences on energy. He has been president of the Geothermal Resources Council and has served as chairman, co-chairman, speaker, and panelist at numerous energy conferences at both local and international levels. His strong belief in the merits of geothermal energy and his enthusiasm for promoting this idea have put Oregon on the map for its geothermal potential.

Bowen expects to be kept busy doing consulting work for private companies and plans to travel in areas of the West where geothermal activity is anticipated. At the present time his office is in his home in Portland.

* * * * *

FIELD-ORIENTED GEOLOGY STUDIES IN OREGON DURING 1974

John D. Beaulieu
Geologist, Oregon Dept. of Geology and Mineral Industries

During the 1974 field season at least 115 geologic field investigations were conducted in Oregon. The list below includes those of which the Oregon Department of Geology and Mineral Industries is aware. For convenience, the State is divided roughly into six sections, and several investigations of more regional extent are included in a seventh category - Regional.

The Department would appreciate receiving information about studies in progress in the State which are not listed here. The resumé's received thus far have been invaluable in completing this list, and the compiler is grateful for this assistance. An annotated list will be issued later in 1975 as a Department open-file report, and availability of copies of that report at cost will be announced in The ORE BIN.

The Department has no information on completion dates of research or reports of other organizations; inquiries should be directed to individual named.

Northwestern Oregon

1. Oligo-Miocene biostratigraphy: Warren O. Addicott, U.S.G.S., Menlo Park
2. Ferruginous bauxite in Columbia, Washington, and Marion Counties: U.S. Bur. Mines, R. N. Appling, Jr., Chief
3. Biostratigraphy of the type Nestucca Formation: Arden Callender, Master's cand. P.S.U.
4. Factor analysis of mass movement: Vern Cimmery, Master's cand., Dept. Geography, P.S.U.
5. Breitenbush Hot Springs - geology: Michael Clayton, Master's cand., P.S.U.
6. Astoria Formation - petrology, stratigraphy, paleoenvironment: M. D. Cooper, Ph.D. cand., O.S.U.
7. Hillslope processes and sediment formation on a basaltic headland: William Dietrich, Master's cand., U. of Wash.
8. Bagby Hot Springs area - geology: Richard Dyhrman, Master's cand., O.S.U.
9. Recent fluvial history of Siuslaw and Alsea Rivers: Joe Feiersen, Ph.D. cand., Dept. Geography, U. of O.
10. Water resources of coastal Lincoln County: F. J. Frank and A. Laenen, U.S.G.S. Portland in coop. with State Engineer
11. Western Cascades from Clackamas River to Santiam Pass: Paul Hammond, Dept. of Geology and Mineral Industries (DOGAMI)

12. Lower Tertiary mollusks: Carole S. Hickman, Ph.D. cand. and Adj. Res. Assoc., Stanford U.
13. Siletz Spit erosion: Paul D. Komar and C. C. Rea, Dept. Oceanography O.S.U.
14. Ground water in the Newberg area: A. R. Leonard, U.S.G.S. Portland in coop. with State Engineer
15. Ground water of northern Clackamas County: A. R. Leonard, U.S.G.S. Portland, in coop. with State Engineer
16. Oil and gas prospects and underground storage: Vernon C. Newton, Jr., DOGAMI
17. Astoria and Yaquina Formations deltaic-turbidite model: A. R. Niem, Prof., O.S.U.
18. Geomorphology of northern and central Coast Range: W. Niem, Master's cand., O.S.U.
19. Saddle and Humbug Mountains area - geology: Peter Penoyer, Master's cand., O.S.U.
20. Foraminifera and biostratigraphy of the Alsea Formation: Weldon Rau, State of Wash. Div. of Geology and Earth Resources
21. Marion Forks area - geology: Tony Rollins, Master's cand., O.S.U.
22. Oregon-Washington continental margin: Parke D. Snively, Jr., U.S.G.S. Menlo Park
23. Seaside to Young River Falls - geology: Pat Tolson, Master's cand., O.S.U.
24. Aggregate source areas: R. O. Van Atta, Prof., P.S.U.
25. Battle Ax-Outerson-Triangulation Peaks area - geology: Craig White, Ph.D. cand., U. of O.
26. Tillamook earthquake of June 16, 1973: Stephen Woodcock, Dept. Oceanography, O.S.U.

Southwestern Oregon

1. Mineral deposits reconnaissance of Douglas, Jackson, and Josephine Counties: U.S. Bur. Mines, R. N. Appling, Jr., Chief
2. Marial and Agness quadrangles - geology: Ewart M. Baldwin, Prof., U. of O.
3. Eocene stratigraphy of southwest Oregon: Ewart M. Baldwin, Prof., U. of O.
4. Environmental geology of western Coos County: John D. Beaulieu, DOGAMI, and Paul W. Hughes, consultant
5. Alpine ultramafic rocks: R. G. Coleman, U.S.G.S., Menlo Park
6. Josephine peridotite and associated rocks: Henry Dick, Yale U., Ph.D. cand.
7. Ashland pluton - geology: Mary Donato, Master's cand., U. of O.
8. Rogue Formation and related units: Michael Garcia, Ph.D. cand., U.C.L.A.

9. Ground water near Winston: D. D. Harris, U.S.G.S. Portland, in coop. with State Engineer
10. Jurassic of North America: R. W. Imlay, U.S.G.S. Menlo Park
11. Marine-fluvial Quaternary sedimentation: R. J. Janda, U.S.G.S. Menlo Park
12. Cretaceous of Pacific Coast: D. L. Jones, U. S.G.S. Menlo Park
13. Blanco Fracture Zone microearthquakes: Paul Jones, Master's cand., Dept. Oceanography O.S.U.
14. Hypersthene source on coast of southwest Oregon: Tom Judkins, Master's cand., U. of O.
15. Compilation map in Wrangle Camp-Dutchman Peak area: M. A. Kays and S. Boggs, Profs., U. of O.
16. Siuslaw jetty extension: Paul D. Komar, Prof., Dept. Ocean. O.S.U.
17. Eocene stratigraphy northwest of Roseburg: E. R. Orwig, Mobil Oil
18. Medford-Coos Bay quadrangles: N. J. Page, U.S.G.S. Menlo Park
19. Pacific Coast sedimentology: R. L. Phillips, U.S.G.S. Menlo Park
20. Dutchman Butte quadrangle - geology: R. Perttu, Master's cand., P.S.U.
21. Nickel occurrences: Len Ramp, DOGAMI
22. Ground water in the Drain-Yoncalla area: J. H. Robison, U.S.G.S. Portland, in coop. with State Engineer
23. Ground water in the Sutherlin area: J. H. Robison, U.S.G.S. Portland, in coop. with State Engineer
24. Gravel resources of Josephine County: Herbert Schlicker, DOGAMI
25. Biostratigraphy of the Roseburg, Lookingglass, and Flournoy Formations: R. E. Thoms, Prof., P.S.U.
26. Galice, Dothan, and Josephine units: Scott Vail, Ph.D. cand., O.S.U.

North-central Oregon

1. Devonian of Oregon: Tom Amundson, senior res., P.S.U.
2. Canyon Mountain Complex: Hans Ave Lallement, Prof., Rice U.
3. Columbia River Basalt stratigraphy: Robert Bentley, Prof., C.W.S.C.
4. Landslides, community of John Day: Howard Brooks and Herbert Schlicker, DOGAMI
5. Erosion processes of the Willamette Basin: W. M. Brown and S. A. Vickers, U.S.G.S. Menlo Park, and David Rickert, U.S.G.S. Portland
6. Clarno Formation - Mitchell area: H. E. Enlows and E. M. Taylor, Profs., O.S.U.
7. Rattlesnake Formation - type section: H. E. Enlows, Prof., O.S.U.
8. Ground water in the Harrisburg-Halsey area: F. J. Frank, U.S.G.S. Portland, in coop. with State Engineer
9. Volcanoes - infrared surveillance: J. D. Friedman, U.S.G.S. Menlo Park

10. Columbia River Basalt - geochemistry: John S. Fruchter, Battelle-Northwest, Richland (formerly Ph.D. cand., U. of O.)
11. Plio-Pleistocene volcanics of the Portland area and Columbia River Gorge - chemical analyses: Gary L. Millhollen, Prof., Purdue U.
12. Quartzville District - geology and mineral deposits: Stephen R. Munts, Master's cand., O.S.U.
13. Lawson Mountain and Stevenson Mountain quadrangles - geology: Philip C. Owen, Master's cand., O.S.U.
14. Mineral resources of Deschutes County: Norm Peterson, DOGAMI, and Ed Groh, consultant
15. Water resources of the Warm Springs Indian Reservation: J. H. Robison, U.S.G.S. Portland in Coop. with State Engineer
16. Jurassic paleontology of the Izee area: Paul Smith, grad. student, PSU
17. Volcanology of the western United States: R. L. Smith, U.S.G.S. Menlo Park
18. Mount Jefferson: Ken Sutton, Master's cand., U. of O.
19. Columbia River Basalt - petrochemistry and isotopic analysis: D. A. Swanson, U.S.G.S. Menlo Park
20. Cascade volcanoes - strain monitoring: D. A. Swanson, U.S.G.S. Menlo Park
21. Biostratigraphy of the Snowshoe Formation: Dave Taylor, Senior res. P.S.U.
22. Broken Top volcano and ash-flow sequence near Bend: E. M. Taylor, Prof., O.S.U.
23. John Day area - geology: T. P. Thayer, U.S.G.S. Menlo Park
24. Geology of chromium: T. P. Thayer, U.S.G.S., Menlo Park
25. Salamanders of the John Day Formation: Bruce J. Welton, Ph.D. cand., U. Cal. Berkeley
26. Columbia River Basalt - genesis: T. L. Wright, U.S.G.S. Menlo Park

South-central Oregon

1. Earth temperature - temporal variations: Dwight Eggers, Dept. Oceanography, O.S.U.
2. Paisley Mountain Intrusive Complex - geology and mineral deposits: J. W. Hammitt, Master's cand., O.S.U.
3. Geothermal investigations: A. H. Lachenbruch, U.S.G.S. Menlo Park
4. Mount McLoughlin to California - Geology: R. H. Naslund, Master's cand., U. of O.

Northeastern Oregon

1. Clover Creek Greenstone - stratigraphy: D. A. Bostwick, Prof., O.S.U.
2. Burnt River Schist - paleontology: D. A. Bostwick, Prof., O.S.U.
3. Elkhorn Ridge Argillite - micropaleontology: D. A. Bostwick, O.S.U.

4. "Little Dog Creek Limestone" - micropaleontology: D. A. Bostwick, Prof., O.S.U.
5. Baker AMS sheet - geology: Howard Brooks, DOGAMI
6. Huntington quadrangle - geology: Howard Brooks, DOGAMI
7. Glacial morphology in eastern Oregon uplands: Elton Bentley, Dept. Geography, C.W.S.C.
8. Gold availability in Grant and Baker Counties: U.S. Bur. Mines, R. N. Appling, Jr., Chief
9. Mineral resources of the proposed Hells Canyon Wilderness area: U.S. Bur. Mines, R. N. Appling, Jr., Chief
10. Baker Observatory: Marvin Carlson, U.S.G.S.
11. Geophysical measurements in the Vale (KGRA) geothermal area: R. Couch, Prof., Dept. Ocean., O.S.U., W. French (affiliation undet.), and A. Johnson, Prof., P.S.U.
12. Water resources of the Umatilla Indian Reservation, Umatilla County: J. B. Gonthier, U.S.G.S. Portland, in coop. with State Engineer
13. Quartzburg mining district - geology: F. R. Johnson, Master's cand., O.S.U.
14. Columbia River Basalt - Imnaha Canyon: W. D. Kleck, Ph.D. cand., W.S.U.
15. Columbia River Basalt - between Imnaha and Grande Ronde Canyons: Steve Riedel, Master's cand., W.S.U.
16. Columbia River Basalt - upper Grande Ronde River: Martin Ross, Master's cand., U. Idaho (formerly student at W.S.U.)
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cand., U. Cal. Berkeley
12. Seismic monitoring: Stephen Woodcock and Jon Hansen, Dept. Ocean.,
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* * * * *

SNAKE RIVER CANYON MAP PUBLISHED

A geologic map of the Snake River Canyon, Oregon-Idaho, together with a preliminary report describing the geology, has been published as GMS-6 in the Department's Geologic Map Series. Map and report were prepared by Tracy L. Vallier, formerly at Indiana State University and now with Scripps Institution of Oceanography in California. Dr. Vallier began his field work as a graduate student at Oregon State University and spent eight summers studying and mapping the complex geology of this rugged canyon of the Snake River. The area mapped extends from the Oxbow, south of Homestead, to the Oregon-Washington boundary.

The Snake River Canyon map, at a scale of 1:125,000, and the 15-page descriptive report are for sale by the Oregon Department of Geology and Mineral Industries at its Portland, Baker, and Grants Pass offices. The price is \$5.00.

* * * * *

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GEOLOGY OF HUG POINT STATE PARK NORTHERN OREGON COAST

Alan R. Niem
Department of Geology, Oregon State University

Hug Point State Park is a strikingly scenic beach and recreational area between Cannon Beach and Arch Cape on the northern coast of Oregon (Figure 1). The park is situated just off U.S. Highway 101, 4 miles south of Cannon Beach (Figure 2). It can be reached from Portland via the Sunset Highway (U.S. 26) west toward Seaside, then south on U.S. 101 at Cannon Beach Junction. The day-use park includes a parking area, picnic, water, and restroom facilities, scenic beaches, and coastal cliffs. No overnight



Figure 1. Sea cliffs and sea caves in Hug Point State Park. Hug Point is the headland farthest to the left.

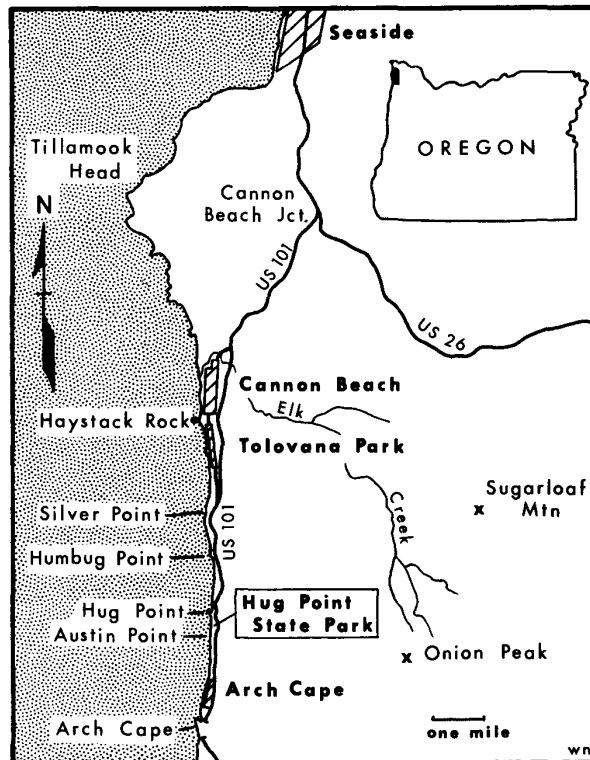


Figure 2. Index map of Hug Point-Cannon Beach area.

camping is available. A 1-mile hiking geologic field trip along the beach and a road log for a 4-mile drive on U.S. 101 in the Hug Point vicinity are described in this report. Points of geologic interest are shown on the maps (Figures 4 and 5).

Hug Point acquired this name because it was necessary to hug the rocks to get around the point without getting wet (McArthur, 1974). In the late 1800's, a stagecoach road was blasted out of the sea cliff to make passage along the beach possible during high tide (Figure 3). Early settlers used the beach for a highway when they traveled between Astoria and Tillamook (Dicken, 1971).

Physiographic Features

The Hug Point-Cannon Beach area is a part of the Coast Range physiographic province, which extends from the Coquille River and the Klamath Mountains on the south to the Columbia River on the north and is bordered

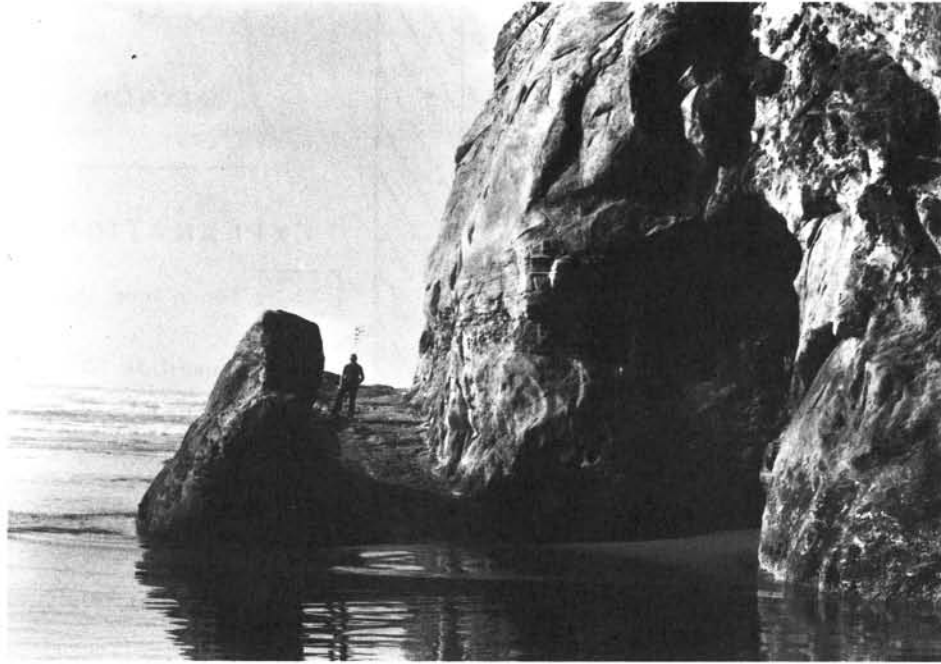


Figure 3. Coastal stagecoach road blasted into the sea cliff at Hug Point.

by the Willamette Valley on the east and by the Pacific Ocean on the west (Baldwin, 1964). Average elevation of the Coast Range is about 1,500 feet. The 3,000-foot peaks adjacent to the Park, Sugarloaf Mountain and Onion Peak, are among the highest in the northern Oregon Coast Range (Figure 2).

The coastline is characterized by steep headlands, sea stacks (small offshore islands), and long narrow beaches. The precipitous headlands, such as Tillamook Head to the north and Arch Cape to the south of Hug Point State Park (Figure 2), are resistant basalt. Hug Point and Austin Point in the Park (Figure 4) consist of well-cemented sandstone and are separated by coves which have been eroded in softer sandstone by the pounding waves of countless winter storms. The sea stacks are eroded remnants of resistant basalt sills and dikes.

The inland area just east of the Park is a region of forested hummocky lowlands and intervening stream valleys carved into sedimentary rocks. Farther east are prominent steep ridges and rugged mountains composed of basalt.

Bedrock Geology

Hug Point State Park and the surrounding area is underlain by the middle Miocene Astoria Formation and by Miocene Depoe Bay Basalt and Cape Foulweather Basalt (Figures 4 and 5).

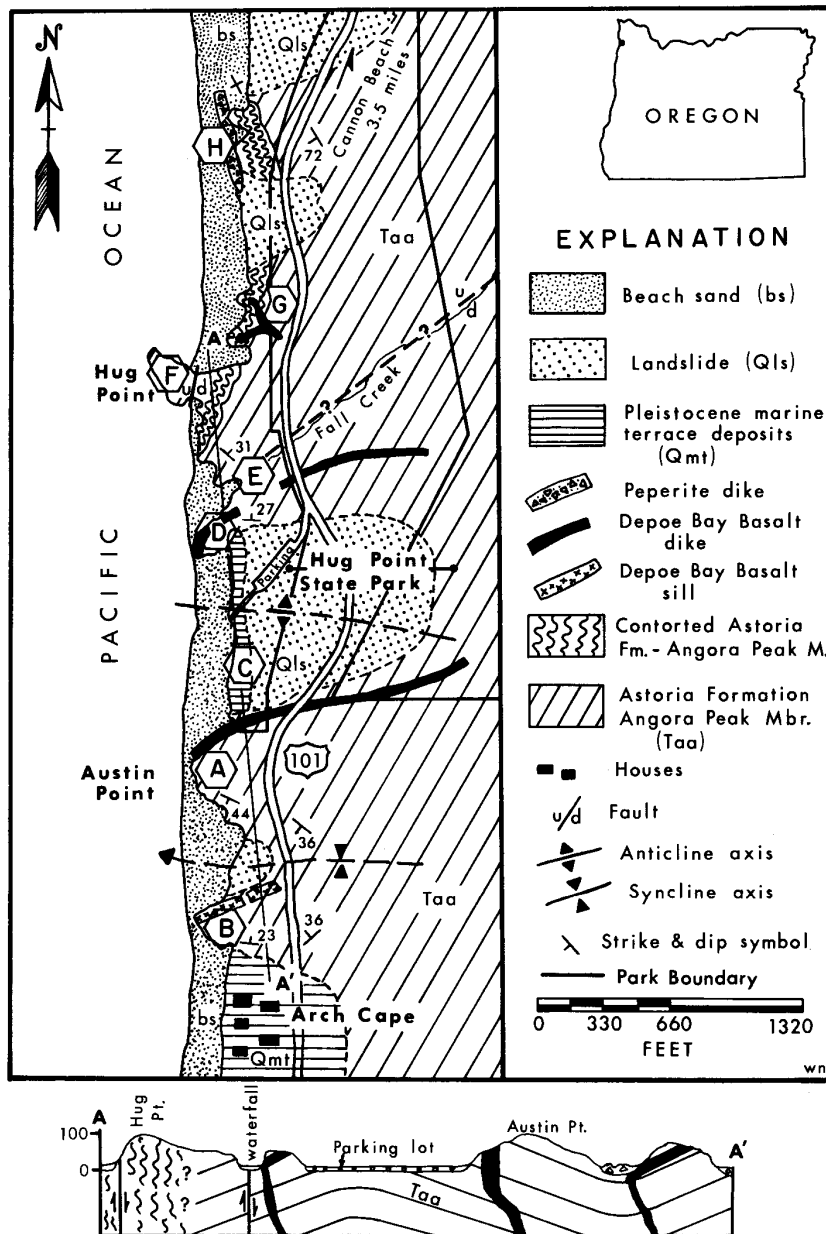


Figure 4. Geologic map and cross section of Hug Point State Park (after Smith, 1975). Letters A through H refer to points of interest on hiking field trip described in text.

Astoria Formation

The Astoria Formation in this area is composed of two informal units, the 1,100-foot thick Angora Peak sandstone member named for outcrops in Angora Peak about 1 mile south of the map area, and the overlying 650-foot thick Silver Point mudstone member named for outcrops at Silver Point.

Angora Peak member: The Angora Peak sandstone member consists of thick layers of laminated and cross-bedded, feldspathic and lithic sandstones interbedded with minor layers of well-laminated, dark-gray, carbonaceous and micaceous siltstones, and channel pebble conglomerates (Smith, 1975). Local coal beds occur near Angora Peak (Cressy, 1974). The well-indurated sandstones are carbonate cemented, typically orange yellow and iron stained, and at Hug Point State Park form sea cliffs 50 to 100 feet high (Figures 1 and 4). The sandstones are medium to very coarse grained, locally pebbly, and moderately to poorly sorted. They are composed of predominantly subangular and subrounded quartz, plagioclase, potash feldspar, and volcanic rock fragments. Fine-grained fossiliferous shallow-marine sandstones and siltstones in the upper part of the unit are well laminated, highly carbonaceous, and micaceous. The channel conglomerates and fluvial cross-bedded sandstones (Figure 6) contain abundant subrounded, poorly sorted pebbles of quartz, pumice, basalt and andesite, chert, quartzite, and tuff.

Silver Point member: The Silver Point mudstone member, which overlies and may interfinger with the upper part of the Angora Peak sandstones, is composed predominantly of dark, laminated, silty mudstones and very thin-bedded, light-gray, tuffaceous siltstones. The lower part of the Silver Point member is characterized by rhythmically interbedded dark-gray mudstones and light-gray, fine- to medium-grained, laminated, feldspathic sandstones (Figure 7). Rare channel graded pebble conglomerates also occur. The laminations are produced by a concentration of muscovite, biotite, and dark carbonaceous plant fragments. Sandstones and conglomerates have sharp bottom contacts and gradational upper contacts, are graded (Figure 8), and locally contain contorted laminations, load casts, flute and groove marks, and mudstone rip-ups. The lower part of the Silver Point member is well exposed in the sea cliff at Silver Point adjacent to U.S. 101 2 miles north of Hug Point (Figures 2 and 7).

Deep-marine microfossils occur in the Silver Point mudstone in Ecola State Park (Niem and Van Atta, 1973; Neel, 1975). The mudstones contain abundant montmorillonite clay and form extremely unstable hummocky slopes. There have been destructive landslides along the Coast where winter wave erosion has undercut the support of cliffs composed of this mudstone. At Silver Point, several scarps and landslide terraces contain asphalt slabs of old U.S. Highway 101. Just south of Silver Point, a 1,200-foot-wide landslide in these mudstones occurred in February 1974 (Figure 9).

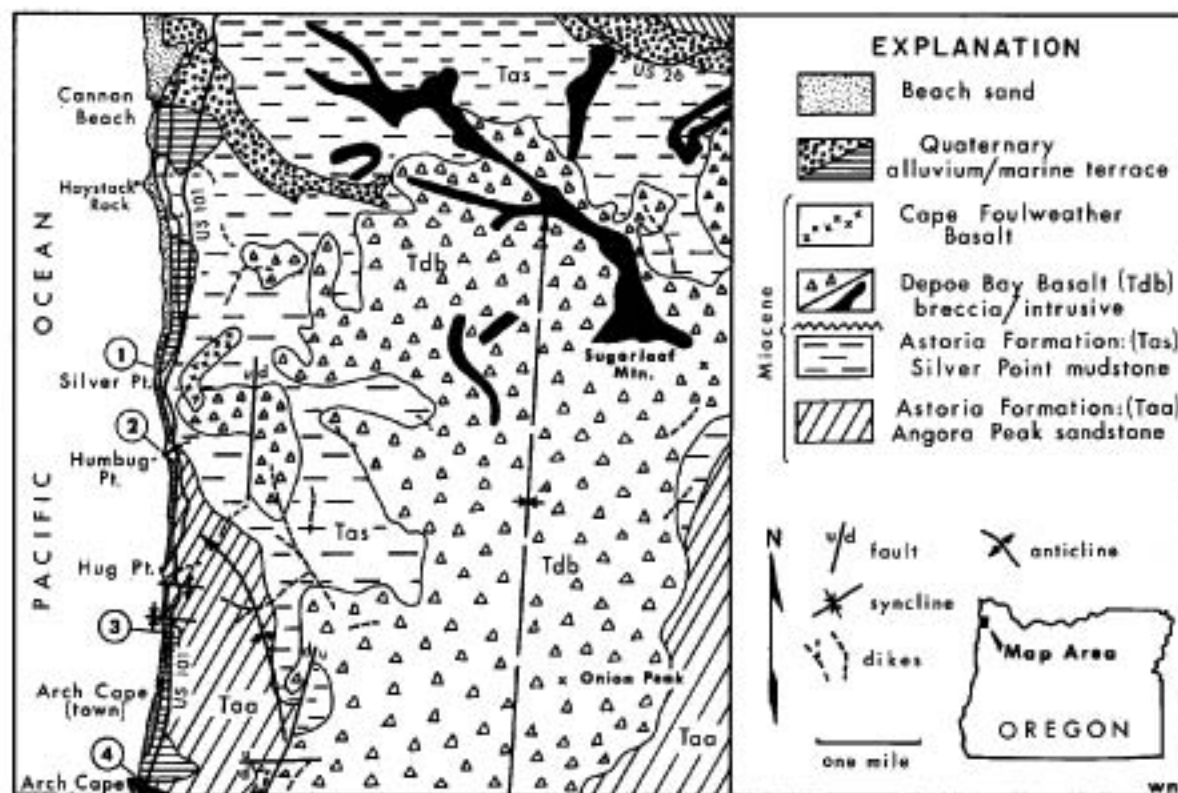


Figure 5. Geologic map of the Arch Cape-Cannon Beach area (after Smith, 1975 and Neel, 1975). Numbers 1 through 4 refer to stops on highway field trip described in text.



Figure 6. Coarse-grained, cross-bedded Angora Peak sandstone beds in Hug Point State Park (Point B on Figure 4).



Figure 7. Interbedded mudstones and sandstones of the Silver Point member in sea cliff below viewpoint at Silver Point on U.S. 101. Note thick lens-shaped sandstone bed in middle of sequence.

Depoe Bay Basalt

The Depoe Bay Basalt, named for exposures at Depoe Bay, Oregon (Snively and others, 1973), is a hard, dark-gray, finely crystalline basalt. In the northern Coast Range, it lies with angular unconformity on the underlying Silver Point and Angora Peak members of the Astoria Formation. At nearby Sugarloaf Mountain and Onion Peak, it forms more than 2,000 feet of resistant basalt breccias and rarer isolated pillow lavas and pillow breccias. The breccias consist of poorly sorted, angular fragments of dark aphanitic basalt and basaltic glass in a matrix of dark-yellow-brown palagonite and basaltic glass (sideromelane and tachylyte). The brecciated lavas were extruded on the ocean floor and formed by fragmentation of hot molten lava flows coming in contact with the cold sea water.

Numerous Depoe Bay Basalt sills, dikes, and irregular intrusions associated with the extrusive Depoe Bay breccias penetrate the underlying Astoria Formation. Some sills are thick (up to 600 feet) and form wave-resistant headlands, such as Tillamook Head near Seaside (Figures 2 and 10) and Neahkahnie Mountain, 4 miles south of Arch Cape. These large sills generally dip gently to the southeast and are commonly in fault contact with the surrounding Astoria Formation. The sills range from finely crystalline basalt to diabase and are characterized by well-developed, nearly vertical columnar jointing. The dikes are finely crystalline to aphanitic basalt and are also columnar jointed. They are generally thinner than the sills and irregular in shape. Small sills and dikes are abundant in Hug Point State Park (Figure 11). Thin, reddish baked zones occur where the hot lava came in contact with the surrounding host rock.

Cape Foulweather Basalt

The Cape Foulweather Basalt was named for exposures at Cape Foulweather north of Newport, Oregon (Snively and others, 1973). The unit overlies the Depoe Bay Basalt and the Astoria Formation in the Oregon Coast Range. It is characterized by large, scattered, yellow phenocrysts of plagioclase (labradorite) in a groundmass of aphanitic to finely crystalline, dark-gray basalt. Cape Foulweather submarine breccias overlying Silver Point mudstones form Haystack Rock near Cannon Beach (Figure 10). A Cape Foulweather Basalt sill is exposed near Silver Point (Figure 5). The Depoe Bay and Cape Foulweather Basalts are middle Miocene in age (14 to 16 million years old based on potassium-argon dating [Snively and others, 1973; Niem and Cressy, 1973]).

Unconsolidated Deposits

Marine terrace deposits occur in small coves between headlands. They are 25 to 40 feet thick and are composed of thin layers of well-sorted,



Figure 8. Graded pebbly sandstone beds in Silver Point mudstone.



Figure 9. Landslide in Silver Point mudstones south of Silver Point, February 1974. (Photo courtesy of Seaside Photo)

reddish, iron-stained beach sands, lenses of rounded basalt gravels, layers of peat and carbonized tree limbs, irregular gray, thin ancient soil horizons, and thin ash beds. The deposits are soft and unconsolidated and can be excavated easily. The anatomy of a marine terrace deposit (30 feet thick) is well exposed along the beach near the parking lot at Hug Point State Park (Figure 4).

Beach sands are laminated, well sorted, and fine grained. Subangular to subrounded quartz and feldspar are the dominant mineral constituents. In the winter, several feet of the beach sands are removed by strong storm waves to form offshore bars, thus exposing the underlying well-rounded basalt gravels on the upper parts of the beach zone.

Landslides are common along the coastal sea cliffs, particularly in the Silver Point mudstones and Angora Peak sandstones (Figure 5) and in marine terrace deposits between Hug Point and Arch Cape (Figure 4). Landslide terrane is hummocky and poorly drained. Cliff exposures of landslides along the beach consist of chaotic mixtures of gray, sticky, plastic muds, with tree limbs and blocks of basalt, and sandstone. Recent movement on landslides is recognizable by cracks in the pavement of the highway and by trees tilted in many directions.

Geologic History

The rocks in the Hug Point-Cannon Beach area were deposited during the Miocene Epoch (approximately 13 to 35 million years ago). During and since the Pliocene Epoch (3 to 13 million years ago), the rocks of the Coast Range have been gently uplifted, faulted, folded, and eroded (Baldwin, 1964). The strata are unconformably overlain, in places, by a thin veneer of Pleistocene marine terrace deposits, Holocene dune and beach sands, and stream alluvium (gravel, silt, and sand).

Miocene Epoch

During the middle Miocene, much of western Oregon was uplifted above sea level (Snively and Wagner, 1963). Along the western margin of the uplifted area, however, local subsidence produced a shallow marine embayment from the Hug Point-Cannon Beach area to Astoria. Other embayments were centered in the Newport and Tillamook areas. Great quantities of sand, mud, and gravel were transported westward from the early Cascade Mountains and eastern Oregon, Washington, and Idaho via an "ancestral Columbia River" (Cressy, 1974). These sediments were deposited in the Hug Point-Cannon Beach area in the form of a large delta (Niem and Van Atta, 1973; Smith, 1975), much like the Mississippi or Niger delta today. The delta contained a distributary river system and intervening coal-forming marshes and swamps. Along the delta front, strong wave-energy reworked the sands in the form of shallow-marine bars, beaches, and spits and into a

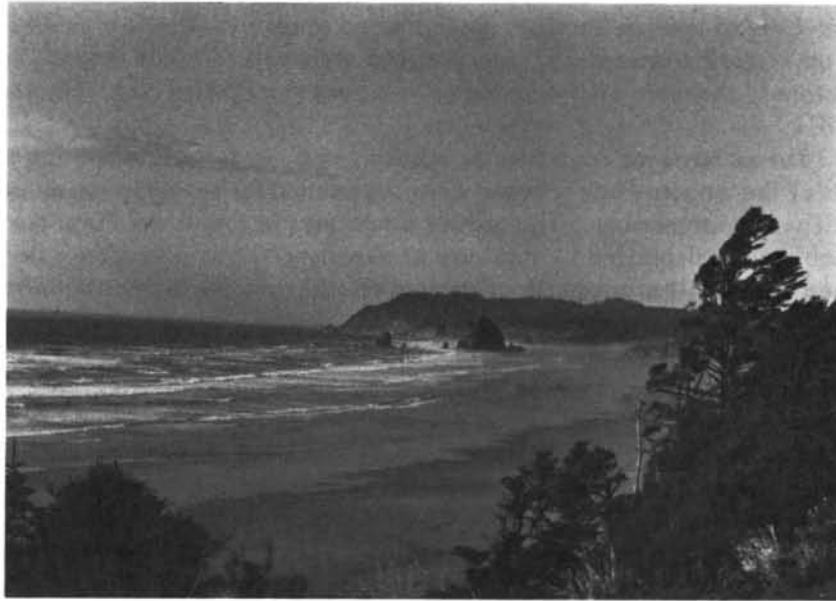


Figure 10. View from Silver Point. Headland in distance is Tillamook Head. Haystack Rock is the largest sea stack in foreground.



Figure 11. Sea-cave with dark basalt dike on left and light-colored Angora Peak sandstone on right. A thin basalt dike also cuts diagonally through the sandstone on right (Point D on Figure 4).

broad sheet of shallow-marine, fine-grained sands with shells of mollusks and other marine animals. These lithified sediments form the Angora Peak sandstones, the main cliff-forming unit in Hug Point State Park (Figures 1 and 4).

The embayment continued to subside, and, in time, the shallow-marine sands of the Angora Peak member were superseded by deep-marine muds of the Silver Point member. The graded sandstones in the Silver Point member probably were deposited by turbidity or density currents of muddy water which formed as a result of submarine slumping or sliding of muds and sands from the delta front into a deeper basin. The graded bedding formed where the coarser and heavier grains suspended in the current settled out first and were followed by the finer grains (Figure 8). The mudstones and thin siltstones represent the clays and silts that settled very slowly by pelagic sedimentation on the submarine part of the delta (prodelta). Uplift and erosion produced an unconformable surface on the Astoria Formation. This was followed by further subsidence and inundation by the sea.

During the later part of the middle Miocene, great volumes of basalt breccias (the Depoe Bay Basalt) were erupted on the deep-sea floor from a north-south trending series of submarine volcanic centers. Eroded remnants of the volcanic rocks now form the two highest peaks in the Hug Point-Cannon Beach area -- Sugarloaf Mountain and Onion Peak. This submarine volcanism was contemporaneous with eruption on land of the Columbia River Basalt of eastern Oregon and Washington (Snively and others, 1973).

The submarine lava flows along the Coast were fed by many basalt dikes. Some dikes and sills intruded and locally deformed thick piles of semi-consolidated Astoria Formation strata (Figures 11 and 12). In certain places, forceful intrusion of hot magma into these water-saturated sediments formed dikes of peperite composed of angular blocks of altered basalt, sandstone, and mudstone (Figure 13). Great volumes of steam were generated as a result of this interaction and may have helped displace and deform the semi-cohesive sediments (Figure 12; contorted zone on Figure 4). Steam blasting incorporated angular pieces of the host sedimentary rock into the dike. A north-trending peperite dike occurs approximately 600 feet north of Hug Point (Figure 4, point H).

Pliocene Epoch (3 to 13 million years ago)

During the Pliocene, the Coast Range was uplifted (Baldwin, 1964). No marine Pliocene strata are recognized in the Hug Point-Cannon Beach area, but thick strata occur in the nearby offshore area (Kulm and Fowler, 1974). During this time of mountain building, a large north-south syncline with its axis trending across Onion Peak and Sugarloaf Mountain and a smaller adjacent anticline were formed (Figure 5). The sedimentary strata and breccia were also displaced several hundred feet by high-angle faults, one set trending east-west and the other north-south (Figure 5). Some

smaller faults are visible in the sea cliffs at Hug Point State Park where adjacent layers of Angora Peak sandstone have been broken and displaced. An anticline and an adjacent syncline in Angora Peak sandstones with east-west trending axes are readily observable in Hug Point State Park (Figure 4, cross section). These small folds may have formed during the Pliocene, or earlier at the time of the middle Miocene intrusions. The syncline near Austin Point has a width at beach level of about 600 feet and the anticline has a width of 1,000 feet. The strata were tilted from 23° to 44° to form these folds.

Pleistocene (11,000 to 3 million years ago) and Holocene Epochs

Erosion became the dominant geologic process after the main uplift and deformation of the Coast Range in the Pliocene Epoch. Stream and sheet erosion excavated valleys in the softer Angora Peak sandstones and Silver Point mudstones, leaving the harder, resistant Depoe Bay Basalt sills and dikes as elongate narrow ridges and the volcanic breccias as high, rugged mountains.

Sea level fluctuated several times during the Pleistocene owing to development of continental glaciers and their subsequent melting. In addition, continued uplift of the Coast Range may have influenced the relative sea level. As a result, wave-cut benches representing former stands of the sea lie 40 to 100 feet above present sea level along this part of the Oregon Coast. In Hug Point State Park, wave erosion planed off the flat surfaces that now form the tops of the sea cliffs. Beach sands and gravels were deposited locally between headlands to form flat marine terraces.

Since the Pleistocene, waves have been carving a new wave-cut bench below the surface of the water and have been eroding away parts of the less resistant rocks to form stacks, caves, notches, cliffs, and narrow sand beaches, leaving the more resistant headlands, such as Hug Point.

Hiking Field Trip Along the Beach

A short, interesting hike may be taken along the beach and sea cliffs beginning at the parking lot. Points of interest along this hike are shown on the enlarged geologic map of the Hug Point area (Figure 4).

A Austin Point. Small headland approximately 600 feet south of parking lot. A thick, dark dike of Depoe Bay Basalt intrudes yellow, cross-bedded, coarse-grained, Angora Peak sandstones. The sandstones dip 40° southwest and form Austin Point (passable at low and slack tides).

B Small headland approximately 780 feet south of Austin Point. A sill of Depoe Bay Basalt 10 feet thick in Angora Peak sandstones. The sill has well-developed, columnar joints that formed perpendicular to the cooling

surface. The baked zone is only a few inches thick. Between Austin Point and this headland is the axis of a westward-plunging syncline. At this location, one limb of the syncline is dipping northward and the other limb can be seen in the southward-dipping beds of Austin Point (Figure 4, cross section).

On the south side of the small headland is a good example of cross-bedding involving pebbly sandstone with very thin mudstone interbeds (Figure 6). Grading along the cross-beds probably represents deposition in large submarine sand waves at the mouth of an ancient river channel. The orientations of the cross-beds indicate that the river currents flowed from east to west. Abundant pebbles of quartz, quartzite, pumice, and chert, basalt, and andesite suggest that the material was eroded from the ancient Cascade Mountains and rocks of eastern Oregon and Idaho and brought here possibly via an "ancestral Columbia River." Some fragmented fossil plant debris, including carbonized logs up to 8 inches long, can be found in these channel deposits. The summer homes south along the beach are built on a flat Pleistocene marine terrace.

Ⓒ Eroded cliff of Pleistocene marine terrace deposits approximately 200 feet south of Hug Point parking lot. The deposits are composed of soft, iron-stained, friable beach sands, carbonized tree limbs, and thin, reddish, clayey ancient soil horizons. This terrace deposit fills an old cove cut into the Angora Peak sandstones. Winter storm waves now undercut the soft terrace deposits, resulting in many landslides. Several live trees are tilted in a variety of directions where landsliding has been recently active. In winter the beach consists of basalt gravels and piles of logs.

Ⓓ Small sandstone headland approximately 400 feet north of parking lot (passable during low or slack tide). Laminated, coarse-grained Angora Peak sandstones, cut by a thick Depoe Bay Basalt dike with well-developed columnar jointing, are partly contorted, but the overall dip is to the north, representing the limb of the anticline whose axis passes approximately through the parking lot (Figure 4). The sandstone contains many small calcareous and pyrite-filled nodules. The southwest side of the headland has been infilled with blocks of alluvium. The abrasional action of beach sand and the hydraulic compressive force of waves have created a deep, narrow sea cave in a crack between the basalt dike and the sandstone (Figure 11).

Ⓔ Waterfall and sea caves 550 feet north of parking lot. Waterfall is in northward dipping Angora Peak sandstone (Figure 14). Ocean waves have undercut the sandstone faster than the downcutting of Fall Creek, resulting in a waterfall here. The pinnacle of Angora Peak sandstone is a resistant erosional remnant. A fault between the pinnacle and Fall Creek is a possible reason for the location of Fall Creek (Figure 4).

Ⓕ Hug Point. Large, deep sea caves and sea notches carved into Angora Peak sandstones by storm waves. South of the Point (Figure 3), blocks and

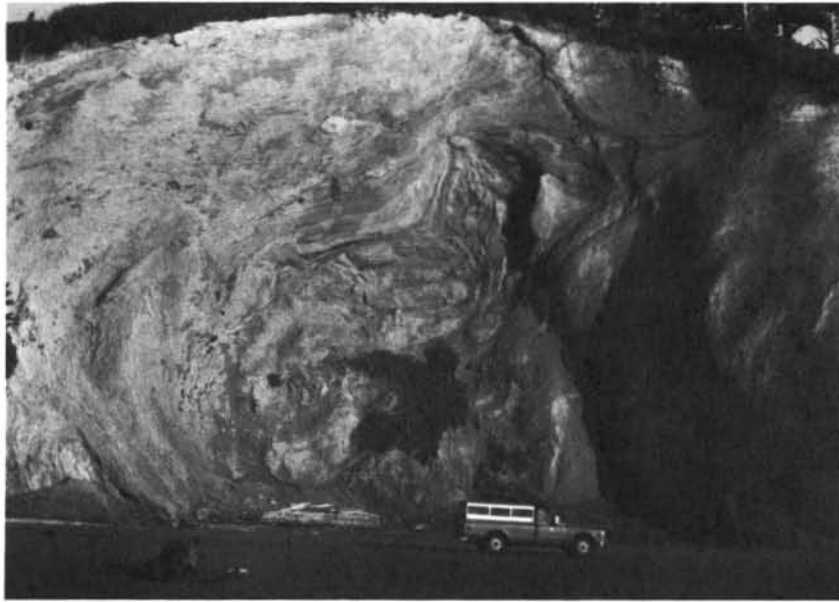


Figure 12. Sea-cliff exposure of vertically deformed sedimentary strata north of Hug Point. Note thin basalt dike cutting across strata in right half of photo (Point G on Figure 4).



Figure 13. Peperite dike composed of numerous angular blocks of altered basalt, mudstone, and sandstone. Exposed in beach north of Hug Point (Point H on Figure 4).

layers of the sandstones are vertical or overturned. Note the abrupt vertical break between the contorted strata and the layers of cross-bedded sandstone 20 feet east of where the old stagecoach road rises above the beach. This break is a high-angle, north-south trending fault (Figure 4); the layers on the west have been moved upward relative to the contorted layers on the east. A narrow sea cave has formed along this fault where the strata were broken and fragmented and thus were easier for waves to excavate.

Follow the old stagecoach road around Hug Point (passable during low and slack tides; Figure 3). Note that the pebbly cross-bedded Angora Peak sandstones that form Hug Point dip 15° northeastward. The wear of many wagon wheels cut deep ruts in the old roadbed.

Ⓔ A sea cliff 70 feet high approximately 200 feet northeast of Hug Point. Vertical standing beds of Angora Peak sandstones in a contorted zone 50 to 100 feet wide (Figures 4 and 12). Differential erosion has cut a bowl-shaped depression into many of the vertical layers. The sandstones are mostly fine grained but contain some local conglomerate channels and pebbly zones. Two thin basalt dikes cut through the deformed sandstones.

Ⓕ Sea cliff 1,000 feet north of Hug Point. Peperite dike at the base of the cliff consists of angular blocks of fine-grained laminated Angora Peak sandstones and altered greenish to dark-gray basalt in a sand matrix (Figure 13). The dike trends north-south, is approximately 15 feet wide, and is partly covered by beach sand. Associated with the dike are vertical beds of very fine-grained, Angora Peak sandstones which are a continuation of the contorted zone from Point G. The peperite dike probably formed as a result of steam blasting and quenching of hot molten basalt magma in contact with water-saturated, semi-consolidated Angora Peak sands soon after their deposition. The forceful intrusion of the magma displaced and folded the strata into a vertical position. Microfaults that formed in the mobilized semi-consolidated sands can be seen in the sea cliff.

Note the hummocky landslide area to the north of this sea cliff. The ocean is undercutting the toe of the slide, setting the scene for continuous landslide movement in this area.

Road Log from Silver Point to Arch Cape on U.S. 101

The stops in this 4-mile road log are shown on the geologic map of the Arch Cape-Cannon Beach area (Figure 5) and include two short hikes to the beach.

STOP 1. Follow U.S. 101 north from the Hug Point parking lot for 2 miles to Silver Point. Pull off the road at southernmost viewpoint.

Sea stacks at Silver Point, west of the first parking lot, are wave-eroded remnants of a once more-extensive basalt sill. To the north



Figure 14. At its mouth, Fall Creek plunges over a waterfall onto the beach between sea caves on left and the pinnacle with a thin vegetative cap.



Figure 15. Dark basalt dike intruded into light-colored Angora Peak sandstones, Humbug Point (Stop 2 on Figure 5).

is the steep cliff of Tillamook Head, a 600-foot thick basalt sill (Figure 10). Haystack Rock in the foreground is composed of Cape Foul-weather Basalt pillow lavas and breccias unconformably overlying Silver Point mudstones. Hug Point can be seen to the south. The large roadcut on the east side of U.S. 101 exposes the Silver Point mudstone member of the Astoria Formation. Approximately 200 feet above this exposure are the overlying Depoe Bay submarine basalt breccias that form the high hills above the roadcut. Recent landslide debris in the center of the roadcut illustrates a common engineering geology problem in these mudstones.

The sea cliff directly below the viewpoint parking lot is a large landslide block composed of interbedded fine-grained graded sandstones and silty mudstones typical of the Silver Point member (Figure 7). A trail over the slumped pavement of old U.S. Highway 101 provides access to the beach.

Proceed south 0.1 mile on U.S. 101.

- 0.1 In the spring of 1972, a section of U.S. 101 two-tenths of a mile in length dropped 3 to 6 inches as the result of a landslide in the Silver Point mudstones. In February 1974 after heavy rains had saturated the mudstones and winter storm waves had undercut support of the toe of the slide, there was extensive renewed movement. U.S. 101 dropped 25 to 35 feet vertically and moved 100 feet toward the sea (Figure 9). The slide covered an area of 1.25 square miles and destroyed this section of U.S. 101 and several summer homes. The headscarp of the slide is a quarter of a mile above the road. In order to stabilize the landslide, highway engineers terraced the slope near the top of the slide to remove excess weight, developed a drainage system to remove surface and ground water, and re-aligned the highway (the road now curves around the slide).
- 0.5 In roadcuts on both sides of U.S. 101, a basalt dike is exposed which intruded and deformed blocks of Angora Peak sandstones.
- 0.7 STOP 2. Humbug Point. Pull off on dirt road at day-use area. Follow small trail to beach. The small headland 100 feet to the north (Humbug Point) is held up by a 20- to 30-foot thick basalt dike surrounded by a chaotic mass of sedimentary blocks of fine-grained, well-laminated Angora Peak sandstone in a pebble sandstone matrix (Figures 15 and 16). The force of the intrusion probably deformed and broke these semi-cohesive strata because this sedimentary breccia zone parallels the trend of the dike. Some small pyrite nodules and crystals can be found between the sedimentary breccia fragments.
- 2.0 Intersection with Hug Point State Park road; continue south on U.S. 101.



Figure 16. Chaotic mixture of blocks of laminated Angora Peak sandstone at Humbug Point.

- 2.3 North limb of syncline of Angora Peak sandstones in deep roadcut on both sides of the road; beds dip 45° to the south.
- 2.5 South limb of syncline of Angora Peak sandstones dipping 35° northward. A thin basalt sill parallels the bedding.
- 2.7 STOP 3. Pull off on the left. Cannon Beach historical marker tells about shipwreck of U.S. Naval schooner in 1846 from which jettisoned cannons washed ashore.
- 3.5 Entering Arch Cape, which is built on flat Quaternary marine terrace gravels and sands.
- 3.6 STOP 4. Town of Arch Cape, take paved road on right to beach (0.1 mile). Walk south about 800 feet to headland that forms Arch Cape (cross small stream). Arch Cape is a large intrusion of Miocene Depoe Bay Basalt that forms a southeast-trending ridge 1 mile long and 400 feet high. Very well-developed fan-like columnar jointing and huge incorporated blocks of Angora Peak sandstone occur on the seaward face of Arch Cape (passable only at low tide). The highway tunnel just south of the town of Arch Cape is bored through this basalt mass.

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* * * * *

GOLD TO FEATURE IN PORTLAND METALS CONFERENCE

GOLD will be a popular topic at the forthcoming Pacific Northwest Metals and Minerals Conference to be held at the Sheraton Motor Inn in Portland April 6-9, 1975. The gold meetings will include the Fifth Gold and Money Session, which will be concerned with international economic outlook, and the Technical Session on Gold, which will offer a wide range of topics on geology, exploration, and operations. The schedule for the Fifth Gold and Money Session is given below and is followed by general information on the technical sessions and the rest of the Conference program.

Fifth Gold and Money Session Tuesday, April 8, 1975

Morning Session - 9:00 a.m.

Presiding chairman: Henry L. Day, Day Mines, Inc., Wallace, Idaho

"Twentieth Century Inflation" - John E. Holloway, Consultant,
Marshalltown, South Africa

"Gold and the Economy: A Study in Contrasts" - Peter L. Bernstein,
Consulting Economist, New York, N.Y.

"Real Money and Counterfeit Money: Their Effect on World Conditions"
Eugene Guccione, Senior Technical Editor, Mining Engineering,
Salt Lake City, Utah

Luncheon - 12 noon

Presiding Chairman: Donald H. McLaughlin, Homestake Mining Co.,
San Francisco, California

Speaker: C. Austin Barker, Vice President-Consulting Economist,
Hornblower & Weeks-Hemphill, Noyes, New York, N.Y.

"International Monetary Outlook and Gold Related Assets"

Afternoon Session - 1:45 p.m.

Panel discussion by luncheon and morning speakers

Moderator: Donald H. McLaughlin

For further information on the Gold and Money Session, contact:

Raymond E. Corcoran, Chairman, Gold and Money Session,
1069 State Office Bldg., Portland, Oregon 97201 (503) 229-5580

Technical Session on Gold

The Technical Session on Gold will be held on Monday and Wednesday, preceding and following the Gold and Money Session. Specialists from gold-mining districts in Canada, Australia, Mexico, and the United States will be presenting papers on gold deposits and operations in their areas. One

of the 12 scheduled speakers will be Department geologist Len Ramp, who will talk on "Oregon's Gold Potential."

Other Sessions and Programs

The Conference will include three days of technical sessions on metallurgy, welding, aluminum technology, and refractory metals. Three field trips have been arranged for Conference participants to visit Precision Castparts Corp. in Portland, the Centralia strip coal mine and power plant in southwestern Washington; and the titanium and refractory metals plants in Albany, Oregon. In addition, there will be a program of activities for the ladies, and on Tuesday evening a Conference banquet. An Industrial Trade Exposition put on by various suppliers and service organizations will be on display.

To obtain complete Conference program, write to:

AIIME Conference Headquarters, 2014 N.E. Sandy Blvd.,
Portland, Oregon 97232

Registration: Attendance for one day, \$7.00, for entire conference, \$17.00; Gold and Money Luncheon, \$6.00.

* * * * *

METCALF INTRODUCES HARDROCK MINERAL ACT

Sen. Lee Metcalf (MT) has introduced S. 282, the "Hardrock Mineral Development Act of 1975," which would repeal the 1872 mining law and establish a leasing system for hardrock minerals. It is identical to S. 3085 (93rd Congress), which was considered during three days of hearings early last year by the Senate Interior Subcommittee on Minerals, Materials, and Fuels.

In introducing the measure, Metcalf stated that the Mining Law of 1872 contains no general requirement for consideration of other resource values of the land. A critical weakness of the 1872 law, he said, is that it puts the land use decision entirely in the hands of the miner; he added that the basic principle of the mining law that mineral development is always the highest use of the land must be modified.

Metcalf stated that he intends to schedule hearings on the measure at an early date. However, the hearings are likely to be delayed for some time since these other items on the subcommittee's agenda currently have higher priority: (1) surface mining, (2) revision of Federal coal leasing procedures, and (3) outer continental shelf oil and gas leasing.

(Amer. Mining Cong. News Bull., no. 75-3, 1975)

* * * * *

PRESIDENT VETOES SURFACE MINING BILL

On Dec. 30, the last day on which he could have approved S. 425, an act to regulate surface mining, President Ford announced he would not do so. Although a formal veto message was not prepared, a "Memorandum of Disapproval" was issued, setting forth the President's reasons for the veto.

In a press statement issued at Vail, Colorado, President Ford listed several principal aspects of the bill which led to its veto, including the following: The excise tax on coal production; excessive direct Federal involvement in reclamation and enforcement programs; coal production losses in 1975 of 2% to 8%, with losses by 1977 of 18% or 141 million tons, according to FEA estimates; surface owner protection provisions that would have limited access to Federal coal lands, produced windfall profits to surface owners, and reduce Federal revenue from leases; and complex procedural requirements and standards which would have involved extensive litigation and potential production impact.

Among the procedural deficiencies listed were a very broad citizens suit provision, a near prohibition on mining that disturbs alluvial valley floors or water supplies in the West, requirements that could have delayed permits for new mining operations or imposed a temporary moratorium on mining permits for Federal lands, requirements to prevent any increase in siltation above premining conditions and designation of areas not suitable for surface mining.

The President also stated that S. 425 provides for excessive Federal expenditures and would have an inflationary impact on the economy. He said the Administration's goal in the new year would be to strive diligently to ensure that laws and regulations are in effect which establish environmental protection and reclamation requirements appropriately balanced against the nation's need for increased coal production.

(Amer. Mining Cong. News Bull., no. 75-1, 1975)

* * * * *

SUMMER FIELD COURSE IN MINING OFFERED

The Colorado School of Mines and the Colorado Mining Association are jointly sponsoring a summer field course in the "Total Concept of the Mining Industry," a 6-hour credit course designed for teachers.

The course will be held at the Colorado School of Mines, Golden, Colorado, June 9 to July 18, 1975. Scholarships are available. For further information write to: Col. W. E. Leckie, Director of Continuing Education, Colorado School of Mines, Golden, Colorado 80401.

* * * * *

GEOLOGIC MAP OF THE UNITED STATES PUBLISHED

A new geologic map of the United States (exclusive of Alaska and Hawaii) compiled by Philip B. King and Helen M. Beikman, has been issued by the U.S. Geological Survey. The new map, which replaces the Survey's 1932 map, is in a set of three sheets on a scale of 1:2,500,000. The compilers have prepared a 40-page illustrated explanatory text which supplements the map and describes the historical development of geologic mapping extending back more than two centuries.

"Geologic Map of the United States - 1974" is for sale by the U.S. Geological Survey, Reston, VA 22092. Price for three sheets is \$5.00.

"Explanatory Text to Accompany the Geologic Map of the United States" (U.S.G.S. Professional Paper 901) is for sale by the Superintendent of Documents, U.S. Govt. Printing Office, Washington, D.C. 20402. The price is \$1.25 (stock no. 2401-02573).

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EARL NIXON

Earl K. Nixon, the first Director of the State of Oregon Department of Geology and Mineral Industries, died December 8. He was 79. Mr. Nixon was appointed to the directorship (a position later changed to State Geologist) in 1937 and resigned in 1944 to become manager of Western Exploration for the Freeport Sulphur Company.

Nixon organized the Department, selected its personnel, and planned its projects. He could foresee the need for strategic mineral development and, in addition to many other mineral studies, had surveys made of the State's resources of quicksilver, chromite, and manganese; reports of these important war minerals were then available when World War II came. Largely by his efforts, three Metals Reserve Company purchasing depots were established in the State. He became consultant for the War Production Board and the Metals Reserve Company and was appointed State Emergency Coordinator of Mines.

Nixon's tremendous drive and enthusiasm are best illustrated by the fact that during his seven years as Director of the Department, a total of 28 bulletins and many minor publications were issued.

His later years were spent in a wide variety of activities including iron-ore exploration in Venezuela for U.S. Steel, promotion of Kansas minerals for the Kansas Geological Survey, and teaching at the Kansas University Department of Mining and Metallurgy.

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AVAILABLE PUBLICATIONS

(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)

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GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck . . .	2.15
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MOUNT ST. HELENS VOLCANO: RECENT AND FUTURE BEHAVIOR

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Mount St. Helens, a prominent but relatively little known volcano in southern Washington (Figure 1), has been more active and more violent during the last few thousand years than any other volcano in the conterminous United States. Although dormant since 1857, St. Helens will erupt again, perhaps before the end of this century. Future eruptions like those of the recent past would affect a broad area beyond the volcano, but the area most likely to be severely affected is not yet heavily populated.

The high probability, based on past behavior, that Mount St. Helens will erupt again indicates that potential volcanic hazards should be considered in planning for future uses of the land that could be affected by an eruption. The potential risk from future eruptions may be low in relation to the lifetime of a person or to the life expectancy of a specific building or other structure. But when dwelling places and other land uses are established, they tend to persist for centuries or even millenia. Major changes in long-established land-use patterns, which become necessary to protect lives or property, can themselves be economically disastrous and socially disruptive; therefore, potential volcanic hazards should be considered while choices can still be made with respect to future land use, even though eruptions may still be decades away.

Because of its smooth, little-eroded slopes, Mount St. Helens has long been known to be younger than the neighboring volcanoes such as Mounts Rainier, Adams, and Hood (1). However, we have learned only recently how young St. Helens is and how often it has erupted in the recent past. Although its history extends back more than 37,000 years (2,3), virtually the entire visible volcano has formed since about 500 B.C., and most of its upper part has been built within the last few hundred years (Figure 2) (4). This knowledge of its formation resulted largely from detailed studies of the

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origin and sequence of the volcano's eruptive products, coupled with nearly 30 radiocarbon dates from which the volcanic chronology is inferred. The numerous dates were made possible by abundant charcoal in the deposits of many pyroclastic flows (avalanches of hot, dry rock debris) and by charcoal and other vegetative matter interbedded with tephra (explosively erupted, airborne debris).

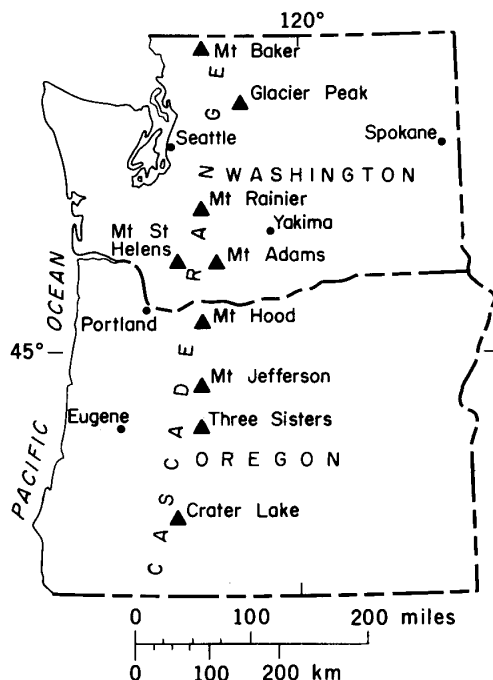


Figure 1. Index map of Washington and Oregon showing location of Mount St. Helens and other volcanoes.

Our purpose in this report is to summarize a remarkable and generally unrecognized record of recent activity at Mount St. Helens and to compare it with the history of some other well-known volcanoes. We also assess the significance of the present dormant interval, which has lasted nearly 120 years. The data now available suggest that since about 2500 B.C. the volcano has never been dormant for more than about five centuries at a time and that dormant periods of one or two centuries or less have been more typical.

Even apparently dormant intervals may have been broken by eruptions that did not leave a conspicuous deposit. The eruptions noted in our chronology include only those which produced deposits large enough to be preserved and recognized today. As many or more eruptions may have occurred



Figure 2. South side of Mount St. Helens volcano (altitude, 2,950 m). The summit consists of a volcanic plug probably emplaced between A.D. 1600 and 1700. Lava flows on the lower flank of the volcano in the center of the photograph are marked by sharp, curved ridges (arrows) formed along margins of flowing lava.

for which stratigraphic evidence either does not exist or has not yet been recognized. We see clear stratigraphic evidence, for example, of only one of the dozen or so 19th-century eruptions that were reported by explorers and settlers after Lewis and Clark's pioneer expedition of 1806 (5).

Since about 400 B.C., Mount St. Helens has shown considerable diversity both in its behavior and in the chemical composition of its eruptive products. Eruptions of basaltic and andesitic lava flows and tephra have been interspersed with eruptions of dacitic domes, tephra, and pyroclastic flows (6). Mount St. Helens has had a complex recent history, and the lithologic diversity of the resulting deposits makes it possible to recognize more volcanic events than if the eruptive products had all been of a single rock type.

Eruptive Chronology

The known eruptions of about the last 4,000 years can be roughly grouped into four periods: 2500 to 1600 B.C., 1200 to 800 B.C., 400 B.C.

to A.D. 400, and A.D. 1300 through the first half of the 19th century (Figure 3).

From 2500 to 1600 B.C., following a dormant period that may have lasted as long as 4,000 years, Mount St. Helens repeatedly erupted large volumes of tephra, and successive domes were formed at the eruptive center. Shattering of the domes, perhaps by volcanic explosions, produced pyroclastic flows that moved beyond the volcano. Pumiceous tephra that were erupted at various times were carried downwind and some covered large lobate areas; at least one of these reached into northeast Oregon and another into western Alberta (2). A quiet interval of perhaps as much as 400 years may have occurred during this eruptive period.

In about 1200 B.C., after an interlude of no more than a few centuries, the volcano began to erupt domes and pyroclastic flows, but with smaller volumes of tephra. During this period, which lasted four or five centuries, many large hot pyroclastic flows of nonvesicular rock debris, pumice, or both, moved away from the volcano in nearly every direction. Some of the rock debris became mixed with water and formed lahars (volcanic mudflows) that streamed many tens of kilometers down river valleys. Radiocarbon dates from charcoal in volcanic deposits suggest that eruptions occurred sporadically throughout this period.

The eruptions of 400 B.C. to A.D. 400 produced both basaltic and andesitic lava flows, which were lacking in the earlier products of the volcano. However, the intermittent explosive eruptions of more silicic tephra, which had characterized the volcano's earlier history, continued and alternated with the eruptions of the more basic lava flows. Thus the new behavior pattern was characterized by eruptions of several different types and of different kinds of rock in quick succession, perhaps even simultaneously from different vents. Eruptions of the volcano formed andesitic or dacitic tephra at least twice, basaltic tephra six times, dacitic or andesite pyroclastic flows no less than three times, and lava flows at least twice. During this period the volcano initially produced lava flows, as well as tephra; then a series of pyroclastic flows was formed starting about 300 B.C.

Although a brief episode of explosive volcanism occurred about A.D. 840, the next major period of frequent and diverse activity evidently began between A.D. 1200 and 1300. From that time on, Mount St. Helens erupted basaltic or andesitic lava flows, dacitic domes, pyroclastic flows, and tephra. The largest tephra eruption of this period occurred about A.D. 1500 and spread pumice at least as far as northeastern Washington. The dacitic dome that forms the present summit of the volcano also was extruded during this period, probably between A.D. 1600 and 1700. The period of activity that roughly coincided with the first half of the 19th century produced tephra, a dacitic dome, and perhaps a few lava flows.

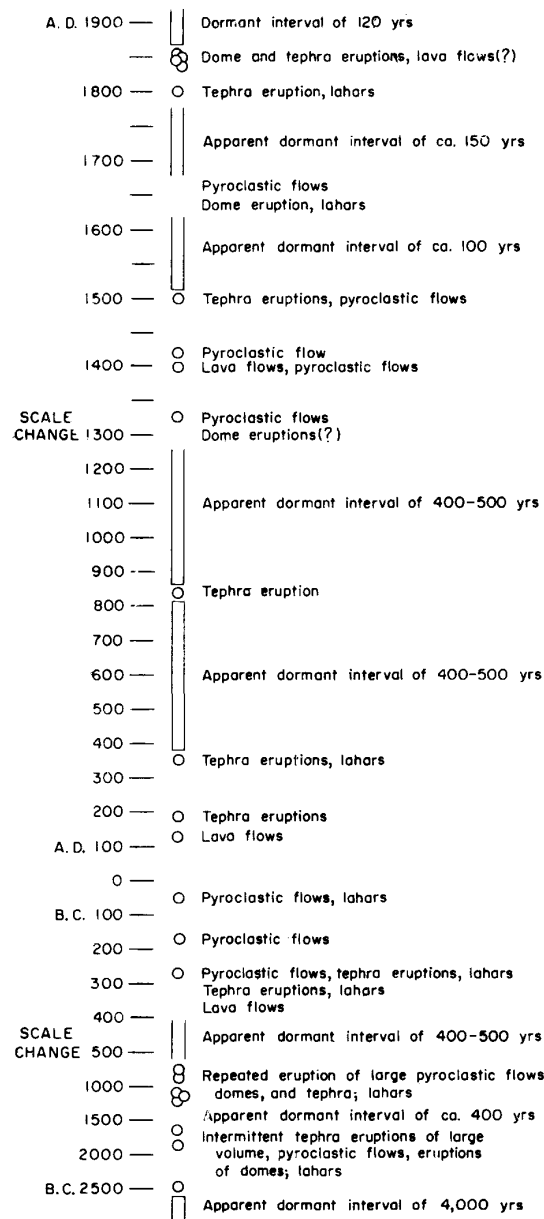


Figure 3. Eruptions and dormant intervals at Mount St. Helens since 2500 B.C. Circles represent specific eruptions either dated or closely bracketed (13); vertical boxes represent dormant intervals.

Frequency, Duration, and Volume

The frequency of eruptive activity can be inferred from the record and dates of known volcanism, but little is known about the duration of individual eruptions. Many eruptions, even relatively violent and voluminous ones, could have occurred within periods of a few days or months; other eruptions probably consisted of a series of small events spread over many decades. Volcanism at Mount St. Helens probably has included many brief but violent eruptive episodes like the catastrophic "Plinian" eruption of Vesuvius in A.D. 79, the eruption of Mount Lamington in Papua (New Guinea) in 1951 and 1952, or the violent outbursts at Santa Maria Volcano, Guatemala, that started in 1922 and still intermittently continue.

The recent stratigraphic record at Mount St. Helens, together with the early 19th century historic record, suggests that if the area had been occupied by record-keeping people, the eruptive history would resemble that of some volcanoes for which long written records are available (Figure 4). Some eruptive episodes probably were virtually single large events; others probably were smaller events repeated at intervals of a few years over a long time.

The historic record at Vesuvius includes at least 10 and possibly 14 eruptions in the 1060 years following the one in A.D. 79 which buried Pompeii (7,8); seven of these also can be identified in the stratigraphic record. Then a period of almost 500 years elapsed during which no unequivocal eruptions occurred; this period ended with the large 1631 eruption. Since 1631, however, the volcano has erupted at intervals of no more than a few decades.

At Fuji, another famous volcano with a long historic record (9), clusters of activity have been separated by dormant periods of varying length, up to 428 years; the volcano has now been inactive for more than 265 years. In contrast, Hekla Volcano in Iceland has erupted at least every hundred years or so since the island was settled (10).

With respect to the volume of material erupted into the air (in contrast to lava flows), Mount St. Helens has produced much less than did pre-historic Mount Mazama at the site of Crater Lake, Oregon, about 6,600 years ago, or Tambora in the East Indies in 1815; the latter was one of the most voluminous (if not the most voluminous) explosive eruptions of historic time. The volume of ejecta produced by some of Mount St. Helens' largest eruptions of the last four millennia, however, has been similar to that produced at certain times by Vesuvius, Fuji, and Hekla. Tephra erupted from Mount St. Helens in 1900 B.C., for example, is estimated to have a volume of at least 3 km^3 , and an eruption in about A.D. 1500 laid down roughly 1 km^3 of similar ejecta. For comparison, the tephra from the 1707 eruption of Fuji is about 0.8 km^3 in volume (9). The largest deposit from a historic Hekla tephra eruption in A.D. 1104 is about 1.5 km^3 in volume (10), and the volume of the tephra deposit resulting from the Vesuvius eruption of A.D. 79 has been calculated to be about 2.6 km^3 (11).

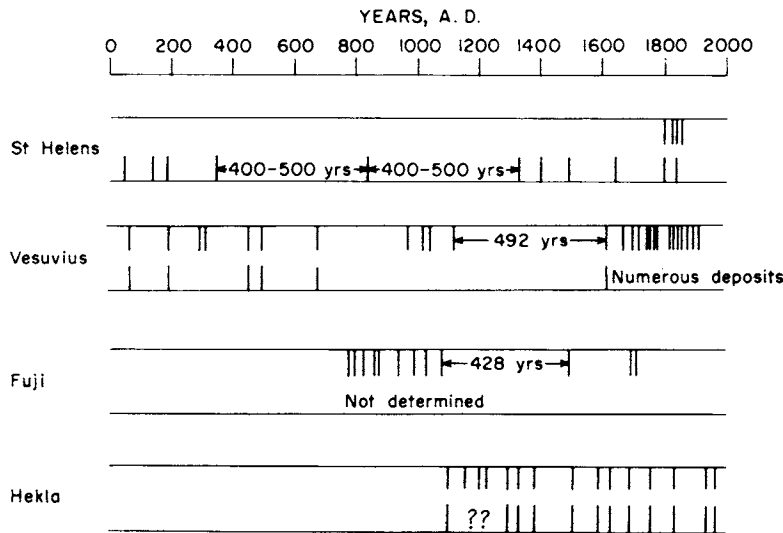


Figure 4. Volcanic activity at Mount St. Helens compared with the activity at Vesuvius (7,13), Fuji (8), and Hekla (9), as shown by the historical records (upper scales) and the stratigraphic record (lower scales).

Dormant intervals of thousands of years during the older history of Mount St. Helens can be recognized from buried weathering profiles in volcanic deposits. The profiles indicate that the weathered deposits were exposed at the surface for a long time before being covered by products of the next eruption. Radiocarbon dating of the youngest weathered deposit in such a profile, as well as of the oldest deposit above it, discloses the approximate length of a dormant interval. The imprecision of the radiocarbon dating method, which amounts to only a few hundred years, is minor relative to the total length of the dormant interval.

Dormant intervals of a few centuries are hard to recognize because weathering profiles developed in such short intervals are weak. The lengths of short intervals are also determined by radiocarbon dates, but the imprecision of the method is then large relative to the length of an interval. However, the radiocarbon method seems adequate to approximate intervals of several hundred years (Figure 3) where there are many dates and good stratigraphic control.

During the last four millennia there has not been a dormant interval of as much as a thousand years at Mount St. Helens. Within this time, however, there were five or six intervals of more than two to about five centuries before A.D. 1800 during which the volcano seems to have been dormant. In addition, 12 dormant periods of one or two centuries in length have been

tentatively identified, and many intervals of a few years or a few decades surely occurred during extended periods of eruptive activity.

A Forecast

The repetitive nature of the eruptive activity at Mount St. Helens during the last 4,000 years, with dormant intervals typically of a few centuries or less, suggests that the current quiet period will not last a thousand years. Instead, an eruption is likely within the next hundred years, possibly before the end of this century. Because of the variable recent behavior of the volcano, we cannot predict whether the next eruption will be of basalt, andesite, or dacite, and whether it will produce lava flows, pyroclastic flows, tephra, or volcanic domes. But if the eruptive period lasts years or decades, a variety of eruptive events and lithologic types can be anticipated (12).

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11. L. Lirer, T. Pescatore, B. Booth, G. P. L. Walker, Geol. Soc. Am. Bull. 84, 759 (1973).
12. The kinds and areal extents of volcanic hazards that can be expected to accompany future eruptions of Mount St. Helens have been assessed (D. R. Crandell and D. R. Mullineaux, in prep).
13. The radiocarbon dates used in this report were based on the best known half-life determination and were corrected for possible initial variations in ^{14}C concentrations by using H. E. Suess' tree-ring calibration curves [Nobel Symp. No. 12 (1970), pp. 303-311].

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GEOLOGIC MAP OF WESTERN OREGON REPRINTED

The Geologic Map of Oregon West of the 121st Meridian, which has been out of print for several months is again available. The map, prepared by the U.S. Geological Survey in cooperation with the Oregon Department of Geology and Mineral Industries, was printed in 1961. The reprinted map is for sale by the Department at its Portland, Baker, and Grants Pass offices at \$2.00 over the counter and \$2.25 by mail.

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FIELD STUDIES SUMMARY ON OPEN FILE

"Field-Oriented Geology Studies in Oregon, 1974," compiled by John D. Beaulieu, Department stratigrapher, has been placed on open file and is available for inspection at the Department's offices in Portland, Baker, and Grants Pass. Copies are available at cost of reproduction at the Portland office.

The report is issued strictly for reference purposes to show what projects were underway and the areas studied during the past year; it is not to be quoted or printed elsewhere.

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WELL RECORDS ON FEDERAL OFFSHORE LANDS AVAILABLE

The U.S. Geological Survey issued OCS (outer continental shelf) order No. 12, in December 1974, releasing all records on wells drilled on Federal shelf lands in the United States. The release involved data on more than 1,100 offshore holes. Eight wells off the Oregon Coast and four off the Washington Coast are included in the release.

West Coast OCS records can be inspected at the U.S. Geological Survey's Regional Oil and Gas Division office in Los Angeles (7744 Federal Building, 300 North Los Angeles Street, Los Angeles, Calif. 90012) and at the Oregon Department of Geology and Mineral Industries office in Portland (1069 State Office Building, Portland, Oregon 97201).

Reproductions of the records are handled by two Los Angeles firms:

Continental Graphics
101 S. LaBrea Ave., Los Angeles, Calif. 90036

Graphic Reproduction Center, Inc.
1712 Newbury Road, Newbury Park, Calif. 91320

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GEOHERMAL GRADIENT REPORT ON OPEN FILE

Geothermal gradient data gathered by the Oregon Department of Geology and Mineral Industries between 1971 and 1973 are now on open file in the Department's Portland office. The information consists of temperature gradients for 75 deep, pre-drilled bore holes (mainly water wells and mineral exploration test holes) located throughout the State. The work was performed by R. G. Bowen and other Department personnel as part of the Department's contract with the U.S. Bureau of Mines to study the geothermal potential of Oregon.

In progress is a detailed study of heat flow utilizing data from many shallow bore holes as well as the information from the deep holes. Results of the study will be contained in a comprehensive report by the Department in cooperation with Dr. David Blackwell, Southern Methodist University, Dallas, Texas, who has worked closely with the Department staff during the study. Dr. Blackwell directed the building and calibrating of the equipment used in measuring the temperature gradients and made conductivity determinations for a number of wells, including those reported in the January 1973 ORE BIN.

The open-file information is presented mainly on computer read-out sheets and consists of tabulated temperature data and graphic plots. The information is released in this preliminary form to assist those doing more detailed geothermal gradient and heat-flow studies for geothermal exploration. Copies of the open-file report are available from the Department for \$10.00, postpaid.

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INFORMATION ON NICKEL DEPOSITS ON OPEN FILE

Last summer the Department began a survey of the nickel deposits in Oregon, particularly those associated with laterized peridotites in the southwestern part of the State. This project has been financially supported through a contract with the U.S. Bureau of Mines as part of its Minerals Availability System program and will be completed next summer.

Several private geologists have indicated an interest in the information developed thus far, and therefore, in order to encourage further exploration in the State, the Department is placing the data on open file for public use. Anyone wishing to inspect the field maps and analyses of drill samples may do so by contacting Len Ramp, District Geologist, Dept. of Geology and Mineral Industries, P. O. Box 417, Grants Pass 97526; telephone (503) 476-2496.

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STATE ENERGY COUNCIL REPORT AVAILABLE

The recently completed energy study of the State of Oregon, requested by the 1973 Legislature, is now available. The report, entitled "Transition," was prepared by the Office of Energy, Research and Planning. It can be obtained from the Office of the Governor, State Capitol, Salem, Oregon 97310 for \$5.00. The report recommends a halt to nuclear fission electric power and advocates a systematic transition to a solar-based economy, utilizing other sources of energy during the transition period.

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VALUE OF U.S. MINERAL OUTPUT SOARS IN 1974

Value of U.S. raw mineral output in 1974 soared to a new high of \$54.9 billion, despite drops in production of many commodities, Secretary of the Interior Rogers Morton reported.

Based on data provided by the U.S. Bureau of Mines, the 1974 record-breaking figure surpasses the 1973 value of \$36.8 billion by almost 50%. Reflected in the totals are value increases for all sectors of the mineral industry, including metallics, nonmetallics, and mineral fuels.

"Most of the raises resulted from higher prices, not increased output," Morton said. "Of the 80 mineral commodities included in the totals, 38 showed production gains, and 63 registered value increases." Noting that the value of processed materials and energy, derived from imported and domestic minerals, was now in excess of \$200 billion, Morton said, "This emphasizes the need for increased productivity, both in raw materials and in their conversion to useful forms, as a major part of our efforts to reduce the serious erosion caused by inflation."

(Amer. Mining Cong. News Bull., no. 75-1, 1975)

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ELTON A. YOUNGBERG RETIRES FROM AEC

Elton A. Youngberg, Manager of the Grand Junction Office of the Atomic Energy Commission, retired December 1974 after 26 years with AEC. Youngberg was on the staff of the Oregon Department of Geology and Mineral Industries between September 1944 and May 1946, during which time he was Field Engineer at the Department's Grants Pass office. Youngberg is the author of Department Bulletin 34, "Mines and prospects of the Mount Reuben mining district, Josephine County, Oregon."

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NAS REPORT VIEWS MINERALS, ENVIRONMENT

The National Academy of Sciences (NAS) has published a 348-page report entitled "Mineral Resources and the Environment" based on a comprehensive two-year study by its Committee on Mineral Resources and the Environment.

The NAS committee identified two schools of thought concerning future adequacy of the world's mineral resources and associated environmental costs. One view is that exhaustion of resources is inevitable unless drastic measures are taken to reduce economic growth. The other is that mineral resources virtually are economically and physically infinite. The committee determined that the U.S. will face serious difficulties in attempting to increase some supplies of minerals from domestic sources and expressed doubt whether even current levels of supply could be maintained for all materials. The report concluded generally that resources must be conserved and that adequate information on mineral resources must be generated. These actions, according to the report, should be designed to conserve resources and increase efficiency in their use.

The study also noted that there are currently no standardized techniques for making either long-term demand forecasts or resource estimates, nor are means available to assess adequately the accuracy of the existing methods. Another conclusion was that reliable data on mineral resources are difficult to obtain because of their proprietary or international nature.

The committee preparing the report was composed of four separate groups that studied technology, supply, environment, and demand. The report of the technology panel concluded that technology will not always be capable of closing gaps between rising demand and limited supply of mineral resources. According to this panel, the Federal government should proclaim and pursue a national policy of conservation of materials, energy, and environmental resources.

The supply panel addressed current methods of estimating mineral reserves and resources and the quality of current resource estimates. It reached the conclusion that a major problem in proving estimates is the difficulty of obtaining proprietary information and the inadequate recognition of economics and rates of mineral production in current resource estimates.

According to this group, world resources of coal are large relative to current energy requirements. As regards reserves and resources of copper, it was concluded that an ore grade of about 0.1% copper represents a point beyond which mining and recovery of copper are unlikely to proceed. If the U.S. production rate is to be maintained until the end of the century, the report states, additional discovery at a significant rate will be necessary. It recommended aiding and stimulating domestic exploration and production. It also recommended that recovery of ocean bed copper resources be encouraged.

The environmental panel concentrated on environmental problems associated with coal production and use, namely pneumoconiosis and emissions of sulfur oxides. A conclusion was reached that the problem of sulfur emissions is not being attacked correctly in that there is too much concentration on larger particles. The report also concluded that current monitoring methods are inadequate and that funds for the study of environmental impacts of fossil fuels should be increased.

The panel addressed the problem of demand for mineral resources and the significance of demand forecasts. Its report pointed out that national obsession with expanding supplies arises from the dramatic gap between projected demand and projected supply. It challenged the credibility of the projections and the assumption that they are not susceptible to change, and emphasized the potential for influencing demand through the market mechanism, policy, and technology.

The report also recommended that substitutes be found for the following: helium, mercury, asbestos, chromium, gold, palladium, and tin. The need for substitutes should be assessed for antimony, tungsten, vanadium, silver, and zinc.

While the report recommends that the private sector retain the main responsibility for developing technology, it said Federal participation is often not only inevitable but necessary, perhaps even desirable.

It was noted that increased Federal intervention can be anticipated in the materials field and to be successful should aim at creating opportunities within a broad framework for individual and corporate enterprise, not stifling such enterprise. The report states that industries must be allowed adequate profits in order to invest in R&D and to attract venture capital. "Price regulation... may be consumer good will in the short term but at the expense of long-term ability to provide the goods and services that consumers will continue to expect."

(Amer. Mining Congress News Bull., no. 75-4, Feb. 14, 1975)

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OLDEST ROCKS ARE OLDER THAN EVER

The oldest rocks known in North America are some Precambrian granitic gneisses in the Minnesota River valley of southwestern Minnesota. In 1970, they were dated at 3,500 million years, but more recent Rb-Sr analyses have been carried out by the same workers, who report (*Nature*, Dec. 6, 1974, p. 467) a new age of 3,800 million years. These ancient rocks range in composition from tonalite to granodiorite and quartz monzonite. They have undergone a complex history of metamorphism and have been intruded by granite, pegmatite, and basalt of various magmatic episodes.

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USBM TO IMPROVE MINERAL INTELLIGENCE FUNCTIONS

A realignment to strengthen the mineral information systems and supply/demand evaluation work of the Bureau of Mines has created two associate director positions by dividing the expanded management functions of the abolished deputy director for mineral resources and environmental development.

Dr. John D. Morgan has been designated to act as the associate director, Mineral and Materials Supply/Demand Analysis, pending his appointment to the post. Under the new organization, he will oversee four new mineral information and evaluation units: metals, minerals, and materials; fuels; international data and analysis; and interindustry and economic analyses. Also, the associate director has responsibility for the state liaison program, which promotes Federal-state cooperation on mineral-related matters, and special programs involving resource conservation and development. These programs will include mineral evaluation studies of potential wilderness areas and effects of mineral operations on the environment.

Dr. Thomas A. Henrie has been named to act as the new associate director, Mineral and Materials Research and Development, pending his appointment to the new position. Metallurgy research, mining research, and the Bureau's helium program come under the new associate director. He will manage all of the Bureau's existing research and development programs involving the extraction, processing, use, disposal, and recycling of minerals and mineral-based materials, including the Bureau's research on mine health and safety programs and on land reclamation.

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GEOHERMAL LEASE SALE POSTPONED

Leasing of 13,000 acres of potentially valuable geothermal land in the Vale Hot Springs Known Geothermal Resource Area (KGRA) has been postponed until August. The auction of geothermal rights had been scheduled for April 23, 1975. The tract is near Vale, Oregon, adjacent to 1,300 acres leased by BLM last year.

According to Max Lieurance, acting state director for BLM, the lease is being delayed because adverse weather in the area has hampered the completion of an inventory of archeological sites. BLM will not lease the area until these sites have been identified and stipulations to protect them written into the lease.

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MOVING? Please send your new address - now!

MINING LAW BULLETIN ISSUED BY STATE OF WASHINGTON

A comprehensive, 109-page, loose-leaf bulletin, "Mining Laws of the State of Washington," has just been issued by the Washington Division of Geology and Earth Resources. The publication contains information on all phases of mining law as it pertains to Federal, state and private lands. Line drawings illustrate some of the more confusing situations often encountered by the claim locator. The publication, issued as Bulletin 67, is available from the Department of Natural Resources, Olympia, Washington 98504, for \$1.50.

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PROJECT INDEPENDENCE REPORT SUBMITTED TO PRESIDENT

The Federal Energy Administration has submitted its Project Independence to the President. The final report indicates what can be expected from several approaches under varying conditions, including differing price levels. It does not attempt to outline actions, leaving final determinations to the Executive and Legislative Branches.

The report draws several conclusions on U.S. energy supply by 1985: Coal production will increase to between 1.0 and 1.1 billion tons per year, depending on world oil prices, but may be limited by lack of markets. Production could be expanded further, but lower electric growth, increasing nuclear capacity, and environmental restrictions will limit.

Nuclear power is expected to grow from 4.5% to 30% of total electric power generation.

Shale oil production could reach 250,000 B/D but only if price rises to \$11.

Geothermal, solar, and other advanced technologies have large potential but will not contribute materially until after 1985. Research is needed to develop these sources because of their lower environmental impact.

Copies of the complete report are available from Superintendent of Documents, Govt. Printing Office, Washington, D. C. 20402; stock no. 4118-00029; price is \$8.35.

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NORTHWEST MINING ASSOCIATION MOVES

The Northwest Mining Association office in Spokane, Washington has moved to the Chamber of Commerce Building, W. 1020 Riverside Ave., zip 99201. Telephone: (509) 624-1158.

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THANK YOU FOR COMMENTS AND SUGGESTIONS

In the September 1974 ORE BIN, we included a pull-out order sheet with space for comments on The ORE BIN and its usefulness. So far, 25 readers have responded: 3 in mineral industries, 4 professional geologists, 2 teachers, 1 physician, 1 forester, and 14 "interested amateurs." Much to our surprise (and very much to our pleasure) everyone likes The ORE BIN. Some comments went like this:

- Think it's great! --All good! --Very enjoyable and informative.
- Extremely fine, informative, and accurate as well.
- Keeps me informed on what's going on in Oregon. --Good buy.
- Has just the right scope.
- Nothing to "dislike" from standpoint of an interested amateur; there is considerable I don't understand but realize it is a journal mainly for professionals; I have learned much.
- Sort of a neat collection of miscellaneous geology to keep me awake. Never know what's coming. Not tied down reading too long.
- A balanced offering of scientific papers, review articles, news items.
- Concise, interesting, and to the point. It is timely, up-to-date and compiled by very efficient and informed people. Reasonable price.
- Like the fact that reprints of many old ones are available.
- There isn't a better little book written for the geologist or miner.
- I like the surprise subject every month.

Preferred subjects mentioned were: geology of various areas of Oregon ("not too technical," someone added); Oregon's resources including geothermal, recycling resources, gravel mining, gem stones, minerals, fossils; new regulations on mining in National Forests.

We were particularly pleased to receive suggestions for future articles. Our commenters want more information on specific minerals and localities; old mines that may be profitable to open up in current mineral shortage; gem stones and minerals; and eastern Oregon. Some asked that more articles be written in language for the amateur.

To satisfy you, the reader, is our principal objective. Your comments and suggestions will always be most welcome.

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Apologies for late arrival of the February ORE BIN. Our printer for the past 2 years suddenly closed his doors, which meant the State Printer had to call for bids on a new contract for us.

AVAILABLE PUBLICATIONS

(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

8. Feasibility of steel plant in lower Columbia River area, rev. 1940: Miller	\$0.40
26. Soil: Its origin, destruction, preservation, 1944: Twenhofel	0.45
33. Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35. Geology of Dallas and Valsequez quadrangles, Oregon, rev. 1963: Baldwin	3.00
36. Papers on Tertiary foraminifera: Cushman, Stewart & Stewart. vol. 1 \$1.00; vol. 2	1.25
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CURRY COUNTY



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LANDFORMS ALONG THE COAST OF CURRY COUNTY, OREGON

Ernest H. Lund
Department of Geology, University of Oregon

The shore of Curry County is the most continuously rugged segment of the Oregon Coast. Highway 101 parallels it, and numerous State parks, waysides, and lookout points along it afford magnificent views of the ocean, the rocks, and the scenery.

The discussion of the geology and related landforms is accompanied by a road log that can be followed either from south to north or north to south. The photographs are keyed into the road log, and four strip maps show locations of geographic features.

Geologic Setting

Curry County lies at the western margin of the Klamath Mountains province, a region composed of some of the oldest rocks in Oregon. Tremendous forces within the earth's crust have made mountains out of rocks that were once sedimentary and volcanic materials on the sea floor. Metamorphic recrystallization and intense folding, faulting, and shearing have altered these rocks to varying degrees. In general, the more ancient the rocks, the more severely they are disrupted and altered.

Since recrystallization hardens rocks, and shearing and fracturing weaken them, the combined effects produce extremes in rock durability. This largely accounts for the differential erosion of bedrock along the coast of Curry County and the resulting ruggedly beautiful scenery.

Most of the bedrock exposed along the County's shoreline is of Mesozoic age, ranging from Late Jurassic (150 to 160 million years old) through Late Cretaceous (65 million years old). Much younger, relatively unaltered bedrock, comprising dikes, sills, and sedimentary beds, of Tertiary age is exposed in a few places. The youngest units are unconsolidated sands and gravels of Quaternary age which lie on marine terraces and along the beaches and rivers.

Geologic formations (rock units) that contribute to coastal scenery are briefly described below in the order of oldest to youngest. For a more thorough discussion, the reader is referred to Dott (1971), from which the following descriptions are summarized.

Mesozoic Rocks

Upper Jurassic bedrock

Dothan Formation: The Dothan Formation crops out along the Curry County coast from Winchuck River, just north of the State line, to Whalehead Cove. It consists mostly of graywacke sandstone but of nearly an equal amount of siltstone and mudstone. About 10 percent of the rock is volcanic, and chert and conglomerate combined make up less than 1 percent. The rock is very much deformed but is somewhat less sheared

than the Otter Point Formation, of which the Dothan Formation is considered in part an age equivalent.

Otter Point Formation: The Otter Point Formation crops out in a belt that extends from Whalehead Cove on the south to Sisters Rocks on the north. It is not continuous along the shore over the entire distance but is interrupted at a number of places by younger formations. To the north, it crops out in The Heads at Port Orford; most of the reefs and sea stacks from Mack Reef northward are of Otter Point rocks.

The Otter Point Formation consists of a very complex mixture of folded and sheared mudstone, sandstone, conglomerate, and volcanic rock. During deformation, serpentinized peridotite, phyllite, and glaucophane schist from other formations mixed with the Otter Point rocks; the whole assemblage has been aptly referred to as chaotic. The name *mélange* has been applied to churned-up assemblages of this type.

The Otter Point Formation has been lightly metamorphosed. Where the rock is not sheared, it is hard and very resistant to erosion, especially the volcanic units, but where it is severely sheared, it has little strength and is easily eroded. Weathering further weakens the sheared rock, making landslides a serious problem. Landslides have damaged the highway at numerous places where it crosses this formation.

Lower Cretaceous bedrock

Humbug Mountain Conglomerate: The Humbug Mountain Conglomerate crops out along the shore over a distance of about 5 miles from Humbug Mountain southward. The rock is mostly conglomerate and is coarsest at its base, but in the higher parts of the formation, beds of sandstone and mudstone are interstratified with conglomerate.

Rocky Point Formation: The Rocky Point Formation crops out along the shore between Humbug Mountain and Hubbard Creek south of Port Orford (Koch, 1966). It overlies the Humbug Mountain Conglomerate stratigraphically, and the two formations have a gradational contact. It is composed mostly of sandstone beds 2 to 5 feet thick alternating with mudstone 3 to 5 inches thick, but also contains some conglomerate, which is finer and less abundant than that of the Humbug Mountain Conglomerate.

Upper Cretaceous bedrock

Cape Sebastian Sandstone: The Cape Sebastian Sandstone is exposed along the shore in the sea cliffs at Cape Sebastian (Howard and Dott, 1961). It is a massive, gray sandstone that weathers to light tan. In the lower parts of the sea cliffs, the formation contains abundant coarse sandstone and lenses of conglomerate that range from 3 inches to 3 feet in thickness.

Hunters Cove Formation: The Hunters Cove Formation overlies the Cape Sebastian Sandstone stratigraphically and is well exposed in the sea cliffs along the southeastern side of Cape Sebastian at Hunters Cove. It makes up the neck of the Cape and is exposed in the first headland north of the Cape. It is exposed along the shore both to the south, between Crook Point and Hostenader Creek, and 38 miles to the north just north of Blacklock Point. The formation consists of alternating thin sandstone and mudstone beds with local conglomerate and thick sandstone lenses.

Tertiary Rocks

Sedimentary bedrock

Beds of Eocene rocks lie in the neck of Cape Blanco. The strata are of thin-bedded mudstone and graywacke sandstone.



Figure 1. Pleistocene marine terrace south of Chetco River. Terrace surface was ocean bottom during the Sangamon interglacial stage, which ended about 60,000 years ago. (Oreg. Hwy. Div. photo by Kinney)



Figure 2. Hastings Rock, rising about 100 feet above the terrace surface, was a sea stack during the Sangamon interglacial stage. Gently sloping terrace is about 50 feet above sea level at Hastings Rock.

Sandstone and conglomerate beds of Miocene to Pliocene age overlie the Otter Point Formation at Cape Blanco (Dott, 1962). They are exposed in the sea cliff along the outer edge of the Cape and in a sea stack and the sea cliff to the southeast. At Blacklock Point, interstratified sandstone and conglomerate overlie the Hunters Cove Formation and extend northward along the shore in a spectacular sea cliff as far as Floras Lake. These beds and those at the Cape correlate in part with the Empire Formation in Coos County.

Intrusive rocks: Numerous light-colored rhyolite dikes and sills intrude the Dothan Formation north of Brookings. Rhyolite is well exposed in the roadcut at the entrance to the Harris Beach visitor information center and in a number of places along the shore at Harris Beach State Park, including the rock knob at the parking lot.

Dark (mafic) dikes of dioritic to gabbroic composition intrude the Otter Point Formation between Horse Prairie Creek and Thomas Creek, where they are exposed in sea cliffs and roadcuts. A black mafic sill 2 to 3 feet thick intrudes the Hunters Cove Formation on the east side of Crook Point.

Quaternary Sediments and Related Landforms

Pleistocene terraces

Pleistocene terraces are numerous along the Curry County coast and are most extensive in the southern and northern parts. A terrace that begins in California extends northward beyond Brookings, where it attains a width of more than a mile. Interesting features of the terraces south of Brookings are the rock knobs that rise abruptly above the terrace surface. These rocks were sea stacks during an interglacial stage of the Pleistocene Ice Age when the terrace surface was part of the sea floor.

The largest terrace extends from Port Orford northward nearly 40 miles to Coos Bay. At Cape Blanco it is about 5 miles wide from the coast to the upland edge.

At many places along the Curry County coast, patches of terrace sediment are perched along the upland front as much as 1,200 feet above sea level. These terrace remnants were formed at different times during the Pleistocene when sea levels were higher, but their present positions high above sea level are the result of uplift, for the ocean surface has probably never been more than 250 feet higher than it is now.

Dunes

Very little of the Curry County coast is favorable to dune formation because most of the shore is bordered by sea cliffs. Dunes have formed near the mouths of some of the streams where there is a beach to supply sufficient sand and the terrain is suitable.

The largest area of dunes is at the mouth of Pistol River, where dunes begin at the south side of the river and form a northwest-southeast oriented lobe about 2 miles long. Dune sand extends along the beach to Crook Point.

A small dune area lies along and behind a beach ridge south of Euchre Creek, and a small area of dunes, remnant of a larger dune mass, is perched on the bluffs south of Elk River (Cooper, 1958). South of Sixes River is a very small but interesting dune where a blowout ascends the slope of the terrace edge, and a mound of sand has accumulated on the terrace surface. This dune is no longer active because a beach ridge capped by grass-stabilized dune sand has cut off the supply of sand from the beach.

Beaches

Despite the fact that along most of the Curry County coast the mountains meet the sea, much of the shore has a sand beach. Where the shore is rocky and rugged,



Figure 3. Edge of terrace. McVay Rock, a large Pleistocene sea stack, was destroyed by quarrying. Hastings Rock is in the upper left of the photograph. (Oreg. Hwy. Div. photo by Kinney)

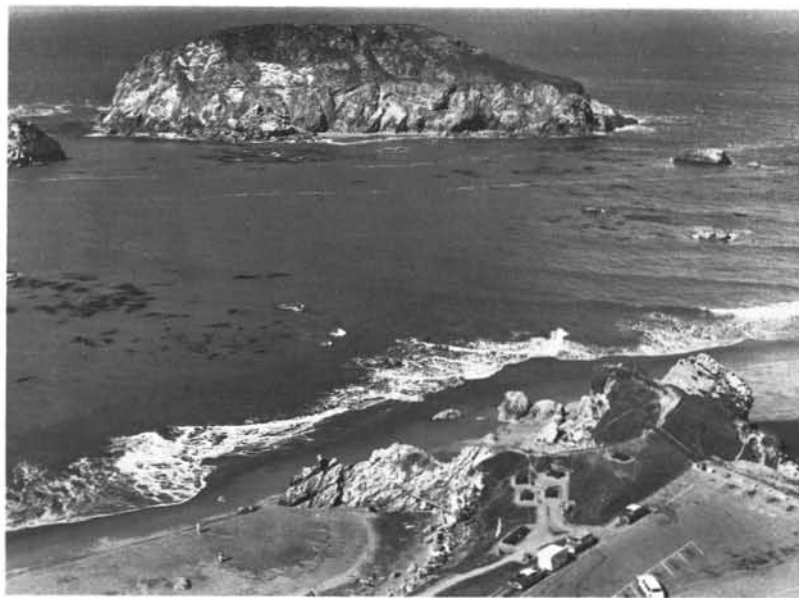


Figure 4. Goat Island at Harris Beach State Park has an area of 21 acres and is Oregon's largest coastal island. The rock between the parking lot and the beach is part of a rhyolite dike. (Oreg. Hwy. Div. photo)

small secluded beaches lie along the edges of coves; where the shore is bordered by terraces or other low terrain, beaches are generally long and wide.

An interesting characteristic of most of the Curry County beaches is their steep slope and narrow swash zone in contrast to the very gentle slopes and wide swash zones of most of the beaches to the north. The water is sufficiently deep immediately off-shore that during times of calm sea the waves break very near or at the beach edge. The surf zone is then very narrow and may consist of the single breaking wave that crashes against the beach and moves quickly up and back over the narrow swash zone. The sand of these beaches consists largely of rock particles and is darker and coarser textured than the predominantly quartz sand of beaches north of Curry County.

Beach ridges at the mouths of many of the coastal streams interfere with the streams' entry into the ocean. These beach barriers may form temporary dams at the mouths of small rivers during low water. When the discharge in streams such as Winchuck, Pistol, Elk, Sixes, and New Rivers and Hunter and Euchre Creeks drops so low that the flow of water is not able to remove the sand and coarser material brought to the rivers' mouths by waves and ocean currents, the outlets are blocked. The water then moves from the impounded stream to the ocean by percolation through the sand and gravel. During the time a stream is dammed, it forms a lagoon behind the barrier; when the stream's flow is large enough, it will again break through to the ocean at a low place somewhere in the ridge. In this way, a stream may change its outlet from time to time. Winter storms may also alter the stream mouths.

During the summer of 1974 Pistol River was flowing directly into the ocean at the southern end of the barrier, and a narrow, mile-long lagoon lay behind the barrier to the north. The outlet of Elk River is deflected northward about a mile, and New River flows behind a beach barrier from Floras Creek northward about 7 miles to Four Mile Creek, where it enters the ocean.

Garrison Lake, just north of Port Orford, and Floras Lake, a few miles south of the Coos-Curry County line, were formed by beach barriers built across the mouths of what were formerly two small bays or indentations in the coast. The volume of water coming into the bays from streams was not enough to maintain sea level outlets, and the barriers converted them into freshwater lakes.

Erosional Landforms

The irregularity in the extremely rugged shoreline, the reefs, the large number of sea stacks and arches, and the innumerable smaller rock masses along the shore give the Curry County coast a distinctive character. The factors that have a bearing on this are many, but two principles will help in understanding the origin of the many landforms that contribute to the superb scenery of this coast. One is that the ocean is steadily wearing away the land, and the other is that soft or badly broken rock erodes faster than hard, intact rock. As the sea encroaches on the land, wave erosion is directed along places of weakness, and the more durable parts form the positive features along the shoreline and offshore.

Except where lowlands along rivers and large creeks break the continuity of a terrace or the hilly terrain along the coast, the shore is bounded either by vertical or nearly vertical sea cliffs or by steep, rubbly slopes, depending upon the ability of the rock to support a vertical surface. Most of the high sea cliffs and rock promontories are basalt units in the sedimentary formations or sedimentary rock that has not been badly sheared. Where the more durable rock is cut by fractures or a narrow shear zone, the waves tend to erode caves in the cliff or tunnels through rock projections.



Figure 5. Rainbow Rock is complexly folded beds of chert in the Dothan Formation.



Figure 6. Terrace surface about 250 feet above sea level on Cape Ferrello.



Figure 7. Whalehead Cove. The outermost of the three sea stacks is Whalehead Rock. (Oreg. Hwy. Div. photo by Kinney)



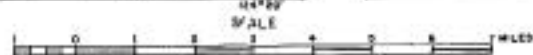
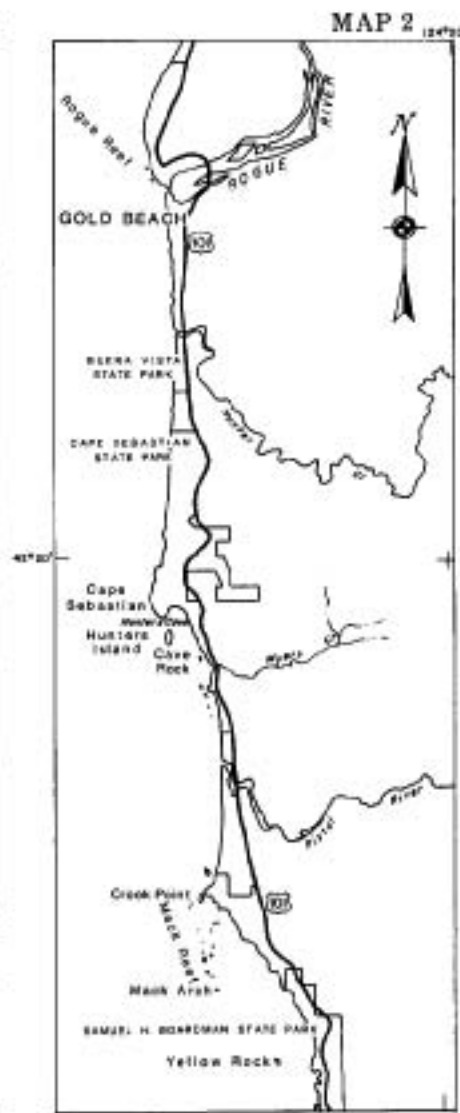
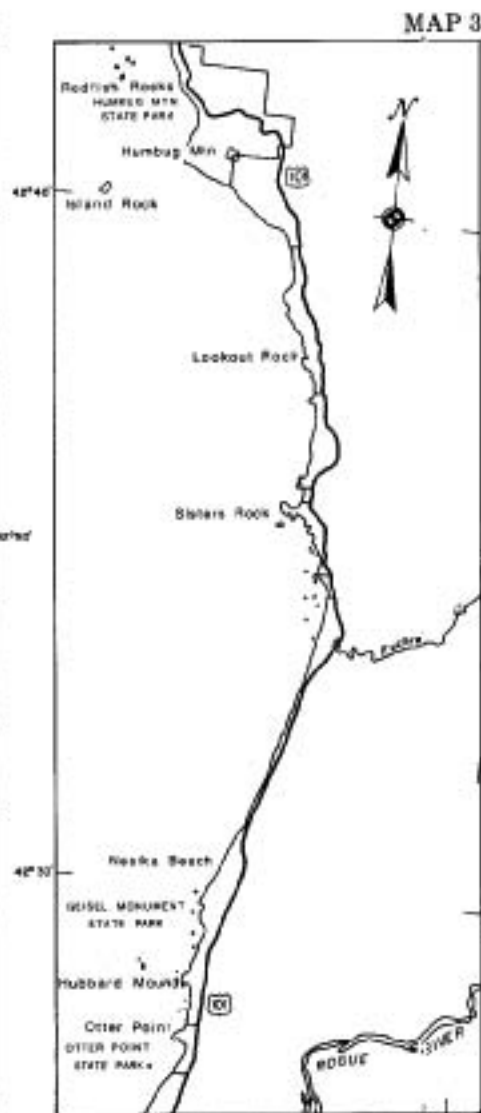
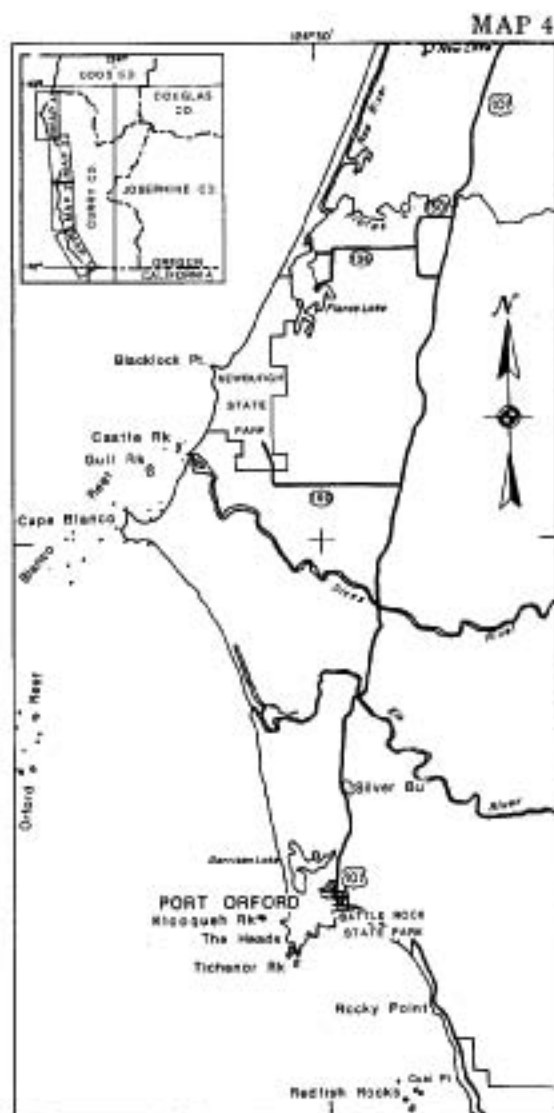
Figure 8. Rugged promontories and coves north of Whalehead Cove. (Oreg. Hwy. Div. photo)



Figure 9. The natural bridges about 1 mile north of Thomas Creek are remnants of the roofs of sea caves that collapsed where the caves intersected. (Oreg. Hwy. Div. photo)



Figure 10. The tunnel through Arch Rock off Deer Point (Arch Rock Point) is probably the remnant of a sea cave formed when the rock was part of the mainland. (Oreg. Hwy. Div. photo)



COASTAL STRIP MAPS OF CURRY COUNTY, OREGON

Along wider fracture zones or other zones of weakness, coves may form between projections of resistant rock.

As erosion shifts the shore landward, rock masses are separated from the mainland; the most resistant survive for a time as stacks, arches, and smaller rock knobs. Clusters or aligned groups of rocks, some standing above sea level, others awash at low tide, but most submerged, make up the reefs along the coast.

Most of the sea stacks and arches are of Otter Point Formation rock. According to Hunter and co-workers (1970), Otter Point sandstone is widely distributed, conglomerates are fairly common, and volcanic rocks are abundant in the offshore stacks. Pleistocene terrace sediments on some of the stacks, including Needle Rock, which is in the Rogue River reef and about $2\frac{1}{2}$ miles offshore, indicate that the stacks were once part of the mainland and give a clue to the rate of shore erosion in this area.

Road Log

Miles S-N	Increase ment	Miles N-S	
0.0		78.2	California-Oregon State line. The coastal plain that extends from California northward to a few miles beyond Brookings is a Pleistocene marine terrace (Figure 1) formed during the Sangamon interglacial stage, which ended about 60,000 years ago. The terrace surface, which slopes gently seaward, was the sea bottom, and the shoreline was along the edge of the hills that border the plain on the east.
0.5	0.5	77.7	Winchuck River. [Map 1 - south end]
1.2	0.7	77.0	Rock knob west of the highway. The rock is hard, graywacke sandstone of the Dothan Formation.
2.0	0.8	76.2	Rock knob on the terrace west of the highway (Figure 2), referred to here as Hastings Rock, rises nearly 100 feet above the terrace surface. It consists of hard, lightly metamorphosed sandstone of the Dothan Formation and was a sea stack when the terrace was the sea bottom. The largest such sea stack, McVay Rock, was an impressive landmark near the edge of the terrace until quarried for stone; only a few small nearby knobs remain (Figure 3).
4.7	2.7	73.5	Harbor (business district).
5.3	0.6	72.9	Chetco River.
6.0	0.7	72.2	Brookings Post Office.
7.6	1.6	70.6	Entrance to Harris Beach State Park. Goat Island (Figure 4), with an area of 21 acres and a height of 184 feet, is Oregon's largest coastal island. It is composed of Dothan Formation. It was established as the Oregon Islands Refuge in 1935 and as the Oregon Islands Wilderness in 1970. The rock knob at edge of beach parking lot is part of a rhyolite dike.
9.5	1.9	68.7	Rainbow Rock viewpoint. Rainbow Rock (Figure 5) is composed of thin, complexly folded beds of chert of the Dothan Formation.



Figure 11. Mack Arch, at the southern end of Mack Reef, is one of Oregon's most picturesque arches.



Figure 12. Crook Point. Sand dunes lie between Crook Point and Pistol River to the north. Cape Sebastian is in the distance. (Oreg. Hwy. Div. photo by Kinney)



Figure 13. (left) Pistol River. At the time this photograph was taken, the river was dammed by a beach barrier, and a mile-long lagoon lay behind the barrier. (Oreg. Hwy. Div. photo by Kinney)

Figure 14. (below) Cape Sebastian and Hunters Island to the south. Viewpoints on this high promontory provide spectacular views. (Oreg. Hwy. Div. photo by Kinney)



- 9.9 0.4 68.3 Samuel H. Boardman State Park southern boundary.
- 10.6 0.7 67.6 Lone Ranch Beach road. Some of Curry County's most rugged shore is just south of Lone Ranch Beach.
- 11.3 0.7 66.9 Cape Ferrelo; road to viewpoint. The top of Cape Ferrelo is an elevated flat terrace surface (Figure 6) 250 feet above sea level.
- 12.1 0.8 66.1 House Rock viewpoint road; terrace sediments in highway roadcuts.
- 13.6 1.5 64.6 Whalehead trail; viewpoint.
- 14.1 0.5 64.1 Whalehead Beach road. Whalehead Island, the outermost of the three (Figure 7), is a sea stack composed of basalt-pebble conglomerate of Otter Point Formation. Shore is very rugged to north (Figure 8).
- 14.9 0.8 63.3 Indian Sands trail; viewpoint.
- 15.6 0.7 62.6 Thomas Creek Bridge, 345 feet above the bottom of the canyon, is claimed to be Oregon's highest bridge.
- 17.4 1.8 60.8 Natural Bridge viewpoint (Figure 9). The "bowl" behind the natural bridges probably was formed by collapse of roof rock of intersecting sea caves. The bridges are what is left of the roofs of the caves.
- 17.6 0.2 60.6 Thunder Rock Cove. [Map 2 - south end]
- 18.6 1.0 59.6 Deer Point (Arch Rock Point). Deer Point and the stacks and arches are Otter Point Formation. When Arch Rock (Figure 10) was still part of the mainland, its arch was probably a sea cave.
- 19.3 0.7 58.9 Samuel H. Boardman State Park northern boundary.
- 21.3 2.0 56.9 Turnout. Mack Arch (Figure 11), directly offshore, is part of Mack Reef, which consists of Otter Point conglomerates and basalts. Terrace sediments are exposed in roadcuts along the highway.
- 21.6 0.3 56.6 Road to Crook Point. The tip of Crook Point (Figure 12) and the rocks around it are mostly of Otter Point Formation basalt.
- 24.3 2.7 53.9 Pistol River (Figure 13). A mile-long lagoon lies behind a beach barrier north of the present (1974) outlet of the river.
- 26.1 1.8 52.1 Viewpoint; cluster of large sea stacks and arches are of Otter Point Formation; those nearest shore can be reached at low tide by a sand connection (tombolo) to the mainland.
- 27.0 0.9 51.2 Viewpoint; Cape Sebastian, Hunters Island, Cave Rock. Hunters Island and the outermost part of Cape Sebastian are composed of Cape Sebastian Sandstone. The neck of the Cape is of Hunters Cove sandstone; Cave Rock is of Port Orford Formation.



Figure 15. Otter Point, penetrated by trenches and caves, is a remnant of a Pleistocene terrace. (Oreg. Hwy. Div. photo by Kinney)



Figure 16. Humbug Mountain, rising high above the sea and the adjacent land, is one of Oregon's most prominent headlands. (Oreg. Hwy. Div. photo)



Figure 17. Battle Rock. A tunnel, seen at the water's edge, penetrates the rock along a fracture zone.



Figure 18. The Heads at Port Orford marks the southern edge of a coastal lowland on a Pleistocene terrace that extends northward beyond Bandon in Coos County. Cape Blanco is in the distance. (Oreg. Hwy. Div. photo by Kinney)

28.6	1.6	49.6	Cape Sebastian (Figure 14); road to viewpoints.
33.1	4.5	45.1	Hunter Creek.
35.1	2.0	43.1	Gold Beach; Curry County Courthouse.
35.9	0.8	42.3	Rogue River (middle of bridge).
36.8	0.9	41.4	Serpentinite in roadcut. [Map 3 - south end]
39.6	2.8	38.6	Old Coast Road (north); to Otter Point (Figure 15).
41.3	1.7	36.9	Geisel Monument Wayside.
41.5	0.2	36.7	Nesika Beach junction (south).
42.7	1.2	35.5	Nesika Beach junction (north).
46.6	3.9	31.6	Euchre Creek; sand dunes south of creek.
49.2	2.6	29.0	Sisters Rocks. These rocks are of lightly metamorphosed sediments of the Otter Point Formation.
51.9	2.7	26.3	Lookout Rock. Humbug Mountain (Figure 16) to the north.
56.1	4.2	22.1	Humbug Mountain State Park picnic area entrance.
56.8	0.7	21.4	Humbug Mountain State Park camping area entrance. Type locality for Humbug Mountain Conglomerate. [Map 4 - south end]



Figure 19. Cape Blanco, a projection of the Pleistocene terrace, is Oregon's westernmost point. (Oreg. Hwy. Div. photo by Kinney)



Figure 20. Blacklock Point marks the northernmost extent of Mesozoic rocks along the Curry County shore. (Oreg. Hwy. Div. photo by Kinney)



Figure 21. Floras Lake occupies the flooded lower end of a stream system dammed by a beach barrier. (Oreg. Hwy. Div. photo by Kinney)

- 60.4 3.6 17.8 Rocky Point (north turnout) for which Koch (1966) named the Rocky Point Formation. Redfish Rocks and Island Rock to the south are of Otter Point Formation basalt.
- 62.6 2.2 15.6 Battle Rock State Park entrance at Port Orford. Battle Rock (Figure 17) is Otter Point basalt. The many-lobed headland, The Heads (Figure 18), is Otter Point sedimentary rock.
- 65.0 2.4 13.2 Rock knob (Silver Butte) east of highway is a Pleistocene sea stack of green metamorphic rock.
- 66.6 1.6 11.6 Elk River.
- 67.5 0.9 10.7 Cape Blanco road (Figure 19). At Cape Blanco Otter Point Formation is overlain by Tertiary sandstones. Pleistocene terrace deposits overlie the Tertiary sandstones and form the flat surface of the Cape.
- 68.4 0.9 9.8 Sixes.
- 70.4 2.0 7.9 Road to airport and Blacklock Point (Figure 20).
- 73.6 3.2 4.6 Denmark.
- 74.0 0.4 4.2 Floras Lake road (south). Floras Lake (Figure 21) is impounded by a beach barrier. Water enters ocean 8 miles to the north.
- 75.1 1.1 3.1 Floras Lake road (north).
- 76.3 1.2 1.9 Langlois.
- 78.2 1.9 0.0 Coos-Curry County line. [Map 4 - north end]

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* * * * *

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RECENT SHORELINE CHANGES OF THE ALSEA SANDSPIT, LINCOLN COUNTY, OREGON

James E. Stembridge, Jr.
Department of Geography, University of Oregon

Erosion of coastal sandspits has been a recognized hazard in Oregon since the demise of the resort community of Bayocean near Tillamook, which was slowly eliminated by the sea beginning in the late 1920's. Currently, the sandspit at Siletz Bay is undergoing severe erosion which is critically endangering structures along a three-mile beach front. Partially as a result of these experiences with eroding sandspits, some planning agencies, such as the Oregon Coastal Conservation and Development Commission, have considered limiting the construction of housing units on sandspits.

This study is a preliminary analysis of a third Oregon spit, the Alsea near Waldport, with respect to recent shoreline changes, human modifications, and potential impact on current and future settlement (Figure 1).

Unlike the Tillamook and Siletz spits, the Alsea sandspit is presently accreting at a rate as great as 10 feet per year at its southwest margin. Erosion at a rate of as much as 2 feet per year is occurring on the bay side of the spit, however, as well as along the northwestern margins of the spit, where the underlying terrace of semi-consolidated Pleistocene dune deposits is exposed to ocean wave action. The many homes recently constructed on the spit do not appear to be in danger of beach erosion damage at the present time.

Air photographs from the year 1939 show the southern portion of the spit to have been quite flat, with a sparsely vegetated foredune on the order of 15 feet above mean high tide. Sand surface elevations rise to nearly 160 feet near the northern extremes of the three large sand blows that comprise the northern portions of the spit area. Heavy forest surrounding the sand blows and dune-locked lakes are other features of the pre-development landscape (Figure 2).

Within the past few years, residential development has occurred on the spit (Figure 3). Subdivision of the northern portion of the study area began in 1970 with the appearance of "Sandpiper Village," which now includes several dozen single-family and condominium-type units. These structures occupy sites on various terraces bulldozed out of the sand blows. "Sandpiper Village" is at present maintaining part of the northern extreme of the non-forested sand area as parkland.



Figure 1. The Alsea sandspit separates Alsea Bay from the Pacific Ocean. The town of Waldport is at the extreme right.

The "Bayshore" subdivision dates from 1963. It occupies the southern portion of the spit and includes a dredged "marina," a private recreation complex, and, more recently, a large motel. Only a couple dozen houses occupy the nearly one square mile area, although the spit is covered with stabilizing vegetation, and has streets and fire hydrants. A few of the houses occupy the main foredune, which has been cut to a height of about 15 feet above mean high tide (Figure 4).

This main foredune is at least partially bulldozed into shape and rests at a position of up to 100 feet inland of its 1939 location. It is well stabilized with European beach grass (*Ammophila arenaria*), except where breached for home sites and by trails from the residential area to the surf zone. Its present height is approximately 35 feet above mean high tide level, increasing at a rate of about 0.5 feet yearly as sand accumulates in the vegetation.

The extreme high tide line has moved as much as 300 feet seaward since 1939 (Figure 5). Part of this general accretion is the building of what appears to be a new foredune as much as 300 feet seaward of the 1939 foredune. This developing dune is in the form of a berm 10 feet above the mean high tide line. The interjacent area, between the developing foredune and the main foredune, is filled with scattered, partially exposed driftwood mixed

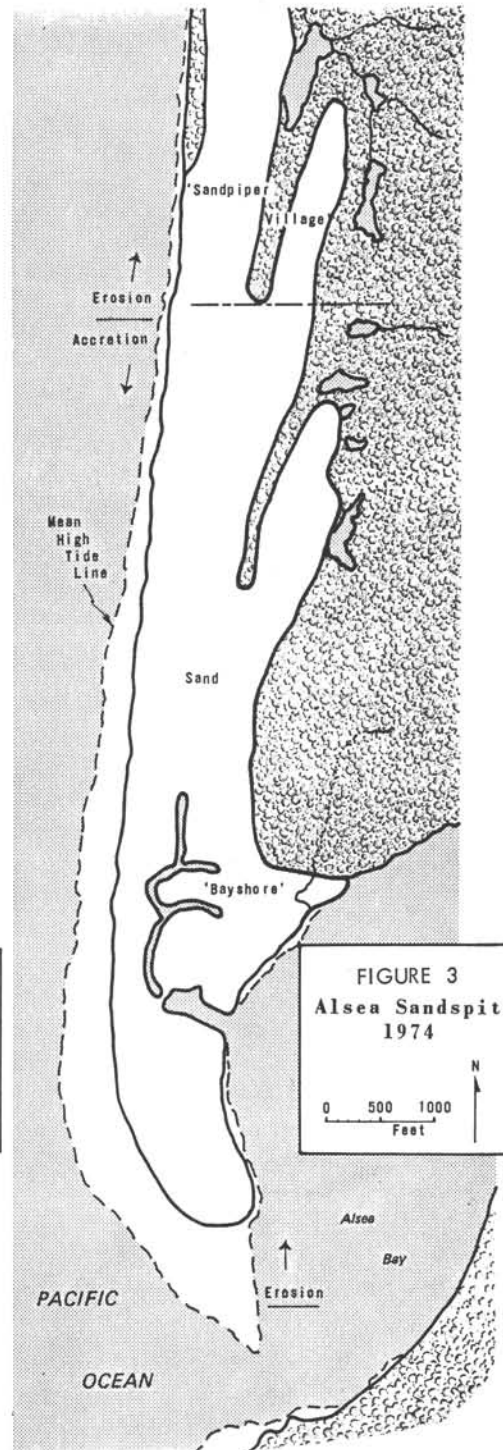
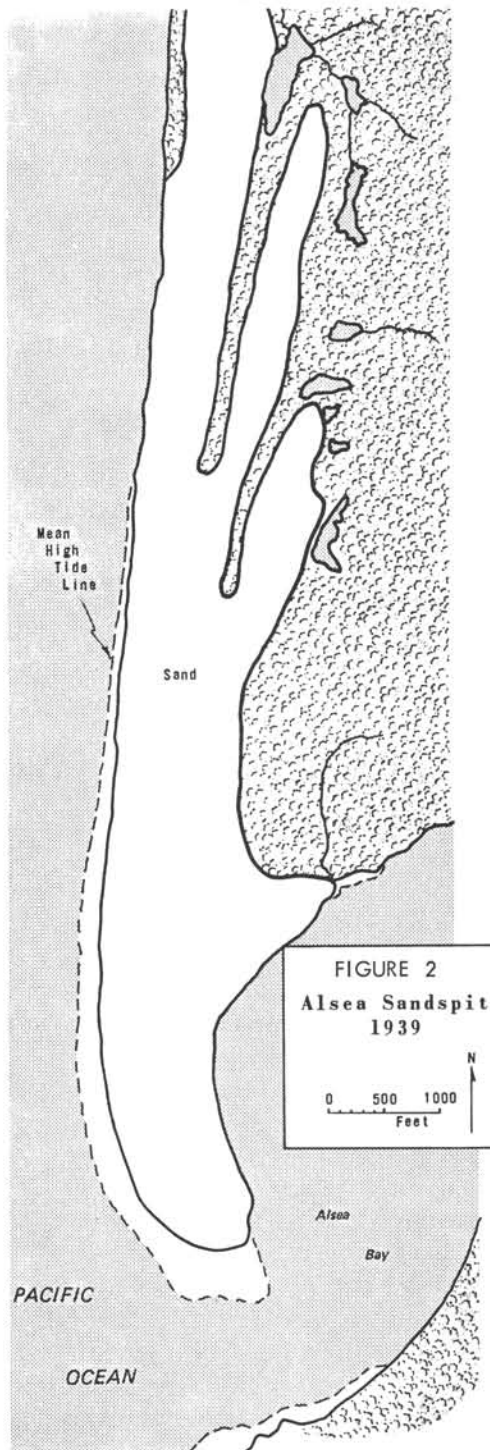


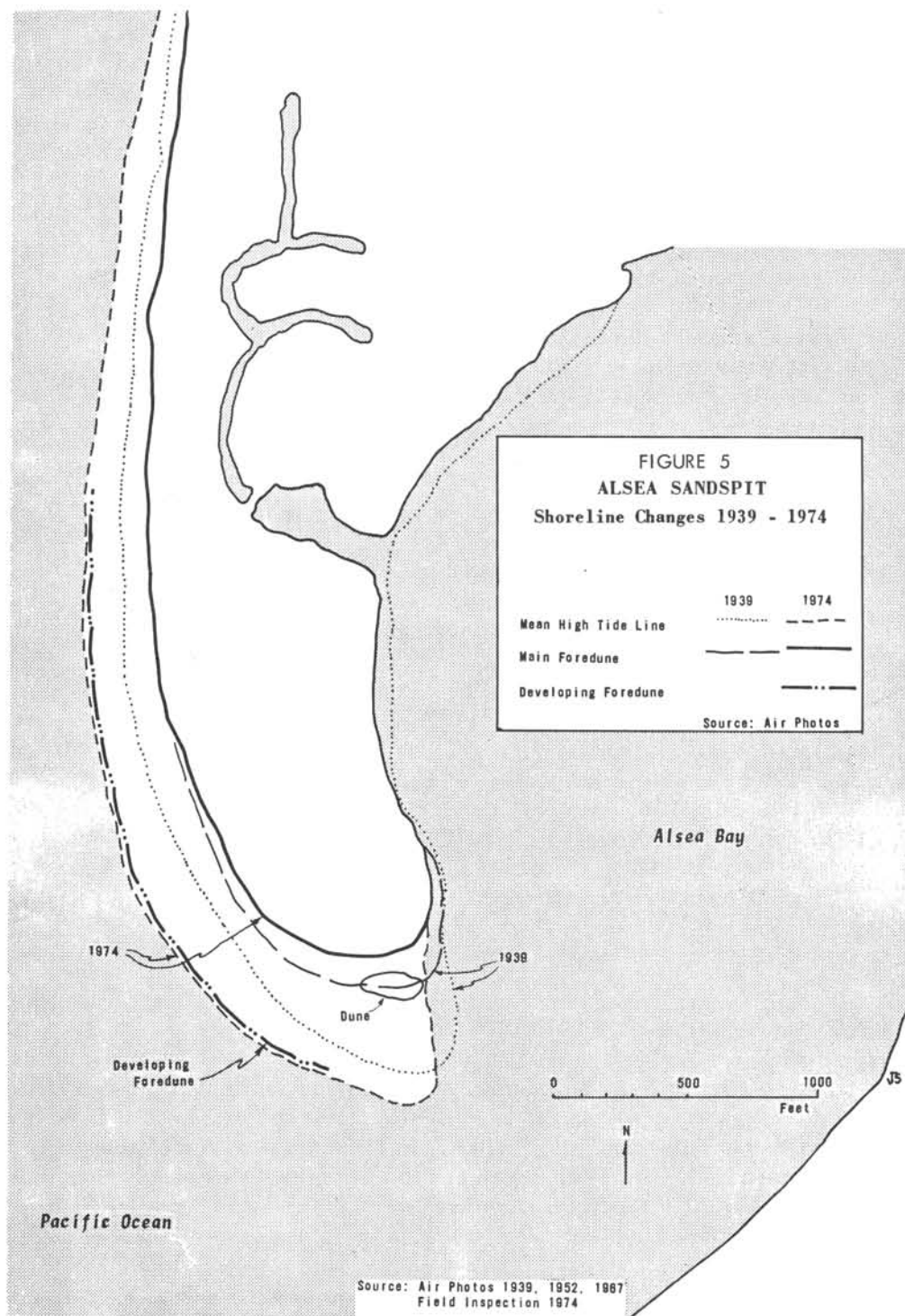


Figure 4. The southern portion of the Alsea sandspit. Note the breached foredune and developing beach berm.

with sand and is not reached by even the highest of high tides. The new foredune is unvegetated, but vegetation has appeared in the interjacent area as much as 200 feet seaward of the main foredune.

The primary process in the accretion of the spit appears to be the deposition of sawlog driftwood combined with sand accumulation. Sand is transported into the area by river and ocean currents from inland sources, from terrace exposures both north and south of the spit, and from the bay side of the spit itself. Also deposited are large numbers of driftwood logs which interrupt the surface wind flow, causing the deposition of wind-blown sand, and retard erosion as well. The vertical limits of this process are on the order of 10 feet above mean high water, the maximum reach of recent storm waves. Additional dune elevation results from deposition associated with the entrapment of wind-blown sand by vegetation. The best example of this latter process is the new 20-foot-high vegetated dune just south of the southernmost portion of the main foredune (Figure 4).

Both the accretion rate and the width of beach that has developed since 1939 decrease in a regular fashion toward the north, reaching zero at a point 1.6 miles north of the spit's present tip (Figure 3). From that point north, erosion prevails, as indicated by bare and frequently inundated driftwood piles, steep unvegetated cliffs, overhanging vegetation, exposed root systems, and small mass movements.



The recently built houses on the spit proper are thus unlikely to experience damage from beach erosion or ocean flooding in the near future, even though some are cut into the main foredune. Those at lower elevations on the spit, however, may be vulnerable to bayside flooding from tsunamis or when storm surges combine with high tides. Blowing sand will continue to be a problem where the foredune has been breached and where there are expanses of unvegetated sand.

Sandspits have been described as oscillatory in that they may experience irregular cycles of erosion and deposition. If the spit at Alsea is currently prograding, the situation could reverse at any time.

Driftwood deposition as a major factor of shoreline evolution may be a feature unique to the beaches of the Pacific Northwest. Sand supply remains the primary key to the understanding of the entire coastal erosion and deposition process. Sorting and measuring the natural fluctuations in sand movements and the variations caused by human occupation of the coastal zone continue as the major tasks.

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OREGON LAKES INVENTORY CONTINUES

"Lakes of Oregon, Vol. 2 - Benton, Lincoln, and Polk Counties," by M. V. Shulters, has been issued as an open-file report by the U.S. Geological Survey Water Resources Div., Portland, in cooperation with the State Engineer, Salem. The inventory describes and illustrates, by map and photograph, all natural lakes in the three counties as well as man-made ponds larger than 5 acres. Copies of the report are available in limited supply from the above agencies.

* * * * *

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Papers which are expected to be included in the proceedings are:

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2. International monetary outlook and gold related assets, by
C. Austin Barker
3. Real money and counterfeit money: Their effect on world conditions, by Eugene Guccione
4. Twentieth century inflation, by John E. Holloway

Gold Technical Sessions

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2. Carlin-type gold deposits, by A. S. Radtke
3. Epithermal transport and deposition of gold, by F. W. Dickson
4. Gold deposits of western Canada, by W. R. Bacon
5. Innovations in cyanidation treatment of low grade gold and silver ores and mine wastes, by H. J. Heinen, R. E. Lindstrom, and D. G. Peterson
6. Lode gold deposits: The case for volcanogenic derivation, by R. W. Hutchinson
7. New ore discoveries of silver and gold in Guanajuato, Mexico, by W. H. Gross
8. Oregon's gold potential, by Len Ramp
9. Placer mining for gold, by W. H. Breeding
10. Recent history of gold exploration in the U.S.A., by J. G. Wargo
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GEOHERMAL LEASE SALES ANNOUNCED BY BLM

The U.S. Bureau of Land Management is offering 92,900 acres of Federal lands within the Alvord KGRA (Known Geothermal Resources Area) in Harney County for geothermal lease at public auction. The Mickey Hot Springs area and the Alvord Hot Springs area are offered in May and the Borax Lake Hot Springs area on June 5. Auctions are held at the BLM Oregon Office, 729 N.E. Oregon St., Portland. A summary of current and future sales is as follows:

Alvord KGRA 92,900 acres (in 44 leasing units)

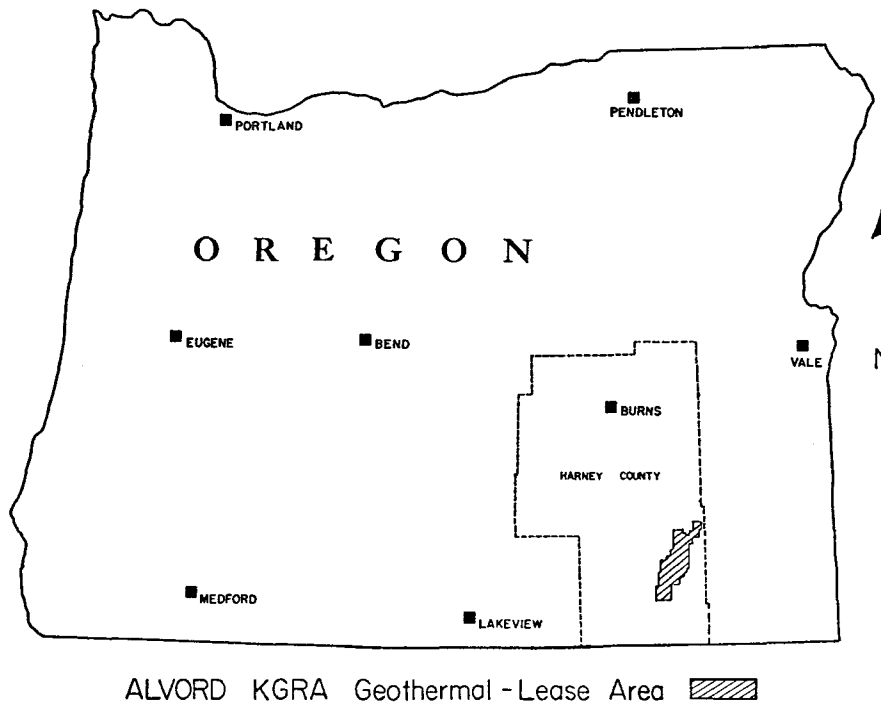
Mickey Hot Springs area,	14 units	May 22, 1975
Alvord Hot Springs area	14 units	May 29, 1975
Borax Lake Hot Springs area	16 units	June 5, 1975

Crump Geyser KGRA tentative date July 31, 1975

Vale Hot Springs KGRA tentative date August 7, 1975

Klamath Falls KGRA tentative date February 26, 1976

Further information and bid forms can be obtained from the Portland BLM office, P. O. Box 2965, Portland, Oregon 97208.



STATE LANDS IN MALHEUR COUNTY LEASED FOR GEOTHERMAL EXPLORATION

Four applications for geothermal resources leases on state-owned lands received final action by the State Land Board on April 24, 1975. Two of the applicants had been waiting in line since February 1974. Rules for leasing had to be adopted and then the applicants were given 120 days to submit their own analysis of the impacts geothermal development would have on the lease site. The applicants' environmental reports were then circulated to interested public agencies and groups for comments. A public hearing was available but no one asked for it.

The lease sites are State school sections in the Alvord Basin, at the foot of Steens Mountain, and near Vale and Adel in Malheur and Lake Counties. Most of the approximately 8,000 acres is intermingled with Bureau of Land Management land and would be operated as units with the BLM's lessees under Federal regulations. The State Department of Geology and Mineral Industries will control the technical operations in exploration and drilling. The State's lease terms are for a 10-year primary term, but rentals escalate from \$1 per acre for the first three years to \$3 per acre in the fourth year and \$5 per acre for each year after that. If a well produces geothermal steam, the State will receive a 10 percent royalty.

* * * * *

WHERE TO MAKE GEOTHERMAL INQUIRIES

Since the first of the year, when R. G. Bowen resigned from the Department to go into consulting work, the Department's geothermal research and field programs have been directed by Don Hull, geothermal specialist at the Baker field office. Persons seeking geothermal information on a professional basis may obtain assistance by either writing or calling Don Hull, Oregon Dept. of Geology and Mineral Industries Field Office, 2033 First Street, Baker, OR 97814 (telephone: 503-476-2496). Information on drilling regulations and permits to drill for geothermal energy in Oregon can be obtained from V. C. Newton at the Department's Portland office (503-229-5580). General, unspecialized questions on geothermal resources in Oregon should be directed to staff members at the Portland office.

Information on Federal lands open for geothermal leasing can be obtained from the office of the Bureau of Land Management, 729 N.E. Oregon St., P.O. Box 2965, Portland, Oregon 97208. Lease information on State lands is available from Division of State Lands, 1445 State Street, Salem, Oregon 97310.

* * * * *

IDAHO GEOTHERMAL REPORT ON OPEN FILE

The U.S. Geological Survey has released Open File Report No. 75-130, "Schlumberger soundings and total field measurements in the Raft River geothermal area, Idaho," by Adel A. R. Zohdy, Dallas B. Jackson, and Robert J. Bisdorf. The 87-page report includes four black and white plates at a scale of 1:250,000.

Material from which copy can be made at private expense is available from the three USGS Public Inquiries Offices in Denver, Salt Lake City, and Spokane, and at the Idaho Bureau of Mines and Geology, Moscow, Idaho.

* * * * *

PLEISTOCENE LAKES IN GREAT BASIN

A map showing the distribution and maximum extent of Pleistocene lakes in the Great Basin has been published by the U.S. Geological Survey as Map I-416. Only ancient shorelines and remnants of these prehistoric lakes now remain. They extend from Fort Rock in eastern Oregon to Salt Lake City, Utah, and south into the Mojave Desert. The map, scale of 1:1,000,000, is for sale by the Branch of Distribution, U.S. Geol. Survey, Federal Center, Denver, Colorado 80225 for 50 cents.

* * * * *

METAL MINES HANDBOOKS REPRINTED

Three Oregon Metal Mines Handbooks, published a number of years ago by the Department, and long out of print, have been reprinted by a firm in Bellevue, Washington. Those available so far are as follows:

Bulletin 14-A: Baker, Union, and Wallowa Counties, 125 pages

Bulletin 14-C, vol. 2, sec. 1: Josephine County, 229 pages

Bulletin 14-C, vol. 2, sec. 2: Jackson County, 208 pages

The Metal Mines Handbooks were compiled in the late 30's and early 40's when metal mining was particularly active owing to economic and, later, war-time conditions. The bulletins contain a wealth of information unavailable elsewhere on history of development, production, and geology of each mine. Gold, copper, lead, zinc, platinum, mercury, chromium, nickel, molybdenum, and antimony are some of the metals that were prospected for, mined, and produced.

For a price list and further information about available reprints on Oregon and other states, write to: George Srein, American Trading Co., P.O. Box 1312, Bellevue, WA 98009.

* * * * *

THEY'LL DIG SOME UP SOMEWHERE

Several years ago one of my favorite comic strips featured a dialogue in which one character asked, "What will they do when they run out of minerals?" The reply by another character was "Oh, they'll dig some up somewhere." That reply fairly well epitomizes what so many people actually believe today. However, those of us who work with the problems of finding new mineral resources and who are also concerned with protecting the environment know that it's just not as simple as "digging some up somewhere."

We find ourselves in a society that having already consumed the easily found, high-grade mineral resources, now continues to demand ever-increasing quantities of all varieties of mineral resources. This is a society whose housing, industry, transportation, tools, clothing, household appliances, and energy fuels are all derived from mineral resources. This growing demand is a phenomenon not only of the United States and other industrial nations, but of the underdeveloped countries who are striving to catch up.

Although demands for mineral resources grow, the restraints on availability are increasing more rapidly. Foreign, mineral-exporting nations withhold production and sales in the interest of higher prices and extending longevity. Exploration and development of offshore oil, gas, and mineral resources faces environmental opposition. Wilderness areas are being set aside from man-made development of any kind, particularly mineral extraction. Restrictive zoning in urban and suburban areas is closing out quarries and mines from the very areas where the demand is greatest. Agricultural lands are being given special protection. Dredging minerals from rivers and the offshore is being restricted because it disturbs the fish. There is strong opposition to strip mining of coal (for what it does to the land) and deep mining of coal (for what it does to water) even though our huge coal reserves are the most immediate solution to energy shortages.

Proponents for the restraints on mineral extraction present an appealing list of justifications. But the demand for mineral resources continues unabated. Just where are they going to dig up some more?

Arthur A. Socolow

(Adapted from *Pennsylvania Geology*, vol. 5, no. 5, 1974)

* * * * *

ARCHIE CRAFT GOES TO WASHINGTON, D.C.

Archie D. Craft, State director for the Bureau of Land Management in Oregon and Washington since 1967, has been appointed Assistant National BLM Director for Technical Services in Washington, D.C. Technical services include engineering, cadastral survey, resource protection, road rights of way, appraisals, records systems, data processing, and safety.

* * * * *

GEOHERMAL WORKSHOP PROCEEDINGS PRINTED

The Proceedings of the Workshop on Environmental Aspects of Geothermal Resources, held at Asilomar, California, November 20-22, 1974, is available. The 123-page bulletin presents the results of six workshop groups, each of whom discussed and evaluated one of six areas of concern related to geothermal development: water quality, air quality, biological impact, hazards, environmental impact, and land-use planning and socio-economic effects. Chairmen of the workshop conference were David N. Anderson and Richard G. Bowen. The volume was prepared by California Department of Conservation, Division of Oil and Gas, and by Oregon Department of Geology and Mineral Industries in association with the National Science Foundation through a research grant. Free copies can be obtained by writing to the Geothermal Section, National Science Foundation, Washington, D.C.

* * * * *

U.S.G.S. ESTABLISHES NEW RESOURCE AND ENVIRONMENT UNIT

A new unit, the Office of Land Information and Analysis (LIA), has been established by the U.S. Geological Survey to consolidate its previously separate resource and environment programs and activities. The largest program to be incorporated into the new office is EROS (Earth Resources Observation Systems) which processes and distributes data from satellites and aircraft. Other Survey programs to be included into LIA are: Urban Area Studies (UAS), Land Resources and Analysis (LRA), Geographic Applications Program (GAP), Land Use Data and Analysis (LUDA), Resource and Land Investigations (RALI), and Environmental Impact Analysis (EIA).

The goal of the new unit will be to assemble complex earth-science data from its many Survey sources, translate this information into a usable form, and make it accessible to those who must plan and make decisions about the use of land, water, and natural resources.

Dr. James R. Balsley, the Survey's Assistant Director for Land Resources, has been named Chief of the LIA office.

* * * * *

ICE AGE COMING?

At a conference entitled "The Present Interglacial; How and When Will It End?", a group of scientists interested in the Quaternary concluded that global cooling and related rapid changes of environment, substantially exceeding the fluctuations experienced by man in historical times, must be expected within the next few thousand years or even centuries.

* * * * *

AVAILABLE PUBLICATIONS

(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

8. Feasibility of steel plant in lower Columbia River area, rev. 1940: Miller . . .	\$0.40
26. Soil: Its origin, destruction, preservation, 1944: Twenhofel . . .	0.45
33. Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen . . .	1.00
35. Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1963: Baldwin . . .	3.00
36. Papers on Tertiary foraminifera: Cushman, Stewart & Stewart. vol. 1 \$1.00; vol. 2 . . .	1.25
39. Geology and mineralization of Morning mine region, 1948: Allen and Thayer . . .	1.00
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey . . .	1.25
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch . . .	1.00
52. Chromite in southwestern Oregon, 1961: Ramp . . .	3.50
57. Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors . . .	3.50
60. Engineering geology of Tualatin Valley region, 1967: Schlicker and Deacon . . .	5.00
61. Gold and silver in Oregon, 1968: Brooks and Ramp . . .	5.00
62. Andesite Conference Guidebook, 1968: Dole . . .	3.50
64. Geology, mineral, and water resources of Oregon, 1969 . . .	1.50
65. Proceedings of the Andesite Conference, 1969: McBirney, editor (photocopy) . . .	10.00
67. Bibliography (4th suppl.) geology and mineral industries, 1970: Roberts . . .	2.00
68. The Seventeenth Biennial Report of the State Geologist, 1968-1970 . . .	1.00
69. Geology of the Southwestern Oregon Coast, 1971: Dott . . .	3.75
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71. Geology of selected lava tubes in the Bend area, 1971: Greeley . . .	2.50
72. Geology of Mitchell Quadrangle, Wheeler County, 1972: Oles and Enlows . . .	3.00
73. Geologic formations of Eastern Oregon, 1972: Beaulieu . . .	2.00
75. Geology, mineral resources of Douglas County, 1972: Ramp . . .	3.00
76. Eighteenth Biennial Report of the Department, 1970-1972 . . .	1.00
77. Geologic field trips in northern Oregon and southern Washington, 1973 . . .	5.00
78. Bibliography (5th suppl.) geology and mineral industries, 1973: Roberts and others . . .	3.00
79. Environmental geology inland Tillamook Clatsop Counties, 1973: Beaulieu . . .	6.00
80. Geology and mineral resources of Coos County, 1973: Baldwin and others . . .	5.00
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82. Geol. hazards of Bull Run Watershed, Mult. Clackamas Cos., 1974: Beaulieu . . .	5.00
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin . . .	3.50
84. Environmental geology of western Linn Co., 1974: Beaulieu and others . . .	8.00
85. Environmental geology of coastal Lane Co., 1974: Schlicker and others . . .	7.50
86. Nineteenth Biennial Report of the Department, 1972-1974 . . .	1.00

GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck \$2.00; mailed . . .	2.25
Geologic map of Oregon (12" x 9"), 1969: Walker and King . . .	0.25
Geologic map of Albany quadrangle, Oregon, 1953: Allison (also in Bulletin 37) . . .	0.50
Geologic map of Galice quadrangle, Oregon, 1953: Wells and Walker . . .	1.00
Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts . . .	0.75
Geologic map of Bend quadrangle, and portion of High Cascade Mtns., 1957: Williams . . .	1.00
GMS-1: Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka . . .	1.50
GMS-2: Geologic map, Mitchell Butte quad., Oregon: 1962, Corcoran and others . . .	1.50
GMS-3: Preliminary geologic map, Durkee quadrangle, Oregon, 1967: Prostka . . .	1.50
GMS-4: Gravity maps of Oregon, onshore & offshore, 1967: Berg and others [sold only in set] flat \$2.00; folded in envelope . . .	2.25
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- 2. Oregon mineral deposits map (22 x 34 inches) and key (reprinted 1973): Mason . . 0.75
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- 4. Prelim. identifications of foraminifera, E. M. Warren Coos Co. 1-7 well: Rau . . 1.00

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- Landforms of Oregon: a physiographic sketch (17" x 22"), 1941 0.25
- Geologic time chart for Oregon, 1961 free
- Postcard - geology of Oregon, in color 10¢ each; 3 - 25¢; 7 - 50¢; 15 - 1.00
- Oregon base map (22 x 30 inches) 0.50
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The ORE BIN
Volume 37, No. 6

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Credit given the State of Oregon Department of Geology and Mineral Industries
for compiling this information will be appreciated.

"GLENDONITES" FROM OREGON AND WASHINGTON

Sam Boggs, Jr.
Head, Department of Geology, University of Oregon

Stone balls thought by some local residents to be Indian relics are common in the gray, Tertiary mudstones of various parts of northwestern Oregon and western Washington. These objects were first described to me as having either a square hole or a square core through their center, and were postulated to be weights that Indians from some ancient tribe used to hold their fishing nets to the stream bottom. I later had an opportunity to examine some of these "relics" and found that they were actually a rather unusual type of calcium carbonate concretion. An elongate, prismatic core or nucleus extends completely through each concretion, and the (broken) ends of this nucleus are visible on the surface of the concretion as rhombic-shaped scars. The nucleus is partially dissolved in a few specimens, leaving the so-called square holes.

The nuclei are the most interesting characteristic of the concretions and are the focus of this study. Although these nuclei have a prismatic or crystalline shape, their granular interior composed of small crystals of calcite clearly indicates that they are pseudomorphic after some original mineral no longer present.

The first published description of the pseudomorphs appears to be that of J. D. Dana (1849), who describes several prisms collected from the Astoria area. Dana also describes similar prisms found near Glendon in New South Wales, Australia and states that "The Glendon prisms differ in nothing (from the Astoria prisms) except in having a smoother exterior...." David and others (1905) named the New South Wales prisms glendonite, after the town of Glendon.

The Oregon and Washington prisms appear very similar to the Glendon prisms, though some differences do exist, and are referred to in this paper as "glendonites."

A detailed petrographic, X-ray, chemical, and isotopic analysis of several "glendonite" prisms was reported by Boggs (1972). The present paper offers a more generalized description of the important characteristics of the "glendonites" and provides a discussion of the probable origin of the prisms and concretions.

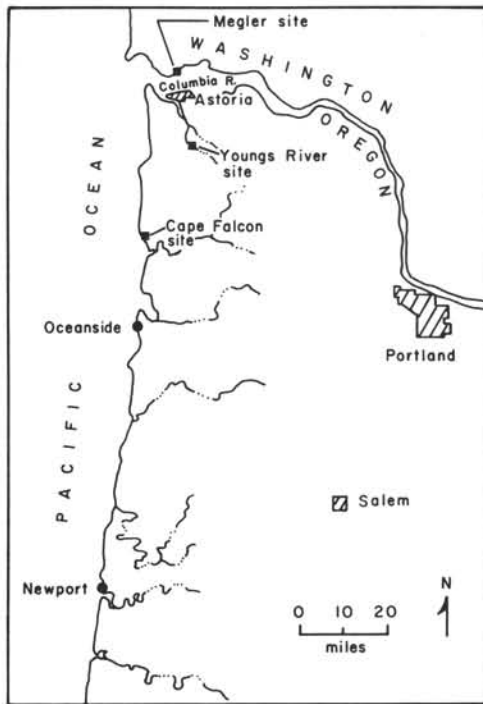


Figure 1. Index map of northwestern Oregon and southwestern Washington showing location of "glendonite" sites.

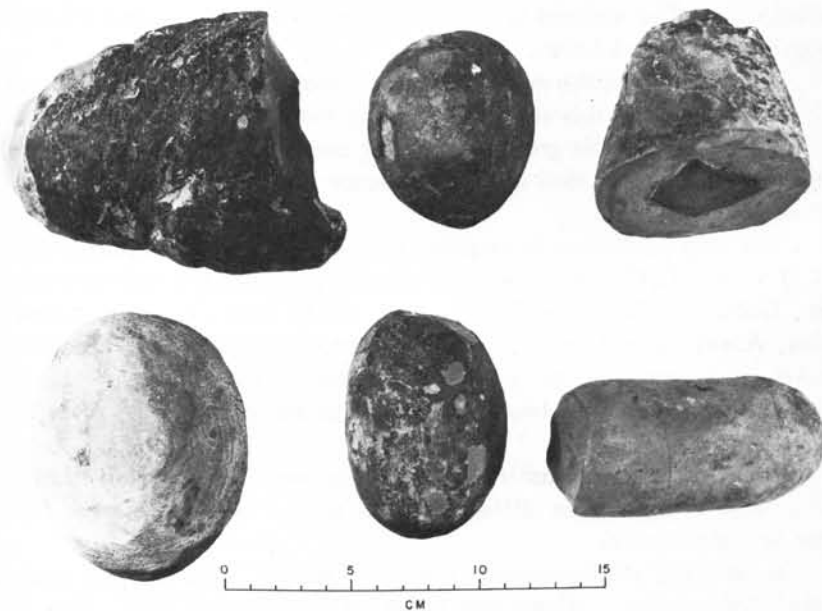


Figure 2. Typical "glendonite" concretions. Note variation in shape of concretions and rhombic cross-sectional shape of "glendonite" nuclei.

Most of the prisms and concretions described in this report were collected from an area on Youngs River a few miles south of Astoria, Oregon (Figure 1). They were first brought to my attention by Douglas Nelson of Astoria. The concretions occur in dark gray, silty mudstones of the Astoria Formation (Miocene age) and are concentrated in a zone 6 to 8 feet thick of thinly but indistinctly bedded mudstone near the base of the exposed unit. Many concretions eroded from the mudstones were found in the nearby stream bed.

Similar "glendonite" concretions were collected from Oligocene-age mudstones exposed near Cape Falcon on the northern Oregon Coast by Rauno Perttu, a former geology student at the University of Oregon. "Glendonite" concretions and prisms were also collected from Astoria Formation mudstones near Megler, Washington by Dr. W. N. Orr, University of Oregon, and from similar beds exposed near Naselle, Washington by Dan Penttila, State of Washington Department of Fisheries. Parke Snively, U.S. Geological Survey, reports (personal communication) that he has collected similar prisms and concretions from the Twin River Formation (Oligocene age) of the Olympic Peninsula and from the Lincoln Formation (Oligocene age) of southwestern Washington.

Description of Concretions

The concretions are highly variable in both shape and size. Some are ovoid to subspherical; others are subconical, discoid, or cylindrical (Figure 2). Many concretions have a thin, dark-brown to black weathering rind which is partially chipped away, producing a rough, hackly surface. The smallest concretion collected is 5.6 cm in length and 3.8 cm in diameter. Some concretions up to about 26 cm in length and 20 cm in diameter were collected and a few considerably larger than this were observed in the field.

An interesting characteristic of the concretions is their failure to completely enclose the "glendonite" nuclei. An excellent example of this feature is illustrated by Figure 3. The projecting part of the "glendonite" commonly breaks away from the concretion, leaving a rhombic-shaped scar on the surface of the concretion as shown in Figures 2 and 4. Study of sawed concretions shows that a few display faint concentric bands that terminate against the "glendonite" nuclei (Figure 5B); however, most concretions show no internal structures except indistinct biogenic(?) mottling (Figure 5C). This mottled texture and the presence of patches of fecal(?) pellets in some concretions suggest that the original muddy sediment in which the concretions formed was probably reworked by scavenging organisms. This could account for the scarcity of relict bedding in the concretions.

Small calcite crystals, ranging in size from about 0.0025-0.005 mm, make up approximately 80 percent of the body of the concretions, excluding

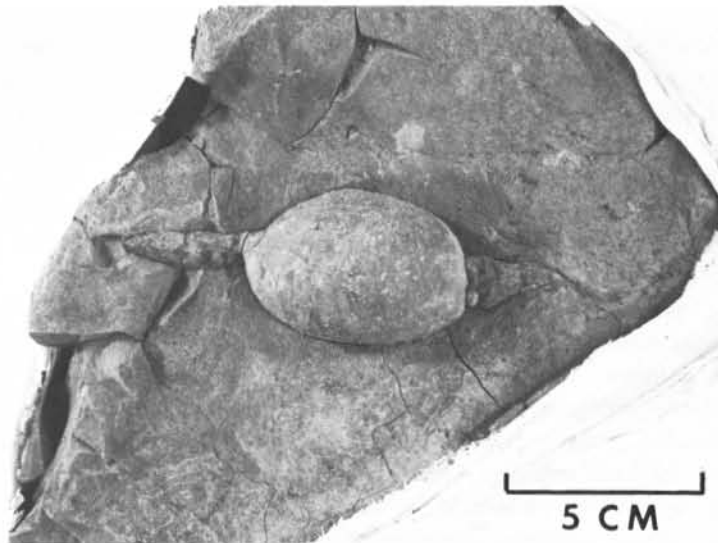


Figure 3. A complete concretion, with "glendonite" nucleus still intact, shown in place within host mudstone.

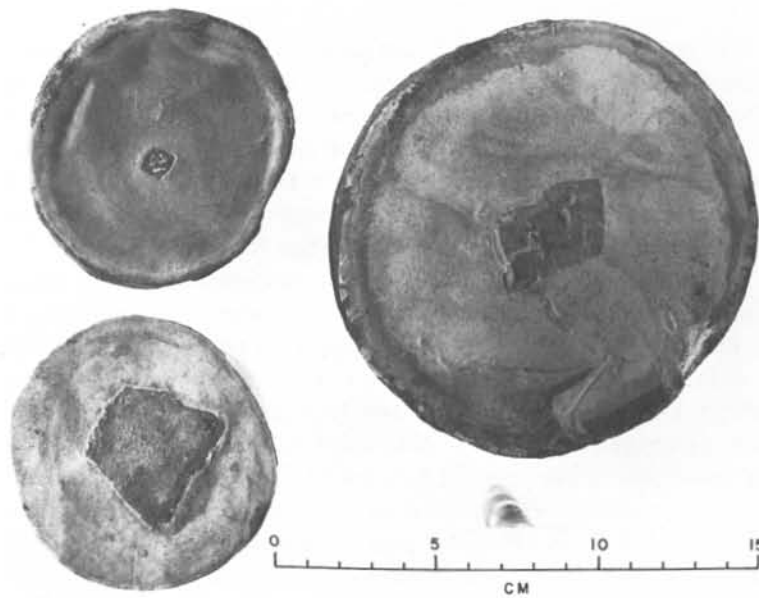


Figure 4. Cross-sectional view of concretions showing typical shape of "glendonites." "Glendonite" in largest concretion has "crusts" of mud (light areas) projecting in from sides.

the "glendonite" nuclei. The remaining material in the concretions is principally silt- to fine sand-size grains of quartz, plagioclase feldspar, biotite, muscovite, and rock fragments with a minor amount of clay minerals. Minor replacement of calcite by chert, opal, and pyrite is evident in a few specimens. Small fossils (microfossils) are common, though not abundant, and fine organic matter is disseminated throughout the concretions. The texture of a typical concretion, as viewed in the microscope, is illustrated in Figure 6.

Description of Glendonites

Most of the "glendonites" are partially enveloped by concretionary calcite as shown in Figures 3 and 5; however, a few escaped concretionary development and are simply enclosed in the host mudstone. A typical "glendonite" has the approximate crystal form of a slender, elongate, rhombic prism with dipyrnidal terminations; none of the specimens has smooth, even crystal faces. The surface of most prisms is scored by irregular ridges and grooves that are transverse to the prism faces (Figures 7 and 8). The markings on some prisms are sharply angular and distinct, conveying the impression that they may be the result of multiple twinning of some original crystal. Many of the prisms appear distorted or "mashed" and, in addition to the more characteristic rhombic form, cross-sectional shape may vary from almost square to pseudo-rectangular, or even irregular.

The prisms are much elongated compared to the terminating dipyrnids, and most appear to have a distinct twist so that the ends are turned in somewhat different directions. The gradual diminution and twisting of the prisms is evident in Figures 7 and 8.

The smallest complete "glendonite" collected is about 2 cm in length, with a maximum cross-sectional dimension of about 0.4 cm. The largest specimen (about 27 cm) is incomplete and total length is probably much greater. The largest cross-sectional dimension of any "glendonite" measured is about 4 cm.

Although the "glendonites" display the external form of a twinned crystal, microscope study shows that the interior of the prisms is composed of an aggregate of crystals of various sizes. Calcite makes up about 98 percent of these crystals. Replacement chert occurs in small patches in many "glendonites" and a small amount of quartz fills some voids. Small, irregular patches of replacement pyrite are also common. Sand-size terrigenous mineral grains, such as quartz, were observed in a few prisms, but most contain no coarse terrigenous material. Fine organic matter, trapped within calcite crystals, is common in all of the "glendonites." With a single exception, fossils were not found in the prisms. The absence of fossils is in sharp contrast to the Australian glendonites in which fossils, particularly brachiopods, are common (David and others, 1905).

The calcite crystals that make up the prisms have four distinct crystal habits. Calcite occurs as large (up to 3.0 mm) tabular to ovoid crystals and

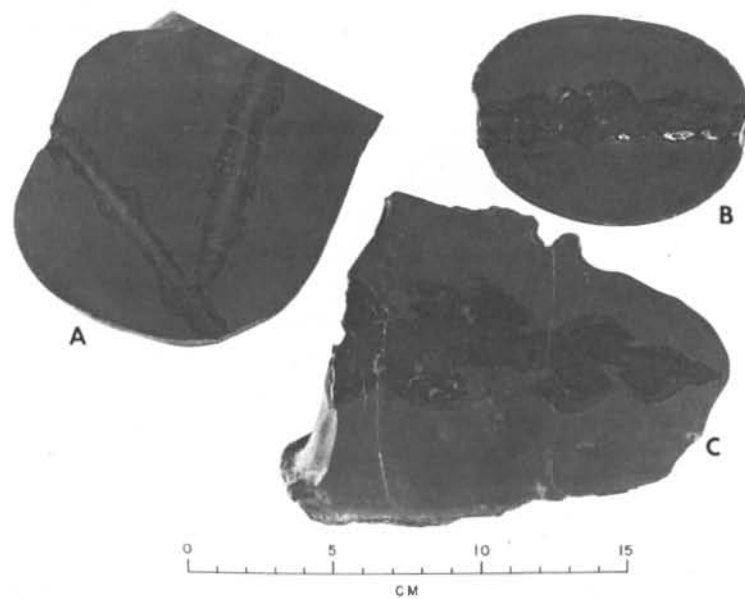


Figure 5. Specimens sawed longitudinally to show interior of concretions and "glendonites."

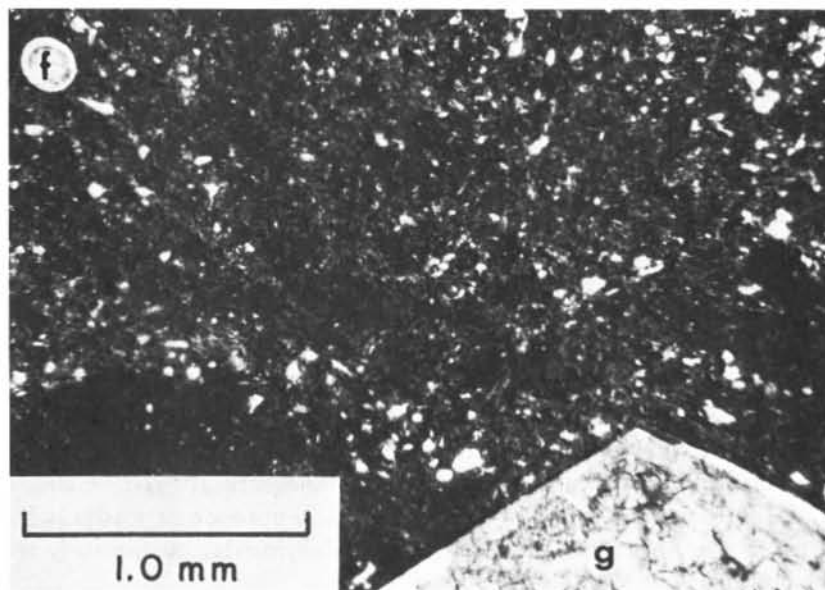


Figure 6. Photomicrograph showing typical texture of concretions. Note "glendonite" nucleus (g) and small fossil (f).

clusters (rosettes) of crystals, radial or spherulitic masses, fibrous but non-radial crystals oriented normal to the prism surfaces, and mosaic crystals that fill former void space.

The large tabular crystals and rosettes are extremely abundant in most specimens (Figure 9). They are commonly clustered near the center of the prisms but may occur throughout and even project into the surrounding concretion. Most of these crystals contain abundant organic matter trapped within the crystal structure. The organic matter occurs both as a very fine brown "dust" and as larger (0.0025–0.01 mm) black particles. The larger particles are particularly abundant and are randomly distributed throughout most crystals (Figure 10); however, they are arranged into more or less distinct zones in some crystals (Figure 11).

Fibrous radiating or spherulitic calcite (Figure 12) is best developed in the outer parts of the prisms but may occur in any part. In some specimens large single crystals or rosettes have acted as nuclei around which the radial calcite was deposited. The spherulites invariably contain abundant fine, brown organic "dust" which colors them light to deep reddish brown. Brown (1925) attributes the yellowish color of the fibrous radiating calcite in New South Wales glendonites to the presence of iron. However, chemical data (Boggs, 1972) show that only a minute amount of iron is present in the spherulites of Oregon and Washington "glendonites." Their brownish color is clearly due to the presence of organic matter. In some prisms the organic matter is concentrated into distinct dark bands that seem to outline the position of former cavities (Figure 12).

Some "glendonites" contain a thin layer (up to 1.5 mm thick) along their outer edge that is composed of fibrous calcite oriented normal to the prism face. This zone is absent in many prisms and is well developed in only a few. The zone may be very complex, containing both fibrous calcite and small spherulites arranged in alternating bands (Figure 13), or may be composed of a single layer of fibrous calcite.

Many of the "glendonites" show evidence of the presence of former cavities. Most such cavities were subsequently filled with clear, sparry calcite that commonly displays a mosaic habit (Figure 14), but small openings are still present in a few prisms, as shown in Figure 5B.

Orientation to Bedding in Mudstones

Bedding in the mudstones is generally rather poorly developed, but it is sufficiently distinct in places to permit measurement of concretion and "glendonite" orientation with respect to bedding (Figure 15). Concretions having a flattened or discoid shape commonly lie with the plane of flattening parallel to the plane of bedding. The orientation of elongate concretions, which have the same orientation as their enclosed "glendonites," ranges from parallel to bedding to an angle of about 30 degrees to bedding. Relict bedding preserved in some concretions also permits the orientation of

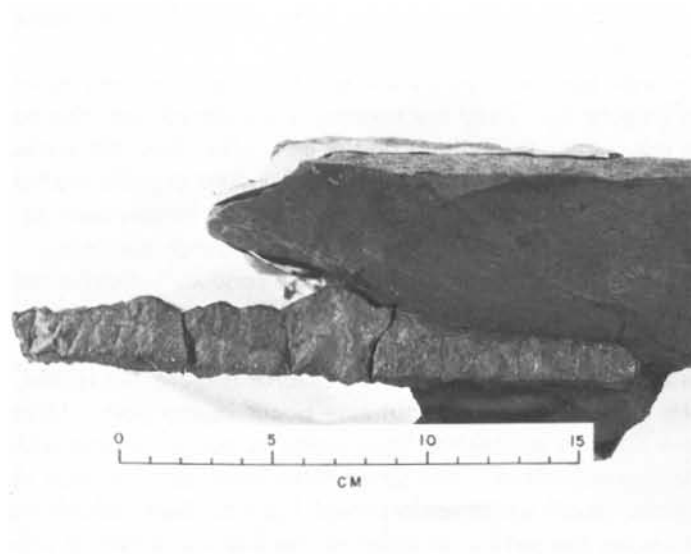


Figure 7. "Glendonite" about 27 cm in length within enclosing mudstone; specimen is broken off at left end.

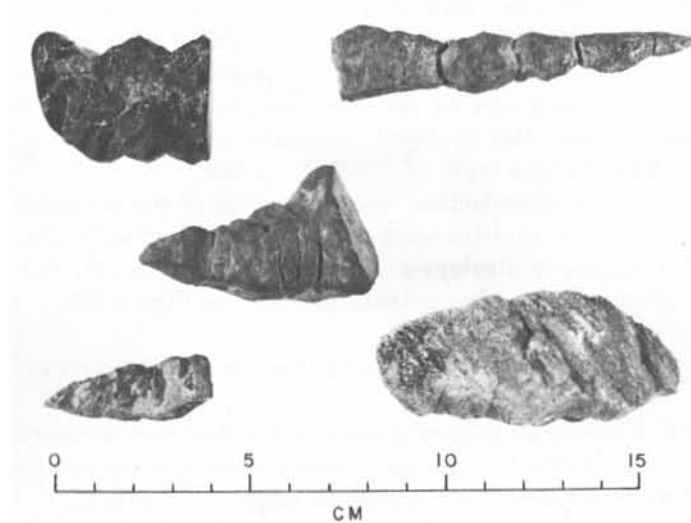


Figure 8. Typical "glendonites" from various localities in Oregon and Washington.

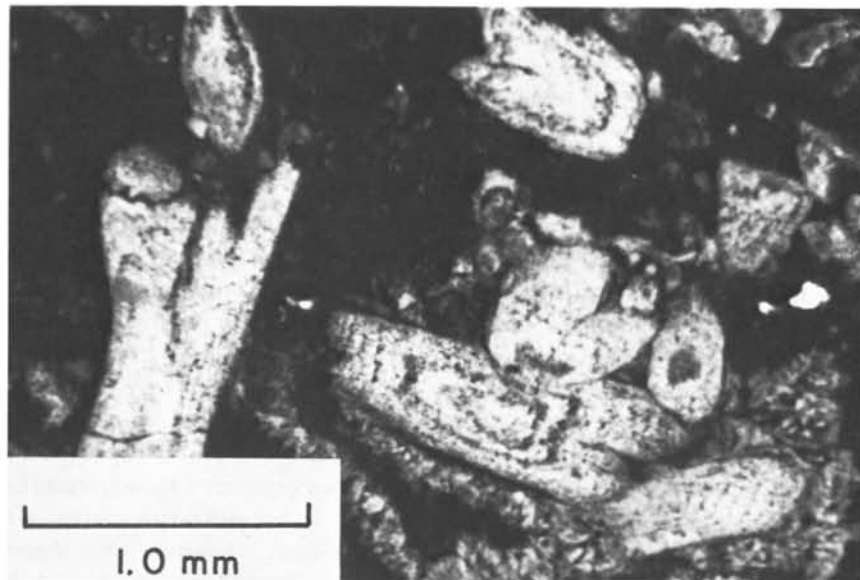


Figure 9. Photomicrograph showing large ovoid calcite crystals and clusters (rosettes) in a typical "glendonite." Dark patches within the crystals are organic matter.

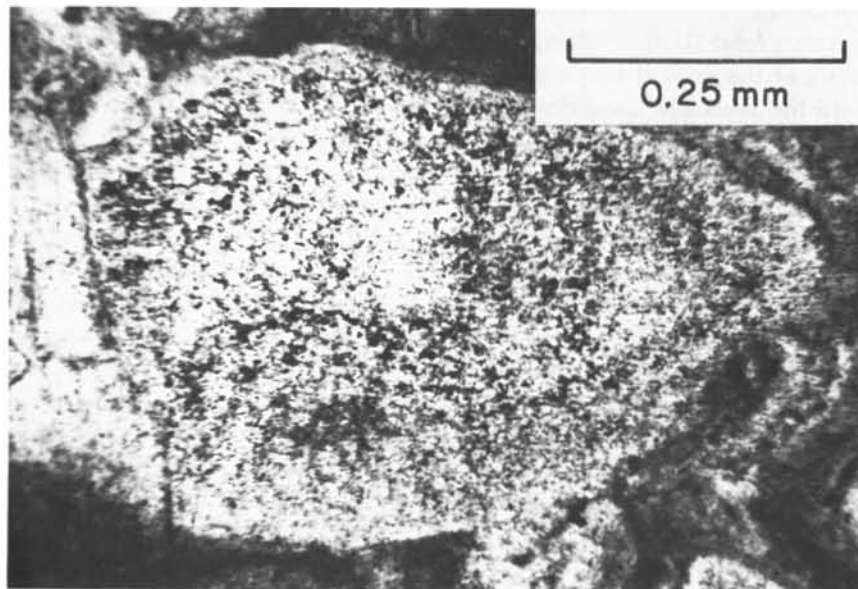


Figure 10. Enlarged view of a single calcite crystal showing abundant organic matter (black) trapped within the crystal.

the "glendonites" to be measured. This orientation ranges from parallel to the bedding to almost 90 degrees to the bedding. A few concretions contain two "glendonites" (Figure 5A) that may lie either in the same plane or at distinctly different angles. Some "glendonites" actually cut across bedding planes, a factor that is of importance in interpreting their origin.

Origin of "Glendonites" and Concretions

The granular interior of the "glendonite" prisms clearly indicates that their external crystal-like shape is inherited from some pre-existing mineral that has subsequently disappeared. The principal problems concerning the origin of the "glendonites" are 1) the identity of the original mineral, and 2) the manner of origin and the time of formation of the "glendonites."

One of the most striking features of the "glendonites" is the highly elongated form of the prisms. The transverse, angular ridges and grooves on the prism surfaces suggest that the elongation is due to repeated twinning. Dana (1849) thought that the form was produced by superposition of one rhombohedron upon the face of another in a continuous series with gradual diminution of the prisms toward the end. However, the shape of all of the "glendonites" is not uniformly rhombic. The growth of multiple crystals in cluster (Figure 5C) seems responsible for some variations in the basic rhombic form; however, it is not clear whether the pseudo-rectangular to square cross-sectional shape of other prisms is a primary feature or has been produced by distortion of originally rhombic-shaped prisms. It is impossible on the basis of available evidence to establish with certainty the crystallographic system of the original mineral, although the orthorhombic system appears most likely. Thus, the original mineral cannot be identified on the basis of the crystal shape of the prisms. Other data do provide some insight into the probable conditions under which this original mineral crystallized and permit an "educated guess" as to its identity.

Associated marine fossils show that the host mudstones for the "glendonites" were deposited under marine conditions. As described above, many of the "glendonites" are oriented at a distinct angle to bedding and some transect or cut across bedding planes. Similar relationships of Australian glendonites to bedding are reported by David and others (1905) and Raggatt (1938). These relationships indicate that the "glendonites" probably grew beneath the water-sediment interface rather than on or above the sediment surface. The association of "glendonites" with biogenic structures such as stirred bedding and fecal pellets, their tendency toward extreme elongation, and the branching character of some "glendonites" (Figure 5A) suggests that the original mineral may have crystallized in the burrows of some type of marine organism.

Several factors show that the "glendonites" and their enclosing concretions are syngenetic. Many of the concretions contain fossils and relict textures which indicate that concretionary development took place by calcite

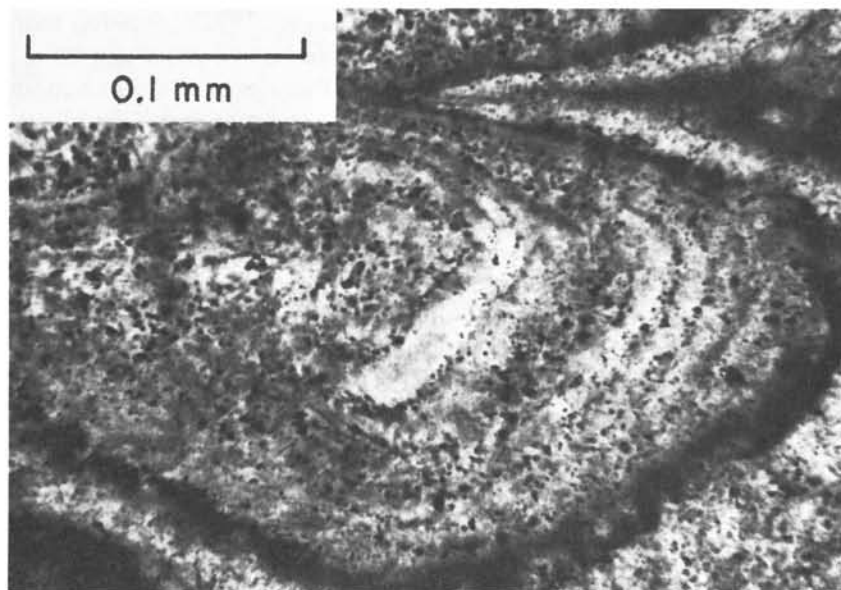


Figure 11. Organic matter (black) in this calcite crystal is arranged in distinct bands or zones.

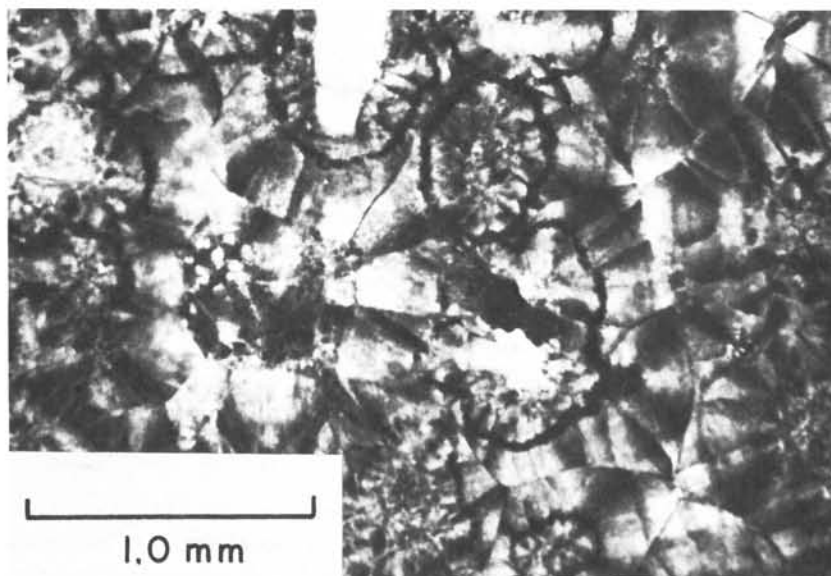


Figure 12. Photomicrograph of calcite spherulites. The black rings in the central part of the photograph are bands of concentrated organic matter.

infilling of pore space in detrital mud. The CaCO_3 content of the concretions ranges from about 75 to 80 percent (Boggs, 1972), showing that the porosity of the original detrital mud must also have been about 75 to 80 percent at the time of concretion formation. Therefore, the mud had undergone virtually no compaction by that time. Early concretionary development is also suggested by the preservation of certain textures such as fecal pellets. These pellets would have been partially crushed or otherwise deformed had extensive compaction preceded cementation.

Substitution of granular calcite for the original mineral did not occur by replacement in the sense of essentially simultaneous solution and precipitation. Instead, there is considerable petrographic evidence to indicate that the original mineral dissolved, leaving a mold that was then filled by precipitation of small calcite crystals. Filling may have occurred in stages, and some open space was present within the original mineral mold at times. Crusts of mud projecting into some "glendonites," the largest specimen in Figure 4 for example, suggest partial collapse of soft mud into a cavity. Also the distorted shape of many of the "glendonites" suggests solution of the original mineral and some deformation of the cavity in the still soft mud before refilling with granular calcite. The inclusion of organic matter within the calcite crystals and the concentration of some organic matter into bands, outlining the former shape of cavities, as well as the presence of sparry calcite filling obvious cavities, are all evidence that the original mineral dissolved, at least in part, before precipitation of granular calcite began. The presence of crude zoning in a few "glendonites" (Figure 5C) indicates the possibility of reversals in environmental conditions, causing two or more separate stages in solution and precipitation.

The following sequence of events in formation of the "glendonites" is indicated: Detrital muds were deposited under marine conditions and then reworked or stirred by organisms of some type. These organisms, living and feeding near the sediment-seawater interface, probably left open burrows in the soft mud. It seems likely that the precursor mineral of the "glendonites" crystallized within these open burrows because the extreme elongation of many of the prisms suggests that they were constrained to grow within some type of tube-like opening. The original mineral must have precipitated as isolated crystals within the watery mud, as no evidence of a more wide-spread deposit is now preserved. This mineral was stable under the initial conditions of formation but dissolved before virtually any compaction of the mud occurred, and the resulting cavity or mold was quickly filled with granular calcite to form the pseudomorph.

Initial precipitation in the crystal molds resulted in crystallization of large ovoid crystals and rosettes that grew in loosely packed masses within the cavities. Fine organic matter, suspended in the water-filled cavities, was incorporated into the crystals as they grew. This initial stage was followed by formation of spherulitic calcite which crystallized in much of the remaining pore space among the larger grains. Minor pore space that still

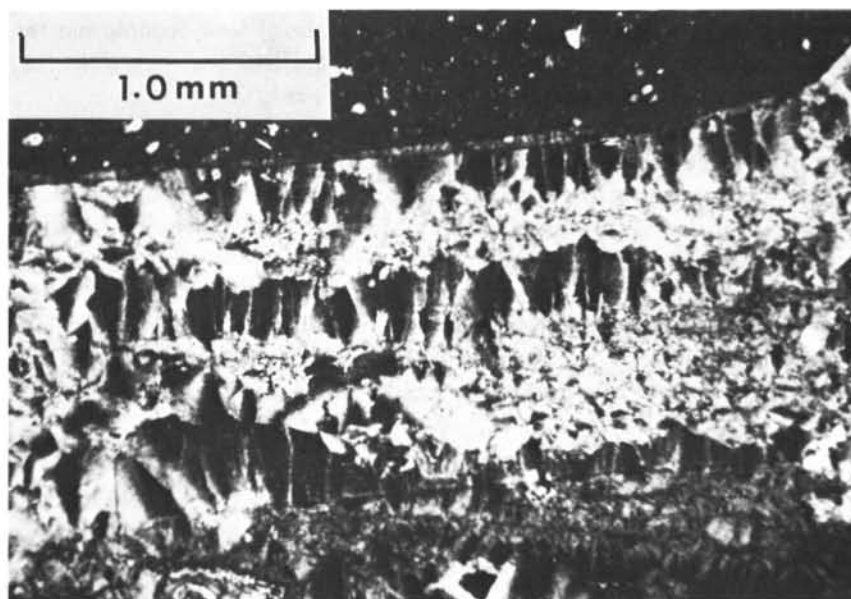


Figure 13. Fibrous, non-radial calcite along the edge of one "glendonite" at the point of contact with the enclosing concretion. Three zones of fibrous calcite, recognizable by dark stripes oriented normal to the pseudomorph surface, are shown separated by two zones of small interfering spherulites.

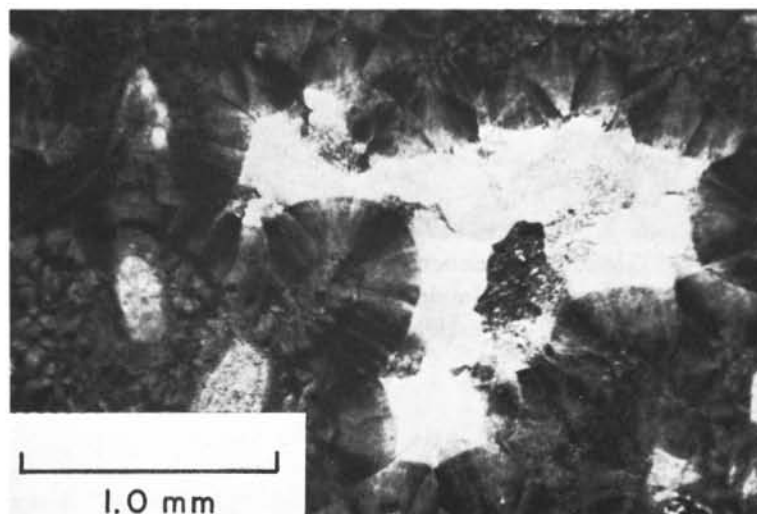


Figure 14. Sparry, mosaic calcite (white) filling former open space among calcite spherulites.

remained after crystallization of the spherulites was later filled by clear sparry calcite. This clear spar, which is devoid of fine organic matter, probably has a much later origin than the spherulites and may even have formed after uplift of the deposits above sea level.

The original mineral from which the "glendonites" inherited their shape is believed to be a carbonate - possibly aragonite or one of the hydrated carbonated minerals such as monohydrate - $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$. Positive identification of the precursor mineral seems unlikely, however, until the crystal system of the "glendonites" can be definitely established. My hope is that this paper will stimulate additional investigation of these interesting objects by other workers and that the crystal system of the pseudomorphs and the identity of the precursor mineral can be established as additional specimens of "glendonite" are discovered and studied.



Figure 15. "Glendonite" concretion in place in enclosing mudstone. The concretion and "glendonite" nucleus are oriented at an angle of about 30° to bedding.

Conclusions

(1) Elongate, prismatic structures called "glendonites" that are commonly found in carbonate concretions in northwestern Oregon and Washington are pseudomorphs. Their rhombic, prismatic shape is inherited from some

original mineral that crystallized in soft muds of the ocean floor during the Tertiary Period. This mineral subsequently dissolved, leaving a mold in the mud that was filled by crystallization of calcium carbonate (calcite).

(2) The original mineral, subsequent pseudomorphs, and the concretions that enclose the pseudomorphs are all syngenetic. They formed in an organic-rich mud a short distance below the depositional interface, and crystallization was completed before significant compaction of the mud occurred. The extreme elongation of the prisms suggests that they may have formed in the burrows of marine organisms.

(3) The crystal system of the original mineral cannot be definitely established on the basis of available data but appears to be orthorhombic. Based upon the probable conditions of origin and general shape of the prisms, the original mineral is believed to be a carbonate - possibly aragonite or one of the (orthorhombic) hydrated carbonates such as monohydrate.

Acknowledgments

The research reported in this paper was supported in part by a grant from the Office of Scientific and Scholarly Research, University of Oregon. I wish to thank Douglas Nelson, Rauno Perttu, William N. Orr, Dan Penttila, and Parke Snavely for aid in collecting specimens for the study.

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GEOHERMAL STUDIES IN THE VALE AREA, MALHEUR COUNTY, OREGON

Don Hull, Economic Geologist
Oregon Dept. of Geology and Mineral Industries Baker Field Office

Introduction

The Oregon Department of Geology and Mineral Industries has been engaged in studies of Oregon's geothermal energy potential for the past 10 years. The results of these activities have been described by Groh (1966), Peterson and Groh (1967), Bowen (1972), and Bowen and Blackwell (1973). Detailed studies of heat flow have been conducted since 1972 in the vicinity of Vale

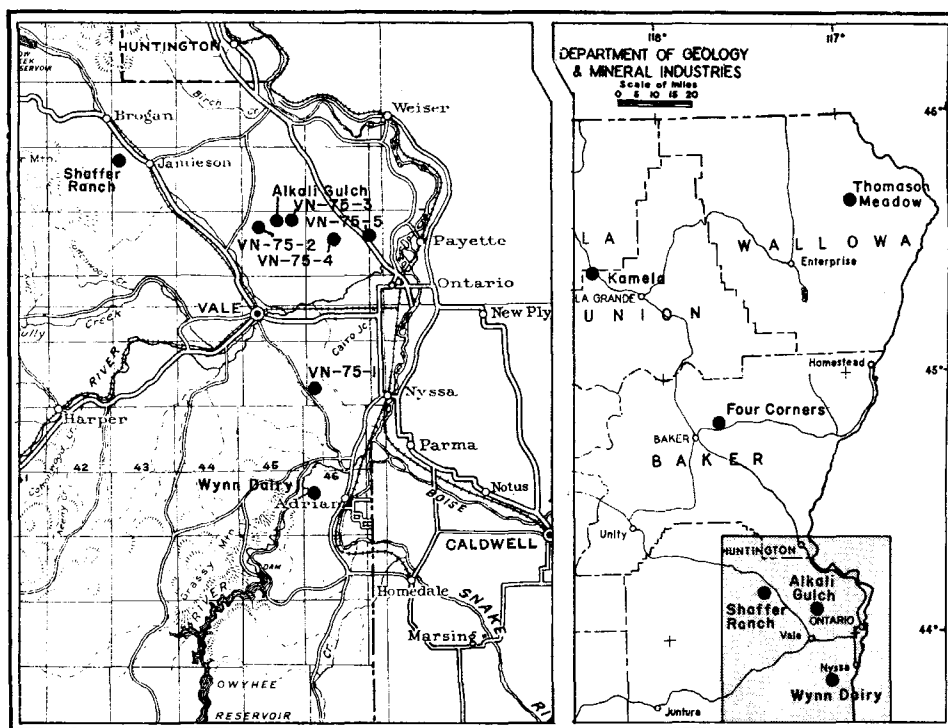


Figure 1. Index maps showing locations of temperature-gradient measurements taken by the Oregon Department of Geology and Mineral Industries between 1972 and 1975. Blow-up of Vale area map on left shows location of holes listed on Table 1; regional map on right shows location of holes listed on Table 2.

in northern Malheur County in southeastern Oregon (see Figure 1) under contract No. S0122129 with the U.S. Bureau of Mines. The studies, initiated by R. G. Bowen in cooperation with Dr. David D. Blackwell of Southern Methodist University, Dallas, Texas, are continuing, and a detailed report is being prepared summarizing the geothermal research conducted by the Department to date. The preliminary results tabulated herein are being released in the hope they will aid in the exploration for and development of geothermal resources.

The final phase of the current geothermal investigation of the Vale area, consisting of the drilling of five holes to obtain heat-flow data, was completed in May and June 1975. Temperature gradients measured in the drill holes are given in Table 1. Thermal conductivity measurements on drill core from these holes and heat-flow calculations are in progress. All gradients are uncorrected for topographic effects. Hole locations are shown in Figure 1.

Temperature Gradients

Four of the five holes in the Vale area were drilled to a depth of 152 meters (500 feet) in siltstone of the Idaho Group of Pliocene age. Hole VN-75-2 was drilled in silty claystone from 0 to 95 feet and in altered basalt (?) from 95 feet to a total depth of 203 feet. Drilling was done by a combination of air rotary, down-hole hammer, and coring techniques.

Hole VN-75-2 encountered warm artesian water at a depth of 105 feet which flowed at a rate of 10 to 14 gallons per minute with a temperature of 75°F (24°C) and a well-head pressure of 5 pounds per square inch. The average gradient, as shown in Table 1, was measured after the hole had been cemented to stop the artesian flow, but the gradient reflects the presence of the thermal water at shallow depth.

Table 1. Temperature gradients in the Vale area, Malheur County

Hole	Section	Township	Range	Depth	Average gradient (°C / km)
VN-75-1	30	19 S.	46 E.	152m (500 ft)	91.9
VN-75-2	8	17 S.	45 E.	62m (203 ft)	153.8
VN-75-3	2	17 S.	45 E.	152m (500 ft)	71.5
VN-75-4	16	17 S.	46 E.	152m (500 ft)	115.3
VN-75-5	13	17 S.	46 E.	152m (500 ft)	73.4

The Department also has a continuing program of measuring temperature gradients in pre-drilled holes such as water wells and mineral exploration holes. The results from holes measured from 1971 through 1973 were placed on open file status in March 1975. Holes probed in 1974 and 1975 are summarized below in Table 2. Detailed temperature logs from all of the holes listed in Tables 1 and 2 are available for inspection, or copying at cost, in the Portland, Grants Pass, and Baker offices of the Department.

Table 2. Temperature gradients in pre-drilled holes

Locality	Section	Township	Range	County	Depth	Average gradient (°C/km)
Thomason Meadow	26	3 N.	47 E.	Wallowa	65m (213 ft)	23.0
Kamela	36	1 S.	35 E.	Union	70m (230 ft)	24.5
Four Corners	34	8 S.	41 E.	Baker	130m(427 ft)	42.7
Schaffer Ranch	7	16 S.	43 E.	Malheur	115m(377 ft)	33.4
Alkali Gulch	3	17 S.	45 E.	Malheur	180m(591 ft)	61.6
Wynn Dairy	7	21 S.	46 E.	Malheur	70m(230 ft)	108.2

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!!! CORRECTION !!!

GEOHERMAL INFORMATION TELEPHONE NUMBER

In the May issue of The ORE BIN (page 85), the telephone number given for Don Hull, geothermal specialist at the Baker Field Office, should be changed to 503 - 523-3133. Our apologies for inconvenience this may have caused you.

* * * * *

GEOHERMAL LEASE BIDS ANNOUNCED ON ALVORD KGRA

Acceptable bonus bids totaling \$179,604.82 have been received on 14 of the 44 units designated for geothermal leasing in the Alvord Known Geothermal Resource Area (KGRA) in Harney County, Oregon. The bids cover 31,182 acres of the 92,000 acres offered for lease; one unit was withdrawn from bidding by BLM. Bids on six of the units were determined to be unacceptable by the U.S. Geological Survey and Bureau of Land Management. There were no bidders on 23 of the parcels. Successful bidders for the June 5, 1975 sale were as follows:

Al-Aquitaine Explorations	Unit 7	2,560 acres	\$7.17 per acre
Al-Aquitaine Explorations	Unit 8	2,400 acres	3.83
Al-Aquitaine Explorations	Unit 12	2,560 acres	6.51
Republic Geothermal	Unit 15	1,920 acres	2.07
Republic Geothermal	Unit 16	649 acres	5.38
Republic Geothermal	Unit 17	2,560 acres	2.07
Republic Geothermal	Unit 18	2,560 acres	10.56
Republic Geothermal	Unit 21	2,402 acres	2.13
Chevron Oil Co.	Unit 24	2,561 acres	17.90
Mapco, Inc.	Unit 30	2,397 acres	4.47
Mapco, Inc.	Unit 31	1,920 acres	2.17
Mapco, Inc.	Unit 32	2,016 acres	6.03
Getty Oil Co.	Unit 34	2,126 acres	5.25
Southern Union Production Co.	Unit 42	2,560 acres	2.53

Following a hearing in the U.S. District Court June 10, 1975, on a petition filed by environmental groups to halt geothermal leasing in the Alvord KGRA, the Court allowed the 14 leases to be awarded.

* * * * *

CITIZENS' FORUM ON ENERGY PUBLISHED

"Proceedings of the Citizens' Forum on Potential Future Energy Sources" has been published by the Oregon Department of Geology and Mineral Industries as Miscellaneous Paper 18. Six papers presented at the Forum, held at Portland State University January 17, 1974, are contained in the volume. Wind power, solar energy, geothermal power, oil-shale conversion, and coal-to-gas process are discussed by authorities in those fields. The 62-page publication, illustrated with many photographs and line drawings, is for sale by the Department at its Portland, Baker, and Grants Pass offices for \$2.00.

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NOTICE TO ORE BIN SUBSCRIBERS

Effective with the July, 1975 issue, The ORE BIN subscription rate will be \$3.00 yearly, or 3 years for \$8.00. Single copies sold over the counter will continue to be 25¢, but copies ordered by mail will cost 35¢ each. Current subscriptions will continue at the former rate until expiration.

GOLD AND SILVER BULLETIN PRICE GOES UP

"Gold and Silver in Oregon," Bulletin 61, formerly priced at \$5.00 is now selling for \$7.50. Increased costs of printing, mailing, storing, and handling are making it necessary for the Department to raise the price of all of its publications. New prices for other bulletins will be announced later.

* * * * *

JOSEPHINE COUNTY AGGREGATE STUDY PUBLISHED

"Aggregate Resources of Josephine County, Oregon," has been issued by Josephine County Planning Department in cooperation with the Oregon Department of Geology and Mineral Industries. Authors are H. G. Schlicker, R. A. Schmuck, and Pedro Pescador. Construction aggregates, in the form of sand, gravel, and crushed rock, are necessary commodities for continuing growth of the County. Resources are in alluvial deposits along floors of the larger valleys and in bedrock exposures at higher elevations.

The 47-page illustrated bulletin describes the deposits, lists 310 source sites, and gives the quantity and quality of the material. Twenty-six fold-out photo maps show distribution of the sand and gravel deposits and adjacent bedrock units.

Copies of the aggregate resource publication are available from Josephine County Planning Department, 200 N.W. D Street, Grants Pass, Oregon, 97526. The price is \$3.00 over the counter and \$3.50 mailed.

* * * * *

ICE BERGS MAY BE TOWED TO ARID LANDS

The Department of Interior reports in a news release that towing tabular icebergs from the Antarctic to some arid areas to provide a freshwater source is considered feasible and warrants further study.

* * * * *

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THE COW HOLLOW GEOTHERMAL ANOMALY, MALHEUR COUNTY, OREGON

R. G. Bowen* and D. D. Blackwell**

During the past four years, the Oregon Department of Geology and Mineral Industries has been conducting a regional study, sponsored by the U.S. Bureau of Mines with grant No. S0122129, on the geothermal potential of eastern Oregon. In the course of the study, an area of anomalously high heat flow was discovered a few miles southeast of Vale, Malheur County, in an area known locally as Cow Hollow (see Figure 1, p. 116-117). The anomaly, which covers an area at least 6 miles by 3 miles, gives heat-flow values ranging from slightly greater to more than three times greater than normal for this region.

In 1973, Bowen and Blackwell (Ore Bin, 1973) reported geothermal gradient and heat-flow values for the Cow Hollow area (at that time referred to as the Chalk Butte area). In 1974, when Federal lands in Oregon were opened for geothermal leasing and multiple filings were made in Cow Hollow, the area, which is entirely under Federal ownership, was established as a Known Geothermal Resource Area (KGRA). A sale of geothermal leases in Cow Hollow has been scheduled by the U.S. Bureau of Land Management for September 25, 1975.

Since publication of the early geothermal information on Cow Hollow, The Oregon Department of Geology and Mineral Industries has gathered additional geological and geophysical data for the area, has drilled 24 shallow (3 to 4 meter) temperature holes, and has published results (Hull, 1975) on a deeper drilling in the area. This summary of the geologic interpretations and geophysical data is published as a preliminary report in order to make the information available for those working to develop the geothermal resources of the area. A future report (Blackwell and Bowen, in prep.) will describe in more detail the heat flow and shallow temperature data together with the geological and geophysical information.

Although the authors accept responsibility for the geologic concepts outlined in this paper, they wish to acknowledge the help given them by Department staff, including V. C. Newton, R. E. Corcoran, Alan Preissler, Deborah Fisher, and Donald Hull.

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Previous Geologic and Geophysical Studies

A geologic map and report on the Mitchell Butte quadrangle, which includes the Cow Hollow area, was prepared by Corcoran and others (1962). A report by Newton and Corcoran (1963) on the western Snake River Basin details the subsurface conditions in the region. A geologic map by Kittleman and others (1967) covers the Owyhee Region south and west of the Cow Hollow area. A reconnaissance surface magnetic map of the area has been prepared by Brott and Blackwell (SMU, unpublished data), and gravity and magnetic maps have been prepared by K. H. Koenen, consulting geophysicist, Portland.

Geology

Stratigraphy

The Cow Hollow area (see Figure 1) lies in the northeastern part of the Mitchell Butte 30' quadrangle and southern parts of the Jamieson and Moores Hollow quadrangles. The area is underlain by a thick sequence of late Tertiary continental sedimentary and volcanic rocks. Quaternary alluvium and terrace gravels mask the Tertiary units in the valleys of the Snake River, Malheur River, and Willow Creek. The youngest Tertiary rocks belong to the Idaho Group of Pliocene age. Originally described as one unit by Cope (1883), the Idaho Group has been divided by Corcoran and others (1962) into three formations: two lacustrine units, the Chalk Butte and the Kern Basin Formations, separated by the Grassy Mountain Basalt.

The Chalk Butte Formation, the uppermost member of the Idaho Group, is composed of tuffaceous claystone and siltstone with lesser amounts of tuff, conglomerate, ash beds, and fresh-water limestone. Thickness of the formation, estimated from well data to the east and west, ranges from 2,500 to 3,500 feet. The Grassy Mountain Basalt, which underlies the Chalk Butte Formation, is reported by Corcoran and others (1962) to be 500 to 1,000 feet thick. Beneath the Grassy Mountain Basalt is the Kern Basin Formation composed of tuffaceous claystone, siltstone, sandstone, and, less commonly conglomerate. The Kern Basin Formation is not exposed in the area, but at its type locality, about 20 miles to the south, it is 750 feet thick.

Underlying the Kern Basin Formation, with apparent unconformity, is the Deer Butte Formation of late Miocene age. The Deer Butte is composed chiefly of lacustrine and fluvial tuffaceous siltstone and shale but also includes prominent beds of well-cemented conglomerate and sandstone. Measured sections of the Deer Butte Formation elsewhere in the Mitchell Butte quadrangle have a maximum thickness of 1,248 feet.

The Owyhee Basalt, which underlies the Deer Butte sediments, is a very widespread and prominent section consisting of basalt flows and

interbedded tuff. It is middle Miocene in age and can be traced southwestward to the Steens Basalt and northwestward to the Columbia River Basalt.

Under the Owyhee Basalt is the Sucker Creek Formation, named by Corcoran and others, 1962. It crops out extensively in the southern part of the Mitchell Butte quadrangle, where it consists mostly of tuffaceous sediments with interbedded rhyolitic and felsitic volcanics in the upper part and basalt flows in the lower part.

Intrusions and associated flows of Tertiary-Quaternary age occupy small areas in the southwestern part of the map area.

Structural geology

Regionally, the structural position of the area is on the west limb of the western Snake River Basin, which is a part of the Snake River downwarp, a large structural trough extending from Yellowstone Park across southern Idaho and into eastern Oregon. The Idaho part of the western Snake River Basin appears to be a large graben, as high-angle faults parallel the general trend of the basin along its northeastern and southwestern edges (Hill, 1963). The bounding faults mapped in Idaho have not been identified in Oregon, however. Corcoran and others (1962) show no faults or structures except the regional northeasterly dip in the Cow Hollow area.

From the data gathered as a part of this study, the authors interpret a major northwest-trending fault zone transecting the Cow Hollow area and believe the geothermal manifestation and high heat-flow anomaly reflect leakage along this fault. The magnetic and gravity mapping appear to corroborate this thesis. The authors have named this the Willow Creek fault after the Willow Creek valley northwest of Vale. Evidence for the Willow Creek fault is mainly from physiographic expression and geophysical measurements. Displacement of lithologic units has not been found and amount of throw has not been determined. The strongest physiographic expression of the fault is the lineament formed by Willow Creek valley extending for 30 miles in a nearly straight line to the northwest of Vale. Southeast of Vale the trend continues but is less conspicuous. The presence of Vale Hot Spring on the fault, several reported warm-water wells in the Willow Creek area, and the high heat flow to the southeast along the zone are additional evidence for the fault.

Lawrence (in press) describes a series of right lateral tear fault zones, one of which he calls the Vale Zone. This zone, consisting of several linear segments, includes Willow Creek and portions of the Snake River in Idaho. The Vale Zone includes what we have called the Willow Creek fault in this paper.

A parallel fault zone, named the Bully Creek fault, lies about 6 miles to the west. Physiographic evidence is similar to the Willow Creek fault but the trends are not as prominent. To the north, Owyhee Basalt has been uplifted on the west side of the Bully Creek fault trend, indicating that the

area between the Willow Creek and Bully Creek faults is a graben. Electric logs from the Sta-Tex "Russell well" east of the Bully Creek fault and from the El Paso "Federal well" west of the fault indicate the western block is uplifted, corroborating the interpretation of a graben between the two faults.

A third fault, approximately perpendicular to the Willow Creek fault, here called the Malheur River fault, is believed to parallel the course of the Malheur River northeast of Vale. Its existence is interpreted largely from geophysical mapping by Koenen, but there is also a strong physiographic expression of a fault at this location. Vale Hot Spring appears to be located on the intersection of the Willow Creek and the Malheur River faults. Rinehart Butte and Vale Butte, situated just east of Vale, are believed by the authors to represent silicified remnants of hot springs that have maintained their topographic expression through resistance to erosion. Corcoran and others (1962) believe the two buttes represent topographic highs in the pre-Idaho terrain and that sediments of the Idaho Group were deposited around these ancient highs.

Geophysical evidence for the Willow Creek fault comes from a ground magnetic profile made in 1973 (Brott and Blackwell, SMU, unpublished data). This information shows a magnetic high along the eastern side of the fault zone to the southeast of Vale. Gravity and magnetic data of the Vale KGRA by Koenen are included on Figure 1. These patterns show strong northwest trends with gravity and magnetic highs on the east side of the zone, consistent with the northwest fault trends as proposed here for the Bully Creek and Willow Creek fault zones. The accompanying cross section (Figure 2) shows this relationship. Koenen (oral communication, 1975) believes the gravity and magnetic maps indicate a series of intrusives along a northwest-trending fault zone.

Geothermal Systems

Heat-flow information

Measuring variations in the rate of heat escaping from within the earth and flowing toward the surface is one of the best methods of prospecting for geothermal resources, and it was the method used for this study. Other geophysical methods, such as electrical and seismic, provide indirect evidence of conditions related to geothermal energy accumulation and help to support the heat-flow data. Detailed information on the mechanics of heat-flow acquisition and reduction is given by Roy and others (1968).

High heat flow always indicates the presence of a geothermal accumulation, but temperature, depth, or size of the accumulation must be obtained by other exploration tools. A high-level anomaly may prove to be only warm geothermal waters at a relatively shallow depth, whereas a lower-level anomaly may represent fluids of very high temperature at greater depths. Although other geophysical and geochemical methods in conjunction with geologic investigations can be used for depth estimates along with

the heat-flow data, it is necessary to sample formation fluids by drilling in order to determine reservoir characteristics.

Basically, heat flow is the product of the geothermal gradient (rate of increase of temperature with depth) and the conductivity of the rocks (rate of passage of heat through the rocks). Units used in heat-flow measurements are microcalories per cm^2 per second and are commonly referred to as HFU's (Heat Flow Units). Worldwide average heat flow of continental areas is about 1.4 HFU. In areas of Tertiary volcanic rocks, such as eastern Oregon and Idaho, average heat flow is closer to 2 HFU (Blackwell, 1969).

The map, Figure 1, shows some of the heat-flow values in the western Snake River Basin gathered as a part of this study as well as data previously published (Bowen, 1972; Bowen and Blackwell, in Ore Bin, 1973), including five recently drilled holes (Hull, 1975), with additional unpublished geothermal data. The Cow Hollow anomaly is represented by the concentration of data along the Willow Creek fault where gradients range from 76° to $214^\circ\text{C}/\text{km}$ and heat-flow values from 2.3 to 6.4 HFU. All of the bore holes, which range in depth from 65 to 395 meters, are in the Chalk Butte Formation. One of the new drill holes, about 1 mile east of the highest heat-flow value, has a heat flow of only 2.3 HFU. Thus the geothermal anomaly appears to be elongated in a northwest direction and is asymmetric, with the sharpest drop in heat flow to the east. The anomaly also appears to be related to leakage along the Willow Creek fault, and suggests that the fault dips to the west, consistent with a down-to-the-west normal fault.

The heat-flow values on the remainder of the map range from 1.9 to 4.6 but the data are too sparse for any conclusions about the presence or absence of other anomalies. The average gradient for 20 wells in the western Snake River Basin, excluding the ones in the geothermal anomaly, is $81^\circ\text{C}/\text{km}$ ($4.4^\circ\text{F}/100\text{ ft.}$) with a range of 44° to $112^\circ\text{C}/\text{km}$. Table 1 lists all geothermal data used as a part of this paper.

Geothermal possibilities

For a geothermal deposit to be economically viable, three reservoir conditions must exist. 1) There must be sufficient heat, since the amount of heat in the fluids determines the use and the value of the deposit. For example, temperatures of 200°C (392°F) or greater are suitable for electric power production; temperatures of 150°C (302°F) to 250°C have potential value for heating and process uses; and temperatures below 150°C can be applied to space heating or lower-grade process uses. 2) There must be a sufficient volume of geothermal fluid in the reservoir to produce the necessary quantities of heat energy for 30 to 50 years. Either this volume of fluid must be present in storage or suitable hydrologic conditions must exist to allow recharge. To meet such requirements, reservoir rocks must be sufficiently porous to hold fluids and sufficiently permeable to allow the fluids to migrate from the reservoir rocks to the bore holes. 3) The system must

Table 1. Geothermal data used for Cow Hollow-western Snake River Basin study

Location	Hole No.	N. Lat.	W. Long.	Elev. meters	Depth interval meters	Gradient °C/km	Topo Cor.* Grad. °C/km	K 10 ⁻³ cal/cm sec. °C	Cor.* Q 10 ⁻⁶ cal/cm ² sec.		Qual.**	Lithology
Willow Creek	17-44S11	44°06'	117°17'	719	-370	94.4		2.8	2.6		B	Siltstone
	17-44S31	43°59'	117°20'	829	15-70	85.7		2.8	2.4		B	Siltstone
South Fork Jacobsen Gulch	VN-75-2	44°07'	117°14'	721	30-60	110		3.0***	3.3		B	Basalt
	VN-75-3	44°07'	117°10'	814	50-150	76		2.54	1.9		A	Siltstone
	VN-75-4	44°05'	117°06'	762	30-150	120		2.53	3.0		A	Siltstone
	VN-75-5	44°06'	117°02'	732	60-150	76		2.53	1.9		A	Siltstone
Bully Creek	18-44S21	43°59'	117°20'	760	25-85	66.8		2.8	1.9		B	
Sand Hollow	19-44S19			777	31-395	87.3****		3.0***	2.6		B	
Cow Hollow	19-45S11	43°55'	117°10'	835	30-65	185.7	176.1	3.0	5.6	5.3	A	Siltstone
	19-45S14	43°54'	117°10'	910	20-145	175.2	158.3	3.0	5.3	4.7	A	Siltstone
	19-45S22	43°53'	117°11'	843	30-115	110.4		3.05		2.9	A	Siltstone
	19-45S25	43°53'	117°09'	813	30-70	232.6	213.6	3.0	6.9	6.4	A	Siltstone
	19-45S26	43°52'	117°10'	822	30-175	119.3	114.0	3.0	3.6	3.4	A	Siltstone
	19-45S28	43°53'	117°13'	872	10-90	70.8	76.5	3.0	2.1	2.3	A	Siltstone
	20-45S6	43°51'	117°15'	823	20-135	73.6	69.8	3.0	2.2	2.1	A	Siltstone
	20-45S10	43°50'	117°12'	780	30-135	114.8	104.0	3.0	3.4	3.1	A	Siltstone
	20-45S18	43°50'	117°16'	849	10-40	71.9	63.2	3.0	2.1	1.9	B	Siltstone
	VN-75-1	43°54'	117°08'	879	25-150	91.4		2.53	2.3		A	Siltstone

*Topographic correction

** Quality: A = ± 10%; B = ± 25%

*** Estimated K

****Van Ostrand, 1938

be confined in some way by a relatively impermeable barrier to the migration of the fluids so that a trap is formed, thereby allowing the fluids to accumulate.

High heat flow, defined by bore-hole data, signifies a concentration of heat at depth in the Cow Hollow area. In addition, temperatures of hot springs surrounding Cow Hollow indicate a regional accumulation of heat at depth. Thermal springs at Vale to the north have a temperature of 98°C (208°F), and several springs along the Owyhee River to the south have temperatures up to 77°C (171°F). The chemical constituents in the thermal springs at Mitchell Butte have been analyzed by Mariner and others (1974), who estimate minimal reservoir temperatures of 72°C (162°F).

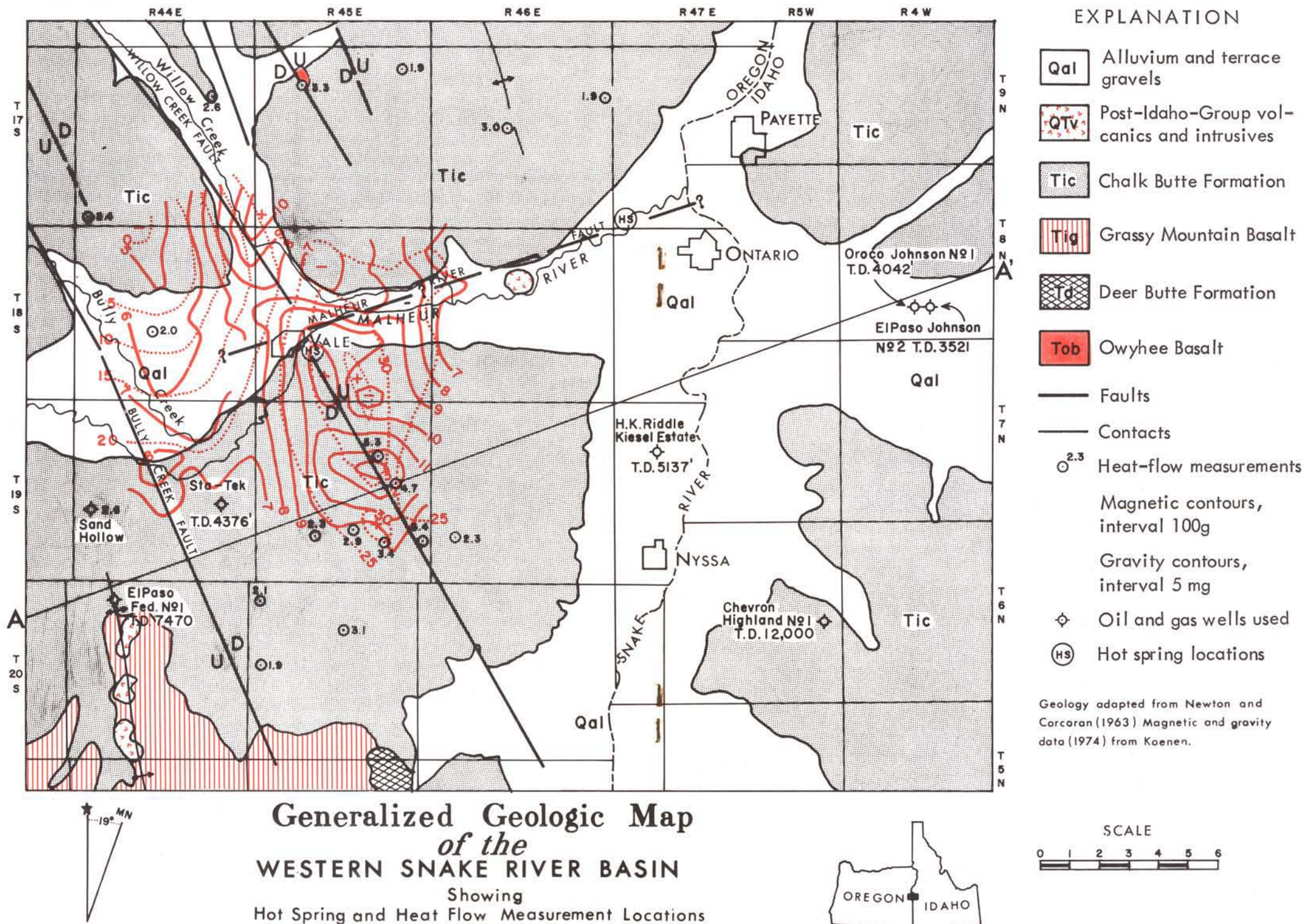
The authors believe the subsurface geologic conditions in the Cow Hollow area are favorable for the presence of a reservoir and trap. Using data from deep oil and gas exploration wells drilled in the western Snake River Basin (Newton and Corcoran, 1963), a cross section has been constructed for the Cow Hollow area to show the geologic sequence and the potential reservoirs (Figure 2). The two basalt flows of this area, the Grassy Mountain Basalt and the Owyhee Basalt, should make excellent geothermal reservoirs as they have sufficient inter-flow permeability to allow the storage and movement of major quantities of fluids. The few thin sands in the sedimentary units (Newton and Corcoran, 1963) may form minor reservoirs.

Another potential reservoir is the silicic rocks of the Sucker Creek Formation. These rocks, called the Idavada Volcanics farther to the east along the southern margin of the Snake River Basin, are a major warm artesian aquifer sequence (Ralston and Chapman, 1968).

Because of its great extent and thickness, making more water available for storage and recharge, the Owyhee Basalt is probably the best potential reservoir. This thick, multiple-flow sequence of fine-grained to porphyritic basalt has been down-warped and buried to depths of several thousand feet in the Snake River Basin and has undoubtedly been subjected to a great deal of heating through the period of late Tertiary and early Quaternary volcanic activity. This heat energy would be transferred to the accumulated ground water in storage in the basalt. Because of the greater mobility and lower density of hot water and steam, the geothermal fluids would tend to migrate updip to the nearest barrier, where they would accumulate. The steam, if present, would tend to concentrate in the upper part of the permeable zones and the hot water in the lower, similar to the layering of steam and water in a man-made boiler or to the layering of oil and gas in a petroleum reservoir.

In the region of this study, the most common type of barrier would be a fault zone where the impermeable tuffaceous sediments are faulted against the truncated edges of the basalt flows. Another type of trap might occur where lava flows and tuffaceous sediments interfinger. In the Cow Hollow area, a trap may have been formed where the west side of the Willow Creek fault has moved down, bringing the Idaho Group sediments into juxtaposition

FIGURE 1



against the truncated edge of the Grassy Mountain and Owyhee Basalts (Figure 2).

Estimate of depths and temperatures

Information on the depths and thicknesses of the shallower rock units in the western Snake River Basin were compiled by Newton and Corcoran (1963). Until recently, there has been little information on the deeper subsurface stratigraphy, but in 1973 a deep oil and gas test well was drilled by Standard Oil Company of California, "Highland," about 14 miles east of Cow Hollow, near Parma, Idaho. This well, drilled to a total depth of nearly 12,000 feet, passed through the Owyhee Basalt and into underlying siliceous volcanics, lacustrine sediments, and interbedded basalts, a sequence that may correlate with the Sucker Creek Formation in the Mitchell Butte quadrangle. It is reported that the Standard "Highland" well encountered high temperatures in the Owyhee Basalt and underlying rocks. In this well, the top of the Grassy Mountain Basalt was at a depth of 3,800 feet (-1,153 msl) and the Owyhee Basalt at 6,720 feet (-4,073 msl). Newton and Corcoran (1963, Plate 3) show a depth to basalt of 3,820 feet (-1,643 msl) in the Oroco Oil and Gas Kiesel No. 1 well, which is about 8 miles east of Cow Hollow and is believed to be in a deeper part of the Basin.

From the general structural pattern for the area as outlined by Corcoran and others (1962), the authors infer that the Chalk Butte Formation is about 1,500 feet thinner in the Cow Hollow area than in the Oroco-Kiesel well to the east. If this is true, then the Grassy Mountain Basalt is at a depth of about 2,500 feet (+100 to -200 msl), and the Owyhee Basalt is at about 5,500 to 6,000 feet (-2,800 to -3,300 msl). These relationships are shown schematically in Figure 2.

Under some conditions it appears to be possible to predict subsurface temperatures using the near-surface gradients. In the western Snake River Basin, the average geothermal gradient is 81°C/km (4.4°F/100 ft.) with most of the observed gradients between 65° and 100°C/km. The lithologies, and therefore also thermal conductivities, in which the measurements were made are relatively uniform so that gradients are directly comparable. Assuming that heat flow is by conduction and remains constant with depth, the temperature in the various stratigraphic units can be predicted if the depth is known. If the depth to the Grassy Mountain Basalt is in the range of 1 to 1.5 km (3,300 to 4,500 ft.), the temperature would be on the order of 120°C ± 30° (248°F ± 50°). If the top of the Owyhee Basalt is on the order of 2 km (6,600 feet), the temperatures would be on the order of 170°C ± 40°. The lower units of the Owyhee Basalt and the underlying silicic rocks could have temperatures correspondingly higher. It is emphasized that these are minimum temperatures based on the projected temperature gradients corresponding to a heat-flow value near the regional average. Since temperatures almost certainly exceeding 200°C occur at depth in porous and

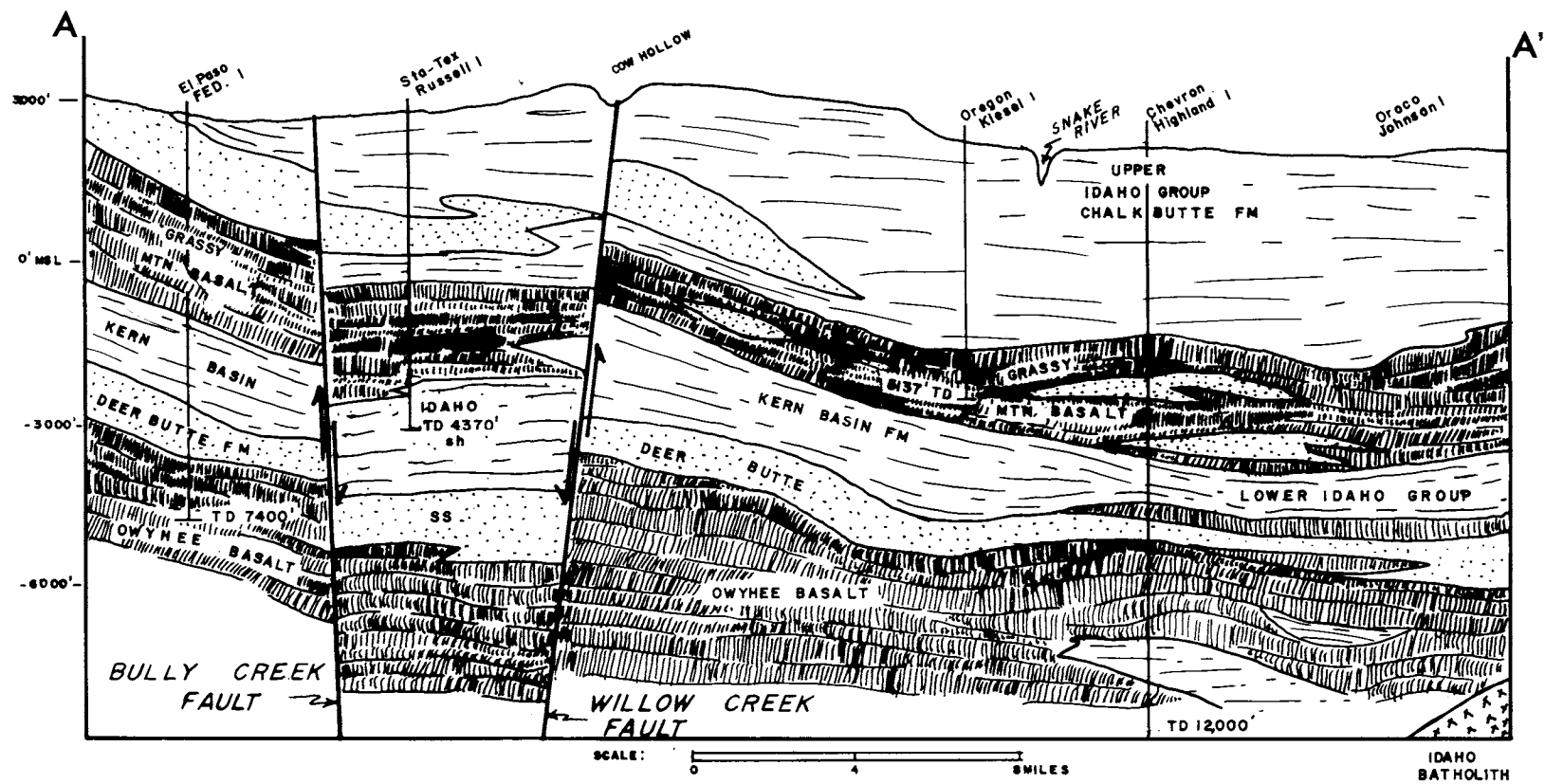


Figure 2. Cross section A-A' (see Figure 1 for location) prepared from oil and gas test-well data.

permeable rocks, fluids with temperatures high enough for commercial power production may leak upwards and occur at much shallower depths as well as regionally at greater depths.

Apparently in the Cow Hollow area such upward leakage is occurring along the Willow Creek fault. The geothermal potential of the anomaly depends on the temperature of the fluids moving along the fault. On the basis of the available data we cannot say how deep the gradients along the fault zone can be extrapolated. If more detailed heat-flow data were available, the anomaly could be compared to type curves for circulation along fault zones (Blackwell, 1974), and the depth of water circulation along the fault, the dip of the fault, and the temperature along the fault might be determined or limits on the parameters estimated. With the data that are available, it appears that the depth of circulation must be 2 km or more (based on the breadth of the anomaly), and the dip of the fault must be 60° or more to the southwest (based on the asymmetry of the anomaly). If circulation along the fault takes place to depths in excess of 2 km, then it must tap fluid at +150°C. Therefore we speculate that the temperatures along the fault at relatively shallow depth (500 to 1,500 m) are on the order of 150°C or more. Of course, the fluid moving upward along the fault zone may be cooling off as it rises so that temperatures at shallow depth may be less than at greater depths. If this condition exists, production testing of the wells in the fault zone should show an increase in temperature as the hotter fluids from the deeper portions of the reservoir displace the cooler ones.

Conclusions

Our studies and those of our colleagues in Idaho indicate that the western Snake River Basin is a major geothermal province, similar in some ways to the Imperial Valley Geothermal Province. Deep drilling should encounter high temperature fluids in permeable rocks below 2 km and at shallower depths where permeability has developed, as along faults and fracture zones. The Cow Hollow area seems to have the necessary conditions for a high-temperature geothermal reservoir: high heat flow, permeable rocks at depth, and a barrier to migration or trap.

Prior to drilling a deep exploratory well, more geologic and geophysical work and more detailed structural geologic studies should be done, more heat-flow holes should be drilled, and additional gravity and magnetic surveys should be done. In addition, some geochemical electrical resistivity, and seismic studies should be made to further define the anomaly. After these more definitive investigations are made, the only sure method of determining if geothermal fluids exist in commercial quantities is to drill enough wells to define the base temperature and production capabilities of the reservoir.

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REICHHOLD ENERGY CORPORATION TO DRILL FOR GAS

The Department issued State Permit No. 65 to Reichhold Energy Corporation, Tacoma, Washington, on June 26, 1975 for the drilling of a 5,000-foot exploratory hole in Tillamook County. The test hole is to be drilled in the NE $\frac{1}{4}$, NE $\frac{1}{4}$ sec. 22, T. 2 S., R. 10 W., Tillamook County. Reichhold officials announced intent to drill several wildcat holes in western Oregon this year. The API number for the test well is 36-057-00004.

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GEOHERMAL DRILLING LAW REVISED

Oregon Legislature passed House Bill 2040 in May 1975; Governor Straub signed it into law June 30, 1975. The new statute is summarized as follows:

- "Geothermal resources" are defined as natural heat of the earth, energy, in whatever form, below the surface of the earth.
- "Prospect wells" are defined as geophysical test wells, seismic shot holes, mineral exploration drilling, core drillings, or temperature gradient drillings which are less than 500 feet in depth.
- "Geothermal wells" are defined as any excavation greater than 500 feet in depth made for discovery or production of geothermal resources. Wells producing fluids less than 250°F bottom-hole temperature and less than 2,000 feet in depth are excluded.

Bonds for geothermal wells were set at \$10,000 per well and a blanket bond of \$5,000 is required for prospect well applications. Bonding of prospect wells was not required in the original law.

House Bill 2040 places authority for geothermal drilling solely with the State of Oregon Department of Geology and Mineral Industries. Conflicts of jurisdiction between state agencies appear to be removed by House Bill 2040. The revised law should encourage an increase in geothermal exploration in Oregon.

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GEOHERMAL TEST WELL IN UTAH SHOWS PROMISE

The first successful geothermal test well in Utah has been announced by the U.S. Geological Survey. The test is located in the Roosevelt Hot Springs KGRA on a tract leased by Phillips Petroleum Co. The test well, completed to a depth of 2,728 feet, showed in excess of 200,000 pounds per hour mass flow rate at a temperature of over 400°.

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GEOTHERMAL DRILLING IN OREGON

Deep Test Holes:

<u>Organization</u>	<u>Date</u>	<u>County</u>	<u>Status</u>
Gulf Oil Co.-U.S.	Sept. 7, 1973	Lake	Abandoned hole at a depth of 5,440'
Magma Energy, Inc.	July 25, 1974	Union	Abandoned hole at a depth of 2,730'

Thermal Gradient Holes:

<u>Organization</u>	<u>Date</u>	<u>County</u>	<u>Status</u>
Thermal Power Co.	Feb. 1975	Klamath	Completed
Dept. Geol. & Min. Indus.	July 1972	Malheur	Completed
Union Oil Co.	Dec. 1974	Malheur	Completed
Gulf Research	July 1974	Lake	Active
U.S. Geological Survey	Aug. 1974	Klamath	Completed
Geothermal Surveys, Inc.	Feb. 1975	Malheur	Active
AMAX Exploration	March 1975	Union	Active
AMAX Exploration	March 1975	Malheur	Active
AMAX Exploration	March 1975	Lake	Active
AMAX Exploration	March 1975	Harney	Active
Phillips Petroleum	April 1975	Malheur	Completed
Dept. Geol. & Min. Indus.	April 1975	Malheur	Active

* * * * *

METAL MINES HANDBOOKS REPRINTED

The Department's Bulletin 14, Oregon Metal Mines Handbooks, have been reprinted by an out-of-state firm after having been out of print for a considerable number of years. The six publications, each covering a section of the state, list all mines in that area known at the time of the original printing, together with information on general geology.

Information on the reprinted handbooks is available from George Srein, American Trading Co., P. O. Box 1312, Bellevue, WA 98009. The six sections, originally published in 1939 to 1951, are:

- A. Baker, Union, and Wallowa Counties
- B. Grant, Morrow, and Umatilla Counties
- C-I. Coos, Curry, and Douglas Counties
- C-II, sec. 1. Josephine County
- C-II, sec. 2. Jackson County
- D. Northwestern Oregon

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DEPARTMENT PUBLICATIONS GO UP IN PRICE

On July 1, 1975, prices of the more recent Department publications were raised to help meet greatly increased printing costs. The ORE BIN is now \$3.00 per year, or 3 years for \$8.00. Current subscriptions will continue at the former rate until expiration. For new prices of Bulletins, Geologic Maps, Short Papers, Miscellaneous Papers, Oil and Gas Investigations Series, and other items, see back cover of this and subsequent issues of The ORE BIN, or write to the Department for the latest listing.

* * * * *

NEW BOARD MEMBER APPOINTED BY GOVERNOR STRAUB

Leeanne G. MacColl (Mrs. E. Kimbark M.) was appointed to the Governing Board of the Oregon Department of Geology and Mineral Industries by Governor Straub on June 28, 1975. She fills the position formerly held by William E. Miller, whose term of office has expired.

Mrs. MacColl is a graduate of Occidental College, Los Angeles, with a major in music and an interest in geology. Since her graduation in 1952 she has been a resident of Portland, where she has been active in a variety of civic affairs. She has been a board member of the Junior Symphony and the Chamber Music Northwest, and is the new president of Friends of Chamber Music. As a member of the League of Women Voters, she has been on the board of the Portland League for 3 years and has served as chairman for committees concerned with environmental problems, transportation, and energy.

Interest in geothermal development began with her visit to the Lardarello fields in Italy in 1972. In 1974 she attended the Geothermal Conference at Klamath Falls and since that time has been encouraging this type of energy development in Oregon.

* * * * *

GRANT COUNTY GEOLOGY TOUR IN AUGUST

On August 14 and 15, Dr. Tom Thayer, geologist with the U.S. Geological Survey and authority on the geology of Grant County, will lead field trips to see the geology of the area. Those who plan to attend must pre-register prior to August 7 so transportation arrangements can be made. Bus fare will be \$7.75 per person per day and lunches \$1.50. Send name, address, phone number, and fee for bus and lunches to Grant County Extension Office, Box 67, Canyon City, Oregon 97820.

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AVAILABLE PUBLICATIONS

(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

26. Soil: Its origin, destruction, preservation, 1944: Twenhofel	\$0.45
33. Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35. Geology of Dallas and Valseet quadrangles, Oregon, rev. 1964: Baldwin	3.00
36. Papers on Tertiary foraminifera: Cushman, Stewart & Stewart. vol. 1-\$1.00; vol. 2-1.25	
39. Geology and mineralization of Morning mine region, 1948: Allen and Thayer	1.00
44. Bibliography (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere.	1.00
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00
52. Chromite in southwestern Oregon, 1961: Ramp	5.00
53. Bibliography (3rd suppl.) geology and mineral resources of Oregon, 1962: Steere, Owen	3.00
57. Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
60. Engineering geology of Tualatin Valley region, 1967: Schlicker and Deacon	7.50
61. Gold and silver in Oregon, 1968: Brooks and Ramp	7.50
62. Andesite Conference Guidebook, 1968: Dole	3.50
64. Geology, mineral, and water resources of Oregon, 1969	3.00
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66. Geology and mineral resources of Klamath and Lake Counties, 1970.	6.50
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71. Geology of selected lava tubes in the Bend area, 1971: Greeley	2.50
72. Geology of Mitchell quadrangle, Wheeler County, 1972: Oles and Enlows	3.00
73. Geologic formations of eastern Oregon, 1972: Beaulieu	2.00
75. Geology, mineral resources of Douglas County, 1972: Ramp	3.00
76. Eighteenth biennial report of the Department, 1970-1972.	1.00
77. Geologic field trips in northern Oregon and southern Washington, 1973.	5.00
78. Bibliography (5th suppl.) geology and mineral industries, 1973: Roberts and others	3.00
79. Environmental geology inland Tillamook Clatsop Counties, 1973: Beaulieu.	7.00
80. Geology and mineral resources of Coos County, 1973: Baldwin and others	6.00
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00
82. Geol. Hazards of Bull Run Watershed, Mult. Clackamas Counties, 1974: Beaulieu	6.50
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00
84. Environmental geology of western Linn Co., 1974: Beaulieu and others.	12.00
85. Environmental geology of coastal Lane Co., 1974: Schlicker and others	12.00
86. Nineteenth biennial report of the Department, 1972-1974	1.00
87. Environmental geology of western Coos and Douglas Counties, Oregon, 1975	in press
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	in press

GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck	\$2.00; mailed - 2.50
Geologic map of Oregon (12" x 9"), 1969: Walker and King	0.25
Geologic map of Albany quadrangle, Oregon, 1953: Allison (from Bulletin 37)	1.00
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Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts	1.50
Geologic map of Bend quadrangle, and portion of High Cascade Mtns., 1957: Williams	1.50
GMS-1: Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka	2.00
GMS-2: Geologic map, Mitchell Butte quadrangle, Oregon: 1962	2.00
GMS-3: Preliminary geologic map, Durkee quadrangle, Oregon, 1967: Prostka	2.00
GMS-4: Gravity maps, Oregon onshore & offshore; [set only]: at counter \$3.00, mailed	3.50
GMS-5: Geology of the Powers quadrangle, 1971: Baldwin and Hess	2.00
GMS-6: Preliminary report, geology of part of Snake River Canyon, 1974: Vallier.	6.50

[Continued on back cover]

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- 19. Brick and tile industry in Oregon, 1949: Allen and Mason 0.20
- 21. Lightweight aggregate industry in Oregon, 1951: Mason 0.25
- 24. The Almeda mine, Josephine County, Oregon, 1967: Libbey 3.00

MISCELLANEOUS PAPERS

- 1. Description of some Oregon rocks and minerals, 1950: Dole 1.00
- 2. Oregon mineral deposits map (22 x 34 inches) and key (reprinted 1973): 1.00
- 4. Rules and regulations for conservation of oil and natural gas (rev. 1962) 1.00
- 5. Oregon's gold placers (reprints), 1954 0.50
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- 3. Prelim. identifications of foraminifera, General Petroleum Long Bell No. 1 well . . . 2.00
- 4. Prelim. identifications of foraminifera, E. M. Warren Coos Co. 1-7 well: Rau 2.00

MISCELLANEOUS PUBLICATIONS

- Landforms of Oregon: a physiographic sketch (17" x 22"), 1941 0.25
- Mining claims (State laws governing quartz and placer claims) 0.50
- Oregon base map (22" x 30"). 0.50
- Geologic time chart for Oregon, 1961 free
- Postcard - geology of Oregon, in color 10¢ each; 3 - 25¢; 7 - 50¢; 15 - 1.00
- The ORE BIN - Annual subscription (\$8.00 for 3 yrs.) 3.00
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The Ore Bin



Vol. 37, No. 8
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GEOPHYSICAL MEASUREMENTS IN THE VALE, OREGON GEOTHERMAL RESOURCE AREA

Richard Couch*, William French*, Michael Gemperle*, and Ansel Johnson**

Introduction

During the period September 15 to September 22, 1974, personnel of the Geophysics Group at Oregon State University, the Earth Science Department at Portland State University, and the Department of Geology at the University of Oregon completed a series of geophysical measurements in the Vale, Oregon geothermal area. The field crews, composed of four co-principal investigators, eight staff, and ten students, obtained measurements at four seismic reflection stations, along two refraction lines, and at two microearthquake array stations. In addition, gravity measurements were obtained at 340 stations, seismic noise measurements at 42 stations, and four short magnetic traverses were made in the vicinity of the refraction lines. The expedition had the following four purposes: 1) To obtain basic data on the geologic structure of the Vale geothermal area; 2) To test the applicability of seismic techniques, singly and in combination, to geothermal exploration; 3) To obtain structural control for a subsequent gravity and aeromagnetic study of the area; and 4) To train students in geothermal exploration techniques. This paper outlines the geophysical measurements made during the September 1974 field program. Publication of partial results of the study is anticipated subsequent to completion of each different phase of the project.

The Geophysical Measurements

Figure 1 shows the location of four seismic reflection sites south and southwest of Vale, Oregon in the Cow Hollow and Sand Hollow areas. Charges of 2.5 to 100+ pounds of Tovex were detonated in 30-foot cased holes at the shot points SP1, SP2, SP3, and SP4. The seismic waves were detected by a 13,000-foot reflection array and recorded on magnetic tape by a 36-channel seismic reflection system. The 13,000-foot reflection array was centered about shot points 1, 2, 3, and 4. Shot size and array arrangement were designed to obtain reflections to a depth of 4 km. The planned penetration depth of 4 km was based on an estimate of the maximum depth of economic recovery of geothermal fluids (G. Bodvarsson, personal communication). The surficial geology in the survey area (Corcoran and others, 1962; Newton and Corcoran, 1963; Kittleman and others, 1965, 1967) suggests a thick sequence of volcanics which abut or overlie the sedimentary strata of the Snake River downwarp. It is difficult to estimate reflection penetration depths in volcanic areas; consequently, the actual depth reached is not yet known.

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**Dept. of Earth Sciences, Portland State University, Portland, Oregon

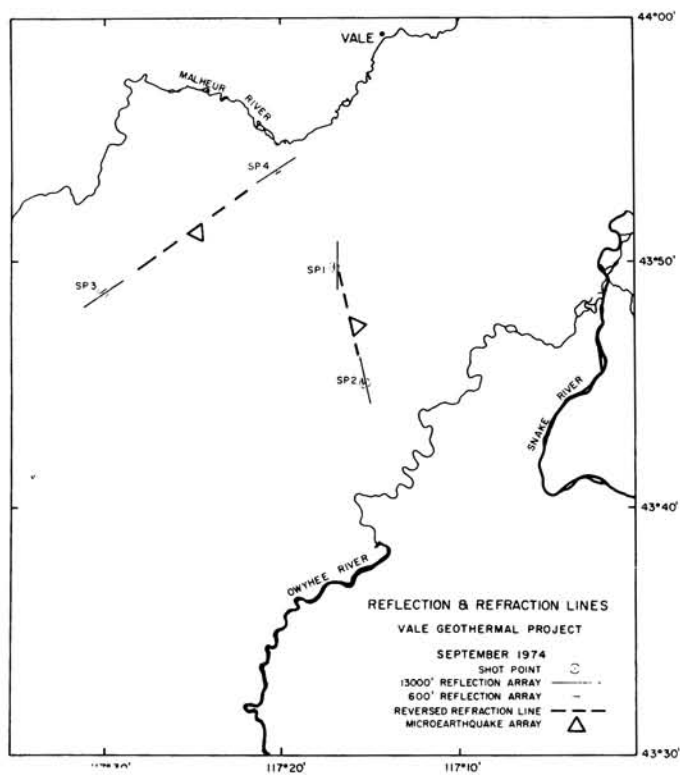


Figure 1. Map of the location of seismic reflection and microearthquake arrays and seismic refraction lines.

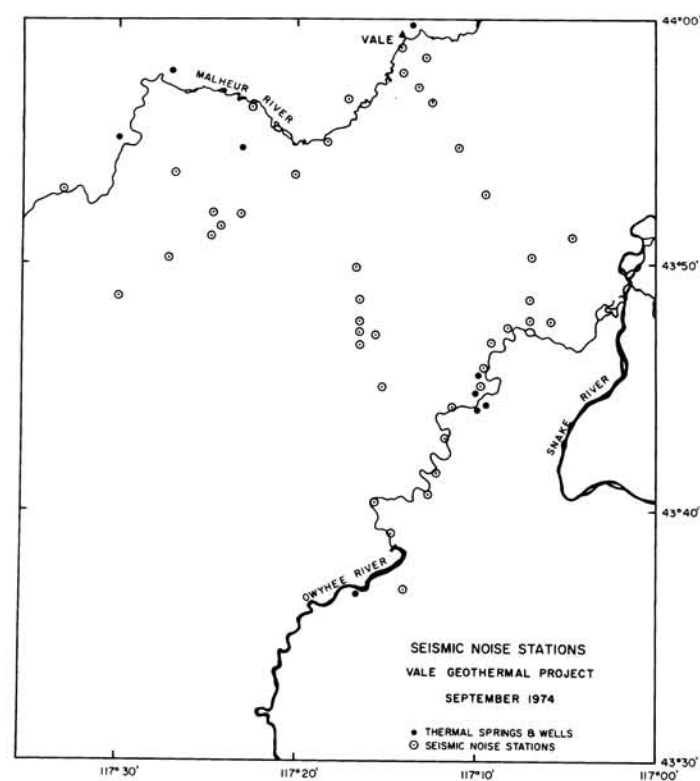


Figure 2. Map of the location of 42 seismic noise measurements made in the vicinity of Vale, Oregon.

Refraction stations extending 6 miles south of shot point 1 (or when reversed, 6 miles north of shot point 2) and 10 miles northeast of shot point 3 (or when reversed, 10 miles southwest of shot point 4) recorded refracted seismic waves from charges detonated during the reflection measurements. The arrivals were recorded on magnetic tape and on chart recorders at stations along the refraction lines shown in Figure 1. Arrivals were obtained over the complete length of line when the largest charges were detonated. The data should yield two reversed refraction lines. Thumper lines were completed at shot points 1, 2, and 3. These lines provide data on the near-surface layers and are the starting points for the refraction analysis.

Figure 1 also shows the location of two microearthquake arrays. The arrays consisted of 2 Hz geophones, 4 vertical and 1 horizontal, located at the apexes of a triangle with sides approximately 1.6 km long. Eighty hours of continuous measurements were made at two array locations, one in the Sand Hollow area and one in the Cow Hollow area. Rodents severing the sensor cables reduced the total number of hours below the number expected. However, because of the low background level of seismic noise in the area, operating gains were higher than anticipated; consequently, each array effectively surveyed a larger area or could detect smaller shocks than planned. Array arrangement and operating gains suggested that microearthquakes of magnitude 0.5 could be detected and approximately located to a radius of more than 30 km.

Tellurometer measurements located all primary reflection, refraction, and microearthquake stations.

Seismic noise measurements, made with a calibrated system to yield noise amplitude spectra in the frequency range 1 to 100 Hz, were completed at 42 locations in the Vale geothermal area. The station locations as shown in Figure 2 extend from near Vale Butte south to the Owyhee Reservoir and from Vale west to Harper. Fourteen stations are in the Cow Hollow and Sand Hollow areas in the immediate vicinity of the seismic refraction lines. Several of the stations are located next to thermal springs mapped (Bowen and Peterson, 1970) in the area. Thirty of the stations have short duration samples, ten have sample periods longer than a day, and several other stations were repeated to test for diurnal variations.

Magnetic surveys were run along the reflection spreads at shot points 1, 2, and 3 to obtain information on lateral variations and variations to depth of magnetic basement, presumably basalt, in the array areas. The sample interval varied from 100 feet to 350 feet, depending on the area. A 4-mile magnetic traverse was also run across Double Mountain to enable a comparison to be made of measured magnetic anomalies and the magnetic signature of a known intrusive outcrop.

Figure 3 shows the location of approximately 300 gravity stations established during the field study and approximately 55 previously established stations (Thiruvathukal and others, 1970). The stations were positioned at established bench marks or located during the surveying of the reflection-refraction stations. Elevations were determined by locating stations at known points or by using paired precision altimeters.

Project Status

Lillie, French, and Couch (1975), in their report on the preliminary results of the analysis of the seismic reflection measurements, list the interval velocities and thicknesses of approximately 9,000 feet of section in the Cow Hollow and Sand Hollow areas. Their results indicate that the seismic reflection information, obtained in volcanic terrane, is consistent with the available geological and well-log data.

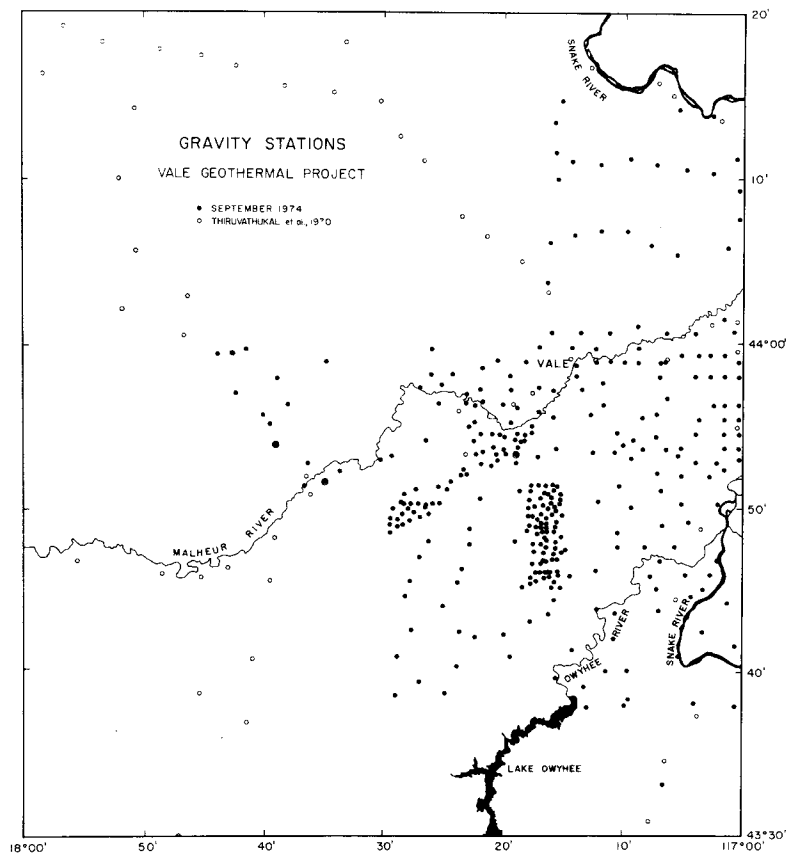


Figure 3. Map of gravity stations in the vicinity of Vale, Oregon.

The reduction and preliminary analysis of the seismic refraction, microearthquake and seismic noise measurements is expected to be completed by May 1976.

Larson and Couch (1975) show free-air and simple Bouguer gravity anomaly maps of the Vale region of Malheur County. The maps outline the gravity anomalies in the eastern portion of the study area (Figure 1) where the areal density of the gravity stations is relatively uniform. The measurement of gravity in Malheur County is continuing. Completion of new free-air and Bouguer maps of the study area are planned for May 1976.

Acknowledgments

We thank J. Gemperle and A. Stevens for technical support. Members of the field crew were R. Blakely, J. Bowers, B. Brown, G. Connard, J. Donovan, D. Eggers, T. Flaherty, P. Jones, K. Keeling, J. Keser, K. Larson, W. Lynn, R. McAlister, M. Moran, G. Ness, T. Plawman, L. Victor, and S. Woodcock. This work was conducted with the cooperation of the Oregon Department of Geology and Mineral Industries and the U.S. Bureau of Land Management.

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* * * * *

PRELIMINARY RESULTS OF A SEISMIC REFLECTION STUDY IN THE MITCHELL BUTTE QUADRANGLE, OREGON

Robert J. Lillie, William S. French, and Richard W. Couch
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Introduction

In September 1974 personnel of the Geophysics Group of Oregon State University, the Department of Earth Sciences of Portland State University, and the Department of Geology of the University of Oregon conducted a geophysical survey of the Vale, Oregon Known Geothermal Resource Area.

Seismic reflection measurements were made during the survey to test the ability of the seismic reflection techniques to provide information on subsurface structure in volcanic areas where geothermal resources commonly occur, to provide seismic velocity and structural constraints for contemporary and continuing gravity and magnetic studies of the area, and to develop new techniques of geophysical exploration for geothermal resources particularly applicable to very complex volcanic terrane. This brief report outlines the preliminary results of the analysis of the seismic reflection measurements made during the survey.

Figure 1 shows the location of four seismic reflection arrays deployed sequentially during the survey. The bars show the location and orientation of the 13,000-foot arrays and the small circles indicate the shot points (SP). A series of charges detonated in cased drill holes 30 feet deep at each shot point permitted testing of different filter and gain settings.

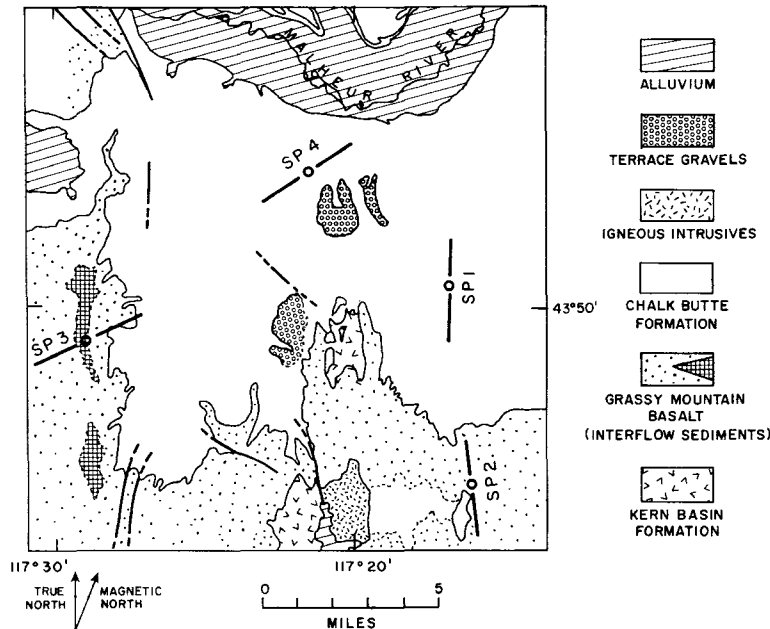


Figure 1. Generalized geologic map of study area near Vale, Oregon showing location of shot points (SP) and seismic array orientations. (Map after Corcoran and others, 1962)

Shallow Refraction Data

Seismic reflection techniques include methods of data reduction which identify both refraction and reflection events present on the records (e.g., Grant and West, 1965). The first arrivals at a sufficient distance from shot points represent critically refracted compressional waves or "head waves." Because instrument gains were high during the field measurements it was possible in most cases to pick refraction arrivals on the original records.

Figure 2 shows plots of time of first arrival versus distance from the shot point for the four seismic lines and the surface topography along the seismic reflection array. Time corrections for topography were not made in this preliminary analysis because data on seismic velocity and variations in thickness of the near-surface weathered zone were not available. The data points plotted in Figure 2, however, are very nearly linear. Analysis of the refraction data in Figure 2 gives the subsurface layer thicknesses and velocities listed in Table 1.

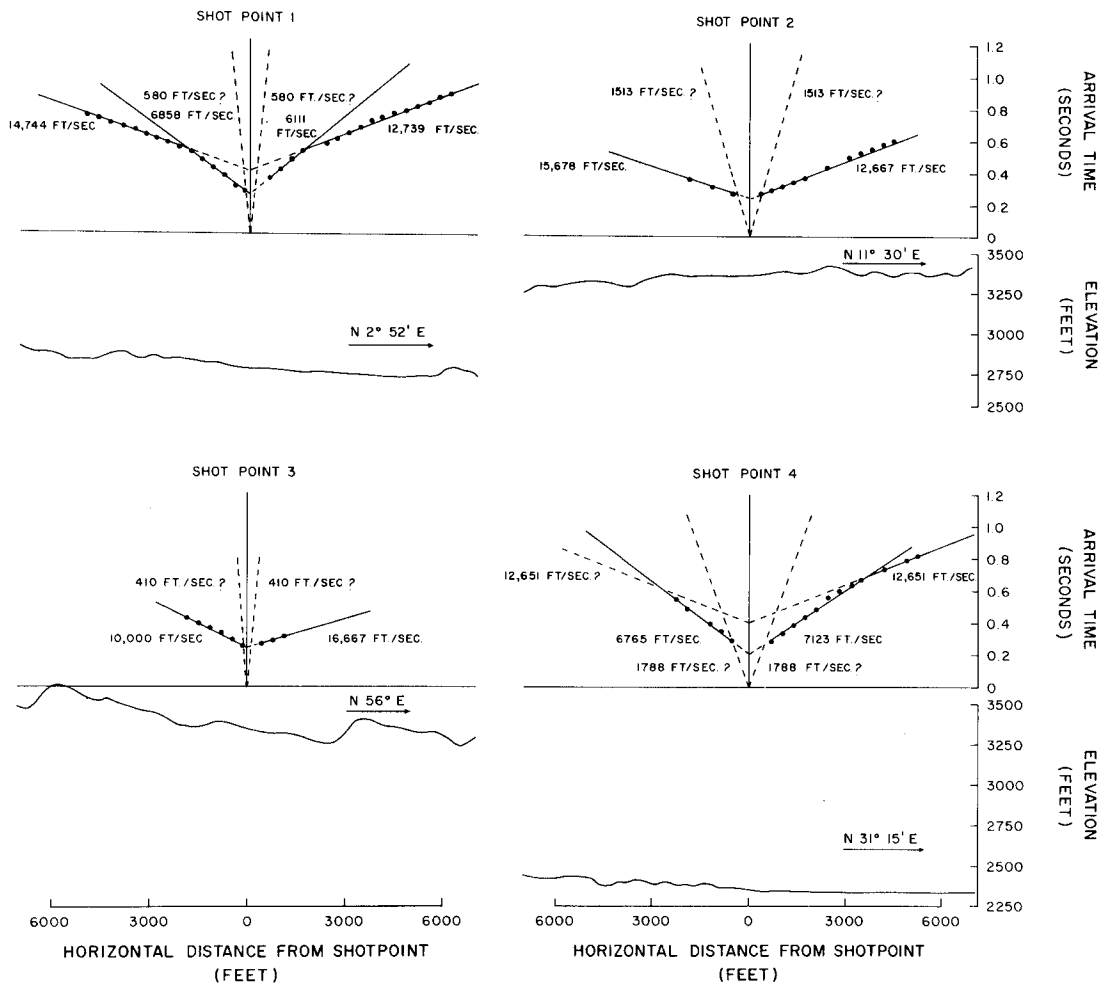


Figure 2. Topography and travel-time curves along seismic reflection lines 1, 2, 3 and 4. Points along the T-T curves represent first arrivals of refracted waves.

Table 1. Layer velocities and thickness from seismic refraction measurements

	Layer	Velocity ft/sec	Thickness ft
Line 1	1	580	70
	2	6,463	540
	3	13,664	-
Line 2	1	1,513	183
	2	14,011	-
Line 3	1	410	50
	2	12,500	-
Line 4	1	1,788	199
	2	6,939	767
	3	12,651	-

The first layer in each case is the thin zone of weathered material at the surface. On all records the first motion of the trace nearest the shot point results from a refraction at the interface immediately below this zone (Figure 2). Thus, the direct wave from the shot through the weathered zone was not recorded as a first arrival. It was necessary, therefore, to estimate the velocity of the weathered zone by extrapolating the travel-time curve from the value at the closest geophone to time zero. The reciprocal of the slope of this line provides an upper limit to the velocity of the weathered zone. Because calculated thicknesses are directly related to calculated velocities, the thicknesses shown for the first layer represent maximum estimates. On lines 2 and 4, for example, the calculated maximum thickness of the weathered zone is 200 feet but the actual thickness may be considerably less.

Velocities calculated for the weathered layer are extremely low. Lester (1932) and Domenico (1974) discuss low velocities observed in loose unconsolidated material above the water table. They verify by theory and actual observation that velocities less than that of sound waves in air (1,180 ft/sec) are possible in loose material containing air in a free state. The amount of air can be less than 1 percent of the total material and still produce the velocities calculated for the surface layer in this study. This is consistent with the near-surface soil conditions during the field study.

Below the weathered zone velocities expected for consolidated materials are observed. On lines 1 and 4, layer 2 has a velocity between 6,000 and 7,000 ft/sec. This is a typical velocity observed in lithified sediments. Below this and immediately below the weathered zone on lines 2 and 3, velocities from 12,000 to 14,000 ft/sec appear abruptly. It seems apparent that these higher velocities represent the basalt which crops out on lines 2 and 3 (see Figure 1).

On line 1, 70 feet of weathered material and 540 feet of sediment overlie the basalt. An analysis of measurements of the Earth's total magnetic field made along the reflection array indicate a surface source along lines 2 and 3 and suggest a depth to magnetic basement of 500 to 700 feet along line 1. The total 610 feet of sediment on line 1 calculated from the refraction data is in good agreement with the depth calculated from the magnetic data.

Though data quality is poor, reflection events are present and are indicated by dots on the records. The change in curvature from one hyperbola to a later one

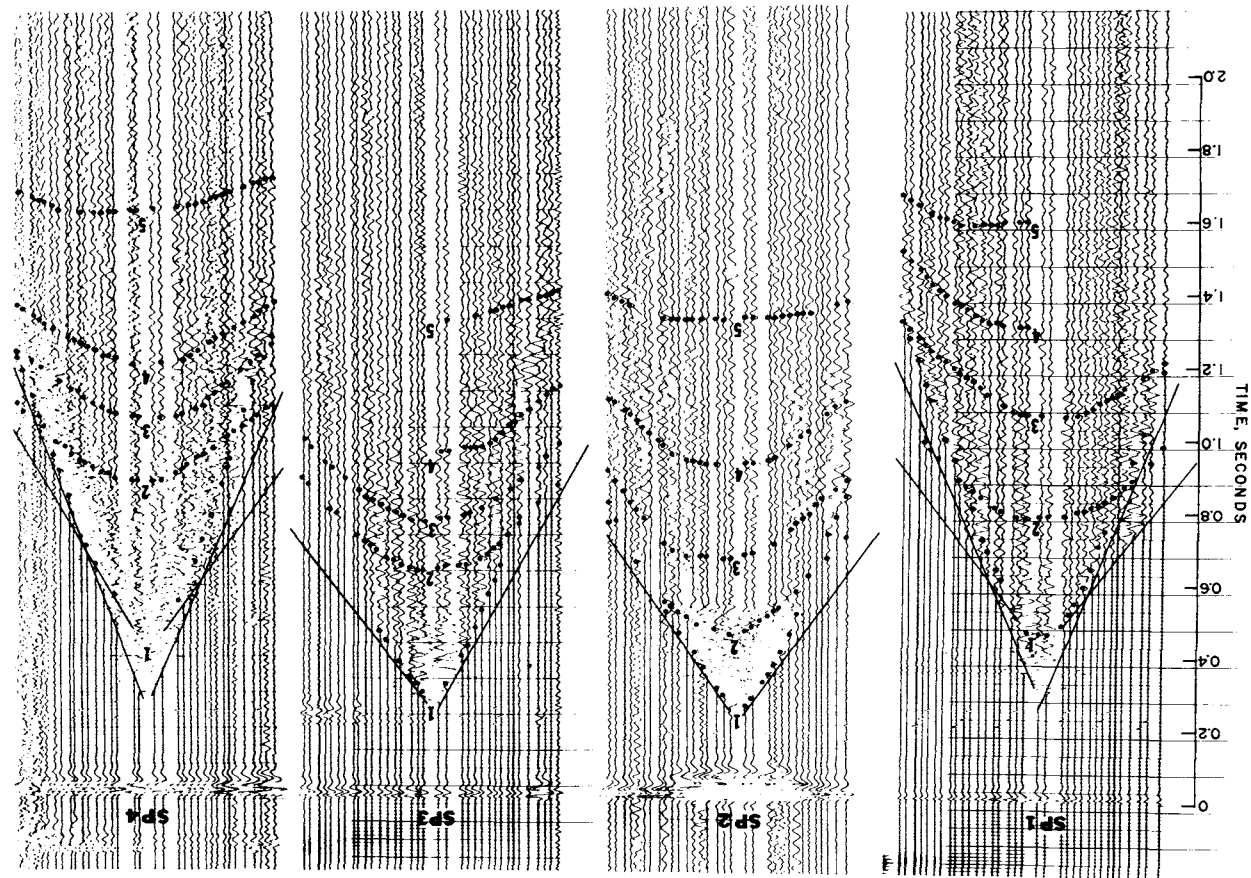


Figure 3. Filtered reflection records obtained at SP 1, 2, 3, and 4. Solid lines represent refracted arrivals and dots represent arrivals of reflected waves.

is a function of the average velocity and thickness of material between the corresponding reflecting interfaces. The interval velocities and thicknesses were estimated using the T^2-X^2 technique (see Grant and West, 1965, p. 141-148). In most instances, it was possible to trace hyperbolas across both sides of the records. Interval velocities and thicknesses were calculated from both sides of the record for the same interval and then averaged. When, because of lack of coherent reflections, it was not possible to extend a hyperbola to both sides of the record, only the interpretable side of the record was used (e.g., see reflectors 4 and 5 on shot point 1). The five reflection events which are consistent for all four shot points are identified by dots in Figure 3.

Table 2 shows results of the analysis of the reflection records. Interval A is the interval between reflectors 1 and 2, B is between 2 and 3, C is between 3 and 4, and D is between reflectors 4 and 5. The calculated velocities of each of the intervals are correlatable from shot point to shot point. The cross sections shown in Figures 4, 5, and 6 use calculated thicknesses for each interval. Refraction evidence discussed earlier was used for the upper layers on each line. The approximate bottom to the weathered zone is shown by a wavy line just below the surface on each section. Dips in each instance are low, and thicknesses between shot points are consistent.

Table 2. Interval velocities and layer thicknesses from seismic reflection measurements

	Velocities (ft/sec)			
	Interval			
	A	B	C	D
Line 1	14,028	7,193	8,772	25,000
Line 2	12,415	9,283	9,176	22,491
Line 3	11,430	8,229	8,375	18,344
Line 4	14,225	8,151	8,586	19,230

	Thicknesses (ft)			
	A	B	C	D
Line 1	2,168	1,035	1,101	3,600
Line 2	1,220	823	1,266	4,376
Line 3	2,110	568	770	3,320
Line 4	2,670	793	773	3,809

The marked contrast of velocities between intervals has definite lithologic implications. Table 3 shows a suggested relation between the seismic intervals discussed here and the stratigraphic sequence of Corcoran and others (1962) for the Mitchell Butte quadrangle.

It is emphasized that not all reflectors chosen in this investigation are contacts between geologic formations. Velocities calculated are interval velocities and are therefore an average of a large thickness of material. Formations mentioned which are predominantly sediment also may contain thin interbedded basalts. These basalts presumably have velocities much higher than the surrounding sediment. The entire

Table 3. Seismic velocity intervals and suggested lithology

Interval	Approx. velocity (ft/sec)	Approx. thickness (ft)	Suggested lithology	Stratigraphic sequence*
Layer 2 from refraction on lines 1 and 4	6-7,000	At least 750	Sediment	Chalk Butte Fm.
A	11-14,000	2-3,000	Basalt	Grassy Mtn. Basalt
B and C	7-9,000	1½-2,000	Sediment	Kern Basin Fm. Deer Butte Fm.
D	18-25,000	3-4,000	Basalt	Owyhee Basalt Sucker Creek Fm.

* From Corcoran and others 1962

formation, however, will show an average velocity close to that of sediment. Likewise, basalt formations with thin interbedded sediments will have a velocity characteristic of basalt when large thicknesses are considered. These interbedded layers are important, though, because they represent sharp changes in lithology and are therefore capable of producing strong reflections. This implies that reflectors may represent sharp lithologic changes within geologic formations and are not necessarily the actual contacts between geologic formations.

Figure 1 is a portion of the geologic map of the Mitchell Butte quadrangle compiled by Corcoran and others (1962). The four seismic reflection lines have been added to the map. Lines 1 and 4 rest upon Chalk Butte sediments whereas older Grassy Mountain Basalt is at the surface on line 2 and 3. Generally, beds at the surface near the lines dip in a northeasterly direction toward the Snake River Basin.

The three cross sections (Figures 4, 5, and 6) are in good agreement with an extrapolation downward of the surface geology. In Figure 4 it is seen that material with a seismic velocity of 12,415 ft/sec (i.e., basalt) crops out on line 2 and shows an apparent dip of about 3.3° to the north. On line 1 about 600 feet of sediment overlies the basalt. Figure 4 shows that the sediment at the surface on line 1 has an apparent dip of approximately 1.8° in a northwesterly direction toward line 4. Since the geologic map shows that the center of line 4 is approximately on strike with the center of line 1, this low apparent dip is reasonable. Basalt with a seismic velocity of 11,430 ft/sec is seen at the surface on line 3. Figure 6 shows that this basalt has an apparent northeasterly dip of approximately 2.4° toward line 4. Again, this is in agreement with the geologic map.

Below the Chalk Butte sediments and the Grassy Mountain Basalt, correlations on the three cross sections all tend to indicate that the low dip toward the Snake River Basin continues. Below about 2,500 feet of Grassy Mountain Basalt, approximately 2,000 feet of lower-velocity material is encountered. This interval probably represents the Kern Basin and Deer Butte Formations, which are both predominantly sediment.

The deepest interval investigated consists of approximately 4,000 feet of very high-velocity material (approximately 20,000 ft/sec). Following the stratigraphic sequence outlined by Corcoran and others (1962), this material corresponds to the Owyhee Basalt. The reflection representing the bottom of this interval (reflector 5)

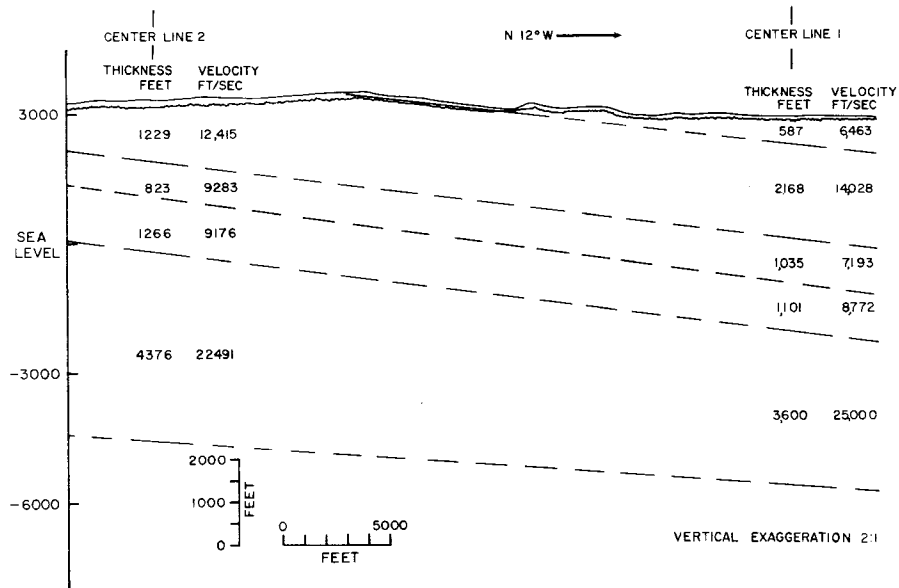


Figure 4. Cross section showing seismic velocities and thicknesses calculated for SP 1 and SP 2.

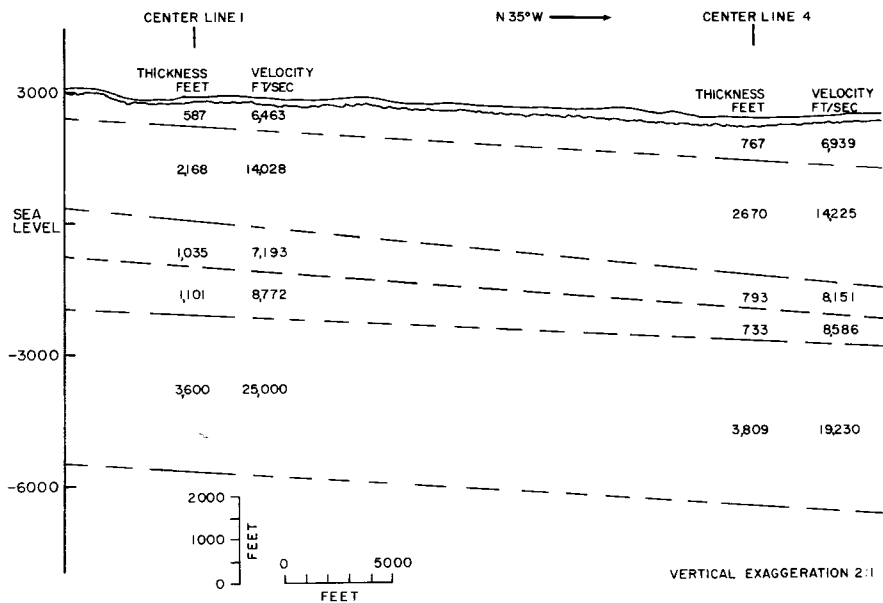


Figure 5. Cross section showing seismic velocities and thicknesses calculated for SP 1 and SP 4.

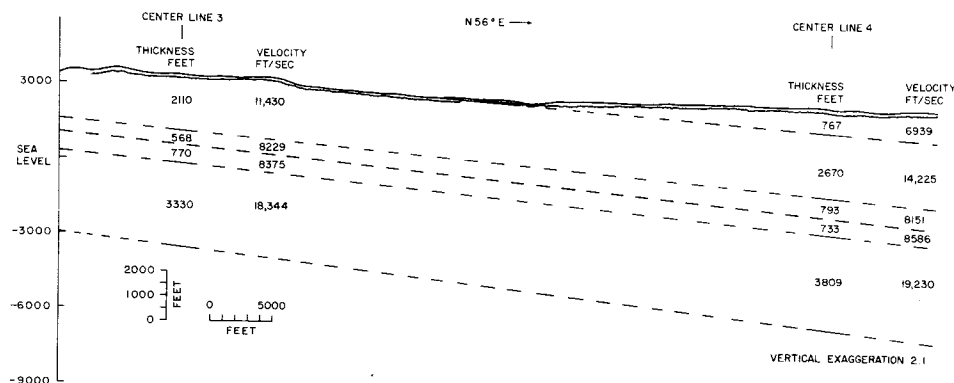


Figure 6. Cross section showing seismic velocities and thicknesses calculated for SP 3 and SP 4.

is very distinct on reflection records 1, 2, and 4. Such a strong reflection is expected in going from massive basalt flows to the underlying sediments of the Sucker Creek Formation. Reflector 5 is therefore believed to be near the top of the Sucker Creek Formation. This puts the limit to the seismic section for this study at a depth of about 9,000 feet.

Acknowledgments

We thank J. Gemperle and A. Stevens for technical support and M. Gemperle for arranging the technical and logistical program. Dr. Stephen Johnson reviewed the manuscript and provided helpful advice.

This work, a joint effort by members of the Geophysics Group, Oregon State University; The Department of Earth Sciences, Portland State University; and the Department of Geology, University of Oregon, was conducted with the cooperation of the Oregon Department of Geology and Mineral Industries and the U.S. Bureau of Land Management. The U.S. Geological Survey supported the analysis of the data under Grant No. 14-08-0001-6-222.

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* * * * *

PRELIMINARY GRAVITY MAPS OF THE VALE AREA, MALHEUR COUNTY, OREGON

Kevin Larson* and Richard Couch**

Introduction

A gravity survey, conducted during August and September 1974 and July 1975 yielded approximately 380 stations in an area between 43°37' and 44°15' N. lat. and 117°00' and 117°30' W. long. This area of approximately 2,700 sq. km., which adjoins the western edge of the Snake River downwarp and consists largely of volcanic terrane, is considered a potential geothermal resource area. Because of the current high interest in geothermal energy and the Vale geothermal resource area in particular, this paper presents preliminary free-air and simple Bouguer anomaly maps of the area prior to formal interpretation. This effort, initiated under the Vale project described by Couch and others (1975) and currently supported by the U.S. Geological Survey, is continuing as a joint effort of the Department of Geology at the University of Oregon and the Geophysics Group, school of Oceanography at Oregon State University.

Field and Data Reduction Techniques

Wordon Gravity Meter 575, a Master gravimeter, calibrated just prior to the field work, was used to obtain measurements of gravity at 380 locations in the Vale area. The gravity base station at the Ontario airport, Oregon (Rinehart and others, 1964; Berg and Thiruvathukal, 1965) provided the primary reference for all field stations. Berg and Thiruvathukal (1965) tied the Ontario base station to the international gravity base station located at the Carnegie Institution, Washington, D.C. Because Rinehart and others (1964) and Berg and Thiruvathukal (1965) report slightly different values for the Ontario base station, a new tie is planned for the near future. The value of gravity at the base station adopted for this preliminary report is 980,303.82 mgl. The establishment of a number of secondary base stations, tied to the Ontario base station, permitted the measurement of gravity at field stations along loops which extended from one secondary base station to another. Station spacing along the loops was approximately 2 to 4 miles.

USGS benchmarks, spot elevations on USGS 15-minute and 7.5-minute topographic maps, and barometer altimetry provided elevation control. The estimated uncertainty in the elevation control provided by the three methods is ± 1 , ± 5 and ± 10 feet respectively. Ties to points of known elevation every two hours provided corrections for temperature and barometric changes which occurred during the periods of measurement. USGS 15-minute and 7.5-minute topographic maps provided horizontal position control. The estimated uncertainty in position is $\pm .01$ minute of latitude and longitude.

* Department of Geology, University of Oregon

**Geophysics Group, School of Oceanography, Oregon State University

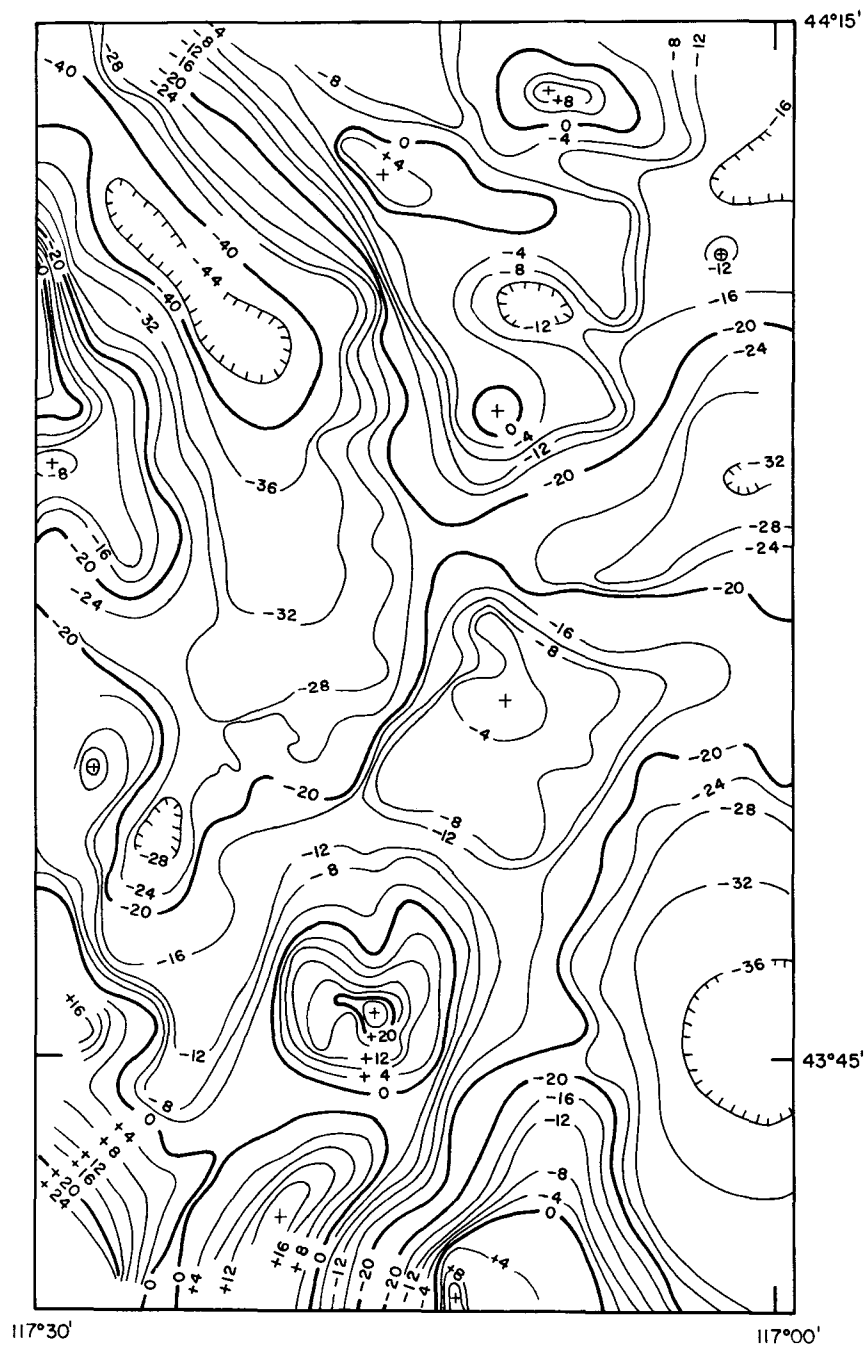


Figure 1. Free-air gravity anomaly map of the area between 43°37.5' and 44°15' N. lat. and 117°00' and 117°30' W. long.

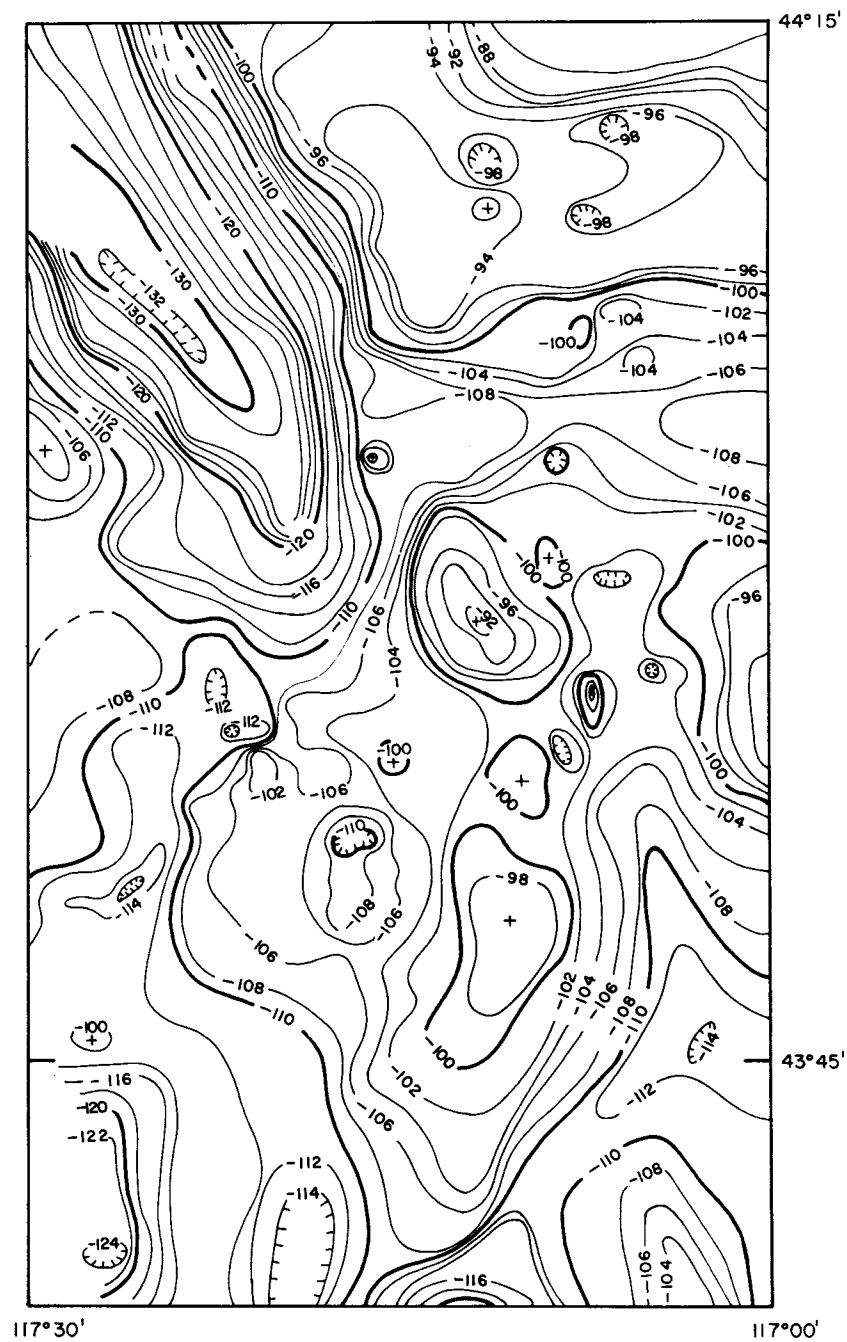


Figure 2. Simple Bouguer anomaly map of the area between 43°37.5' and 44°15' N. lat. and 117°00' and 117°30' W. long. Bouguer reduction density is 2.67 gm/cm³.

The observed gravity (OG) was corrected for meter drift and tidal gravity changes. The International Gravity Formula (IGF) $TG = 978049.0(1 + 0.0052884 \sin^2 \theta - 0.0000059 \sin^2 2\theta)$ where θ is the latitude, yields theoretical gravity (TG). The equation $F.A. = OG - TG + (.09411549 - 0.000137789 \sin^2 \theta)h - 0.67 \times 10^{-8}h^2$, where h is the elevation in feet above sea level, yields the free-air gravity (F.A.) anomaly; and the equation $SB = FA - 0.012774 dh$, where d is the Bouguer reduction density, yields the Bouguer anomaly. Bouguer anomalies in this report assume a reduction density of 2.67 gm/cm^3 .

The Free-air Gravity Anomaly Map

Figure 1 shows the free-air gravity anomaly map for the area between $43^\circ 37.5'$ and $44^\circ 15'$ N. lat. and $117^\circ 00'$ and $117^\circ 30'$ W. long. The contour interval is 4 mgl and heavy contours occur at intervals of 20 mgl. Anomaly amplitudes range from -46 mgl in the northwest portion of the mapped area near Jamieson, Oregon, to +26 mgl in the southwest portion of the area near Negro Rock Canyon. A series of contiguous gravity highs which trend approximately north-south are observed in the center of the area. A series of relative gravity lows flank the gravity highs on the east and west. The average free-air anomaly over the area is negative, indicating a small mass deficiency.

The Simple Bouguer Gravity Anomaly Map

Figure 2 shows the simple Bouguer anomaly map for the area. The contour interval is 2 mgl and heavy contours occur at 10 mgl intervals. The Bouguer reduction density for the map is 2.67 gm/cm^3 . Gravity anomaly amplitudes range from -132 mgl in the northwest part of the mapped area to -84 mgl in the northeast part. The marked gravity low in the northwest is elongate and trends approximately $N30^\circ W$. A series of gravity highs locate a relative gravity high in the south-central and east-central parts of the area. A broad relative gravity high is also noted in the northeast part of the area.

General Remarks

The gravity maps show anomalies with a general north-south trend consistent with observed surface structures in the area. Topography causes part of the observed anomalies, and topographic effects are more evident on the free-air gravity anomaly map. The gravity low in the northwest portion of both maps occurs in the valley which extends from Vale to Brogan, Oregon. The relative gravity high in the northeast is coincident with the hilly terrain of that area. Both field work and interpretation are continuing.

Acknowledgments

Howard Bernstein and Michael Kopicki assisted in the field efforts; G. Stephen Pitts assisted in the data reduction. Janet Gemperle drafted the maps, and A. Stevens, K. Keeling, and G. Connard provided technical support. This work was supported in part by the U.S. Geological Survey under Grant No. 14-08-0001.

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* * * * *

CENTRAL OREGON FIELD TRIP GUIDEBOOK REPRINTED

A popular guidebook, abundantly illustrated by photographs and colored geologic maps and outlining five geologic field trips to see interesting volcanic features in central Oregon, has been reprinted. The guidebook is the Department's Bulletin 57, "Lunar Field Conference Guidebook," published in 1965 when the area around Bend and in the nearby Cascade Range was used as an outdoor laboratory for studying the lunar surface prior to Moon landings. The subjects of the 51-page guidebook are trips to 1) Devils Hill, Broken Top, and Lava Butte; 2) Newberry Volcano; 3) Hole-in-the-Ground and Fort Rock; 4) Belknap Crater, Yapoah Crater, and Collier Cone; and 5) Crater Lake. The publication can be obtained from the Department's offices in Portland, Baker, and Grants Pass for \$3.50.

* * * * *

BUREAU OF LAND MANAGEMENT GETS NEW OREGON DIRECTOR

Murl W. Storms has been appointed Oregon State Director of the Bureau of Land Management by BLM Director Curt Berkland in Washington, D.C. Storms, a 26-year veteran resource manager for BLM, succeeds Archie D. Craft, who recently was appointed Assistant Director for Technical Services in the BLM head office in Washington, D.C.

As new State Director, Storm's responsibilities include management of 16 million acres of national resource lands in Oregon and Washington.

Storms is a graduate of the University of Washington, where he received his B.S. degree in Forestry in 1949. In 1962 he received an M.S. degree in Natural Resources Administration from the University of Michigan. Much of his career since 1955 has been spent in Oregon, most recently as Chief, Division of Resources, Oregon State Office, 1966-1971. From 1971 until his present appointment, he was Chief of BLM's Division of Forestry in Washington, D.C.

Storm takes the oath of office August 19 in Roseburg, Oregon during dedication of the new BLM district office there.

* * * * *

SOUTHEASTERN-OREGON REPORTS RELEASED ON OPEN FILE

"Geothermal significance of eastward increase in age of upper Cenozoic rhyolite domes in southeastern Oregon," by N. S. MacLeod, G. W. Walker, and E. H. McKee, has been placed on open file by the U.S. Geological Survey as USGS open-file report No. 75-348. This preliminary report summarizes available data and its geothermal implications and is an extension of earlier work (see July 1974 The ORE BIN). A copy of the 22-page report is available for inspection at the Department's library in Portland, where copies may also be purchased for \$2.50.

The U.S. Geological Survey has issued Open-file report USGS 75-346 entitled "Gravity and magnetic profiles and maps, Crump Geyser area, Oregon," by Donald Plouff and Arthur Conradi, Jr. Grump Geyser area, a Known Geothermal Resource Area, is situated in Warner Valley in southeastern Lake County. The report consists of 12 plates and a 2-page text. A copy is available for inspection at the Department's library. Reproducible copy is at the USGS Library, 345 Middlefield Rd., Menlo Park, Calif., 49025.

Two sets of geophysical data on the Alvord Valley area recently received from the U.S. Geological Survey can be consulted at the Oregon Department of Geology and Mineral Industries library. Reproducible copy is on file at: U.S. Geological Survey, 678 U.S. Court House, Spokane, Washington 99201. The open-file materials is:

1. "Audio-magnetotelluric apparent resistivity maps for part of Harney County," by C. L. Long and D. I. Gregory. Five plates, scale 1:62,500.
2. Principal facts and preliminary interpretation for gravity profiles and continuous truck-mounted magnetometer profiles in the Alvord Valley, Oregon," by Andrew Griscom and Arthur Conradi, Jr. 20 pages, 18 plates, 9 tables.

* * * * *

USBM ISSUES MINERAL SUPPLY/DEMAND DATA

A concise, statistical supply/demand profile for 84 mineral and fuel commodities in the United States during the decade 1964-1973 is given in a special publication just issued by the U.S. Bureau of Mines.

The 96-page report, titled "Minerals in the U.S. Economy," covers 47 metals, 32 nonmetals, and five fuels. Annual statistics are tabulated on U.S. and world output, foreign and domestic components of the U.S. supply, and demand by major use categories. "Flow" diagrams for each commodity show, at a glance, relationships in 1973 among international suppliers, U.S. imports, domestic production, government and industry stockpiles, and consumption categories.

Much of the material has appeared previously in the Minerals Yearbook and other Bureau publications. However, it has now been assembled for the first time in condensed form, with the new flow diagrams added.

A single copy of "Minerals in the U.S. Economy" can be obtained without charge from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Ave., Pittsburgh PA 15213. Requests should specify the complete title.

* * * * *

ERDA SUBMITS FIRST PLAN TO CONGRESS

The Energy Research and Development Administration (ERDA) has submitted to Congress its "Energy Research, Development and Demonstration Plan."

ERDA outlined five major changes in the nation's energy research and development efforts that must be made "rapidly and simultaneously" to help solve the energy problems confronting the nation. The following changes in priorities are urged:

Emphasis on overcoming the technical problems inhibiting expansion of high-leverage existing systems, notably coal and light-water reactors.

An immediate focus on conservation efforts.

Acceleration of commercial capability to extract gaseous and liquid fuels from coal and shale.

Inclusion of the solar-electric approach among the "inexhaustible resource" technologies to be given high priority.

Increased attention to underused new technologies that can be rapidly developed.

ERDA emphasized that the priorities from now to 1985 are:

(1) To preserve and expand our major existing energy systems: coal, light-water reactors (the highest nuclear priority), and gas and oil from new sources and enhanced recovery techniques.

(2) To increase efforts on conservation, to increase the efficiency of energy use in all sectors of our economy, and to extract more usable energy from waste materials.

Copies of Volume 1 of the full ERDA report to Congress may be obtained from the Assistant Administrator for Planning and Analysis, Energy Research and Development Administration, Washington, D.C. 20545.

* * * * *

HISTORICAL MATERIAL ON MINING WANTED BY OHS

Oregon Historical Society would appreciate donations of materials on early-day mining activities in Oregon or the Pacific Northwest. Old publications, letters, records, and photographs connected with mining are desired. Names of miners and location of mining activities are needed to give the photographs historic value.

Before sending your historical items, write a letter of inquiry, listing the material you have available, to: Library, Oregon Historical Society, 1230 S.W. Park, Portland, Oregon 97205.

* * * * *

MOUNT HOOD BIBLIOGRAPHY AVAILABLE

A bibliography on the geology of Mount Hood, by Mike McCarthy, student at Portland State College, has been issued as open-file report No. O-75-5. References are listed alphabetically by author, and most include a brief summary of the contents. The report contains more than 80 references to literature on Mount Hood, spanning nearly 150 years from early exploring expeditions in the West to present-day studies. The bibliography is preliminary and subject to corrections and additions. Copies are available from the Department's Portland office for \$1.00.

* * * * *

AVAILABLE PUBLICATIONS

(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

26. Soil: Its origin, destruction, preservation, 1944: Twenhofel	\$0.45
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35. Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin	3.00
36. Papers on Tertiary foraminifera: Cushman, Stewart & Stewart. vol. 1-\$1.00; vol. 2-	1.25
39. Geology and mineralization of Morning mine region, 1948: Allen and Thayer	1.00
44. Bibliography (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere	1.00
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57. Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
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GEOLOGIC MAPS

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- Postcard - geology of Oregon, in color . . . 10¢ each; 3 - 25¢; 7 - 50¢; 15 - 1.00
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The Ore Bin



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VOLCANOES OF THE PORTLAND AREA, OREGON

John Eliot Allen
Emeritus Professor of Geology, Portland State University

Introduction

In our present concern with possible volcanic activity in the Cascades, it seems appropriate to summarize what we know about past volcanic activity in the Portland area and its possible structural significance. A recent paper (Allen, 1974) noted that several vents and lava tubes on the west side of the Portland Hills represented the westernmost group of large Plio-Pleistocene centers of volcanic activity in the Northwest.

This, however, by no means suggested the total extent of late volcanism in the Portland area. Within a 13-mile radius of Kelly Butte (Plate 1) there are over 32 volcanic vents; within a 20-mile radius centered at Troutdale there are 90 volcanic centers. Most of these were originally small cinder cones like Pilot Butte and Lava Butte near Bend, Oregon, but some of them, such as Mount Sylvania in southwest Portland, Highland Butte 10 miles southeast of Oregon City, and Larch Mountain south of the Columbia River Gorge, were low, broad lava domes of the type called "shield volcanoes."

The densest concentration of volcanic vents lies west of the town of Boring, where 20 centers occur within an area of about 36 square miles. Because of this grouping near Boring, Ray Treasher (1942) first gave the name "Boring lava" to the lava, cinders, and ash which emanated from volcanic centers in the Portland area within a time span of from perhaps 10 million to less than 1 million years ago (Trimble, 1963). Some, like Bob's Mountain in Washington, may be very young indeed.*

* More exact dating of the Boring Lava is urgently needed. Potassium-argon analyses are very expensive, but even five or six would help to determine the age range. Beeson (pers. commun., 1975) and his students have already determined from geochemical studies that Boring Lava from different localities falls into at least three types - a suggestion that its extrusion might span a long time range.



Photo 1. Looking east from Portland Heights toward Mount Hood. At least eight vents of Boring Lava are shown in east Portland and several more in the distance. (Photo courtesy State Highway Division)

Trimble (1963) mapped the areal extent of the Boring lava in the Portland area and mentioned (p. 36-42) that it erupted from 30 centers, but gave the exact location of only a few vents. Geomorphologic study of the new 7½-minute quadrangles (not available to Trimble) allows fairly accurate location of many of these and also other vents. The degree of assurance attributed to the identification given is indicated by the legend symbols (certain, probable, possible) used on Plate 1.

I wish to thank my colleagues at Portland State University for their suggestions while I was writing this paper and for their careful review of it.

Types of Volcanoes

Depending upon the viscosity of the lava, and, in turn, upon the chemical composition and gas content, molten volcanic material may produce a variety of different landforms (MacDonald, 1972; Williams, 1948). Figure 1 summarizes these variations in form which accompany differences in gas content, viscosity, and composition. As the silica content in the magma increases from basalt to andesite to rhyolite, the violence of the eruption usually increases along with the viscosity in the order presented.

The Boring Lava landforms are restricted to types 2 and 3 (Figure 1). The type of activity was well described by Foshag and Jenaro (1956) in their paper on the birth and development of a recent volcano, Paricutin, in central Mexico. Between 1943 and 1947, the volcano built up to over 1,000 feet and emitted lava flows from its base that eventually totalled a thickness of 500 to 800 feet and covered over 10 square miles.

Volcanism in the Paricutin area (Figure 2-B) during the last 100,000 years has nearly duplicated what occurred in the Portland area a million or more years ago. Like the northern Willamette Valley, the Paricutin area lies adjacent to a line of great composite volcanoes which extends for 500 miles.

Identification Procedures

In identifying the Portland area vents on topographic maps, judgments were made as to the degree of erosion of the original landform. For example, relatively recent cinder cones (e.g., Bob's Mountain, No. 9, Plate 1) show a crater outlined by an arcuate ridge, usually lower on one side as the result of breaching by erosion. Within the vent area of a cinder cone, there is frequently a hardened plug of massive lava surrounded by outward-dipping layers of cinders which are less resistant to erosion than the plug. Upon further erosion, if the plug stood high within the cone, the resistant plug may eventually stand out as a distinct promontory above the lava surrounding the cone. If the plug did not rise above the lava, erosion of the cone may leave only the dome of lava. The latter is true for many of the Portland area vents. Since the period of activity in the Portland area lasted for




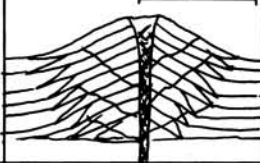



	Type	Characteristics	Examples	Sketches
	1. Flood or plateau basalt	Very liquid lava; flows very widespread; emitted from fractures	Columbia River Plateau	One mile: 
	2. Shield volcano	Liquid lava emitted from a central vent; large; sometimes has a collapse caldera	Larch Mtn., Sylvania, Highland Butte, Hawaiian volcanoes	
	3. Cinder cone	Explosive liquid lava; small; emitted from a central vent; if continued long enough, may build up shield volcano	Mount Tabor, Mount Zion, Chamberlain Hill, Pilot Butte, Lava Butte	
	4. Composite volcano	More viscous lavas, much explosive (pyroclastic) debris; large, emitted from a central vent	Mount Hood, Mount St. Helens	
	5. Plug dome	Very viscous lava; relatively small; can be explosive; commonly occurs adjacent to craters of composite volcanoes	Mount Lassen, Shastina, around Crater Lake, Mono Craters	
	6. Caldera	Very large composite volcano collapsed after an explosive period; frequently associated with plug domes	Crater Lake, Newberry Caldera	

Figure 1. Types of volcanoes including examples and sketches.

perhaps 10 million years, all degrees of erosion have shaped the present landforms. An excessive degree of erosion may leave considerable doubt as to the identification. Indeed, a number of the vents in the "possible" category may represent upland remnants of a larger shield which has been dissected by radial streams.

In summary, the symbols on Plate 1 define the degrees of assurance as follows:

Certain: Crater rim remnants, massive vent lavas or pyroclastics exposed, isolated promontories at elevations equal to or above adjacent areas.

Probable: Pronounced promontories equal in elevation or only slightly lower than other possible sources; sloping for considerable distances away from the summits.

Possible: Low promontories within a dissected shield area, lower in elevation than others.

Lavas and Pyroclastics

"The Boring lava is composed mainly of basaltic flow rocks, but locally contains tuff-breccia, ash, tuff, cinders and scoriaceous phases" (Trimble, 1963, p. 38). The Boring Lava, originating in the Portland area, is quite different from Yakima Basalt (Columbia River Basalt), which originated outside the area. The Boring, as compared to the Yakima, is gray rather than dark gray to black, and the jointing is generally massive or blocky rather than columnar or brickbat. Still more characteristic of the Boring Lava, as seen in thin section, is the meshwork of minute plagioclase laths (pilotaxitic texture) commonly with open spaces between the laths (diktytaxitic texture). The Boring Lava contains olivine, rare in Yakima Basalt, and there is a very distinct geochemical difference between the two types of lavas (Beeson, personal communication 1975).

Location of Vents

Because of the necessarily small scale of Plate 1, Table 1 was compiled; it lists the vents on the map by legal subdivisions (section, township, and range), gives their elevation, and indicates the U.S. Geological Survey maps upon which they were located.

Density of Vents and Possible Structural Patterns

Eight-five of the vents in the Portland area are shown on Figure 2-A. For comparison, Figure 2-B shows 175 vents in the Paricutin area (Williams, 1950, pl. 8), and Figure 2-C shows 205 vents in the Newberry Crater quadrangle (Williams, 1957). The squares in all three figures are 6 miles on a side (36 square miles) and the number within each square represents the

Table 1. Location and elevation of 95 vents, including multiple vents, in the Portland area

Map No.	Name	Location Sec. T. Range	Quadrangle	Elevation
<u>North of the Columbia River (17 vents)</u>				
1	Green Mountain	SE2, 2N, 3E	Camas 15'	804
2	Brunner Hill (2 vents)	SE23, 2N, 3E	Camas 15'	680
3	Prune Hill (W)	NE 8, 1N, 3E	Camas 7½'	555
4	Prune Hill (E)*	SE 9, 1N, 3E	Camas 7½'	610
5	Mount Norway (2)	SE34, 2N, 4E	Camas 15'	1,111
6	Nichol's Hill	NE 2, 1N, 4E	Camas 15'	1,113
7	Bear Prairie	SE24, 2N, 4E	Bridal Veil 15'	1,300
8	Pohl's Hill	SE19, 2N, 5E	Bridal Veil 15'	1,395
9	Bob's Mountain	NW22, 2N, 5E	Bridal Veil 15'	2,110
10	Bob's Mountain (S)	NE15, 2N, 5E	Bridal Veil 15'	1,690
11	Bob's Mountain (N)	W½22, 2N, 5E	Bridal Veil 15'	1,775
12	Unnamed	SW18, 2N, 6E	Bridal Veil 15'	2,785
13	Unnamed	SE24, 2N, 5E	Bridal Veil 15'	2,550
14	Mount Pleasant	NE18, 1N, 5E	Bridal Veil 15'	1,010
15	Mount Zion	SW9, 1N, 5E	Bridal Veil 15'	1,465
<u>West of the Willamette River (14 vents)</u>				
16	Unnamed	NE21, 1N, 1W	Linnton 7½'	455
17	Unnamed	NE27, 1N, 1W	Linnton 7½'	650
18	Unnamed	NW27, 1N, 1W	Linnton 7½'	505
19	Unnamed	SW27, 1N, 1W	Linnton 7½'	550
20	Unnamed	SE27, 1N, 1W	Linnton 7½'	565
21	TV Hill	C 36, 1N, 1W	Linnton 7½'	1,275
22	Swede Hill	NW1, 1S, 1W	Linnton 7½'	995
23	Unnamed	NW1, 1S, 1W	Linnton 7½'	974
24	Elk Point (2)	SE 1, 1S, 1W	Portland 7½'	975
25	Mount Sylvania (2)	SW32, 1S, 1E	Lake Oswego 7½'	975
26	Cook's Butte (2)	SW 16, 2S, 1E	Lake Oswego 7½'	718
<u>East of Willamette River and north of Powell Valley Road (Hwy 26) (19 vents)</u>				
27	Mount Tabor*	NW5, 1S, 2E	Mount Tabor 7½'	535
28	Rocky Butte (2)	NE 28, 1N, 2E	Mount Tabor 7½'	612
29	Kelly Butte (2)*	NE 9, 1S, 2E	Mount Tabor 7½'	400
30	Chamberlain Hill	NW32, 1N, 4E	Bridal Veil 15'	890
31	Ross Mountain	SE 31, 1N, 5E	Bridal Veil 15'	1,380
32	Pepper Mountain (2)	NE34, 1N, 5E	Bridal Veil 15'	2,137
33	Devil's Rest (2)	NE24, 1N, 5E	Bridal Veil 15'	2,450
34	Larch Mountain	NE32, 1N, 6E	Bridal Veil 15'	4,056

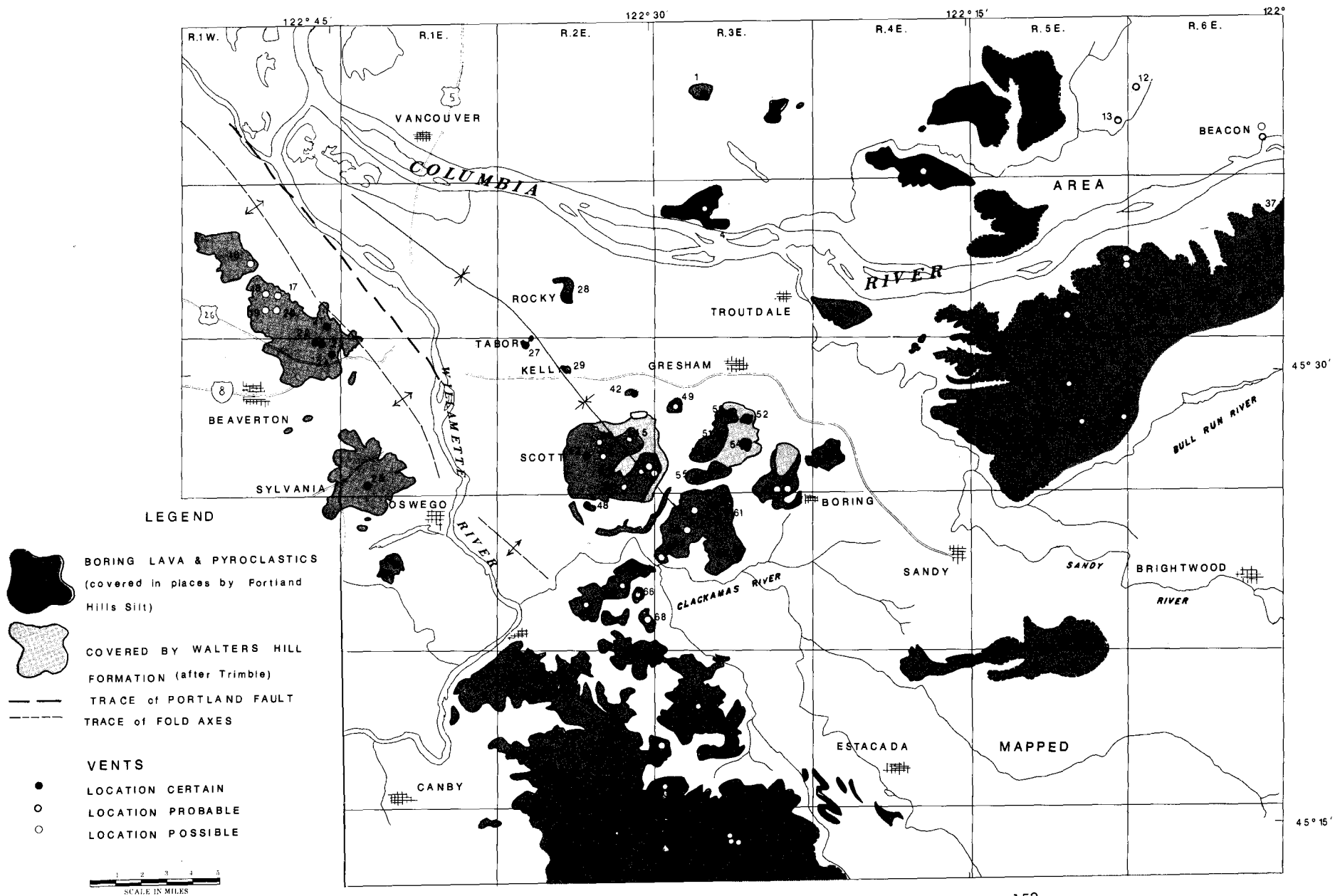
* Top of hill is Troutdale Formation

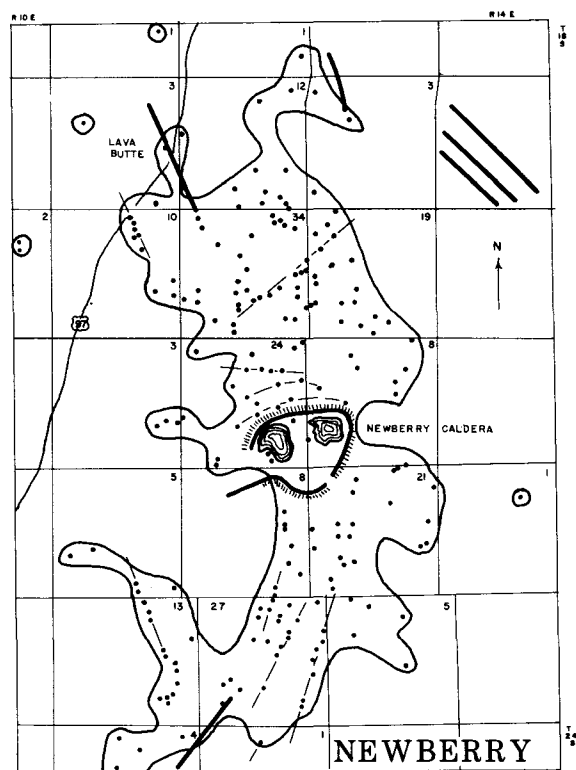
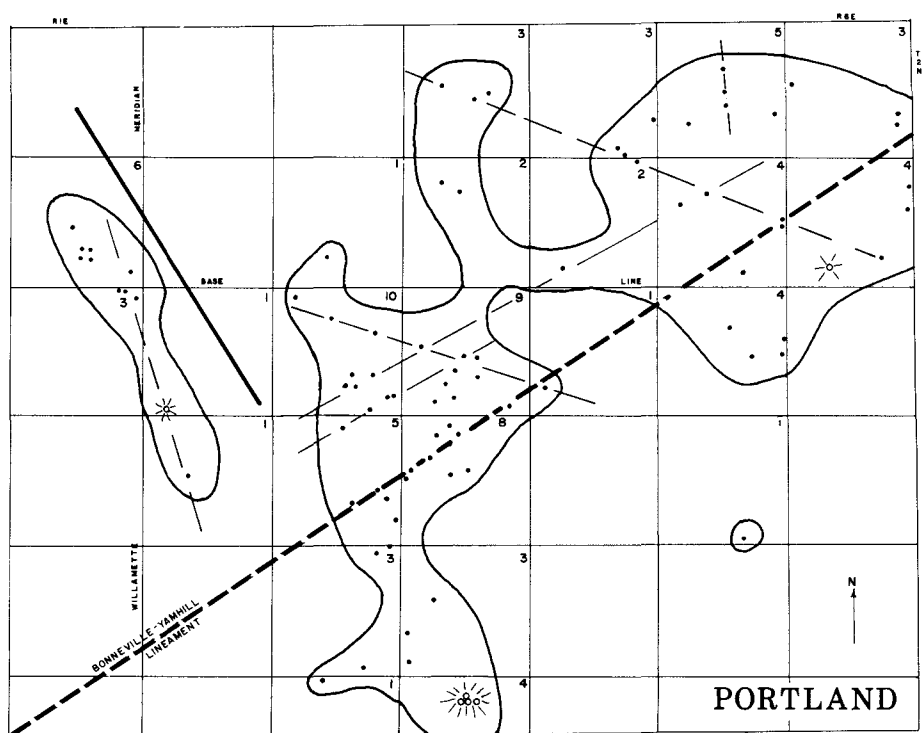
Table 1, continued

Map No.	Name	Location	Quadrangle	Elevation
East of Willamette River and north of Powell Valley Road (continued)				
35	Unnamed	SW26, 1N, 6E	Bridal Veil 15'	3,820
36	Palmer Peak	NE13, 1N, 6E	Bridal Veil 15'	4,010
37	Nesmith Point	NE12, 1N, 6E	Bridal Veil 15'	3,880
38	Unnamed	SE10, 1S, 5E	Cherryville 15'	1,780
39	Unnamed	NW23, 1S, 5E	Cherryville 15'	2,280
40	Walker Peak	NE 24, 1S, 5E	Cherryville 15'	2,450
41	Lookout Point	NE 13, 1S, 5E	Cherryville 15'	2,645
42	Powell Butte*	NW13, 1S, 2E	Gladstone 7 $\frac{1}{2}$ '	560
43	Mount Scott (2)	W $\frac{1}{2}$ 27, 1S, 2E	Gladstone 7 $\frac{1}{2}$ '	1,095
44	Cemetery	SE 22, 1S, 2E	Gladstone 7 $\frac{1}{2}$ '	910
45	Unnamed	SW24, 1S, 2E	Gladstone 7 $\frac{1}{2}$ '	810
46	Scout Camp (3)	N $\frac{1}{2}$ 36, 1S, 2E	Gladstone 7 $\frac{1}{2}$ '	945
47	Unnamed	SE 35, 1S, 2E	Gladstone 7 $\frac{1}{2}$ '	866
48	Mount Talbert*	NW 3, 2S, 2E	Gladstone 7 $\frac{1}{2}$ '	745
49	Unnamed (2)	SE 18, 1S, 3E	Damascus 7 $\frac{1}{2}$ '	635
50	Unnamed	NE 21, 1S, 3E	Damascus 7 $\frac{1}{2}$ '	995
51	Unnamed	SW21, 1S, 3E	Damascus 7 $\frac{1}{2}$ '	997
52	Unnamed	N $\frac{1}{2}$ 22, 1S, 3E	Damascus 7 $\frac{1}{2}$ '	925
53	Unnamed	NW28, 1S, 3E	Damascus 7 $\frac{1}{2}$ '	1,129
54	Unnamed	N $\frac{1}{2}$ 27, 1S, 3E	Damascus 7 $\frac{1}{2}$ '	1,085
55	Unnamed	N $\frac{1}{2}$ 32, 1S, 3E	Damascus 7 $\frac{1}{2}$ '	777
56	Unnamed	N $\frac{1}{2}$ 33, 1S, 3E	Damascus 7 $\frac{1}{2}$ '	877
57	Unnamed (3)	W $\frac{1}{2}$ 36, 1S, 3E	Damascus 7 $\frac{1}{2}$ '	1,010
58	Unnamed	SE 30, 3S, 4E	Sandy 7 $\frac{1}{2}$ '	902
59	Unnamed	C 5, 2S, 3E	Damascus 7 $\frac{1}{2}$ '	695
60	Unnamed (2)	W $\frac{1}{2}$ 4, 2S, 3E	Damascus 7 $\frac{1}{2}$ '	840
61	Unnamed	SE 4, 2S, 3E	Damascus 7 $\frac{1}{2}$ '	882
62	Unnamed	NW 8, 2S, 3E	Damascus 7 $\frac{1}{2}$ '	575
63	Unnamed (2)	NW18, 2S, 3E	Damascus 7 $\frac{1}{2}$ '	555
64	Unnamed	NW15, 2S, 3E	Damascus 7 $\frac{1}{2}$ '	830
65	Unnamed (2)	SE 23, 2S, 2E	Gladstone 7 $\frac{1}{2}$ '	800
66	Unnamed	SW24, 2S, 2E	Gladstone 7 $\frac{1}{2}$ '	825
67	Unnamed	N $\frac{1}{2}$ 27, 2S, 2E	Oregon City 7 $\frac{1}{2}$ '	580
68	Unnamed	SE 25, 2S, 2E	Oregon City 7 $\frac{1}{2}$ '	775
69	Hunsinger Peak	NE 2, 3S, 2E	Oregon City 7 $\frac{1}{2}$ '	657
70	Unnamed	NW17, 3S, 2E	Redland 7 $\frac{1}{2}$ '	885
71	Unnamed	SW 19, 3S, 2E	Redland 7 $\frac{1}{2}$ '	835
72	Unnamed	NW31, 3S, 2E	Redland 7 $\frac{1}{2}$ '	873
73	Highland Butte (4)	E $\frac{1}{2}$ 9, 3S, 2E	Redland 7 $\frac{1}{2}$ '	1,594
74	Lenhart Butte	SW35, 2S, 5E	Cherryville 15'	2,117

*Top of hill is Troutdale Formation

PLATE I





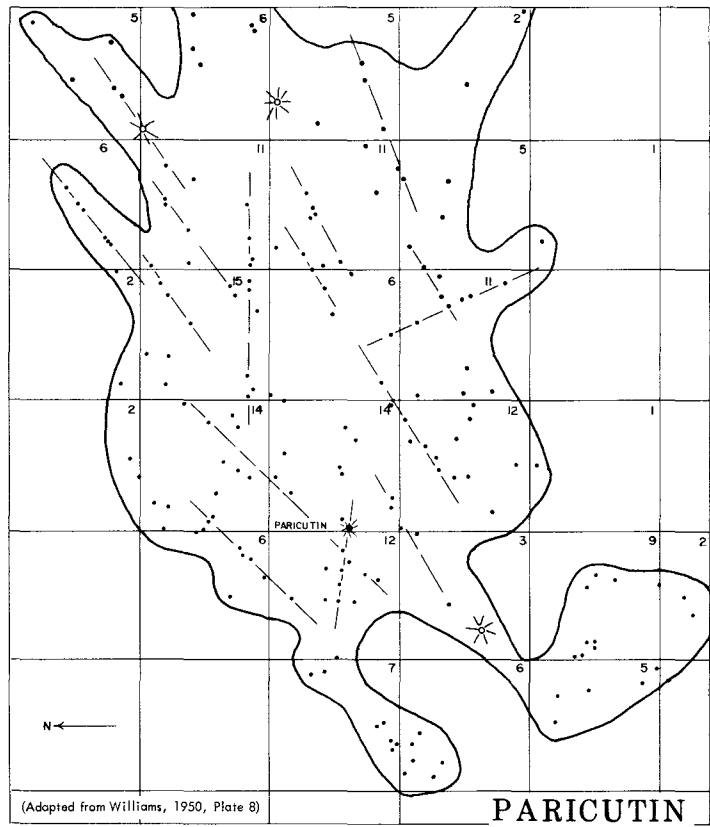


Fig. 2B

- ☼ COMPOSITE VOLCANO
- ☼ SHIELD VOLCANO
- VENT
- 6 No. of VENTS PER TOWNSHIP
- Some POSSIBLE FRACTURE PATTERNS
- APPROX. BOUNDARY of VENT AREA
- FAULT
- LINEAMENT

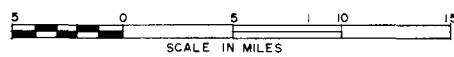


Figure 2. Comparison of vent patterns in: A - Portland area; B - Paricutin area; and C - Newberry Crater area.

number of vents. In the Portland area, there are no more than 10 vents in any one square; at Paricutin there are 15 and at Newberry 34. The average density of vents at Paricutin is thus almost double that of Portland; and Newberry is double that at Paricutin.

Many lineations (possible subjacent faults or fracture patterns) suggested by aligned vents could be drawn. Only a few of the most prominent are shown on Figure 2. It would be possible to program a computer with the location of the vents, to determine the best fits for these and alternate lineaments, and to determine the best probabilities.

One of the most obvious lineations in the Portland area (more than ten vents) corresponds to the Yamhill-Bonneville lineament, first suggested by Hammond (personal communication 1972) from completely different lines of evidence. Other geomorphic evidence also supports alignments in the Portland area (Schmela and Palmer, 1972).

Problems

The conjectural relationships of the possible strain patterns indicated by the lines of vents with such structures as the Portland Hills anticline and Willamette syncline, the (so-called) Portland Hills fault (Benson and Donovan, 1974), or with regional patterns, remains to be explored. The presence or absence of a fault bounding the east side of the Portland Hills has been a subject of controversy for 35 years. It was first suggested by Treasher (1942), but he did not show it on his map. Trimble (1963) did not show it on his map or cross section or mention it even as a possibility. Balsillie and Benson (1971) and Schmela and Palmer (1972) made strong arguments for its presence.

Many volcanic fields around the world are formed in grabens (down-dropped blocks of the Earth's crust). Allen (1966) suggested that the High Cascade volcanoes in Oregon are underlain by such a down-dropped block. If the Portland fault does exist, most of the Portland area lies on the down-faulted block, and the Boring volcanoes are related to the deformation.

Conclusions

1. The late volcanism in the Portland area is more extensive than is generally recognized.
2. Geomorphic studies of volcanic landforms and patterns can contribute structural evidence of value in the development of new geologic concepts.
3. Research is needed on the dating of the Boring Lava and development of the volcanic, geomorphic and structural history of the Portland area.

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- _____, 1957, Geologic map of the central portion of the High Cascade Mountains, Oregon: Oregon Dept. Geol. and Mineral Indus.

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COOS BAY COAL REPORT ON OPEN FILE

"Economic Factors Affecting the Mining, Processing, Gasification, and Marketing of Coos Bay Coals," by Ralph S. Mason, Deputy State Geologist, and Paul Hughes, Consultant, has been issued by the Department as open-file report O-75-6. The 61-page report is available for \$2.00. Four topographic sheets showing coal reserves are also for sale at \$2.00 each.

The report was prepared by the Oregon Department of Geology and Mineral Industries in cooperation with Coos County Board of Commissioners, the U.S. Bureau of Mines Process Evaluation Group, and the Oregon Economic Development Department.

* * * * *

GEOHERMAL LEASES ISSUED IN LAKE COUNTY

Only four bids were offered July 31 for geothermal leases on 18 parcels of national resource lands in Lake County, Oregon. The bids were opened and accepted by the Bureau of Land Management. The land is within the Crump Geyser Known Geothermal Resource Area (KGRA).

The bids, all submitted by Chevron Oil Co., San Francisco, Calif., ranged from \$5.12 to \$3.11 per acre for the 9,462 acres in the four parcels. The remaining 14 parcels may be reoffered by BLM at a later date.

The amount bid is the bonus per acre offered the government for a lease. The successful bidder also pays an annual rental of \$2.00 per acre for the first five years of the lease. For each of the next five years the rental is the amount of the preceding year, plus an additional \$1.00 per acre. Upon production, a royalty is paid instead of rental.

Another group of parcels near Vale, Oregon will be offered by BLM for geothermal leasing on September 25, 1975.

* * * * *

GEOHERMAL REPORTS ON OPEN FILE

The Department has recently placed two geothermal reports on open file. Copies are available at costs indicated below.

1. "Geothermal Studies and Exploration in Oregon," by R. G. Bowen, D. D. Blackwell, and Donald Hull. Open-file report No. O-75-7.

The report is a 65-page summary of geothermal data gathered by the Department between 1972 and 1975 under a U.S. Bureau of Mines contract. Some of the information has previously been issued as open-file or published progress reports. As an outcome of the project, six anomalously high heat-flow areas were identified. The report contains temperature data from 140 bore holes and 5 deep holes drilled for the project and from 81 pre-drilled holes and 6 monitor wells. \$2.00

2. "An estimate of southeast Oregon's geothermal potential," by Deborah Miles Fisher. Open-file report O-75-8.

The 9-page report demonstrates the feasibility of adapting methods used by oil companies for calculating petroleum reserves to estimating geothermal resources in an untested area. Calculations are based on a comparison with statistics from The Geysers, an operating geothermal field in California. \$1.00

* * * * *

REICHOLD ABANDONS FIRST HOLE, PLANS THREE MORE

Reichhold Energy Corp., Tacoma, Washington abandoned its "NNG-Crown Zellerbach 1" test hole near Tillamook at 5,557 feet in July and moved to a second site near McCoy in Polk County. The company has been issued 4 permits by the State Department of Geology and Mineral Industries.

Permit No. 65 API 36-052-00004 NNG-Crown Zellerbach 1	NE $\frac{1}{4}$ sec. 22, 2S, 10W Tillamook County	Abandoned at 5,557'
Permit No. 66 API 36-053-00021 NNG-Finn 1	SW $\frac{1}{4}$ sec. 17, 6S, 4W Polk County	Drilling; projected depth 7,000'
Permit No. 67 API 36-047-00007 NNG - Merrill 1	SW $\frac{1}{4}$ sec. 24, 8S, 4W Marion County	Location ready
Permit No. 68 API 36-009-00006 NNG-Crown Zellerbach 2	NW $\frac{1}{4}$ sec. 8, 4N, 3W Columbia County	Location ready

These drilling ventures are being done under a partnership arrangement between Reichhold Energy Corp. and Northwest Natural Gas Co. Both companies operate industries within the state; Reichhold manufactures fertilizer from natural gas, and Northwest Natural distributes gas in western Oregon.

Well records on drilling in Oregon are required to be kept confidential for two years after completion or abandonment but then are opened to the public.

* * * * *

KLEPPE NOMINATED TO BE INTERIOR SECRETARY

On September 9, President Ford nominated Thomas S. Kleppe of North Dakota to be Secretary of the Interior. The nomination has been referred to the Senate Interior and Insular Affairs Committee, but no hearings have been scheduled on his confirmation.

Kleppe is presently Administrator of the Small Business Administration and served in the U.S. House of Representatives from 1967 to 1971. Kleppe was a member of the House Agriculture Committee during his four years in Congress.

* * * * *

SOUTHWESTERN OREGON MINING ACTIVITY

During the past few months there has been a considerable amount of small-scale gold placer mining in southwestern Oregon. Most of this work is done by individuals using portable equipment to extract nuggets from small gravel deposits in the stream beds.

Mining companies continue to show interest in exploring for large deposits containing gold, silver, and copper. Ranchers Exploration and Development Corp. is conducting an exploration drilling program on the copper prospects near Bolivar Mountain northwest of Grants Pass. This mineralized area has been known for many years, but to date no one has been successful in outlining a sufficiently large ore body to warrant development.

American Selco, Inc. is drilling on the old Turner-Albright copper deposit in southwestern Josephine County. A small amount of gold was produced at the Turner-Albright property many years ago, and if the price of copper goes up and sufficient tonnage is discovered the mine may be reactivated.

Interest remains high in exploration for and development of nickel in the extensive areas of ultramafic rock. Chromite is also receiving attention by mining companies in southwestern Oregon.

* * * * *

HAVE YOU FOUND A METEORITE?

The Oregon Museum of Science and Industry (OMSI) at Portland and the Center for Meteorite Studies at the Arizona State University in Tempe, Arizona 85281 are cooperating in a program to facilitate the discovery of meteorites in the Pacific Northwest's unexplored meteorite areas and also to lend assistance in such discovery all across the nation. Meteorites are still occasionally dropping at random from the skies today, just as they have for an enormous length of time in the past. As these fragments come from remote regions in outer space where they have been in a condition of cosmic preservation for thousands of millions of years, the strange pieces of sky stone and iron offer scientists much information about their history and origin, and in a related way, also information about the history and origin of the solar system and of the earth. Thus meteorites provide valuable research material as well as being interesting relics for museum display or a rockhound's cabinet.

If you are fortunate enough to find a meteorite, notify OMSI or the Oregon Department of Geology and Mineral Industries.

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AVAILABLE PUBLICATIONS

(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

26. Soil: Its origin, destruction, preservation, 1944: Twenhofel	\$0.45
33. Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35. Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin	3.00
36. Papers on Tertiary foraminifera: Cushman, Stewart & Stewart. vol. 1-\$1.00; vol. 2-	1.25
39. Geology and mineralization of Morning mine region, 1948: Allen and Thayer	1.00
44. Bibliography (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere.	1.00
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00
52. Chromite in southwestern Oregon, 1961: Ramp	5.00
53. Bibliography (3rd suppl.) geology and mineral resources of Oregon, 1962: Steere, Owen	3.00
57. Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
60. Engineering geology of Tualatin Valley region, 1967: Schlicker and Deacon	7.50
61. Gold and silver in Oregon, 1968: Brooks and Ramp	7.50
62. Andesite Conference Guidebook, 1968: Dole	3.50
64. Geology, mineral, and water resources of Oregon, 1969	3.00
65. Proceedings of the Andesite Conference, 1969: McBirney, editor (photocopy)	10.00
66. Geology and mineral resources of Klamath and Lake Counties, 1970.	6.50
67. Bibliography (4th suppl.) geology and mineral industries, 1970: Roberts	3.00
68. Seventeenth biennial report of the Department, 1968-1970	1.00
69. Geology of the southwestern Oregon Coast, 1971: Dott	4.00
70. Geologic formations of western Oregon, 1971: Beaulieu	2.00
71. Geology of selected lava tubes in the Bend area, 1971: Greeley	2.50
72. Geology of Mitchell quadrangle, Wheeler County, 1972: Oles and Enlows	3.00
73. Geologic formations of eastern Oregon, 1972: Beaulieu	2.00
75. Geology, mineral resources of Douglas County, 1972: Ramp	3.00
76. Eighteenth biennial report of the Department, 1970-1972	1.00
77. Geologic field trips in northern Oregon and southern Washington, 1973.	5.00
78. Bibliography (5th suppl.) geology and mineral industries, 1973: Roberts and others	3.00
79. Environmental geology inland Tillamook Clatsop Counties, 1973: Beaulieu	7.00
80. Geology and mineral resources of Coos County, 1973: Baldwin and others	6.00
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00
82. Geol. Hazards of Bull Run Watershed, Mult. Clackamas Counties, 1974: Beaulieu	6.50
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00
84. Environmental geology of western Linn Co., 1974: Beaulieu and others.	12.00
85. Environmental geology of coastal Lane Co., 1974: Schlicker and others	12.00
86. Nineteenth biennial report of the Department, 1972-1974	1.00
87. Environmental geology of western Coos and Douglas Counties, Oregon, 1975	in press
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	in press

GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck \$2.00; mailed -	2.50
Geologic map of Oregon (12" x 9"), 1969: Walker and King	0.25
Geologic map of Albany quadrangle, Oregon, 1953: Allison (from Bulletin 37)	1.00
Geologic map of Galice quadrangle, Oregon, 1953: Wells and Walker	1.50
Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts	1.50
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for compiling this information will be appreciated.

SOME RADIOCARBON DATES IN SURFICIAL DEPOSITS OF THE PORTLAND AREA

Paul E. Hammond
Department of Earth Sciences, Portland State University

Five samples of carbonized wood fragments were obtained from borehole drillings by local engineering firms. Two samples were obtained from a borehole located near the corner of S.W. Barnes and Miller Roads atop the West Hills. One sample was taken in silty clay at 730 feet (222.5 m) above sea level, giving an age of greater than 40,000 years. The second sample was taken from the same borehole in scoria of Boring Lava at 725 feet (221 m) above sea level. The age is also greater than 40,000 years. These dates indicate that Boring Lava volcanism occurred here more than 40,000 years ago, and that at least part of the volcanic deposits in this area were covered by sediments more than 40,000 years ago.

The third sample was taken at 17 to 18.5 feet (5.2 to 5.6 m) below sea level in a borehole from a dock along the west bank of the Willamette River north of Linnton. The sample was in gray silt and gives an age of $4,800 \pm 100$ years ago.

The fourth and fifth samples were taken from another borehole nearby on the bank. The fourth, in similar gray silt, at 27 to $28\frac{1}{2}$ feet (8.2 to 8.7 m) below sea level, gave an age of $5,420 \pm 100$ years ago. The fifth, of special interest because it was obtained from a thin layer of volcanic ash at 42 to $43\frac{1}{2}$ feet (12.8 to 13.3 m) below sea level, gives an age of $6,490 \pm 100$ years ago. This layer of ash may be from the climactic eruption of Mount Mazama dated variously as about 7,000 years ago (Kittleman, 1973, p. 2950) or 6,600 years ago (Fryxell, 1965, p. 1288), but because the radiocarbon analysis obtained for this ash indicates a younger age of about 100 or more years, possible correlation of the ash layer with Mazama or other Cascade volcanic eruptions must await petrographic analysis.

The ages of the last three samples reveal the youthfulness of the sedimentary filling in the Portland basin. The deepest sample has the oldest age and the shallower samples have progressively younger ages, indicating a gradual filling of the basin. If the assumption is made that the sediments were deposited at a level near the average elevation of the stream surface and not in a deep pool within the stream channel, it can be surmised that

(1) the Portland basin has been subsiding during the past 5,000 or more years, (2) the sediments have been compacting, or (3) sea level has been rising during the same period of time, thus raising the level of the Columbia and Willamette Rivers in this area. If I assume that the ages of the samples represent sedimentary accumulation and/or subsidence, the average rate can be determined:

<u>Elevations of samples</u>	<u>Ages (years)</u>	<u>Rate</u>
17'-18.5' (5.2-5.6 m) below sea level	4,800 \pm 90	10' (3 m) per 620 years
27'-28.5' (8.2-8.7 m) below sea level	5,420 \pm 100	
42'-43.5' (12.8-13.3 m) below sea level	6,490 \pm 100	15' (4.6 m) per 1,070 years

Between the bottom two samples, 15 feet (4.6 m) of sediments accumulated in about 1,070 years, for an average of 0.17 inch (.43 cm) per year. Between the top two samples 10 feet (3 m) accumulated in about 620 years, for an average of 0.19 inch (0.49 cm) per year. Thus, until studies of the sediments can be made to determine their level of stream deposition, and additional dates on sediments at scattered locations at different depths can be obtained, the possible rate of accumulation and/or subsidence in the Portland basin could be about 0.18 inch (0.46 cm) per year.

Additional samples of both carbon material and basaltic rock obtained in boreholes are being requested by the Department of Earth Science, Portland State University.

Funding for dating the samples was provided by the Publication and Research Committee at Portland State University. The dating was determined at the Radiocarbon Dating Laboratory at the University of Washington. Samples were provided by Gennaro Avolio of CH₂M Hill and Dan Griswold of Foundation Sciences, who reviewed an early draft of this paper. Ken Robbins of Dames and Moore and Larry Kittleman of the University of Oregon are thanked for their discussions of the volcanic ash and its significance. A. W. Fairhall of the University of Washington is also thanked for the analyses and his review of the paper.

References

- Fryxell, Roald, 1965, Mazama and Glacier Peak volcanic ash (layers): relative ages: *Science*, v. 147, p. 1288-1290.
 Kittleman, L. R., 1973, Mineralogy, correlation, and grain-size distributions of Mazama tephra and other post-glacial pyroclastic layers, Pacific Northwest: *Geol. Soc. America Bull.*, v. 84, p. 2957-2980.

* * * * *

FIBERS FROM BASALT

Basalt covering large areas of Washington, Oregon, and Idaho could provide the raw material for a profitable new Northwest industry, according to Dr. Richard Dailey, Associate Professor of Economics and Director of the University of Idaho's Center of Business Development and Research. His findings are based on cooperative research between the University and Washington State University. Basalt fibers can be manufactured economically, Dr. Dailey states, and are superior in many applications to more conventional materials, such as glass fiber, rock wool, or asbestos.

Experiments showed that the fibers form easily in a temperature range of 1300° to 1370°C. The finest fibers had a silk-like sheen and were golden brown, soft, and flexible enough to be spun and woven into fabrics. European and Russian reports show that basalt fiber products can almost entirely replace glass fiber and asbestos products.

Dailey believes that the basalt fibers could wholesale for less than 20 cents per pound. By comparison, textile glass fibers average 44 cents per pound, wool glass fibers run 29 cents and various types of asbestos fibers range from 12 to 51 cents. Further research at the two schools will be directed toward applications of the basalt fibers.

A copy of the report "Economic Criteria for Producing Basalt Fibers in the Pacific Northwest," by Dean Wullenwaber and Richard T. Dailey may be consulted in the Oregon Department of Geology and Mineral Industries library in Portland.

* * * * *

OIL AND GAS WELL RECORDS RELEASED

The Department released to open file on September 1, 1975 all the well records on the Standard Oil Company "Blue Mountain Unit No. 1." The hole was drilled in the summer of 1973 to a total depth of 8,414 feet. The well was located in the NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 34, T. 37 S., R. 41 E., Malheur County, approximately 30 miles north of McDermitt, Nevada and 4 miles west of U.S. Highway 95.

* * * * *

GEOHERMAL WELL RECORDS TO BE RELEASED

The Department will release to open file on November 15, 1975 all well records on the Gulf Oil Company Favell-Utley No. 1 geothermal drilling in Lake County. The hole was drilled in the NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 17, T. 39 S., R. 20 E., approximately 1 $\frac{1}{2}$ miles south of Hunters Hot Spring. Total depth reached in the drilling was 5,440 feet.

* * * * *

OUR MINERAL SUPPLY IN JEOPARDY

The mineral account in America's land bank is in danger of becoming overdrawn, according to a study on withdrawals of Federal land from mining and mineral leasing just completed by two Interior Department employees.

The study is a bombshell, although it was completed by the two volunteer researchers on their own time and effort over an 18-month period and is strictly their own independent survey. [See table on opposite page.] It is not backed officially or unofficially by the Interior Department.

Gary Bennethum, staff assistant to the Assistant Secretary of Interior for Land and Water Resources, and L. Courtland Lee, a geologist in the Division of Mineral Resources of the Bureau of Land Management, have made an in-depth survey of withdrawals vis-a-vis mining and mineral leasing laws.

Their conclusions are that:

The Federal agencies have "firmly withdrawn nearly 400 million acres from the operation of the (1872 Hardrock) Mining Law and over 500 million acres" of Federal land from the mineral leasing laws. "In addition, over 100 million acres for the mining law and 70 million acres for the mineral leasing laws are encumbered or are being managed in such a way as to constitute a de facto withdrawal from minerals development."

"In 1968 only about 17 percent of the 742.3 million acres of public domain was withdrawn from operation of the 1872 Mining Law" which is applicable to public domain lands which never passed out of Federal ownership. "In 1974 approximately 53 percent of our original assets were withdrawn from the mining law. An additional 14 percent was included in de facto withdrawals....In 1974 the total acreage completely or partially withdrawn from the mining law amounted to 67 percent, or two-thirds of all public lands. What is perhaps even more alarming is the fact that this situation has occurred without the knowledge of the government."

Even more Federal land has been withdrawn from mineral leasing. "In 1968 about 17 percent of the 924.2 million acres" of Federal land "theoretically available was withdrawn from the leasing laws. Another 63 million acres were encumbered by existing leases, mostly for oil and gas development....Between 1968 and 1974 the situation for mineral leasing changed dramatically. Surface managing agencies developed and implemented land-use planning systems. Also significant new legislation was enacted which severely impacted the availability of lands for mineral leasing. The result is that as of 1974, 64 percent of Federal lands had been withdrawn from our mineral leasing account. Another 9 percent was restricted by already existing leases." So, overall, 73 percent of all Federal land was totally or partially withdrawn from operation of the mineral leasing laws by 1974.

"One of the major reasons this situation has occurred is the lack of any mechanism for assessing the cumulative impact of thousands of discrete or separate withdrawal actions. Each interest group working to have more land withdrawn does not consider the cumulative impact of its and other groups'

Federal Lands Excluded from Mineral Exploration and Development, 1974 (in millions of acres)

165

<u>Under 1872 Hard-Rock Mining Law</u>	
Alaska Native Claims Act	249.6
U.S. Forest Service roadless areas	55.9
Military	41.3
State selections, pending state selections, and unperfected entries	25.6
BLM roadless study areas	19.2
Wildlife refuges	15.3
Power site withdrawals	15.2
National Park System	14.6
National Wilderness System	10.7
Reclamation	5.7
BLM primitive areas (all types)	5.6
Utility corridors	5.35
Indian purposes	4.2
U.S. Forest Service proposed wilderness	3.8
Oil shale withdrawals	3.7
Alaska wildlife ranges	3.3
Proposed withdrawals	2.6
Recreation	1.9
Atomic Energy Commission	1.4
BLM Classification Act	0.7
Wild and Scenic Rivers	0.5
Small Tract Act	0.5
Natural areas	0.3
Miscellaneous	7.6
Total closed to mining under 1872 law	495.
Total theoretically open*	247.

<u>Under mineral leasing laws</u>	
Alaska Native Claims Act	249.6
U.S. Forest Service roadless areas	55.9
Military	48.1
Wildlife refuges	28.1
State selections, pending state selections, and unperfected entries	25.6
National Park System	24.6
BLM roadless study areas	19.2
Power site withdrawals	15.2
National Wilderness System	11.6
BLM primitive areas (all types)	5.6
Utility corridor in Alaska	5.3
U.S. Forest Service primitive areas	3.8
Oil shale	3.7
Proposed withdrawals	1.2
TVA acquired land	0.9
Indian purposes	0.8
Atomic Energy Commission	0.7
Wild and Scenic Rivers	0.5
Oil reserve buffer zone	0.1
Miscellaneous	26.
Closed to leasing, subtotal	526.
Acreage already under lease	73.8
Total closed to new leasing	599.8
Total theoretically open**	224.4

*Includes land under lease and 10 million mining claims

**Coal leasing now suspended on Federal lands

successful efforts....Since the size of the total (mineral) account has been assumed to be limitless and since no overall accounting is kept, withdrawals have been encouraged with little regard for their cumulative effect."

"We think some attention will have to be paid to the trend toward accelerated withdrawals because it seriously erodes the long-range mineral position of this country. It affects our economy, our ability to protect jobs, and it is forcing American industry to look elsewhere for minerals. It makes us vulnerable to mineral cartels like the OPEC oil cartel."

(From Western Resources Wrap-up, Series XI, No. 35, Aug. 28, 1975)

* * * * *

BLM RESUMES ACTION ON OIL AND GAS LEASE APPLICATIONS

Funds have been allocated this fiscal year for the Bureau of Land Management to start processing the backlog of oil and gas leasing applications in Oregon and Washington that have been on file since November 1971.

Standard BLM procedure is to conduct an environmental analysis prior to the issuance of a lease and attach as conditions of the lease detailed stipulations to insure the protection of the environment. In addition, before operations commence, detailed plans must be submitted by the lessee and approved.

An environmental assessment recently was completed by the Salem BLM district for the Columbia planning unit, almost all of which is located in Columbia County. As a result of this assessment, the District Manager recommended that, with the stipulated safeguards, leasing should proceed in this planning unit. Issuance of Federal leases should encourage Reichhold Energy Corp. to drill its acreage in Columbia County this year.

* * * * *

ORE BIN INDEX REVISED AND ENLARGED

A 50-page author and subject index for The ORE BIN covering the period 1950 through 1974 has been published by the Department as Miscellaneous Paper 13, Revised. The new index includes the work done for the original 1950-1969 version plus additional entries from that period and the more recent literature since 1969. The new edition was prepared by Nora T. Musotto and edited by Carol S. Brookhyser.

"Index to The ORE BIN, 1950-1974," Miscellaneous Paper 13, Rev., is for sale by the Department at its Portland, Baker, and Grants Pass offices for \$1.50.

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GEOLOGY AND MARINE ARCHAEOLOGY

James S. White
Oregon Department of Fish and Wildlife

A recent article in Cosmopolitan magazine described treasure diving as a combination of history, meteorology, shipbuilding, metallurgy, sociology, weapons, and chemistry. They forgot geology. In History Under the Sea, the Smithsonian's publication on marine archaeology, Mendel Peterson discusses digging out an underwater wreck, removing the "overburden," including the ballast. Again geology is forgotten.

Why geology? As a means of tracing the vessel. When sailing ships (and others) were built, rocks were placed in the bilge area to weight and hold the ship upright. Ships without heavy cargo needed more weight, ships with freight to haul had less ballast. So - ships were initially ballasted with local rocks, then in their travels some stones were dropped off, some gained. In other words, ballast rock in the worm-eaten, rotted hull can give the investigator clues to where the ship was built and where it went, just as dirt and lint in trouser cuffs and in shoes give crime-lab detectives clues to where the suspect has been.

As an example, the lumber schooners that plied the Pacific Coast in the late 19th century were largely ballasted with local basalt, normally quarried from a convenient location. A wreck at Seabeck, Washington and another in Gig Harbor, Washington were ballasted with quarried basalt, easy enough for a geologist to recognize.

But why do we need a geologist? Because both of these wrecks are nearly devoid of remaining wood - a mere hundred years (more or less, depending on the type of wood) of teredos and rot have completely removed it. The iron work is also completely oxidized, not enough iron remaining to activate a metal detector. Brass pins and spikes may remain, but they were not generally used before 1850. Nothing comparable, however, happens to the rock ballast.

Another wreck lies on the bottom near Manzanita, Oregon. Of this one, about all that remains is the pattern of ballast rock. Unlike the old schooners' ballast, this ship's rocks are rounded, picked up from some beach or river bed. This was ballasting practice prior to about 1820, when it seems to have been abandoned in favor of quarried rock whose square corners helped to prevent shifting in rough seas.

Geology establishes that the Manzanita wreck is not a local vessel, for the ballast* found low in the pile (and thus most likely original ballast,

*Some of the ballast rocks are on display in the museum of the Dept. of Geology and Mineral Industries, 10th floor, State Office Building, Portland.



Some ballast rocks from the Manzanita wreck.

since to remove all ballast is to invite capsizing) includes quantities of gneiss and quartzite, both uncommon in the port areas of western United States but common rocks of Europe. Other rocks unfamiliar to our Pacific shores but possibly from Mexico, such as dacite, suggest a stop along the way.

Eventually the excavation of the Manzanita site may reveal glassware, dishes, or other traceable artifacts. However, geology has paved the way by establishing that the pattern of rocks in the form of a ship is not a natural phenomenon and that the origin of the wreck is of sufficient interest to warrant further study.

* * * * *

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OPIE DILLDOCK IS BACK

A geographic feature in the Cascade Mountains of Oregon has now been officially named Opie Dilldock Pass in honor of the popular newspaper cartoon character of the early 1900's, the U.S. Board on Geographic Names announced.

Donald J. Orth, a geographic names expert with the U.S. Geological Survey, and executive secretary of the Board's Domestic Names Committee, said that final approval of the name for use on all Federal maps and other publications ends a long period of confusion concerning the name of the Pass.

"Over the years," Orth said, "the name of the Pass has been spelled several different ways on State and Federal maps and reports. Adding to the difficulties, the source of the name has been variously attributed to the 'opodeldoc' liniment of a 14th century alchemist, to a more recent camphor and soap liniment known as 'Knight's Opedildock,' and to the legend of an early explorer named Obie Dilldock who allegedly was buried near the Pass."

"Last December," Orth said, "the Oregon Geographic Names Board officially adopted Opie Dilldock, the cartoon character, as the original source and proper spelling for State use. At the same time, the Oregon Board asked the U.S. Board to adopt the same usage for Federal publications. At its July meeting, Opie Dilldock was one of 110 names formally adopted for use on Federal maps and other publications."

Part of the Oregon Skyline Trail, Opie Dilldock Pass is located in the Willamette National Forest of central Oregon, about 15 miles southwest of Sisters, Oregon, and provides passage for hikers between a jumbled lava rock field and the Three Sisters mountain range.

The comic strip "Old Opie Dilldock," the work of Frank M. Howarth, was syndicated by the Chicago Tribune from 1907 to 1914.

"Opie Dilldock," said Orth, "was noted for telling tall tales that had him escaping from nearly impossible situations in the nick of time. Perhaps the U.S. Forest Service rangers who named the Pass in 1932 felt that the small passageway through the lava rock field provided a typical last-minute escape route from a tight situation."

First created in 1890, the interagency Board on Geographic Names shares responsibility with the Secretary of the Department of the Interior to establish and maintain uniform geographic name usage throughout the Federal Government. The Board serves as the central authority for geographic name proposals and inquiries and develops procedures to be followed in standardizing domestic and foreign names as well as underseas and extra-terrestrial feature names. The Board generally does not propose name changes, usually following a policy of recognizing present-day local usage or preference. The U.S. Geological Survey, the nation's largest civilian mapping agency, provides staff support for the Board's Domestic Names Committee.

* * * * *

EVERY OREGONIAN'S SHARE OF AGGREGATE

Ralph S. Mason

Joe Pungle, his wife, and two children woke up one morning to find a 69-ton pile of sand and gravel and stone dumped on their driveway. On top of the pile was a note which read: "Dear Joe, here is your fair share of the aggregates which were produced in Oregon this year."

While Joe and his family were pondering what to do with this small mountain of industrial mineral, a truck from the State Highway Department drove up. Somebody had goofed, the driver said; he was to pick up that portion of the load which actually should have been delivered to the State Highway job a mile away. Right behind the Highway truck came two more, one from the County Road Department and one from the City Streets Division. Both claimed their fair share and drove off.

Breakfast for the Pungles was a shambles. Seven contractors, ranging from a local stonemason to a general contractor, dropped by with their pickups and hauled away various amounts of aggregate destined for a driveway, a patio, a fireplace, some concrete block, a landfill, a landscape job, and sidewalk repair.

By this time the pile had shrunk considerably. After a man from a local stoneyard took a load of cobbles and an employee from the railroad picked up some engine sand needed to keep the locomotive wheels from spinning on slippery rails, the pile was nearly gone.

About this time Mrs. Pungle selected several nice rounded stones for her aquarium, and a workman from a foundry drove up and took two barrelsful of sandblast sand. This left only a few shovelful of coarse sand, which Joe swept up carefully and put in a bucket for use on his driveway some icy morning.

The driveway was now clear, and as Joe Pungle drove to work, he understood for the first time the many uses of plain old sand and gravel and common rock. He even waved at the driver of a gravel truck he passed on the new concrete overpass.

* * * * *

ALLEN GOES TO NEVADA BUREAU OF MINES

John Eliot Allen, former head of Department of Earth Sciences at Portland State University and more recently Professor Emeritus at that University, has joined the staff of the Nevada Bureau of Mines and Geology, University of Nevada, Reno, where he will serve as Geologist on Special Projects.

* * * * *

LET'S GET INTO THE SWING

The men who drill for oil and natural gas from offshore platforms don't go to work on the 8:10. Instead, many of them swing up on baskets from bobbing crew boats, for seven days at a stretch. This, of course, helps the rest of us get to work in more conventional ways - by trains, buses and cars.

Unfortunately, given America's critical need for domestically produced oil and natural gas, there isn't enough offshore drilling going on. Federal and State authorities have dragged their feet on offering new acreage for exploration. As a result, offshore production is confined essentially to the Gulf of Mexico, a small area off the West Coast, and a small area off Alaska. There hasn't been a single well drilled off the U.S. Atlantic Coast.

America's Outer Continental Shelf, lying up to 600 feet beneath the sea, is an area of huge oil and gas potential. Covering 875,000 square miles, it is equal in size to all the states east of the Mississippi. While the whole shelf is not prospective petroleum acreage, the U.S. Geological Survey estimates undiscovered offshore oil reserves to be 65 to 130 billion barrels; the gas, 395 to 790 trillion cubic feet. Even Mobil's somewhat more conservative estimates indicate there's half as much oil and gas under the shelf as the U.S. has produced in its entire history, on and offshore.

Estimates are only educated guesses, of course, until there's actual drilling. But experience in the Gulf of Mexico encourages optimism. Offshore production, mostly in the Gulf, now accounts for some 16 percent of all U.S. oil production - about 1.8 million barrels a day - and for nearly 20 percent of the natural gas produced in this country.

Yet despite the promise of the offshore areas, only about 2 percent of the shelf has been leased by Washington for exploration.

More offshore drilling opportunities must be provided. And soon. For lead times in offshore petroleum development are long. From the time an offshore lease sale is announced, it can take four to seven years to find a field, delineate it, and bring it into commercial production, even in the relatively familiar waters of the Gulf. In new areas, such as the Atlantic, this process may take even longer.

America cannot afford further delay in developing this potential energy resource.

(reprinted from YEA '75, Mobil Oil Corp.)

* * * * *

NORTHWEST MINING ASSOCIATION TO MEET IN DECEMBER

The Northwest Mining Association will hold its 81st annual convention December 5-7 at the Davenport Hotel in Spokane. The Association encompasses Alaska, Idaho, Montana, Oregon, Washington, the provinces of British Columbia, Alberta, and the Yukon and Northwest Territories.

* * * * *

NATION'S GEOTHERMAL RESOURCES ASSESSED

"Assessment of Geothermal Resources of the United States - 1975," edited by D. G. White and D. L. Williams, and published as U.S.G.S. Circular 726, may be obtained free upon request from the U.S. Geological Survey, Branch of Distribution, 1200 South Eads Street, Arlington, VA 22202.

The report shows that natural heat is contained in rocks beneath the surface of all 50 states, and that huge quantities exist in "hot spots" in the western states and in some parts of the Gulf Coast. According to Dr. V. E. McKelvey, U.S.G.S. Director, the assessment shows that geothermal energy is an extremely important alternative energy source and that its potential is large enough to justify exploration, technological research, and development.

* * * * *

REVISED U.S. COAL RESOURCES REPORTED

Coal resources of 1,731 billion tons are known and 2,237 billion tons are believed to be present in the United States, according to U.S.G.S. Bulletin 1412, "Coal Resources of the United States, January 1, 1974," by Paul Averitt. The Bulletin is for sale for \$1.60 from U.S.G.S. Branch of Distribution, 1200 South Eads St., Arlington, VA 22202.

* * * * *

A PIPELINE AND ARCHAEOLOGY

The trans-Alaska pipeline being built to bring oil 800 miles across Alaska is the springboard of a major archaeological project that would not have been possible, or at least not as intensive, without the massive construction project. The route of the pipeline, from the North Slope to the southern ice-free port of Valdez, is an ideal area for a major "dig" because it cuts right across the suspected route of ancient man's migration to the New World. Cooperation between pipeliners and archaeologists has resulted in an agreement whereby the archaeologists get first crack at the land along the right-of-way, with major digging being done by construction crews. The pipeline crews also undergo periodic briefings by the scientists on what to look for and how it applies to their work. In two summers' time, nearly 300 important prehistoric sites and more than 20,000 relics have been discovered. By normal procedures, the amount of work accomplished would have taken at least 5 full years. One important theory coming from the project's results is that American Indians and Eskimos may be descended from common ancestors, rather than from separate cultures, as was previously believed.

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* * * * *

AVAILABLE PUBLICATIONS

(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

26. Soil: Its origin, destruction, preservation, 1944: Twenhofel.	\$0.45
33. Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35. Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin	3.00
36. Papers on Tertiary foraminifera: Cushman, Stewart & Stewart.	vol. 2-1.25
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57. Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
60. Engineering geology of Tualatin Valley region, 1967: Schlicker and Deacon	7.50
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84. Environmental geology of western Linn Co., 1974: Beaulieu and others.	12.00
85. Environmental geology of coastal Lane Co., 1974: Schlicker and others	12.00
86. Nineteenth biennial report of the Department, 1972-1974	1.00
87. Environmental geology of western Coos and Douglas Counties, Oregon, 1975	in press
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	in press

GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck \$2.00; mailed -	2.50
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GMS-3: Preliminary geologic map, Durkee quadrangle, Oregon, 1967: Prostka	2.00
GMS-4: Gravity maps, Oregon onshore & offshore; [set only]: at counter \$3.00, mailed	3.50
GMS-5: Geology of the Powers quadrangle, 1971: Baldwin and Hess	2.00
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- 3. Prelim. identifications of foraminifera, General Petroleum Long Bell No. 1 well . . . 2.00
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- Landforms of Oregon: a physiographic sketch (17" x 22"), 1941 . . . 0.25
- Mining claims (State laws governing quartz and placer claims) . . . 0.50
- Oregon base map (22" x 30"). . . 0.50
- Geologic time chart for Oregon, 1961 . . . free
- Postcard - geology of Oregon, in color . . . 10¢ each; 3 - 25¢; 7 - 50¢; 15 - 1.00
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APPRAISING VOLCANIC HAZARDS OF THE CASCADE RANGE*

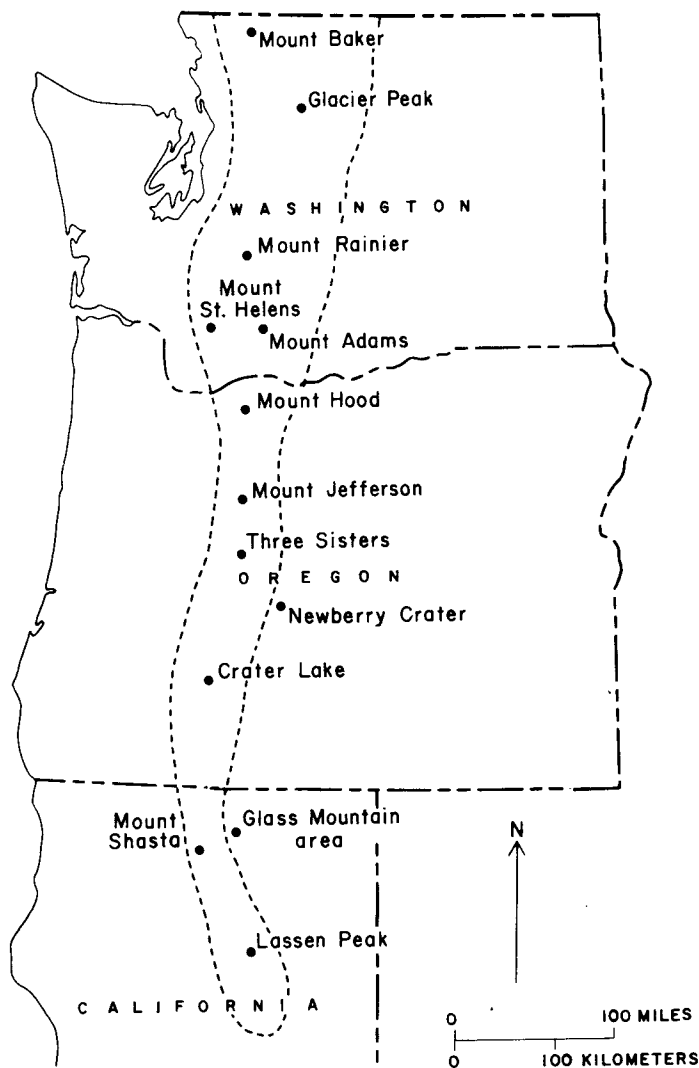
Dwight R. Crandell and Donal R. Mullineaux
U.S. Geological Survey, Denver, Colorado

The hazard to life and property in the western United States from volcanoes is small by comparison with that from earthquakes, storms, and floods. Nevertheless, the hazard is real and warrants concern. If volcanic events similar to the most violent ones during the last 5,000 years at each of two volcanoes occurred today without warning, thousands of people could be affected. An eruption at Mount St. Helens in Washington could endanger 40,000 persons, and one at Mount Rainier, Washington could affect as many as 50,000. The number of people at risk near these and other volcanoes will surely increase during the next century. Such long-range expectations should concern us now because patterns of land use adopted today will become increasingly difficult to change in the future.

Hazards Appraisals and Predictions of Eruptions

Anticipation of the effects of eruptions at specific volcanoes should be distinguished from prediction of the eruptions themselves. Prediction techniques now being used on volcanoes throughout the world include a wide variety of geophysical and geochemical methods. In the United States, the seismicity of a few volcanoes is being monitored by seismometers and seismic-event counters. Their thermal state is being observed by aerial and ground-based infrared studies and by continuous recording of fumarole temperatures. Possible changes in the surface of the ground on and adjacent to some volcanoes are being monitored by geodetic measurements and tiltmeters. Some of the monitoring techniques now being utilized at the Cascade volcanoes, however, are on an experimental basis rather than being fully operational.

* Adapted from: Appraising Volcanic Hazards of the Cascade Range of the Northwestern U.S., *Earthquake Inform. Bull.*, v. 6, no. 5, p. 3-10, Sept.-Oct. 1974; and Technique and Rationale of Volcanic-Hazards Appraisals in the Cascade Range, Northwestern U.S., *Environ. Geol.*, v. 1, p. 23-32, New York, Springer-Verlag.



Major volcanoes in and near the Cascade Range.

A principal objective of monitoring is to save lives by warning of an impending eruption. Monitoring techniques are all based on the detection of events that occur before eruptions, and their success depends on detection in time to evacuate an endangered populace. Although premonitory events have been detected at some volcanoes, the lack of recent activity precludes our knowing what events and which monitoring techniques will provide the most reliable warning at a specific volcano; furthermore, geophysical monitoring does not indicate the kinds or scale of eruptions to expect, or the areas that might be affected by future eruptions. And, in general, by the

time premonitory events have been detected, it is too late to prevent property losses in areas that are subsequently affected by eruptions. Consequently monitoring alone is of little value in deciding which long-range uses of land around a volcano are compatible with the potential risk. This problem can be solved only by obtaining detailed knowledge of how the volcanoes have been behaving and the extent of areas affected by them in the past. This knowledge can also be used in determining what actions should be taken to prevent or reduce loss of lives or property after premonitory events have been recognized, as well as during the initial stages of an eruption. Both monitoring and volcanic hazards appraisals are important and complement one another, but they apply to different aspects of the volcanic risk problem.

Technique of Volcanic Hazards Appraisals

A volcanic hazards appraisal includes a forecast of the kinds of eruptions that can be expected, an anticipation of volcanic events that will endanger human lives and property, and the location of areas that can be affected by the events. The information necessary to achieve these objectives is obtained from four closely interrelated studies: genetic, stratigraphic, chronologic, and cartographic.

Genesis

The analysis of a volcano's behavior is based on a knowledge of the ways in which various products of volcanism originated. Determination of

Table 1. A summary of recent activity of some major volcanoes in the Cascade Range and adjacent areas. Population at risk is that which could be directly affected by an eruption like the most catastrophic known of the last 12,000 years at that volcano

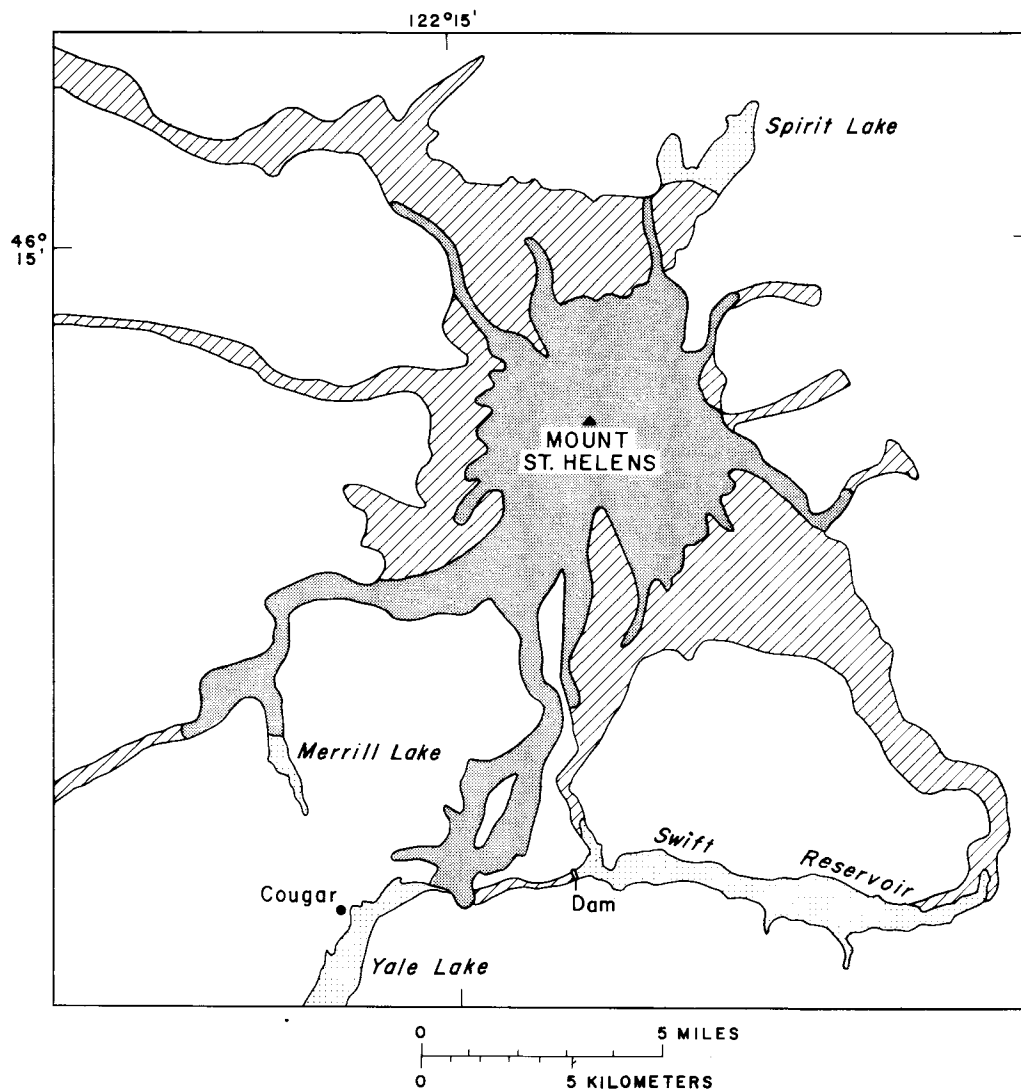
	Mt. Baker	Glacier Peak	Mt. Rainier	Mt. St. Helens	Mt. Adams	Mt. Hood	Mt. Jefferson	Three Sisters	Mt. Mazama (Crater Lake)	Newberry Volcano (Newberry Crater)	Mt. Shasta	Glass Mtn. area	Lassen Peak-Chaos Crags area
Active in historic time	X		X	X		X					?	?	X
Known products of eruptions, last 12,000 years:													
Lava flow	X		X	X	X	X	X	X	X	X	X	X	X
Tephra (airborne rock debris)	X	X	X	X		?		X	X	X	X	X	X
Pyroclastic flow		X	X	X					X		X		X
Mudflow	X	X	X	X	X	X					X		X
Estimated population at risk:													
More than 1,000	X		X	X		?			X		X		
Less than 1,000		?			X		X	X		X		X	?

the genesis of some kinds of volcanic deposits is probably the hardest part of the whole study. For example, coarse, poorly sorted and unstratified deposits of volcanic rock debris formed by glaciers and avalanches can be similar in appearance to deposits formed by hot pyroclastic flows and mudflows. Also, the fine-grained deposits formed by clouds of ash accompanying hot pyroclastic flows resemble tephra, volcanic material which has been erupted into the air and then carried away from a volcano by winds. It is important to distinguish between different modes of origin because each mode implies a different kind of potential hazard from future eruptions.

Stratigraphy

The stratigraphic aspect of the study of a specific volcano requires a decision as to what interval of its history will be most appropriate to examine in detail. The study should be extended back far enough in time to include a wide range of kinds of volcanic events. The history of Mount Rainier probably goes back at least a million years, but because events before the last major glaciation, which began about 25,000 years ago, are poorly recorded and difficult to date, the eruptive record of only the last 10,000 years has been studied. At Mount St. Helens the entire life of the volcano, which may have come into existence shortly before 38,000 years ago, is under study. The volcanic hazards appraisal now underway at Mount St. Helens will be based on the eruptive events of only the last 4,000 years, however, since

Table 2. Generalized stratigraphic sequences of the last 4,000 years which have been recognized on three sides of Mount St. Helens volcano			
Tephra deposit and age (years)	Southeast side	Southwest side	North side
	Lahars Lava flows	Pyroclastic flows	Lahars Lava flows
W (450)	Tephra W	Tephra W . . .	Tephra W
			Lava flows
B(1500-2500). . .	Lahars and tephra B . . .	Lahars Tephra B	Pyroclastic flows, lahars and tephra B
		Lava flow(s)	Lava flow(s)
P(2500-3000). . .	Pyroclastic flows,	Tephra P	Pyroclastic flows, lahars and tephra P
	lahars and tephra P		
Y(3000-4000) . . .	Pyroclastic flows,	Tephra Y	Tephra Y
	lahars and tephra Y		



Areas covered by lahars and pyroclastic flows (line pattern) and lava flows (gray) from Mount St. Helens during the last 4,000 years.

virtually the entire visible volcano was formed within this time and this period seems to have been preceded by a long interval of little or no activity. Furthermore, the behavior of the volcano is well documented by at least four major eruptive periods within the last 4,000 years, which included many tens of eruptive events.

An especially important aspect of a volcanic hazards appraisal is a detailed study of surficial deposits around a volcano. Surficial deposits provide information about a volcano's past behavior. The behavior pattern for volcanoes that have been inactive or rarely active during historic time can be reconstructed only by inferring various kinds of events from the volcanic deposits they created. A more complete record of eruptive activity can often be found beyond the flanks of a volcano rather than on the volcano itself where rocks as well as surficial deposits are readily removed by erosion or covered by the products of new eruptions. Thus, eruptive products which are easily transported from the volcano by wind, pyroclastic flows, mudflows, and river and deposited in more stable environments may provide the best record, and perhaps the only record, of a significant part of a volcano's history.

Rocks and surficial deposits of volcanic origin should not be studied to the exclusion of everything else. If a volcano is within a region of alpine glaciation, a knowledge of the extent of glaciers in late Pleistocene and Holocene time can be useful in establishing the ages of certain episodes of volcanism. Weathering profiles can approximately date volcanic deposits when they are compared with those on texturally and lithologically similar glacial deposits of known age in the same area. Intervals when there was no pyroclastic activity at a volcano can be recognized from weathering profiles and also from tephra-free sequences of deposits, such as peat, which are on the near downwind side of a volcano.

Chronology

Rocks and surficial deposits of volcanic origin can be relatively dated by their stratigraphic relation to one another and to glacial drift, by weathering profiles, and by geomorphic relations where deposits form successive terraces within a valley. These stratigraphic units can also be put into a framework of absolute time by means of radiocarbon age determinations. Charcoal, which can be used for radiocarbon dating, is abundant in many pyroclastic-flow deposits; wood is common in mudflows; organic material is often found interbedded with airfall tephra. Tree growth-rings have been used to date or limit the age of deposits as much as several hundred years old at Mount St. Helens and more than 700 years old at Mount Rainier. Lichen diameters are also being used for dating lava flows, mudflows, and avalanche deposits in unvegetated areas.

The importance of airfall tephra in establishing a chronologic framework for stratigraphic successions on all sides of a volcano cannot be over-



South side of Mount Rainier and Reflection Lake, Washington. The lake was formed about 5,000 years ago when a mudflow formed a natural dam.

emphasized. Once a recognizable tephra layer has been dated, it provides a time horizon wherever it can be found. The airfall tephra most useful for correlation purpose may be a product of a different volcano than the one being studied. For example, although there have been at least 11 pyroclastic eruptions at Mount Rainier during the last 10,000 years, the most useful layers for correlating stratigraphic sequences there were erupted by two other volcanoes. These layers are much more widely distributed and are of more consistent thickness and grain size than those from Mount Rainier.

Distribution of volcanic deposits

After a detailed knowledge about a volcano's recent behavior has been acquired, it is necessary to determine what areas have been affected by past eruptions in order to forecast the possible extent of similar phenomena in the future. This may be done by mapping the distribution of lava flows, tracing mudflows and pyroclastic-flow deposits down valleys, and determining the extent of airfall tephra. Future eruptions may not affect exactly the same areas in the same way and to the same degree, but a map of areas affected in the past can be used as a rough guide. From such a map of some deposits at Mount St. Helens we might infer that a significant potential hazard to property exists from lava flows within a distance of

about 15 km from the volcano, and a hazard to property and lives from pyroclastic flows within about the same distance. Further, mapping shows that a potential hazard from mudflows extends down valley floors for tens of kilometers, and a potential hazard from tephra fallout reaches many tens of kilometers downwind.

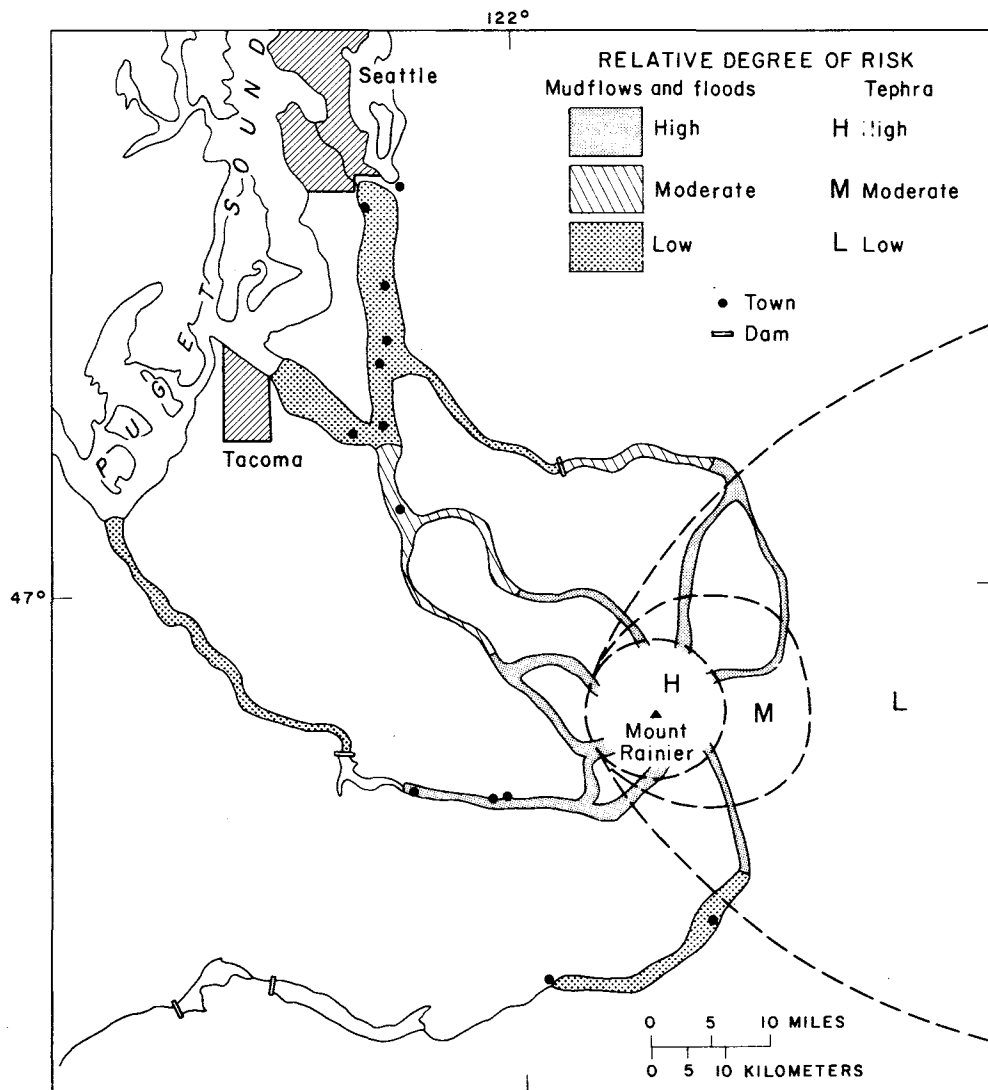
Risk Zones

Inferences like these lead to the preparation of a map on which zones of relative risk are defined. An assignment of the degree of risk is based not only on the past history of events affecting a specific area, but also on changes which have occurred at the volcano which might influence future events such as meteorological conditions, especially prevailing winds, and man-made changes such as dams and reservoirs. These factors must all be considered when analyzing what will most probably occur in the future and the risks that will result. A risk-zone map of the area near Mount Rainier shows that the greatest hazard on valley floors is from mudflows and floods. In each valley the risk generally decreases with increasing distance from the volcano and with increasing height above the valley floor in any part of the valley. At Mount Rainier, the record of postglacial eruptions suggests that tephra fallout is a significant hazard only very close to the volcano and that the degree of risk decreases abruptly in all directions except to the east, downwind from the volcano, and decreases fairly rapidly even in that direction.

Goals and Rationale

The eruptive behavior of volcanoes can be characterized, and the potential hazards defined from the four aspects of volcanic-hazards appraisals just described. Both kinds of information are important for planning optimum use of land around volcanoes. Defining zones of differing degrees of risk is a particularly troublesome problem. Time may show that the boundaries of the risk zones and the levels of risk within them are much overrated or underrated. Perhaps the greatest ultimate benefit of showing risk zones graphically will be to call attention to areas where some degree of risk exists, rather than to the specific degree of risk.

Forecasting future eruptive behavior of a volcano from the events of the past raises a fundamental question: How can we be sure that the volcano will not change its "life style"? It has been said that andesitic volcanoes typically become more explosive late in life. What assurance have we that the next eruption of Mount Rainier, for example, will be the same kind as has occurred repeatedly during the last 10,000 years, rather than a catastrophic Mount Mazama-type eruption which will destroy the volcano and devastate the entire adjacent region? Although it cannot be said that Mount Rainier will never be another Crater Lake, the possibility of such a



Relative degrees of potential hazard from tephra, mudflow, and floods which could result from an eruption of Mount Rainier.



Mount Hood from the east showing the canyons deeply eroded into the vast lava flows below Newton-Clark glacier. A late September picture.

violent eruption occurring within the next few centuries is so remote that it cannot be planned for either economically or pragmatically. Measures that would protect the public fully from such an eruption would require costly major changes in land use over a very large area of western Washington. It would be unrealistic to propose to the people and legislature of a State that they should prepare today for such an eruption. For one thing, we do not know which, if any, of the volcanoes will erupt in this manner. We believe that a more credible case can be made for preparing for the kinds of events which have occurred fairly often at a specific volcano, and which, therefore, are likely to occur there again. In the event that a catastrophic eruption does begin, the only solution probably will be a mass evacuation of the region.

The Cascade Range volcanoes have been so peaceful during the present century that there has been virtually no concern for potential volcanic hazards. As a result, dams and reservoirs have been built in valleys which have been repeatedly affected by large mudflows, pyroclastic flows, or lava flows in the very recent geologic past. No special provisions have been

made for the quick emptying of some of these reservoirs in the event of a volcanic eruption upstream. In other areas near volcanoes, new homes are being built on top of mudflow deposits no more than a few centuries old.

It is hoped that appraisals of volcanic hazards will provide information which will help responsible officials and planning agencies, as well as individuals, make informed decisions concerning the future use of land near volcanoes. This information should help people at various levels of government anticipate what problems will arise when the next eruption occurs. Plans can be made in advance for the necessary communications and warning systems, and for safely evacuating people from threatened areas. The ultimate objective is to minimize the risk to people and property from future eruptions.

* * * * *

REICHHOLD-NORTHWEST NATURAL GAS FINISH 1975 PROGRAM

Reichhold Energy Corp., Tacoma, Washington and Northwest Natural Gas Co. finished drilling four deep exploratory holes in October. The companies undertook a joint venture to search for oil and gas in western Oregon this past summer and if the geologic structures do not contain commercial hydrocarbon deposits, they will study the potential for underground storage of natural gas. Data on the exploratory drillings are contained below:

Permit No. 65 API 36-052-00004 NNG-Crown Zellerbach 1	NE $\frac{1}{4}$ sec. 22, 2S 10W Tillamook County	Abandoned at 5,557 feet
Permit No. 66 API 36-053-00021 NNG-Finn 1	SW $\frac{1}{4}$ sec. 17, 6S, 4W Polk County	Abandoned at 7,258 feet
Permit No. 67 API 36-047-00007 NNG-Merrill 1	SW $\frac{1}{4}$ sec. 24, 8S, 4 W Marion County	Abandoned at 5,282 feet
Permit No. 68 API 36-009-00006 NNG-Crown Zellerbach 2	NW $\frac{1}{4}$ sec. 8, 4N, 3W Columbia County	Abandoned at 5,805 feet

Well records on drilling in Oregon are required to be kept confidential for 2 years after completion or abandonment but then are opened to the public.

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IN MEMORIAM
Roscoe E. Stewart

Roscoe E. Stewart, former micropaleontologist with the Department, died in Portland, Oregon on Sunday, November 1, 1975, at the age of 84. He was employed by the Department in 1944 and retired in 1959 after 15 years of service. Roscoe Stewart and his wife, Katherine C., contributed much to the knowledge of West Coast micropaleontology.

He began his education at Northwestern University in Illinois in 1915. His schooling was interrupted by World War I when he served overseas as an officer in France and Germany. He resumed his education at the University of Chicago after returning home from the war and graduated with a B.S. degree in geology in 1923. Roscoe attended Columbia University, New York, where he studied micropaleontology. The following year he and his wife, Kay, studied under the renowned Dr. Joseph Cushman at the Cushman Laboratory in Sharon, Mass. Roscoe and Kay continued their paleontological studies at the University of Southern California and both received M.S. degrees from that school in 1935. This common interest, which began at the University of Chicago where they first met, was continued over the next three decades. They coauthored the Department's Bulletin 36, Papers on Tertiary Foraminifera, with Dr. Cushman, and Roscoe published several articles with the Department on micropaleontology.

Survivors include a daughter, Mary Jane (Mrs. Campbell) Wade, Charlottesville, Virginia.

* * * * *

COOS AND DOUGLAS COUNTIES ENVIRONMENTAL GEOLOGY

"Environmental Geology of Western Coos and Douglas Counties, Oregon," the latest of the Department's bulletins on environmental geology of Oregon counties, has been published as Bulletin 87. Authors are Dr. John D. Beau-lieu, Department stratigrapher and environmental geologist, and Dr. Paul W. Hughes, a consulting geologist.

The study area is the western half of Coos County and the northwestern-most corner of Douglas County extending east to Scottsburg. The report is written for the use of planners, engineers, and construction personnel, as well as the professional geologists and resource specialists. It discusses engineering geology, mineral resources, geologic hazards (wave and wind erosion, floods, tsunamis, storm surges, landslides, stream erosion, and earthquake potential), and geology of estuaries and relates these to land uses.

The 148-page report, including 16 maps in color and at a scale of 1:62,500, is available for \$9.00 at the Department offices in Portland, Baker, and Grants Pass.

* * * * *

PLAN FOR ISSUANCE OF EARTHQUAKE PREDICTIONS PROPOSED

For the first time, a Federal plan for issuance of earthquake predictions and warnings has been proposed for consideration by Federal, State, and local agencies. The plan was outlined in early November by Dr. V. E. McKelvey, Director of U.S.G.S., at a conference on earthquake warning and response.

McKelvey emphasized that although not now operational, a capability for reliable earthquake prediction can be expected to be developed in the near future.

"We are now entering an age," the U.S.G.S. Director said, "when scientific instruments are detecting geophysical signals that can be interpreted to forecast earthquake occurrence. Because of increasing optimism about reaching the long-sought goal of earthquake prediction, it is not premature to consider a plan to issue predictions."

"A prediction, as we are using it here," McKelvey explained, "is a statement that an earthquake will occur at a certain time and place, have a certain magnitude, and produce certain effects. A warning is a recommendation or order to take some defensive action, such as to reduce the water level in a reservoir or to evacuate a building."

In the proposed plan, the U.S. Geological Survey has the responsibility to issue a prediction, but local officials have the responsibility to issue a warning. The following are some key elements in the proposed plan:

- Scientists of the USGS Office of Earthquake Studies receive and interpret data from field instruments and are the starting point for contact with the public.

- A peer review will be provided by the USGS Earthquake Prediction Council composed of five to ten Survey scientists with experience covering all aspects of earthquake prediction technology, plus scientists from outside the USGS with expertise to contribute.

- The Earthquake Prediction Council's report would go to USGS headquarters, Reston, Va., where the decision would be made on issuing a prediction.

- USGS headquarters would issue a statement to the Governor of the State potentially affected, to Federal agencies with responsibilities for disaster preparedness and response, and to the public.

- The Governor's office would alert the State office(s) concerned with disaster response and might also call together his own group of experts to evaluate the evidence.

Scientists not funded by the USGS who find evidence of an earthquake precursor are not specifically considered in this plan. "We believe, however," McKelvey said, "that these other scientists would discuss their data with either the USGS Council or the State review group."

* * * * *

THESES ON OREGON GEOLOGY ADDED TO LIBRARY

The following unpublished master's theses and doctoral dissertations have been added to the Department's library (not available on loan, however):

- Armentrout, John M., 1973, Molluscan paleontology and biostratigraphy of the Lincoln Creek Formation, late Eocene-Oligocene, s.w. Washington. Univ. Wash. doctoral.
- Avolio, Gennaro W., 1973, Granulometric analysis of recent sediments of Tillamook Bay, Oregon. PSU master's.
- Cordell, Donald A., 1973, Geology of the Pedro Mountain tonalite and associated rocks, n.e. Oregon. Univ. Oregon master's.
- Dingus, Delmar D., 1974, The nature and properties of amorphous colloids formed from Mazama tephra. OSU doctoral.
- Doak, Wm. H., 1972, Cation retention and solute transport related to porosity of pumiceous solids. OSU doctoral.
- Donato, Mary M., 1975, The geology and petrology of a portion of the Ashland Pluton, Jackson County, Oregon. Univ. Oregon master's.
- Dudas, Marvin J., 1973, Mineralogy and trace element chemistry of Mazama ash soils. OSU doctoral.
- Gaston, Larry R., 1975, Biostratigraphy of the type Yamhill Formation, Polk County, Oregon. PSU master's.
- Hales, Peter O., 1975, Geology of Green Ridge area, Whitewater River quadrangle, Oregon. OSU master's.
- Harris, Billy L., 1973, Genesis, mineralogy, and properties of Parkdale soils, Oregon. OSU doctoral.
- Jackson, Ronald L., 1975, A mineralogical and geochemical study of the ferruginous bauxite deposits in Columbia County, Oregon and Wahiakum County, Washington. PSU master's.
- Jarman, Clara B., 1973, Clay mineralogy and sedimentary petrology of the Cretaceous Hudspeth Formation, Mitchell, Oregon. OSU doctoral.
- Johnson, Floyd R., 1975, Geology of the Quartzburg mining district, Grant County, Oregon. OSU master's.
- Kienle, Clive F., Jr., 1971, The Yakima Basalt in western Oregon and Washington. Univ. Calif., Santa Barbara doctoral.
- Klosterman, Keith E., 1974, An evaluation of the ERTS I imagery in a structural study and a map application of ERTS I imagery in s.w. Washington, n.e. Oregon, and part of w. Idaho. Univ. Wash. master's.
- Mathiot, Richard K., 1973, A preliminary investigation of the land use limitations of the major landforms along a portion of the Lincoln County coast, Oregon. PSU master's.
- Maynard, Leroy C., 1974, Geology of Mount McLoughlin. Univ. Oregon master's.
- Neal, Kenneth G., 1973, A tectonic study of part of n. Eagle Cap Wilderness area, n.e. Oregon. PSU master's.

Parker, Donald J., 1974, Petrology of selected volcanic rocks of the Harney Basin, Oregon. OSU doctoral.

Reckendorf, Frank F., 1973, Techniques for identifying flood plains in Oregon. OSU doctoral.

Rooth, Guy H., 1974, Biostratigraphy and paleoecology of the Coaledo and Bastendorff Formations, s.w. Oregon. OSU doctoral.

Seeley, Wm. O., 1974, Geology of the s.e. quarter of the Dixonville quadrangle, Oregon. Univ. Oregon master's.

Stembridge, James E., Jr., 1975, Shoreline changes and physiographic hazards of the Oregon Coast. Univ. Oregon doctoral.

Storm, Allen B., 1975, Stratigraphy and petrology of the Grassy Mountain Formation, Malheur County. Univ. Oregon master's.

Stovall, James C., 1929, Pleistocene geology and physiography of the Wallowa Mountains with special reference to the Wallowa and Hurricane Canyons. Univ. Oregon master's.

Tang, Rex Wai-Yuen, 1974, Geothermal exploration by telluric currents in the Klamath Falls area, Oregon. OSU master's.

Tucker, Elizabeth R., 1975, Geology and structure of the Brothers Fault Zone in the central part of the Millican s.e. quadrangle, Deschutes County, Oregon. OSU master's.

Wells, Ray E., 1975, The geology of the Drake Peak rhyolite complex and the surrounding area, Lake County, Oregon. Univ. Oregon master's.

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COASTAL EROSION REPORTS ISSUED BY OSU

Two reports recently issued by the School of Oceanography, Oregon State University, discuss the effects of erosion of two large spits on the Oregon Coast where housing developments have been either threatened or destroyed. The reports, which may be consulted at the Department library, are:

1. "Development and Erosion History of Bayocean Spit, Tillamook, Oregon," by T. A. Terich and P. D. Komar; Oregon State Univ. Sch. of Ocean. Reference 73-16, 145 pages, photos, maps.
2. "The Erosion of Siletz Spit, Oregon," by C. C. Rea and P. D. Komar; Oregon State Univ. Sch. of Ocean. Reference 75-4, 105 pages, photos, and maps.

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BLM ISSUES OIL AND GAS LEASES IN COLUMBIA COUNTY

Eight oil and gas leases on 14,079 acres of Federal land in Columbia County have been issued by the Bureau of Land Management. The land is between Vernonia and Scappoose; leases are for 10 years at 50¢ per acre per year.

Four BLM leases were issued to Gas Producing Enterprises, Inc., of Houston, Texas. They totaled 8,459.12 acres. Other leases were to: Janet K. Dorman, Golden, Colorado, 1,620.20 acres; David A. Forson, Lakewood, Colorado, 1,892.96 acres; Dorothy L. Wahle, Littleton, Colorado, 280.0 acres; and Faye A. Reuth, Lakewood, Colorado, 1,826.90 acres.

* * * * *

WEYERHAEUSER-PPL TO DRILL GEOTHERMAL TEST

The Department issued a geothermal drilling permit to Weyerhaeuser and Pacific Power & Light Co. on October 28, 1975 to drill a 2,000-foot exploratory hole approximately 8 miles northwest of the city of Klamath Falls in the NW $\frac{1}{4}$, sec. 15, T. 37 S., R. 7 E., Klamath County. The hole is being drilled on lands owned by Weyerhaeuser under a joint operating agreement.

* * * * *

SAN JUAN OIL CO. TO DRILL FOR STEAM

The Department issued a permit to the San Juan Oil Co. of Tulsa, Oklahoma to drill a 7,500-foot geothermal well in Lake County. The well is located in NW $\frac{1}{4}$ sec. 22, T. 38 S., R. 24E., approximately 1 mile southeast from the town of Adel in Warner Valley. San Juan is drilling the well on a Gulf Oil Co. lease under a "farm out" arrangement.

* * * * *

AVAILABLE PUBLICATIONS

(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

26. Soil: Its origin, destruction, preservation, 1944: Twenhofel	\$0.45
33. Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35. Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin	3.00
36. Papers on Tertiary foraminifera: Cushman, Stewart & Stewart.	vol. 2-1.25
39. Geology and mineralization of Morning mine region, 1948: Allen and Thayer	1.00
44. Bibliography (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere.	1.00
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00
52. Chromite in southwestern Oregon, 1961: Ramp	5.00
53. Bibliography (3rd suppl.) geology and mineral resources of Oregon, 1962: Steere, Owen	3.00
57. Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
60. Engineering geology of Tualatin Valley region, 1967: Schlicker and Deacon	7.50
61. Gold and silver in Oregon, 1968: Brooks and Ramp	7.50
62. Andesite Conference Guidebook, 1968: Dole	3.50
64. Geology, mineral, and water resources of Oregon, 1969	3.00
65. Proceedings of the Andesite Conference, 1969: McBirney, editor (photocopy)	10.00
66. Geology and mineral resources of Klamath and Lake Counties, 1970.	6.50
67. Bibliography (4th suppl.) geology and mineral industries, 1970: Roberts	3.00
68. Seventeenth biennial report of the Department, 1968-1970	1.00
69. Geology of the southwestern Oregon Coast, 1971: Dott	4.00
70. Geologic formations of western Oregon, 1971: Beaulieu	2.00
71. Geology of selected lava tubes in the Bend area, 1971: Greeley	2.50
72. Geology of Mitchell quadrangle, Wheeler County, 1972: Oles and Enlows	3.00
73. Geologic formations of eastern Oregon, 1972: Beaulieu	2.00
75. Geology, mineral resources of Douglas County, 1972: Ramp	3.00
76. Eighteenth biennial report of the Department, 1970-1972.	1.00
77. Geologic field trips in northern Oregon and southern Washington, 1973.	5.00
78. Bibliography (5th suppl.) geology and mineral industries, 1973: Roberts and others	3.00
79. Environmental geology inland Tillamook Clatsop Counties, 1973: Beaulieu.	7.00
80. Geology and mineral resources of Coos County, 1973: Baldwin and others	6.00
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00
82. Geol. Hazards of Bull Run Watershed, Mult. Clackamas Counties, 1974: Beaulieu	6.50
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00
84. Environmental geology of western Linn Co., 1974: Beaulieu and others.	12.00
85. Environmental geology of coastal Lane Co., 1974: Schlicker and others	12.00
86. Nineteenth biennial report of the Department, 1972-1974	1.00
87. Environmental geology of western Coos and Douglas Counties, Oregon, 1975	in press
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	in press

GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck \$2.00; mailed -	2.50
Geologic map of Oregon (12" x 9"), 1969: Walker and King	0.25
Geologic map of Albany quadrangle, Oregon, 1953: Allison (from Bulletin 37)	1.00
Geologic map of Galice quadrangle, Oregon, 1953: Wells and Walker	1.50
Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts	1.50
Geologic map of Bend quadrangle, and portion of High Cascade Mtns., 1957: Williams	1.50
GMS-1: Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka	2.00
GMS-2: Geologic map, Mitchell Butte quadrangle, Oregon: 1962	2.00
GMS-3: Preliminary geologic map, Durkee quadrangle, Oregon, 1967: Prostka	2.00
GMS-4: Gravity maps, Oregon onshore & offshore; [set only]: at counter \$3.00, mailed	3.50
GMS-5: Geology of the Powers quadrangle, 1971: Baldwin and Hess	2.00
GMS-6: Preliminary report, geology of part of Snake River Canyon, 1974: Vallier.	6.50

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SHORT PAPERS

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| 18. Radioactive minerals prospectors should know, 1955: White and Schafer | \$0.30 |
| 19. Brick and tile industry in Oregon, 1949: Allen and Mason | 0.20 |
| 21. Lightweight aggregate industry in Oregon, 1951: Mason | 0.25 |
| 24. The Almeda mine, Josephine County, Oregon, 1967: Libbey | 3.00 |

MISCELLANEOUS PAPERS

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|---|------|
| 1. Description of some Oregon rocks and minerals, 1950: Dole | 1.00 |
| 2. Oregon mineral deposits map (22 x 34 inches) and key (reprinted 1973): | 1.00 |
| 4. Rules and regulations for conservation of oil and natural gas (rev. 1962) | 1.00 |
| 5. Oregon's gold placers (reprints), 1954 | 0.50 |
| 6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton | 3.00 |
| 7. Bibliography of theses on Oregon geology, 1959: Schlicker | 0.50 |
| (Supplement) Bibliography of theses, 1959 to Dec. 31, 1965: Roberts | 0.50 |
| 8. Available well records of oil and gas exploration in Oregon, rev. 1963: Newton | 1.00 |
| 11. A collection of articles on meteorites, 1968 (reprints from The ORE BIN) | 1.50 |
| 12. Index to published geologic mapping in Oregon, 1968: Corcoran | 0.50 |
| 13. Index to The ORE BIN, 1950-1974. | 1.50 |
| 14. Thermal springs and wells, 1970: Bowen and Peterson | 1.50 |
| 15. Quicksilver deposits in Oregon, 1971: Brooks | 1.50 |
| 16. Mosaic of Oregon from ERTS-1 imagery, 1973: | 2.50 |
| 18. Proceedings of Citizens' Forum on potential future sources of energy, 1975 | 2.00 |

OIL AND GAS INVESTIGATIONS

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| 1. Petroleum geology, western Snake River basin, 1963: Newton and Corcoran | 3.50 |
| 2. Subsurface geology, lower Columbia and Willamette basins, 1969: Newton | 3.50 |
| 3. Prelim. identifications of foraminifera, General Petroleum Long Bell No. 1 well | 2.00 |
| 4. Prelim. identifications of foraminifera, E. M. Warren Coas Co. 1-7 well: Rau | 2.00 |

MISCELLANEOUS PUBLICATIONS

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| Landforms of Oregon: a physiographic sketch (17" x 22"), 1941 | 0.25 |
| Mining claims (State laws governing quartz and placer claims) | 0.50 |
| Oregon base map (22" x 30"). | 0.50 |
| Geologic time chart for Oregon, 1961 | free |
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| Accumulated index - see Misc. Paper 13 | |

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THE WALLOWA "ICE CAP" OF NORTHEASTERN OREGON
an exercise in the interpretation of glacial landforms

John E. Allen
Emeritus Professor of Geology, Portland State University

Introduction

The geology of the Wallowa Mountains was first mapped in 1938 (Ross) and 1941 (Smith and Allen). Since that time, little work has been done on the effects of the Pleistocene ice which mantled much of the Wallowa high country more than 15,000 years ago. From elevations above 8,000 feet, the ice flowed down the canyons, reaching as low as 3,000 feet on Pine Creek. It has been the custom to call this glacial cover an "ice cap," implying that a more or less continuous sheet of névé covered the central area of the mountains. Only one map showing the inferred maximum extent of the ice has been published (Crandell, 1965). The accompanying map (Figure 1) is a demonstration of what can tentatively be deduced from a geomorphic study of topography on maps which were not available in 1941. Undoubtedly field checks will revise the map in detail, but the large picture should remain valid.

Procedures

Seven 15-minute and four 7½-minute U.S. Geological Survey topographic quadrangle maps (see list at end of text) were used to determine the extent of the ice (Figure 1). These maps reveal many glacial landforms, both erosional and depositional (see Figure 2); the following can be easily recognized (definitions are adapted from Gary and others, 1972):

Erosional landforms (see accompanying photographs)

- arête - a narrow, jagged, serrate mountain crest, or a narrow, rocky, sharp-edged ridge or spur, commonly present above the snow line in glaciated mountains
- bastion - a prominent mass of bedrock extending from the mouth of a glacial trough and projecting far out into the glacial valley



Above: Cirque and tarn; terminal moraine from "little ice age" about 4,000 years ago. Eagle Cap on skyline and arête to right. (Oregon Hwy. Div. photo)

Below: Ice Lake dammed by recessional moraine. Matterhorn Peak (upper left) and Sacajawea (upper right) are highest peaks in Wallowas. (Oregon Hwy. Div. photo)



cirque - a deep, steep-walled, flat- or gently-floored, half-bowl-like recess or hollow commonly at the head of a glacial valley or saddle-shaped depression in a ridge
 col - a deep pass formed by the headward erosion of two cirques
 hanging valley - a glacial valley whose mouth is at a relatively high level on the steep side of a larger glacial valley
 matterhorn - a high peak with prominent faces bounded by intersecting walls of three or more cirques
 tarn - a relatively small, steep-banked lake or pool occupying an ice-gouged rock basin
 U-shaped valley - a valley having a pronounced parabolic cross profile suggesting the form of a broad letter U, with steep parallel walls and a broad, nearly flat floor; a glacial trough

Depositional landforms (see accompanying photographs)

moraine - a mound, ridge, or other distinct accumulation of unsorted, unstratified glacial drift, predominantly till, deposited chiefly by direct action of glacier ice in a variety of topographic landforms that are independent of control by the surface on which the drift lies
 lateral moraine - a low, ridge-like moraine deposited at or near the side margin of a mountain glacier
 recessional moraine - an end moraine built during a temporary but significant halt or pause in the final retreat of a glacier
 terminal moraine - an end moraine, extending across a glacial valley as an arcuate or crescentic ridge, that marks the farthest advance or maximum extent of a glacier
 morainal lake - a glacial lake occupying a depression and dammed by a terminal or recessional moraine
 outwash - stratified detritus removed or "washed out" from a glacier by melt-water streams and deposited in front of or beyond the terminal moraine

In studying the topographic maps, the elevation of lateral moraines was particularly helpful in determining the extent of the ice in the valleys. Evidences of glacial extent, recognizable in the field but not on topographic maps, were noted by Smith and Allen (1941). These included the location of glacial erratics and the elevations of ice-scoured and polished surfaces (see photographs).

Interpolation of projected thicknesses of the ice, carefully checked by remnants of lateral moraines and medial moraine spurs at tributary valley mouths, permitted drawing appropriately spaced contour lines for the surface of the ice (Figure 1).

Below the firn area (zone of accretion), the thickness of the ice is inferred to have decreased gradually (in the zone of ablation) to the terminus. Rock steps and steeper stretches in the present valley profile were taken into



Above: U-shaped valley of Eagle Creek near Boulder Park.
(Oregon Hwy. Div. photo)

Below: Bastions project into U-shaped valley of West Fork of
Wallowa River. Small cirques and hanging valley on left.
Sentinel Peak in distance is a "matterhorn."



consideration in estimating the thickness of the ice. Glacial cirque ice is mapped as being halfway up the cirque walls.

In a few instances, landslides may have been interpreted as névé fields or incipient cirques at lower elevations on the periphery of the area, and bastions may have been interpreted as moraines at glacial junctions.

Conclusions

The so-called "ice cap" which fed the radiating glacial streams during the Pleistocene turns out to be multiple in nature. The Lake Basin ice field had a surface at least 8,500 feet above sea level; over the ridge to the west the Minam Lake ice field was a few hundred feet lower. The Aneroid Lake ice field and the several Imnaha ice fields were at about 8,400 feet elevation. Nunataks (isolated rock knobs projecting above the ice) are surprisingly rare; most of the high peaks appear to have been connected by narrow unglaciated ridges.

Thin ice fields covered much of the plateau surface south of the Imnaha valley, feeding glaciers down Lake and Clear Creeks. This area may have been more extensively covered by ice than is shown (Ross, 1938, p. 58).

The nine large glaciers (each more than 10 miles long) and their tributaries covered about 279 square miles (see Figure 1). Other isolated ice fields and glaciers added 58 square miles for a total of about 337 square miles covered by ice during the Pleistocene. This is a closer approximation than "200 square miles" or "500 square miles" - figures which have been bandied about for years - but it is a minimum figure, since thickness of the ice was conservatively estimated where definite evidence was lacking on the topographic maps.

In length, the Lostine glacier (22 miles) was slightly longer than the Minam (21 miles) and the Imnaha (20 miles). The other six major glaciers were from 12 to 13 miles in length.

In area covered, the Minam glacier was the largest, with 67 square miles, followed by the Lostine (55) and the Imnaha (50). The Wallowa glacier covered 35 square miles. The other five major glaciers covered between 11 and 18 square miles each.

In elevation reached by the lower ends of the glaciers, the Lostine came down to 3,380 feet above sea level; the Minam was a close second at 3,600 feet. The six other major glaciers reached between 4,000 and 4,200 feet. The Pine Creek glacier apparently reached to 2,960 feet at some time (pre-Frazier) during the Pleistocene (Crandell, 1965).

In thickness of ice, without field-checking, the maximum seems to have been about 2,500 feet in the upper Lostine and Minam glaciers. The Wallowa was thickest at its junction with the East Fork, about 1,500 feet. The Hurricane was less than 1,000 feet thick throughout.



Above: Moccasin Lake, a tarn lake in upper Wallowa River drainage. Eagle Cap on left.

Below: Glacier Lake, a tarn at head of West Fork of Wallowa River. Cusick Mountain in upper right. Three cols on skyline. (Oregon Hwy. Div. photo)





Above: Terminal moraine of Wallowa River glacier dammed river to form Wallowa Lake. (Oregon Hwy. Div. photo)

Below: Lateral and terminal moraines hem in Wallowa Lake. U-shaped valley of West Fork of Wallowa River in upper left and many cirque basins on skyline. (U.S. Forest Service photo)



FIGURE 1

EXTENT of PLEISTOCENE GLACIERS

in the

WALLOWA MOUNTAINS, OREGON

SUMMARY OF DATA ON WALLOWA GLACIERS

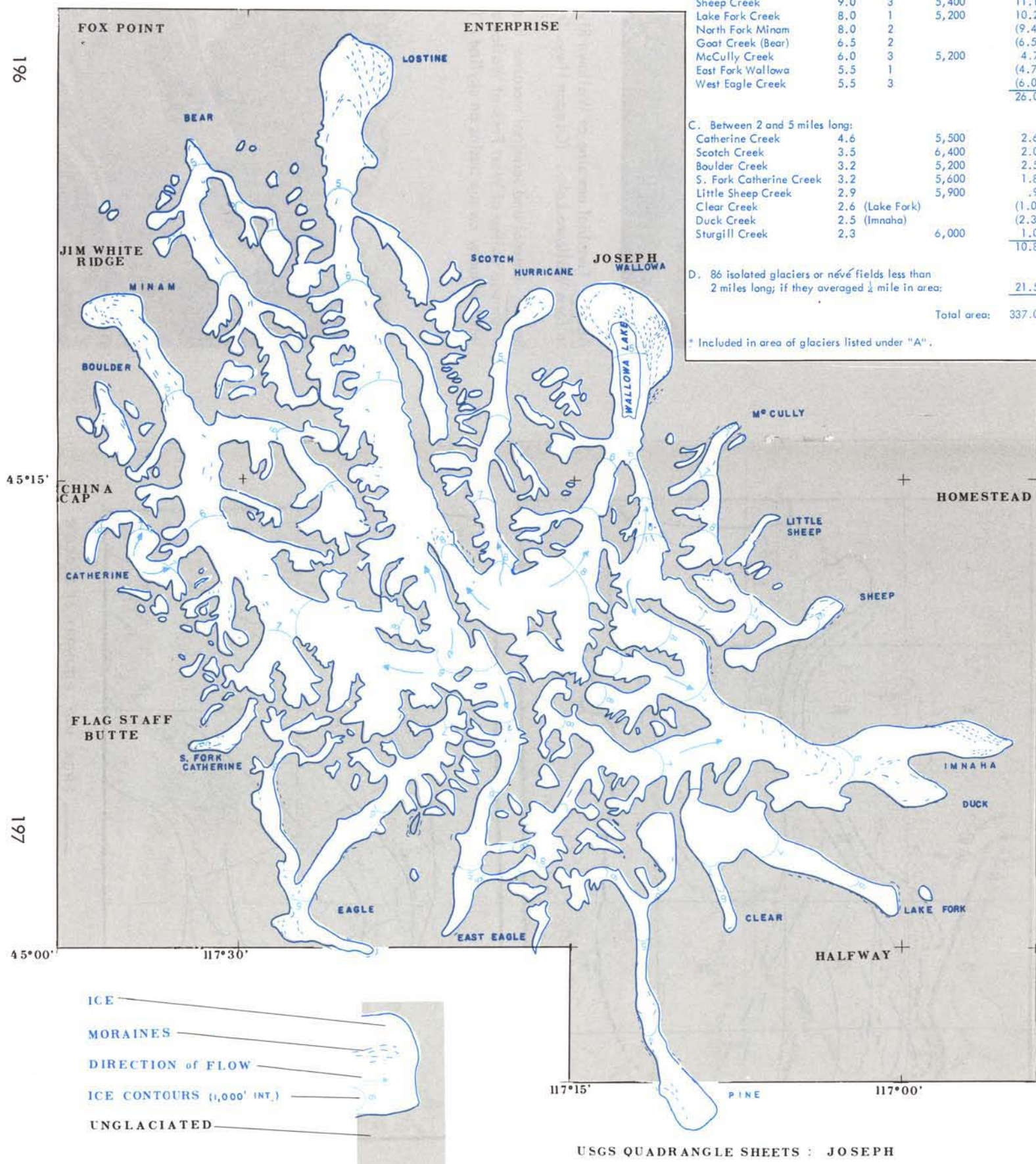
Name	Length (miles)	No. of major branches	Elevation at lower end (feet)	Area of ice (sq. miles)
A. Glaciers more than 10 miles long:				
Lostine River	22	4	3,380	55.0
Minam River	21	5	3,600	67.5
Imnaha River	20	5	4,200	50.5
Wallowa River	13	2	4,200	35.4
Hurricane Creek	13	1	4,200	11.5
East Eagle Creek	13	1	4,100	12.2
Eagle Creek	13	1	4,000	18.5
Bear Creek	12	2	4,200	15.5
Pine Creek	12.6	2	2,690	12.6
				278.7

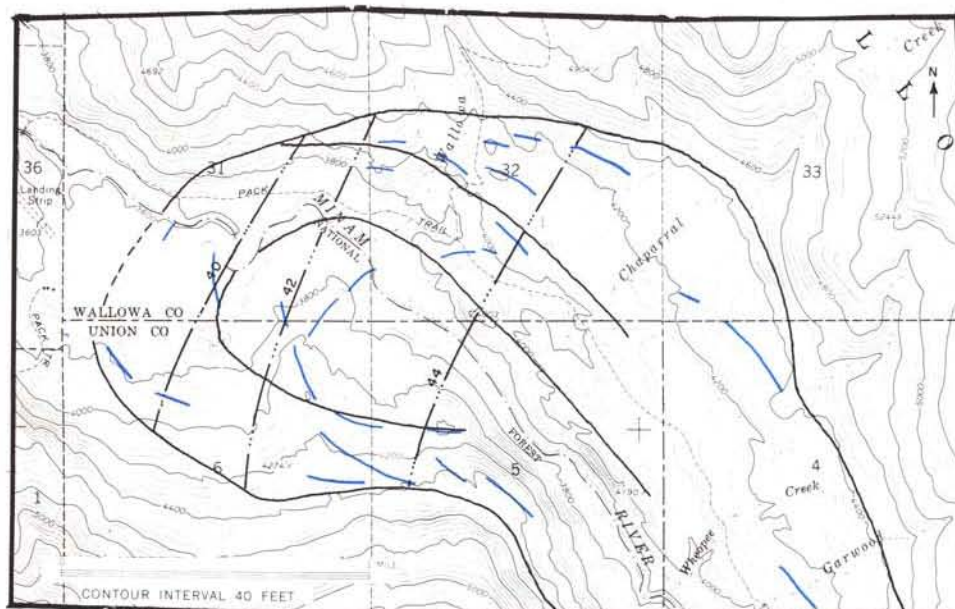
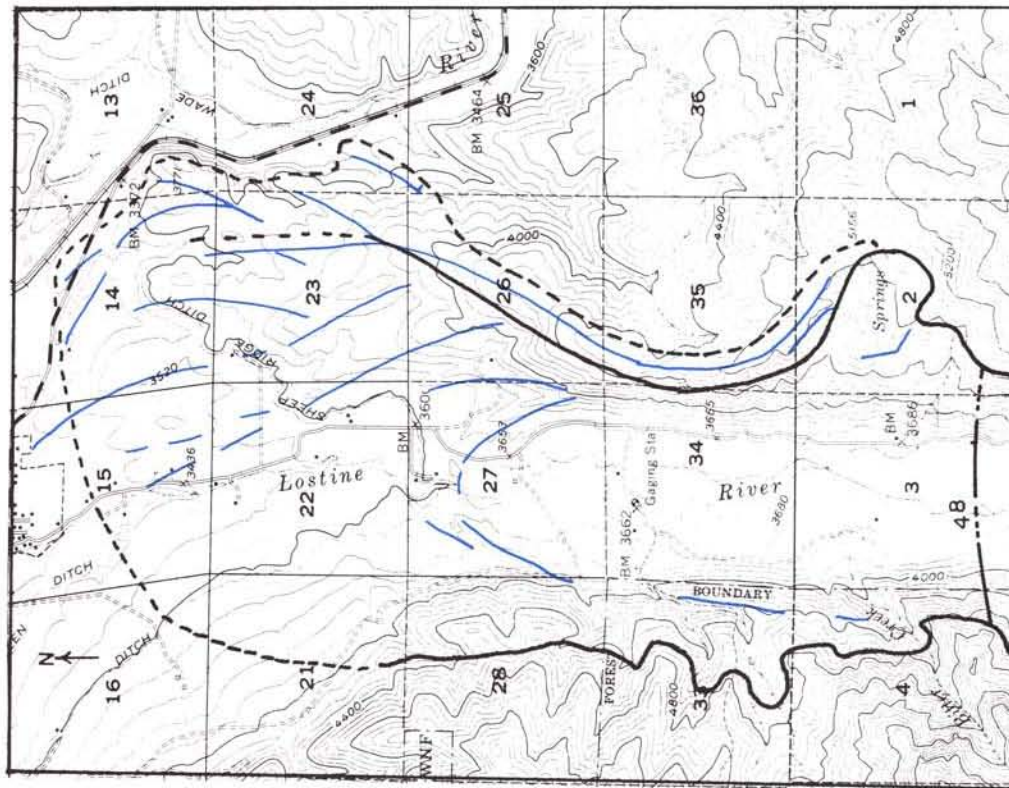
B. Between 5 and 9 miles long (tributary or isolated):				
Sheep Creek	9.0	3	5,400	11.1
Lake Fork Creek	8.0	1	5,200	10.2
North Fork Minam	8.0	2		(9.4)*
Goat Creek (Bear)	6.5	2		(6.5)*
McCully Creek	6.0	3	5,200	4.7
East Fork Wallowa	5.5	1		(4.7)*
West Eagle Creek	5.5	3		(6.0)*
				26.0

C. Between 2 and 5 miles long:				
Catherine Creek	4.6		5,500	2.6
Scotch Creek	3.5		6,400	2.0
Boulder Creek	3.2		5,200	2.5
S. Fork Catherine Creek	3.2		5,600	1.8
Little Sheep Creek	2.9		5,900	.9
Clear Creek	2.6	(Lake Fork)		(1.0)*
Duck Creek	2.5	(Imnaha)		(2.3)*
Sturgill Creek	2.3		6,000	1.0
				10.8

D. 86 isolated glaciers or névé fields less than 2 miles long; if they averaged $\frac{1}{2}$ mile in area:				
				21.5
Total area:				337.0

* Included in area of glaciers listed under "A".





SCALE
0 1 MILE
EXCEPT AS NOTED

— PROX. MAX. BOUNDARY of GLACIER

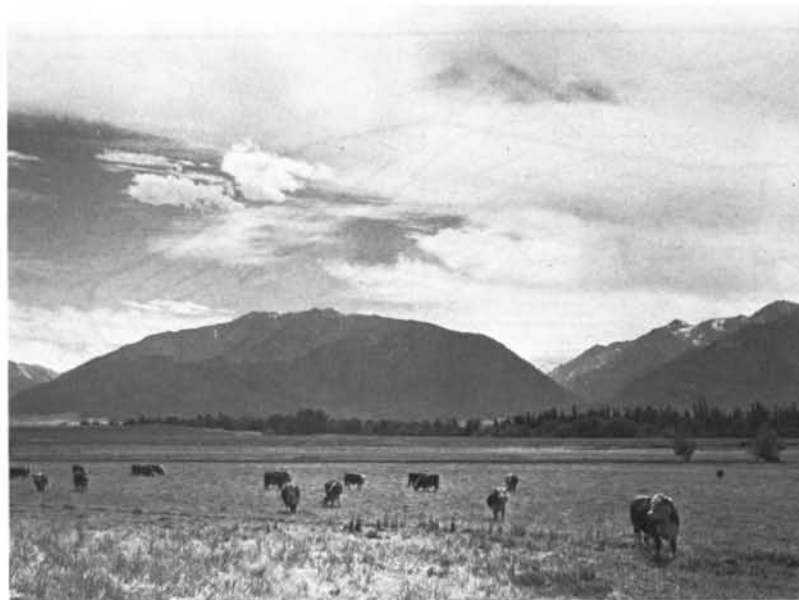
— MORAINES

FIGURE 2

The Frazier glaciation, the latest major advance of alpine glaciers in the Wallowas, ended about 15,000 years ago. Since that time, climatic fluctuations have caused small glacial advances, such as the "little ice age" about 4,000 years ago, which left terminal moraines high in the major glacial valleys.



Moraine on Thorp Creek, tributary of Hurricane Creek, is a prominent topographic feature. "Ballet dancer" is Warren D. Smith, noted Oregon geologist, deceased.



Outwash from Wallowa glaciers formed broad plains of sand and gravel at foot of mountains near Joseph. (Oregon Hwy. Div. photo)



Above: Striated, ice-scoured rock surface exposed in Lostine Canyon. Note geologic pick for scale.

Below: Erratic boulders of granodiorite perched on limestone bedrock near Marble Point, 2,500 feet above Lostine River, indicate elevation of glacial ice.



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Topographic Quadrangle Maps

<u>15-minute</u>		<u>7½-minute</u>
Enterprise	Homestead	Fox Point
Joseph	Sparta	Jim White Ridge
Eagle Cap	Halfway	China Cap
Cornucopia		Flagstaff Butte

* * * * *

MOUNT RAINIER HISTORY DESCRIBED

"Quaternary Stratigraphy and Extent of Glaciation in the Mount Rainier Region, Washington," by D. R. Crandell and R. D. Miller, is a recent publication by the U.S. Geological Survey and designated Professional Paper 847. The 59-page report includes a geologic map of the region and a topographic map of Mount Rainier National Park. According to the authors, a nearly continuous ice cap once mantled the Cascade Range, with ice extending down the Cowlitz River about 120 km (193 miles). Today each of the five major river valleys contains glacial deposits of repeated glaciations, and drift from at least two ancient glaciations has been recognized.

Professional Paper 847 is for sale by U.S.G.S. Branch of Distribution, 1200 S. Eads St., Arlington, VA 22202. The price is \$1.60.

* * * * *

POTENTIAL GEOTHERMAL LAND WITHDRAWN FROM MINERAL EXPLORATION

A recent news release from the U.S. Department of the Interior, Bureau of Land Management, announces that 31,114.7 acres (approximately 50 square miles) of land in Malheur County centering around Jordan Craters has been established as a "Research Natural Area." According to the news release, the arrangement will "aid BLM in managing and protecting the area to insure preservation of the total environment." Not stated in the release was the fact that this action also withdraws the land from mineral entry.

As noted in the October 1975 ORE BIN, about two-thirds of all public lands are now completely or partially withdrawn from mining activities. Here is another instance of a tract of land essentially reserved for ecological study, a single-use purpose which is contrary to the multiple-use concept espoused for many years by the Federal government.

The Jordan Craters lie within a large area of relatively young volcanic rocks, one of the most promising regions for future geothermal development. Even though the Jordan Craters Research Natural Area of approximately 31,000 acres is only a small part of the total volcanic field, its withdrawal has a negative effect on mineral exploration activities in the surrounding territory; past experience has shown that companies looking for geothermal or mineral resources always give a wide berth to public lands withdrawn "to insure preservation of the total environment."

Every public land withdrawal is justified in the eyes of the Federal agency responsible for managing it, and in most instances, the area involved for any one withdrawal is comparatively small. But as has been clearly pointed out by Bennethum and Lee in the October 1975 ORE BIN, the cumulative effect of withdrawals is tremendous. To quote from these authors: "We think some attention will have to be paid to the trend toward accelerated withdrawals because it seriously erodes the long-range mineral position of the country. It affects our economy, our ability to protect jobs, and it is forcing American industry to look elsewhere for minerals. It makes us vulnerable to mineral cartels like the OPEC oil cartel."

--- R. E. Corcoran

* * * * *

INTERIOR DEPARTMENT POSTS FILLED

Thomas S. Kleppe, former U.S. Representative from North Dakota, was made Secretary of the Interior on October 9, 1975, succeeding Stanley K. Hathaway, who resigned in July. On November 20, 1975, the Senate confirmed the nomination of D. Kent Frizzell to be Under-Secretary of the Interior. Frizzell, a Kansan who has been solicitor of the Interior Department, fills a post that has been vacant since May 1.

* * * * *

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